325
1/29/65

ORNL-3750
UC-4 - Chemistry
TID-4500 (37th ed.)

MASTER

ANALYTICAL CHEMISTRY DIVISION
ANNUAL PROGRESS REPORT
FOR PERIOD ENDING NOVEMBER 15, 1964

OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

Printed in USA. Price \$5.00. Available from the Clearinghouse for Federal
Scientific and Technical Information, National Bureau of Standards,
U.S. Department of Commerce, Springfield, Virginia

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ORNL-3750
UC-4 - Chemistry
TID-4500 (37th ed.)

Contract No. W-7405-eng-26

ANALYTICAL CHEMISTRY DIVISION
ANNUAL PROGRESS REPORT
For Period Ending November 15, 1964

M. T. Kelley, Director
C. D. Susano, Associate Director

JANUARY 1965

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

Summary

PART A. ANALYTICAL RESEARCH

1. Analytical Instrumentation

Two papers were presented at the 3rd International Congress of Polarography. The first summarized the controlled-potential dc polarography done at ORNL since mid-1959; the second described the quasi-reference electrode (Q.R.E.) and research results obtained with it in controlled-potential polarography, controlled-potential voltammetry, and chronopotentiometry.

A prototype controlled-potential dc polarograph-voltammeter was designed and constructed; solid-state instead of vacuum-tube operational amplifiers and power supplies are used. The instrument is to be used with the short-drop-time Smoler vertical-orifice dropping-mercury electrodes (D.M.E.) and with solid working electrodes. The prototype will be used for continued research in polarography and voltammetry and as the basis for design of several controlled-potential dc polarograph-voltammeters for work in the Analytical Chemistry Division.

To facilitate the evaluation of dc polarographic instrumentation, computer programs were written. These programs solve the Koutecký equation for a value of the diffusion coefficient and provide computer-plotted, normalized, theoretical curves (simple, reversible, diffusion-controlled process) for the regular polarographic wave and for the first-, second-, and third-derivative waves.

Two ORNL model Q-2564 high-sensitivity coulometric titrators were fabricated and installed, one in the High-Radiation-Level Analytical Laboratory (HRLAL) and the other in the High-Level Alpha Radiation Laboratory. A check-out and test procedure and a troubleshooting guide were prepared for this instrument. About 25 complete sets of engineering drawings for the titrator were sent to interested installations in the United States and abroad.

A paper that described the application of the derivative method to stationary-electrode voltammetry with linearly varying potential was presented at the 148th American Chemical Society Meeting. The accuracy and reproducibility of first-derivative linear-sweep voltammetry are about the same as those of regular linear-sweep voltammetry; the sensitivity is at least an order of magnitude greater.

A safety circuit for the expensive (\$633) multiplier phototube of the ORNL model VII flame spectrophotometer was designed and installed. Already, the circuit has twice provided automatic shutdown that saved the phototube.

Study of the significance of the placement of the reference electrode in controlled-potential coulometry was continued with the $\text{Bi}^{3+}\text{-UO}_2^{2+}$ system. There was no chemical evidence that variation in placement of the reference electrode, even under drastic cell conditions, causes the voltage that drives the electrochemical reaction to exceed the command voltage set into the potentiostat.

The development of analytical instruments necessary to the MSRE and TRU programs was continued (see Sect. 4). Some of the results may be applied in the future to in-line monitoring problems. Several remotely operated instruments for use in hot cells were redesigned to simplify manipulation and maintenance.

For the MSRE program, the following instrument development was done or is in progress. Applications of the Q.R.E. to the analysis of molten salts by electrochemical methods were continued. The ORNL model Q-1734 remotely operated filter photometer was redesigned to make greater use of commercially available components and of better materials of construction and to simplify operation of the instrument in hot cells. Two of these units were fabricated for use in the HRLAL. An assembly drawing of the redesigned photometer is

given in ORNL-Dwg. 64-3171. The ORNL corrosion-resistant servopipetter was redesigned to permit easier manipulations in hot cells. The new design features are a single cable connection (removable by the master-slave manipulators) to the pipetter and a new stand and mount that replace the ORNL screw-operated elevator. The relative standard deviation of 100- μ l deliveries is 0.2%. Five of the new units (designated Q-1348B) were fabricated at ORNL, tested with satisfactory results, and delivered to the HRLAL. Terminal engineering drawings for the Q-1348B are being prepared. The remotely operated decapper was redesigned to accommodate sample bottles of various heights and diameters. Two of the new decappers were fabricated for use in the HRLAL. Application of the ORNL model Q-2564 high-sensitivity coulometric titrators to analyses for the MSRE program was continued. Another of these titrators that was constructed recently was checked out against the design specifications. For the following equipment that is essential to the remotely operated analysis of MSRE samples, design work was completed, engineering drawings were prepared, and a spare set of the instruments is being constructed: one pyrohydrolysis unit, one transfer-tube decoupling device, one modified Spex Industries Inc. Mixer/Mill, two powder-transfer devices, one redesigned ladle-cutting device, five electrochemical apparatuses, and 250 copper pulverizer-mixers (copper ladles).

For the TRU program, the following instrument development work has been done or is in progress. Drawings for an alternative pipet delivery unit and an alternative stand-jack for the ORNL model Q-1728 velocity-servo, automatic, recording potentiometric titrator were prepared and were added to the Q-1728 series of drawings. Two of these titrators, at least one of which is to be used with these alternative units, are to be fabricated and will be checked out after construction to ensure that the design specifications have been met by the fabricator. The following remotely operated apparatus for use in the TRU analytical hot cells is under development. The ORNL corrosion-resistant servopipetter is being redesigned to deliver a full 1-ml sample and to be capable of passage through an 8 $\times$ 8 in. cylindrical access area; it is to be capable of assembly and disassembly within the hot-cell enclosure. Engineering drawings of this device will be prepared. A remotely operated analytical balance for weighing

TRU samples prior to their analysis is being designed. Remotely operated solvent-extraction apparatus for use within the TRU analytical hot cells is being designed, and engineering drawings will be prepared after the prototype unit has been proved satisfactory.

2. Analytical Studies of Molten-Salt Systems

Absorption spectrophotometric studies of various molten-salt systems were continued. The atmosphere of the nickel high-temperature spectrophotometric cell assembly was freed from water, oxygen, and HF by placing chips of titanium sponge in the sample compartment. This procedure resulted in the stability of the absorption spectrum of U^{4+} in LiF-NaF-KF for 15 hr.

The absorption spectrum of U^{3+} at 500°C in LiF-BeF₂-ZrF₄ was obtained by reduction of U^{4+} by either Zr or U metal. The molar absorptivity of the strongest U^{3+} peak at 875 $m\mu$ in the near-infrared region was estimated to be 40 liters mole⁻¹ cm⁻¹. In the ultraviolet region, at 360 $m\mu$, the molar absorptivity is about 500 liters mole⁻¹ cm⁻¹. The spectrum of U^{3+} in LiF-BeF₂ appears to be identical with that in LiF-BeF₂-ZrF₄. The intensity of the 360- $m\mu$ peak in these melts provides a sensitive means of observing reactions that generate or consume U^{3+} .

A special holder for very small crystals was devised to obtain spectra from 280 to 750 $m\mu$ of crystals whose diameter is of the order of 0.1 ma.

The absorption spectrum of UF₆ was obtained using a vacuum-tight fluorinated-nickel gas cell equipped with crystalline Al₂O₃ windows and Teflon gaskets. The spectrum is complex in the region 340 to 420 $m\mu$ with a maximum at 368 $m\mu$, at which wavelength the molar absorptivity of UF₆ is 5.5 liters mole⁻¹ cm⁻¹.

The experimental equipment used to investigate the electroanalytical characteristics of molten-fluoride salt systems was modified to eliminate possible contamination from moisture. With this equipment the decomposition potentials of such metals as Zr, Cr, Fe, Ni, and Mo in molten fluorides were obtained.

Rapid-scan and anodic-stripping voltammetry of nickel in molten LiF-NaF-KF were studied. By means of the anodic-stripping technique, as

little as 1 ppm of nickel can be measured in the melt. Voltammetry was also applied to the MSR coolant in fuel salts. The presence of hafnium was indicated by these studies. Further studies were also carried out in an effort to determine chromium in the fuel salt.

Work was continued on the development of a reference electrode that would be compatible with molten-fluoride salts. The platinum quasi-reference electrode is not particularly stable. The Ni-NiO electrode appears to be a useful reference with the three-electrode controlled-potential circuit; however, it is not satisfactory in the two-electrode circuit because the cell current that flows through the reference electrode seems to produce polarization and subsequent erratic potential measurements.

Several instrumental approaches to the on-stream analysis of radioactive molten-salt systems were investigated, including electron-spin-resonance measurements and x-ray absorption or emission measurements. None of these techniques seemingly offer much promise for this application.

3. Effects of Radiation on Analytical Methods

The study of the effect of ^{60}Co gamma radiation on the reaction of nickel with dimethylglyoxime (*I*) was completed. A postirradiation effect on the Ni-*I* complex was noted in that the color of the complex returns after it has been removed from the source of radiation. The radiation damage to the colored complex is apparently due to reduction of the Ni(III) in the complex. A detailed study of the effect of gamma radiation on the determination of uranium(VI) in phosphoric acid solutions of uranium(IV) oxide was completed. Errors due to radiation can be minimized by excluding oxygen from solutions of UO_2 and by maintaining the UO_2 concentration as low as possible. Studies of the effect of gamma radiation on hydrochloric, sulfuric, phosphoric, and acetic acid solutions of arsenazo III were completed. Similar studies of 2-thenoyltrifluoroacetone (TTA) were initiated.

Studies were also initiated on the radiolysis of solutions of high chloride concentration. Free chlorine is not produced at chloride concentrations below 1 *M*. Organic solvents such as methanol are effective in eliminating chlorine produced by radiolysis in high chloride concentrations.

4. Analytical Chemistry for Reactor Projects

Analytical research and development is being carried out for the MSRE, GCR, and TRU Programs. Since details of the progress of these programs are included in the respective periodical reactor-project progress reports, only a brief summary is included in this annual report. For the MSRE, development and evaluation of methods required for the analysis of the fuel and related problems and investigation of the feasibility of various techniques for in-line monitoring are being studied. For the GCR, evaluation of various types of detectors in the gas chromatographic determination of impurities in helium was continued. For TRU, the effort is to provide methods of analysis needed to control the process being carried out at ORNL. Radiochemical, instrumental, and ionic methods are under investigation.

5. Chemical Analysis of Advanced Reactor Fuels

A gas chromatograph was designed for the analysis of corrosive gases such as nitrogen dioxide, dinitrogen trioxide, chlorine, and nitrosyl chloride. The use of tantalum appears to provide the necessary corrosion-resistant material. Gas chromatography was used to analyze aliphatic diluents used in solvent-extraction processes. The argon-beta ionization detector was successfully applied to this problem.

The combustion-gas chromatographic determination of organic carbon in aqueous and nitric acid solutions was studied further in an effort to increase the recovery of known amounts of organic carbon.

The sealed-tube dissolution technique was applied with limited success to a variety of difficultly soluble compounds such as graphite-coated UO_2 , carbides, and several organic compounds. In general, the perchloric acid ("liquid fire") technique is more successful for the dissolution of fluidized coke or graphite-coated materials.

The horizontal-orifice Teflon dropping-mercury electrode (D.M.E.) was used to obtain fundamental polarographic data for the $\text{Tl}^+ \rightleftharpoons \text{Tl}^0$ reaction in 0.1 *M* KCl-1 *mM* HCl and the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ reaction in 1 *M* HCl. The data obtained are interchangeable with those taken with glass D.M.E.'s. The horizontal-orifice Teflon D.M.E. was also

used to determine for the first time the polarographic characteristics of the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ reaction in hydrofluoric acid solutions of concentrations from 1 to 12 M. A procedure was developed for fabricating a vertical-orifice Teflon D.M.E.

A study of the chronopotentiometry of plutonium in mineral acid media was completed. Diffusion coefficients of the different plutonium species were measured, and the possible analytical usefulness of chronopotentiometry for the determination of plutonium was evaluated.

6. Special Research and Development Problems

Studies with 10 M LiCl solutions have shown that the free-acid concentration of such solutions can be determined in the presence of hydrolyzable cations by direct titration without the addition of complexing agents. When several hydrolyzable cations are present, these cations can be differentiated by titration provided there is sufficient difference in their solubility products. Although not particularly precise, the titration is useful as a rapid semiquantitative method.

The investigation of solid indicator electrodes made of pyrolytic graphite and "glassy" carbon was continued to determine their applications and limitations. These studies included differential potentiometry, particularly for hot-cell operation, voltammetry, amperometry, and chronopotentiometry.

An apparatus using flame ionization detection was developed to measure total concentration of organic contaminants in the atmosphere of reactor-fuel-burnup test assemblies. Hydrocarbon concentrations equivalent to 5 ppb of methane in air can be detected. An instrument was assembled in a portable cabinet for making measurements at various sources. Subsequent investigations revealed that aerosols generated by dispersed oxides of uranium interfered with the hydrocarbon determination.

Modifications were made to the apparatus for the determination of oxygen, carbon, and hydrogen in alkali metals. Some of these modifications were required to determine both oxygen and hydrogen in the same sample.

A microtitration cell that does not require an internal electrode was fabricated of pyrolytic graphite for potentiometric titrations of highly radioactive solutions. Both redox and acid-base

potentiometric titrations are possible with this cell for microliter volumes of solutions at a relative standard deviation of 0.3%.

7. Analytical Biochemistry

A new program was initiated to establish a biochemistry group in the Analytical Chemistry Division. Assistance is being provided to the Biology and Chemical Technology Divisions in their program to recover and separate the transfer ribonucleic acids (t-RNA's) from *Escherichia coli* bacteria. Since an immense number of assays is required to determine the efficiency of the solvent-extraction process used to separate the t-RNA's, initial efforts are concerned with modifying procedures to reduce the overall time required for analysis. The precision of alternative methods of rapidly adding reagents by means of various automatic repetitive pipetting is being studied.

8. X-Ray and Spectrochemical Analyses

The analysis of powdered solids was investigated by the x-ray absorption-edge method with a rotating sample holder. Disposable one-piece polystyrene cells were fabricated for use in the analysis of radioactive solutions by the same method. Computer codes were written for determining the height of an x-ray absorption edge by extrapolation and for analyzing multicomponent alloys by x-ray fluorescence. Ruthenium and selenium were determined at the 0.5- $\mu\text{g}/\text{ml}$ level by atomic absorption with an air-hydrogen flame and an end-fed absorption tube. A procedure was developed for separating traces of barium from the alkali metals, alkaline-earth elements, and other elements by coprecipitation on lead chromate. The barium is subsequently determined by flame photometry.

9. Mass Spectrometry

The new double-magnetic-deflection mass spectrometer was put in service in a laboratory arranged for containment of alpha radioactivity. Ion detection is by secondary electron multiplier, and pulse counting is used instead of current measurement. Only 1 to 2 ng of sample is required; rare

isotopes in concentration as low as 1 ppm can be measured.

The isotopic composition of atmospheric neon was measured by use of ^{20}Ne and ^{22}Ne standards of high isotopic and chemical purity; the composition (atom percent) is indicated to be: ^{20}Ne , 90.514 ± 0.031 ; ^{21}Ne , 0.266 ± 0.005 ; ^{22}Ne , 9.220 ± 0.029 .

10. Infrared Spectroscopy

Infrared spectroscopy was used to determine the effect of gamma radiation on such compounds as butyl- α -methylbenzylphenol, 2-thenoyltrifluoroacetone, dimethylglyoxime, sodium dimethylglyoxime, α -benzylphenol, di-*sec*-butylphenylphosphonate, ion-exchange resins, and fractions of the products from the nitric acid degradation of diethylbenzene. Infrared absorption spectra were measured for the water-soluble acidic solids and ether-soluble waxes that are the products of the hydrolysis of uranium carbides and thorium carbides with water or nitric acid. Other studies involved the detection and/or identification of impurities in commercial solvents, process streams, or compounds (inorganic and organic) prepared at ORNL; the identification of commercial products; or the characterization of organic compounds. Semiquantitative or quantitative determinations were made of a number of compounds.

11. Optical and Electron Microscopy

The electron microscope facility for the examination of ultrastructures of radioactive materials was established in Building 3019 and will be in operation about January 1965. Studies were made of particulates from simulated fallout experiments in connection with the Nuclear Safety Program. The Philips EM 200 electron microscope was installed; resolution of the order of 6 Å or better has been achieved with it. Research assistance was given in electron microscopy and diffraction and in optical microscopy to other divisions in studies of the surface and internal structure of thin films and solids, particle sizes and shapes, and radiation-induced physical and chemical changes in a wide range of materials. An electron microscopical study was made of the effect of cationic surfactants on the structure of thoria

sol-gel beads. The examination of the ultrastructure of certain exchange resins was begun. Vapor-deposited thin metallic films were made for the Physics Division to be used in their semiconductor experiments.

12. Nuclear and Radiochemical Analyses

Branching-ratio measurements and decay-scheme studies were made on ^{141}Ce , ^{79}Kr , ^{99}Mo - ^{99m}Tc , and a new isomer, ^{82m}Br . A study of successive neutron-capture reactions on La and Ce was begun. A search for new alpha emitters resulted in the discovery of alpha emission in ^{148}Eu . Nuclear levels were studied in a number of even- A nuclei, and neutron-deficient hafnium radionuclides produced in ORIC by (α, xn) reactions were investigated. The use of lithium-drifted germanium diodes for such decay-scheme studies and the effect of spectrometer live time on precision were evaluated. An IAEA ^{137}Cs standard intercalibration was done, and the absolute determination of ^{125}I by the sum-coincidence method was made. A gamma-spectrometric determination of ^{232}U was developed and applied. New half-life values for ^{76}As , ^{137}Cs , ^{140}La , and ^{232}U were measured. Trialkyl- and hexaalkylphosphorothioic triamides and metal di- n -butyl phosphorodithioates were studied as extractants for metals. Trivalent actinides were separated from lanthanides by liquid-liquid extraction with tricaprylmethylammonium thiocyanate. Technetium was separated and determined by cyclohexanone extraction. Cellulose column chromatography was used to separate trace quantities of 13 metal ions from uranium. Separation of tellurium isomers in different chemical media was studied; work continued on the determination of Kr and Xe fission yields from uranium. Studies relative to ore selection for Project Coach were made. A search for a naturally occurring transuranic radionuclide was unsuccessful. Cooperative work in low-level analysis continued. Two new liquid scintillators, 1-methylnaphthalene and N,N',N'' -trimethylborazine, were studied. A liquid-scintillation method for absolute counting of beta emitters was developed. Several different computer techniques were applied to the resolution of gamma-ray spectra.

A radio-release method was developed for the measurement of sulfur dioxide in the atmosphere. Radiotracers were used to study and to improve

chemical procedures for sodium, lithium, and phosphorus. The problem of separation of sodium from activated samples received continuing attention.

A study of precision in activation analysis was begun. In applications of activation analysis to forensic problems, ammunition primer and gunshot residues, as well as hair and paper, were studied. Trace-element nutritional investigations in humans and animals were continued, and a number of unusual samples, both biological and chemical, were analyzed. Analyses for trace elements in uranyl nitrate solutions and in high-purity Be, Al, and Fe were made by neutron activation. In addition, isotopic neutron sources were used for the analysis of organo-boron compounds and high-cross-section materials in reactor fuel elements.

A rapid method to calculate the output spectra from the 14-Mev neutron generator was formulated; a catalog of 14-Mev neutron reactions for elements of $Z = 3$ to 30 was prepared. Work on fast-neutron cross sections for titanium continued. An improved sample-irradiation and sample-handling system (primarily for oxygen determination) was designed. The neutron generator was used for the analysis of a number of materials and for the evaluation of neutron yields from experimental targets. Excitation functions and other nuclear data were gathered from experimental runs made at the 5.5-Mev Van de Graaff accelerator with ^3He particles; the potential usefulness of such procedures for activation analysis is being investigated.

13. Inorganic Preparations

The preparation of fused salts for the Metals and Ceramics Division and for the Chemistry Division continued on a reduced scale. For the latter division other preparations were several 30-g quantities of K_2S in fairly high purity and pound quantities of high-purity KCl and LiCl.

The Reactor Chemistry Division was provided with one or more preparations each of anhydrous AlCl_3 , ZrCl_4 , ThCl_4 , and MgCl_2 and a preparation of UCl_3 of fairly high purity.

For the Solid State Division dysprosium phosphide, DyP, was prepared in practically 100% purity, and a study of the holmium-sulfur system is being made. High-purity KCl is being produced for this division on a routine basis.

The Metals and Ceramics Division was provided with further preparations of K_2O and some alkali-metal niobates. The preparation of alloys that contain rare-earth metals was continued for the Physics Division. Other miscellaneous isolated preparations on a small scale were made for several other groups.

14. Organic Preparations

A number of special organic compounds that are not commercially available were synthesized on request from other research divisions. These compounds were: methyl isocyanide, N,N',N'' -trimethylborazine, 6-amino-3,9-diethyltridecane, two new monoacid esters, and α,α' -dipiperidyl.

PART B. SERVICE ANALYSES

15. Quality Control

The Statistical Quality Control Program increased during the year. Some 5200 control tests were made. A significant improvement occurred in the quality of work.

16. Mass Spectrometric Analysis

The Mass Spectrometry Laboratory analyzed 950 samples of 34 elements for the Stable Isotope Separation program. In addition, a wide variety of special gas samples were analyzed. Relative isotopic abundances were determined, and a number of radioactive samples were analyzed.

17. Spectrochemical Analysis Laboratory

In the Spectrochemical Analysis Laboratory, over 18,000 results were reported on some 1200 samples; the stable isotopes of about 34 elements were determined. A third of the analyses were for the Isotopes Division. The Wadsworth and Ebert spectrographs were relocated; one arc-spark stand now serves both instruments. With one exposure, 60 to 65 trace elements can be determined.

18. Process Analyses

The Process Analyses Laboratories performed 146,500 analyses. The Low-Level Radiochemical Laboratory was combined with the Radioisotopes-Radiochemistry Laboratory. A new glove-box line was installed in Building 3019 and will soon be in operation. A brief statement of the new developments in each laboratory follows.

The High-Level Alpha Radiation Laboratory reported over 10,000 results. Low levels of plutonium were determined for the Savannah River Laboratory. Plutonium sols were analyzed for nitrogen. Protactinium was determined in samples that contained various interferences.

The General Analyses Laboratory continued work on the determination of free HF and on measurements of coating density. A Technicon AutoAnalyzer was used to determine uranium and the detergent, ABS. Computer programs were coded for pycnometer density, total anion, permeability, and porosity measurements.

The General Hot Analyses Laboratory continued to work on the preparation for handling, treating, and analyzing radioactive materials anticipated from proposed programs. Methods and equipment were established for the MSRE and Curium Programs, and the training of the personnel was initiated. Special hot-cell work included electrolytic disintegration of graphite spheres, dissolution of irradiated graphite, and carbon determination.

The Materials Testing Laboratory continued the analysis of various fluoride salts, rocks and ores, alloys, and aqueous and organic solutions derived from fuel-reprocessing and waste-disposal studies. Specification tests were made on salts to be used in the MSRE.

The Radioisotopes-Radiochemistry Laboratory has had an increase in personnel and in the volume and variety of work performed. The low-level work and the intermediate-level work were consolidated and will be located at Y-12. Hot-cell gamma spectrometry is now being done in Building 3525. Many of the gamma spectra are now resolved by computers. The mass distribution of fission products formed by epicalmium-induced fission of ^{237}Np was measured.

The High-Radiation-Level Analytical Facility recently experienced a wide diversification of analytical work. The samples received varied

from graphite-coated uranium particles to large pieces of irradiated tubing. Procedures for the analysis of high-level alpha-emitting materials were adapted for use in glove-box-type shielded work cells.

The new High-Level Analytical Laboratory is completed. Minor changes and installation of equipment are now in progress. This laboratory should be ready to receive samples by November 1964.

A mockup of a cell in the Transuranium Facility is being constructed for use in the development and evaluation of methods.

19. Reactor Engineering Service Laboratory

The Reactor Engineering Service Analytical Chemistry Laboratory made ~5700 analyses on some 1160 samples, about half of which were from the Reactor Division. Both the samples and the methods of analysis varied widely.

PART C. ORNL MASTER ANALYTICAL MANUAL

20. ORNL Master Analytical Manual

The first revision to the cumulative indexes for the *ORNL Master Analytical Manual* was prepared by means of the same IBM 7090 computer program used last year. Information about the methods written in 1963 was added, thus making the indexes cumulative for the years 1953 through 1963. The updated indexes are available from the U.S. Department of Commerce; they are designated TID-7015 (Indexes), Revision 1.

A new Section 4, "Mass Spectrometric Methods," and also the Subsections 9 02, "Molten-Salt Reactor Experiment (MSRE) Methods," and 9 06, "Transuranium (TRU) Process Methods," were added to the *Manual*. Altogether, 106 new methods and revisions to 46 methods were issued, and the Table of Contents was revised. The sixth supplement to the reprinted form of the *Manual* (TID-7015, Suppl. 6) was issued.

The forthcoming need for new methods for the Division was determined, and methods-writing work was planned accordingly.

Contents

SUMMARY	iii

PART A. ANALYTICAL RESEARCH

1. ANALYTICAL INSTRUMENTATION	1
1.1 Recent Developments in DC Polarography	1
1.2 The Quasi-Reference Electrode (Q.R.E.), A Simple Reference Electrode. Applications in Controlled-Potential Polarography, Controlled-Potential Voltammetry, and Chronopotentiometry	2
1.3 Controlled-Potential DC Polarograph-Voltammeter. Design and Evaluation	3
1.4 Calculation of Diffusion Coefficient from the Koutecky Equation	3
1.5 ORNL Model Q-2564 High-Sensitivity Coulometric Titrator	4
1.6 Theory and Application of the Derivative Method to Stationary-Electrode Voltammetry with Linearly Varying Potential	4
1.7 Safety Circuit for the Multiplier Phototube of the ORNL Model VII Flame Spectrophotometer	4
1.8 Significance of Placement of the Reference Electrode in Controlled-Potential Coulometry	5
2. ANALYTICAL STUDIES OF MOLTEN-SALT SYSTEMS	5
2.1 Absorption Spectrophotometric Studies Related to Molten-Salt Systems	5
2.1.a Nickel High-Temperature Spectrophotometric Cell Assembly	5
2.1.b Containers for Molten-Fluoride Salts	5
2.1.c Absorption Spectra of U^{3+} in $LiF-BeF_2-ZrF_4$ and in $LiF-BeF_2$	6
2.1.d Studies of the Absorption Spectra of Molten Alkali-Metal-Alkali-Metal- Halide Systems	7
2.1.e Holder for Use in Obtaining Absorption Spectra of Small Crystals	7
2.1.f Absorption Spectrum of UF_6 Gas	7
2.2 Voltammetry of Molten-Fluoride Salt Systems	8
2.2.a New and Modified Equipment	8
2.2.b Decomposition Potentials of Pure Metals in Molten-Fluoride Salts	8
2.2.c Voltammetry of Ni^{2+} in Molten $LiF-NaF-KF$	9
2.2.d Voltammetry of the MSR Coolant Salt and MSR Fuel Salt	9
2.2.e Reference Electrodes Compatible with Molten-Fluoride Salts	10
2.3 Instrumental Approaches to Analysis of Fused Salts	11
3. EFFECTS OF RADIATION ON ANALYTICAL METHODS	12
3.1 Effect of ^{60}Co Gamma Radiation on the Reaction of Nickel with Dimethylglyoxime	12

3.2	Effect of ^{60}Co Gamma Radiation on the Determination of Uranium(VI) in Phosphoric Acid Solutions of Uranium(IV) Oxide.....	12
3.3	Effect of ^{60}Co Gamma Radiation on Arsenazo III Solutions.....	13
3.4	Effect of ^{60}Co Gamma Radiation on 2-Thenoyltrifluoroacetone (TTA) Solutions	13
3.5	Radiolysis of Chloride Solutions	13
4.	ANALYTICAL CHEMISTRY FOR REACTOR PROJECTS	14
4.1	Molten-Salt Reactor Experiment	14
4.2	Gas-Cooled Reactor	15
4.3	Transuranium Element Processing	15
5.	CHEMICAL ANALYSIS OF ADVANCED REACTOR FUELS	16
5.1	Gas Chromatograph for the Analysis of Corrosive Gases	16
5.2	Qualitative and Quantitative Analysis of Aliphatic Diluents by Gas Chromatography	16
5.3	Combustion-Gas Chromatographic Determination of Carbon in Aqueous and Nitric Acid Solutions	17
5.4	Dissolution or Decomposition of Various Materials.....	17
5.5	Polarography in Hydrofluoric Acid and Other Glass-Corroding Media.....	18
5.5.a	Evaluation of the Horizontal-Orifice Teflon D.M.E. for Use in Obtaining Fundamental Polarographic Data	19
5.5.b	Significance of Junction Potentials in the Measurement of $E_{1/2}$ Values	19
5.5.c	Polarography of the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ Reaction in Aqueous Hydrofluoric Acid with the Horizontal-Orifice Teflon D.M.E.	19
5.5.d	Extension of the Use of the Horizontal-Orifice Teflon D.M.E. by Others.....	20
5.5.e	Vertical-Orifice Rapid Teflon D.M.E.....	21
5.6	Chronopotentiometry of Plutonium	21
6.	SPECIAL RESEARCH AND DEVELOPMENT PROBLEMS	22
6.1	Reactions in Concentrated Lithium Chloride Solutions.....	22
6.2	Disposal of Radioactive Wastes in Natural Salt Formations	22
6.3	Solid Indicator Electrodes	23
6.3.a	Glassy-Carbon Indicator Electrode	23
6.3.b	Oxide Film Formation on the Pyrolytic-Graphite Electrode	23
6.3.c	Differential Potentiometry	23
6.3.d	Voltammetry	23
6.3.e	Amperometry	23
6.3.f	Chronopotentiometry	24
6.3.g	Instrumentation.....	24
6.4	Flame Ionization Determination of Parts-per-Billion Concentrations of Organic Contaminants in Air	24
6.5	Determination of Oxygen in Alkali Metals by a Modification of the Amalgamation Method.....	25
6.6	Determination of Carbon in Alkali Metals by High-Temperature Oxidation	26
6.7	Determination of Hydrogen in Alkali Metals by Amalgamation and Vacuum Extraction	26
6.8	Nonaqueous Titrimetry of Phenols	27

6.9	Titrimetry of Acids in Irradiated Liquids	27
6.10	Determination of Solids in Radioactive Waste-Disposal Slurries.....	27
6.11	Determination of Chloride with a Pyrolytic-Graphite Indicator Electrode	27
6.12	Pyrolytic-Graphite Cup as Both Vessel and Indicator Electrode for Micro Redox and Acid-Base Potentiometric Titrations.....	27
6.13	Coulometric Determination of ^{99}Tc	28
6.14	Colorimetric Determination of Samarium with Arsenazo III.....	28
6.15	Analysis of Arc-Fused Europium Molybdate	28
6.16	Coulometric Determination of Nickel	28
7.	ANALYTICAL BIOCHEMISTRY	29
8.	X-RAY AND SPECTROCHEMICAL ANALYSES.....	30
8.1	X-Ray and Spectrochemical Analyses (X-10)	30
8.1.a	X-Ray Analysis	30
8.1.b	Atomic Absorption	31
8.1.c	Flame Photometry	31
8.2	X-Ray and Spectrochemical Analyses (Y-12)	32
8.2.a	Disposable Spectrographic-Excitation Chamber for Radioactive Samples.....	32
8.2.b	Determination of Certain Impurities in Lithium Fluoride Powder by Spark Excitation.....	33
9.	MASS SPECTROMETRY.....	34
9.1	TRU Mass Spectrometry	34
9.2	Isotopic Composition of Atmospheric Neon.....	35
10.	INFRARED SPECTROSCOPY.....	35
11.	OPTICAL AND ELECTRON MICROSCOPY	36
11.1	Electron Microscopy of Radioactive Materials	36
11.1.a	Electron Microscope Facility for Studying Radioactive Materials	36
11.2	Nuclear Safety Program	37
11.3	Electron Optical Instrumentation	38
11.4	Electron and Optical Microscopy and Electron Diffraction Research Assistance to Other Laboratory Divisions	38
11.5	Ultrastructure Studies of Exchange Resins.....	39
12.	NUCLEAR AND RADIOCHEMICAL ANALYSES	39
12.1	Nuclear Properties of Radionuclides	39
12.1.a	Gamma-Ray Branching in the Decay of ^{141}Ce	39
12.1.b	Gamma Transitions in the Decay of ^{79}Kr	40
12.1.c	Decay of ^{99}Mo - ^{99m}Tc	41
12.1.d	New Isomer of Bromine: ^{82m}Br	41
12.1.e	Studies of Rare-Earth-Element Alpha Emitters	41
12.1.f	Properties of Nuclear Levels in a Number of Even- A Nuclei ($184 \leq A \leq 192$)	41
12.1.g	Studies of Neutron-Deficient Hafnium Radionuclides.....	42
12.1.h	Half-Life Measurements	42

12.1.i	Redetermination of the Half-Life of ^{232}U	42
12.1.j	Half-Life of ^{76}As	43
12.2	Measurement of Radioactivity	43
12.2.a	Epithermal Neutron Irradiation of Lanthanum to Produce ^{136}Cs	43
12.2.b	Gamma-Ray Spectroscopy with Lithium-Drifted Germanium Diode Detectors	43
12.2.c	Effect of Gamma Spectrometer Live Time on Precision of Measurements.....	44
12.2.d	International Atomic Energy Agency (IAEA) Intercomparison of Determinations of ^{137}Cs	45
12.2.e	Absolute Determination of ^{125}I in Clinical Applications	45
12.2.f	Determinations of ^{232}U by Gamma Spectrometry.....	45
12.3	Radiochemical Studies	46
12.3.a	Trialkyl- and Hexaalkylphosphorothioic Triamides as Extractants for Metal Ions. Selective Extraction of Hg^{2+} , Ag^{+} , and Cu^{+}	46
12.3.b	Metal Di- <i>n</i> -Butyl Phosphorodithioates as Extractants for Metals.....	46
12.3.c	A New Approach to the Separation of Trivalent Actinide Elements from Lanthanide Elements. Selective Liquid-Liquid Extraction with Tricaprylmethylammonium Thiocyanate	46
12.3.d	Rapid Separation and Determination of Technetium	47
12.3.e	Separation of Trace Metals from Uranium by Cellulose Column Chromatography	48
12.3.f	Chemical Effects of Isomeric Transitions. Separation of Tellurium Isomers in Different Chemical Media	48
12.3.g	Yields of Krypton and Xenon from Fission of Uranium	49
12.3.h	Ore Selection for Project Coach	49
12.3.i	Search for Natural Transuranic Radioactivity	50
12.3.j	Low-Level Analyses	50
12.4	Liquid Scintillators.....	51
12.4.a	Liquid Scintillators That Contain 1-Methylnaphthalene.....	51
12.4.b	N,N',N'' -Trimethylborazine as a Liquid-Scintillator Solvent for Thermal Neutron Detection	51
12.4.c	Absolute Counting of Beta Emitters by the Liquid-Scintillation Method.....	51
12.5	Application of Computers.....	53
12.5.a	Electronic Resolution of Gamma-Ray Spectra	53
12.5.b	Computer Program for Accumulating Standard Gamma-Ray Spectra and for Quality-Control Measurements.....	53
12.6	Application of Radioisotopes to Analytical Chemistry	53
12.6.a	Radio-Release Method for the Evaluation of Atmospheric Pollution. Sulfur Dioxide	53
12.6.b	Application of Radioisotopes to the Determination of Sodium, Lithium, and Phosphorus.....	54
12.6.c	Separation of Sodium	54
12.7	Activation Analysis	55
12.7.a	Study of Precision in Activation Analysis.....	55
12.7.b	Application of Activation Analysis to Forensic Science.....	55
12.7.c	Analysis of Bond Paper	56
12.7.d	Wool Analysis.....	56
12.7.e	Absorption of Trace Elements by Hair	56
12.7.f	Hair Analysis	57
12.7.g	Applied Neutron Activation Analysis	57
12.7.h	Activation Analysis of Uranyl Nitrate Solutions.....	57

12.7.i	Activation Analysis of High-Purity Materials	57
12.7.j	Neutron-Absorption Analysis with Isotopic Sources	58
12.7.k	Helium-3 Activation Analysis	58
12.8	14-Mev Neutron Generator	59
12.8.a	Output Spectrum from 14-Mev Neutron Generators; Its Rapid Estimation and Its Influence in Cross-Section Measurements and Activation Analysis	59
12.8.b	Catalog of 14-Mev Neutron Reactions	59
12.8.c	Titanium Irradiations at the 14-Mev Neutron Generator	59
12.8.d	Determination of Oxygen with 14-Mev Neutrons	59
12.8.e	Miscellaneous Uses of the 14-Mev Neutron Generator	60
13.	INORGANIC PREPARATIONS	60
14.	ORGANIC PREPARATIONS	61
14.1	Compounds Prepared	61
14.1.a	Methyl Isocyanide	61
14.1.b	N,N',N''-Trimethylborazine	62
14.1.c	6-Amino-3,9-diethyltridecane	62
14.1.d	Monoacid Esters	64
14.1.e	α,α' -Dipiperidyl	64
14.2	Determination of Aldehydes and Ketones	64
14.3	Purification of α -Methylnaphthalene	64
14.4	Current Programs	64

PART B. SERVICE ANALYSES

15.	QUALITY CONTROL	68
16.	MASS SPECTROMETRIC ANALYSIS	69
17.	SPECTROCHEMICAL ANALYSIS LABORATORY	69
18.	PROCESS ANALYSES	70
18.1	High-Level Alpha Radiation Laboratory	70
18.2	General Analyses Laboratory	70
18.3	General Hot Analyses Laboratory	71
18.4	Materials Testing Laboratory	72
18.5	Radioisotopes-Radiochemistry Laboratory	73
18.6	High-Radiation-Level Analytical Facility (HRLAF)	73
19.	REACTOR ENGINEERING SERVICE LABORATORY	74

PART C. ORNL MASTER ANALYTICAL MANUAL

20.	ORNL MASTER ANALYTICAL MANUAL	75
20.1	Cumulative Indexes to the <i>ORNL Master Analytical Manual</i>	75
20.2	Maintenance of the <i>ORNL Master Analytical Manual</i>	75

PRESENTATION OF RESEARCH RESULTS	77
INDEXES	97
Key Word Index	99
Author Index.....	125
ORGANIZATION CHART.....	133

Part A. Analytical Research

Research in a variety of fields of analytical chemistry was conducted during the past year for the Reactor, Physical Research, and Isotopes Development Divisions of the Atomic Energy Commission. Research was also conducted for the

various research divisions of the Oak Ridge National Laboratory on specific problems associated with the programs of the Laboratory.

The progress in these investigations is presented in the following sections.

---

1. Analytical Instrumentation

M. T. Kelley

D. J. Fisher

1.1 RECENT DEVELOPMENTS IN DC POLAROGRAPHY

D. J. Fisher   W. L. Belew
M. T. Kelley

A paper was presented¹ that summarized the work done at ORNL in controlled-potential dc polarography since mid-1959. The viewpoints and conclusions reached in the course of this work were discussed. The topics included were:

1. Potentiostatic compensation for polarographic cell resistance; principles of potentiostatic (controlled-potential) electrolysis
2. Time-derivative dc polarography
  - (a) Requirements for quantitative time-derivative dc polarography
  - (b) Additional requirements for optimum resolution and sensitivity

3. Signal-to-noise ratio (S/N)
  - (a) Definition of S/N
  - (b) Measurement of low-concentration polarograms
  - (c) Relative S/N of various kinds of polarized mercury electrodes
  - (d) Reproducibility of regular wave height and of first-derivative peak height
  - (e) Direct proportionality of first-derivative peak height to $\bar{i}_d$
  - (f) Relative signal levels in regular and in first-, second-, and third-derivative dc polarography
4. Resolution
  - (a) Criterion for relative resolving power of various methods of polarography
  - (b) Geometrical overlapping of successive waves
  - (c) Relative resolution of regular and of first- and second- derivative dc polarography
  - (d) Relative resolution of sinusoidal ac, square-wave, and first-derivative dc polarography
  - (e) Mathematical resolution of overlapped first-derivative dc polarograms
  - (f) Mathematical resolution of regular polarography compared with first-derivative dc polarography

---

¹D. J. Fisher, W. L. Belew, and M. T. Kelley, "Recent Developments in DC Polarography," presented at the 3rd International Congress of Polarography, Southampton, England, July 19-25, 1964 (to be published in the proceedings of the Congress).

5. DC polarography in nonaqueous solvents and, particularly, in solvent extracts
  - (a) Electrochemical requirements for polarography in nonaqueous solvents, especially in solvent extracts
  - (b) Controlled-potential dc polarography of metal complexes in solvent extracts

1.2 THE QUASI-REFERENCE ELECTRODE (Q.R.E.), A SIMPLE REFERENCE ELECTRODE. APPLICATIONS IN CONTROLLED-POTENTIAL POLAROGRAPHY, CONTROLLED-POTENTIAL VOLTAMMETRY, AND CHRONOPOTENTIOMETRY

D. J. Fisher   W. L. Belew
M. T. Kelley

The most essential requirement of any simple electrode that is to be used instead of a true reference electrode is constancy of potential during a particular experiment. The quasi-reference electrode (Q.R.E.) is a bright-platinum wire, or other inert conductor, immersed directly in the test solution; the immersed area may be very small. This electrode is used instead of a true reference electrode, but it must be used with potentiostatic or other circuits that prevent the drawing of the cell current through the Q.R.E. With this arrangement, the results are like those obtained with a true reference electrode, except that the Q.R.E. potential lacks thermodynamic meaning; hence, this simple electrode is called a quasi-reference electrode.

For a true reference electrode, the reaction that permits the passage of current through the electrode is reversible and is known; the electrode will not be polarized significantly if the current is substantially lower than the exchange current of the reaction. However, the resistance of the associated salt bridge and interface junctions may be high enough to cause significant iR error and current phase shift. Also, junction potentials may be of significant and variable magnitude. Nevertheless, when properly applied, the potential of a true reference electrode relative to that of a standard hydrogen electrode is predictable and reproducible. If electrolysis is performed with a potentiostat, only the potentiostat input current, which is very low, must be sustained by the electrode used as reference. Two extreme cases are represented by a

true reference electrode and by the Q.R.E., since in the latter case the reaction or reactions that permit passage of potentiostat input current through the Q.R.E. cannot be predicted. Sometimes it is inconvenient to use a true reference electrode having an exchange current high enough to permit the passage of cell current with negligible polarization. Also, such an electrode may not be available. It is important that a reference electrode having only a moderate exchange current (i.e., less than the cell current) can be used and will function in a potentiostatic circuit as a true reference electrode.

In many practical situations, the lack of thermodynamic significance of the potential assumed by the Q.R.E. is tolerable. The Q.R.E. has been used successfully for controlled-potential polarography, controlled-potential voltammetry, and chronopotentiometry in aqueous, organic, and molten-salt solvents of unspecified composition but constant overall composition. The form of the polarographic waves is conventional, but the observed $E_{1/2}$ is meaningless; a slow drift in Q.R.E. potential does not change the heights of regular polarograms or, at fast scan rates, of derivative polarograms.

The Q.R.E. is rugged, small, convenient to use, and simple to construct. It does not introduce impurities such as water or Hg^{2+} , Ag^+ , K^+ , or Cl^- ions. It can be used in corrosive solutions, will operate at high temperatures, and has a very low resistance. The Q.R.E. may be used instead of a true reference electrode when the quantity being measured as a function of concentration or of some other chosen variable is either the change in emf between the working and reference electrodes or the change in current at a constant or scanned applied cell voltage. The predominant consideration leading to the choice of any simple rather than true reference electrode is the relative convenience of use of these electrodes. The Q.R.E., like any other simple electrode, is not meant to compete with true reference electrodes if they are necessary or available and are equally convenient to use.

The Q.R.E. was discussed at the 3rd International Congress of Polarography.²

²D. J. Fisher, W. L. Belew, and M. T. Kelley, "A Simple Quasi Reference Electrode. Applications in Controlled-Potential Polarography and Voltammetry and in Chronopotentiometry," presented at the 3rd International Congress of Polarography, Southampton, England, July 19-25, 1964 (to be published in the proceedings of the Congress).

1.3 CONTROLLED-POTENTIAL DC POLAROGRAPH-VOLTAMMETER. DESIGN AND EVALUATION

D. J. Fisher   H. C. Jones
M. T. Kelley   R. W. Stelzner
W. L. Belew

A new controlled-potential dc polarograph-voltammeter was designed in which solid-state instead of vacuum-tube operational amplifiers and power supplies are used. A prototype unit was constructed. This compact instrument is intended for use with solid working electrodes and with short-drop-time Smoler vertical-orifice D.M.E.'s at which the current is diffusion controlled. Its features are

1. a fast potentiostatic circuit whose input voltages are referenced to circuit ground potential,
2. scan rates of 0.1, 0.2, 0.3, 0.5, 1.0, 2.0, 3.0, 5.0, 10.0, and 20.0 v/min,
3. current ranges (full-scale) from 0.02 μ a to 10 ma based on the 1, 2, 5 repetitive system,
4. X-Y recorder presentation of instantaneous or average current values as a function of the potential difference between the working and reference electrodes,
5. X-Y recorder presentation of the first, second, and third derivatives of the average current, each with calibrated scales, as a function of the potential difference between the working and reference electrodes, the recorded derivative waves and the recorded regular polarographic wave all having about the same height for a one-electron-change redox reaction ($n = 1$), thus eliminating scale-hunting,
6. prior-wave compensation by injection of a constant current of suitable magnitude into the input of the current amplifier.

The use of solid-state amplifiers and power supplies has reduced the amount of heat generated within the instrument. The use of solid-state amplifiers should also result in better control of the potential in the electrochemical cell because of the greater tolerance of these amplifiers to capacitive loading.

The polarograph-voltammeter is being evaluated with the Smoler vertical-orifice D.M.E.; it will also be evaluated with solid working electrodes. To

facilitate evaluation of the instrument in its polarographic function, normalized theoretical waves were calculated and plotted at 1-mv increments by a computer (Control Data Corporation model 1604-A). Regular and first-, second-, and third-derivative dc polarographic waves were plotted for a simple, reversible, diffusion-controlled process. The plots were computed for $n = 1, 2$, and 3. The amplitude and form of recorded polarographic waves will be compared with those of the theoretical waves. Similarly, the instrument will be evaluated in its voltammetric function.

The prototype will be used for continued research in polarography and voltammetry and as the basis of design of several controlled-potential dc polarograph-voltammeters for use in the Analytical Chemistry Division.

1.4 CALCULATION OF DIFFUSION COEFFICIENT FROM THE KOUTECKÝ EQUATION

R. W. Stelzner   W. L. Belew

The Koutecký equation,³

$$\bar{i}_d = 607nmC \left(\frac{D^{1/2}t^{1/6}}{m^{1/3}} \right) \left[1 + 34 \left(\frac{D^{1/2}t^{1/6}}{m^{1/3}} \right) + 100 \left(\frac{Dt^{1/3}}{m^{2/3}} \right) \right],$$

is regarded as the best mathematical description of the diffusion current in simple, reversible, diffusion-controlled, dc polarographic phenomena. By a trigonometric transformation, this cubic equation was solved for D ; this solution is suitable for use in making desk calculations of D . Also, a computer program, DIFFUSE, that solves the Koutecký equation for D was written.⁴ This program uses the subroutine VIETA to calculate explicitly the physically realizable root.

³J. Koutecký, "Correction for Spherical Diffusion to the Il'kovič Equation," *Czech. J. Phys.* **2**, 50 (1953).

⁴R. P. Rannie, Mathematics Division.

1.5 ORNL MODEL Q-2564 HIGH-SENSITIVITY COULOMETRIC TITRATOR

H. C. Jones

Two ORNL model Q-2564 titrators^{5,6} were fabricated by the Instrumentation and Controls Division and are now in use, one in the High-Radiation-Level Analytical Laboratory (HRLAL) and the other in the High-Level Alpha Radiation Laboratory. The Instrumentation and Controls Division completed the Q-2564 series of drawings. A check-out and test procedure (ORNL Test Specification ST-260) was written for use in ensuring that each newly constructed titrator meets the performance specifications. A set of simplified operating instructions was also prepared, and a troubleshooting guide was written for use with ST-260 in maintaining the titrators.

A paper describing this instrument and giving procedures for titrating micro- and milligram amounts of uranium and iron was written for publication in the open literature. About 25 complete sets of engineering drawings of the titrator were sent to interested installations in the United States and abroad.

1.6 THEORY AND APPLICATION OF THE DERIVATIVE METHOD TO STATIONARY-ELECTRODE VOLTAMMETRY WITH LINEARLY VARYING POTENTIAL

T. R. Mueller

S. P. Perone⁷

The theoretical shapes of the first, second, and third time derivatives of linear-sweep voltammetric curves were calculated for plane and spherical stationary electrodes for the case of simple reversible ion-ion or ion-amalgam electrode processes. Derivative-measurement techniques were tested experimentally with reversible electrodepositions at the hanging-mercury-drop electrode by electrolysis with linearly varying potential. Analytical

⁵H. C. Jones, D. J. Fisher, and W. D. Shults, "High-Sensitivity Coulometric Titrator," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1962*, ORNL-3397, p. 3.

⁶H. C. Jones, "ORNL Model Q-2564 High-Sensitivity Coulometric Titrator," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 3.

⁷Assistant Professor, Department of Chemistry, Purdue University, Lafayette, Ind.

characteristics of first-, second-, and third-derivative measurements were studied, the latter two in a cursory way only. The accuracy and reproducibility of first-derivative linear-sweep voltammetry are about the same as those of regular linear-sweep voltammetry, but the sensitivity is at least an order of magnitude greater.

This work was reported in a paper given at the 148th American Chemical Society Meeting⁸ and is tentatively scheduled for publication in the January issue of *Analytical Chemistry*.

1.7 SAFETY CIRCUIT FOR THE MULTIPLIER PHOTOTUBE OF THE ORNL MODEL VII FLAME SPECTROPHOTOMETER

R. W. Stelzner

The EMI/US⁹ 9558QA multiplier phototube, which costs \$633, is used in the ORNL model VII flame spectrophotometer¹⁰ to span the wavelength range from 2000 to 8700 Å. The phototube is powered from a John Fluke Manufacturing Company model 412A voltage-regulated power supply. When certain circuit failures occur in this power supply, voltages greater than the tube manufacturer's recommended maximum are applied to the phototube, possibly resulting in its loss.

A safety circuit has been developed and installed that senses the onset of an excessive applied voltage of either polarity and automatically shuts down the power supply, even when the instrument is unattended. A 1-ma relay and a suitable resistor string, plus the existing switching circuitry of the model 412A power supply, are used to accomplish rapid shutdown and manual start-up. In two such power-supply failures, the safety circuit operated successfully to save the multiplier phototube.

⁸S. P. Perone and T. R. Mueller, "The Application of Derivative Techniques to Stationary Electrode Polarography," presented at the 148th Meeting of the American Chemical Society, Chicago, Illinois, Aug. 30–Sept. 4, 1964.

⁹Electra Megadyne, Inc. (EMI/US) has been purchased by Whittaker Corporation, 9229 Sunset Blvd., Los Angeles, Calif., and has been renamed GENCOM Division, Whittaker Corporation, 151 West 46th Street, New York 36, N.Y.

¹⁰H. C. Jones, D. J. Fisher, and M. T. Kelley, "Model VII Flame Spectrophotometer," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, pp. 7–8.

1.8 SIGNIFICANCE OF PLACEMENT OF THE REFERENCE ELECTRODE IN CONTROLLED-POTENTIAL COULOMETRY

T. R. Mueller

The $\text{Cu}^{2+}\text{-UO}_2^{2+}$ experiment,¹¹ made to detect possible error in the controlled potential (driving voltage of electrochemical reaction at the controlled working electrode exceeding command volt-

¹¹R. W. Stelzner, D. J. Fisher, and M. T. Kelley, "Reference Electrode Placement in Controlled-Potential Coulometry," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, pp. 9-12.

age set into the potentiostat) arising from non-uniform current distribution in an electrochemical cell, was repeated with the $\text{Bi}^{3+}\text{-UO}_2^{2+}$ system in 1 M HClO_4 . Since the exchange current for the reduction of Bi^{3+} is small with respect to that of Cu^{2+} , the probability of loss of uranium should be greater in the $\text{Bi}^{3+}\text{-UO}_2^{2+}$ system than in the $\text{Cu}^{2+}\text{-UO}_2^{2+}$ system. As for the $\text{Cu}^{2+}\text{-UO}_2^{2+}$ system, so for the $\text{Bi}^{3+}\text{-UO}_2^{2+}$ system, there was no chemical evidence (loss of uranium) that variation in placement of the reference electrode, even under drastic cell conditions, causes measurable error in the controlled potential.

2. Analytical Studies of Molten-Salt Systems

J. C. White

2.1 ABSORPTION SPECTROPHOTOMETRIC STUDIES RELATED TO MOLTEN-SALT SYSTEMS

J. P. Young

Absorption spectrophotometric studies of various molten-salt systems were continued. The primary objective is to evaluate the applicability of absorption spectrophotometry to the determination of ionic species in molten-fluoride-salt systems of interest to the Reactor Chemistry Division. To do this, it is necessary to investigate the nature of the dissolved species as well as their stability and compatibility with respect to other dissolved species and solids that are in contact with the melt.

2.1.a Nickel High-Temperature Spectrophotometric Cell Assembly

Hydrolytic contamination of melts occurred in the operation of the nickel high-temperature cell assembly described previously.¹ It was assumed that small amounts of HF gas, liberated from the

molten-fluoride samples, reacted with a NiO coating on the interior surface of the nickel cell and that the resultant water reacted with the melt to liberate HF. Because of the relatively large area of nickel metal compared with the small volume of sample, this process could go on indefinitely. The hydrolytic contamination was eliminated by cleaning the interior of the cell assembly with nickel wool and placing chips of sponge titanium in the sample compartment to react preferentially with H_2O , O_2 , and HF gas. The stability of the absorption spectrum of U^{4+} in LiF-NaF-KF over a period of about 15 hr indicated that contamination had been eliminated.

Installation of limit-control switches in the power supply of the high-temperature cell assembly has made possible the safe operation of the assembly overnight, if necessary.

2.1.b Containers for Molten-Fluoride Salts

The formation and stability of U^{3+} in LiF-BeF_2 and in $\text{LiF-BeF}_2\text{-ZrF}_4$, which are the coolant and fuel solvent respectively of the MSR, were studied by allowing various metal reductants to react with the molten salt that contained U^{4+} . The procedure often consisted in placing a piece of the metal

¹J. P. Young, "Spectrophotometric Studies of Molten-Salt Systems," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, pp. 25-30.

reductant of interest in a windowless container of the pendent-drop type² and filling the container with the molten salt by immersion. The filled container was brought immediately into the optical path for observation. All the containers for molten salts were made of copper, which is reasonably compatible with reactants and possible products. Studies by the Reactor Chemistry Division have shown that BeF_2 -containing melts do not wet a clean copper surface. It is thought that the original captive-liquid cell³ functions because liquids wet the surface of the container. It was assumed that the small "keeper" holes of the captive-liquid cell might not be needed in a cell designed to hold nonwetting liquids. Recent experimental results confirm this assumption. The path length and constancy of path length of liquids contained in such a modified cell are not known. These studies are being continued.

²J. P. Young, "Spectrophotometric Studies of Molten Salts," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1960*, ORNL-3060, pp. 67-70.

³J. P. Young, "Windowless Spectrophotometric Cell for Use with Corrosive Liquids," *Anal. Chem.* **36**, 390 (1964).

2.1.c Absorption Spectra of U^{3+} in $\text{LiF}-\text{BeF}_2-\text{ZrF}_4$ and in $\text{LiF}-\text{BeF}_2$

The absorption spectrum of U^{3+} at 500°C in $\text{LiF}-\text{BeF}_2-\text{ZrF}_4$ compared with its previously reported¹ spectrum in $\text{LiF}-\text{NaF}-\text{KF}$ is shown in Fig. 2.1. A solution of U^{3+} in $\text{LiF}-\text{BeF}_2-\text{ZrF}_4$ was prepared by reduction of U^{4+} with either Zr^0 or U^0 . For this system, the molar absorptivity of the strongest U^{3+} peak in the near-infrared region (875 $\text{m}\mu$) is estimated to be 40 liters $\text{mole}^{-1} \text{cm}^{-1}$. In the visible-ultraviolet region, the spectrum of U^{3+} is very intense, and the position of the main peak is in the ultraviolet rather than the visible, as might be expected. Indeed, dilute solutions of U^{3+} in BeF_2 melts are yellow, whereas those of U^{3+} in $\text{LiF}-\text{NaF}-\text{KF}$ are red. The molar absorptivity at the wavelength of maximum absorbance, 360 $\text{m}\mu$, is estimated to be 500 liters $\text{mole}^{-1} \text{cm}^{-1}$. The spectrum of U^{3+} in $\text{LiF}-\text{BeF}_2$ appears to be identical with that in $\text{LiF}-\text{BeF}_2-\text{ZrF}_4$.

The intensity of the 360- $\text{m}\mu$ peak of U^{3+} in these melts provides a sensitive means of observing reactions that either generate or consume U^{3+} . An example of this use is the kinetic study made of

Fig. 2.1. Spectra of U^{3+} in Molten-Fluoride Media.

the reduction of U^{4+} (~ 1000 ppm) with Zr^0 in $LiF\text{-}BeF_2\text{-}ZrF_4$. It was assumed that the reduction of U^{4+} is essentially quantitative and that it is therefore possible to measure the loss of U^{4+} by formation of U^{3+} , observed spectrophotometrically. Such spectrophotometric absorption measurements indicate that the reduction of small amounts of U^{4+} by Zr^0 is first order with respect to U^{4+} concentration over the temperature range studied (480 to 540°C); the specific rate constants are 0.042, 0.065, and 0.10 per minute at 480, 510, and 540°C respectively.

In the molten solvents $LiF\text{-}BeF_2$ and $LiF\text{-}BeF\text{-}ZrF_4$ at 500 to 550°C, U^0 is partly oxidized to U^{3+} . The mechanism of this reaction is not understood. Possibly, contaminant ions in the melt, such as Fe^{2+} , Cr^{2+} , and Ni^{2+} , are being reduced. No spectrophotometric evidence for the existence of Zr^{3+} has been observed under any experimental situation where it might be expected to occur, for example, the reaction of Zr^0 with Zr^{4+} . Likewise, in the reaction of U^{4+} with Zr^0 , no peaks attributable to any species other than U^{3+} are observed.

A paper in which the results of these studies were discussed was presented.⁴

2.1.d Studies of the Absorption Spectra of Molten Alkali-Metal-Alkali-Metal-Halide Systems

The vacuum-tight crystalline Al_2O_3 cell mentioned previously¹ was constructed and used. This work is being done in cooperation with H. R. Bronstein.⁵ Attempts were made to observe the absorption spectra of the systems $K\text{-}KBr$ and $Na\text{-}NaI$, both above and below their melting points. However, in the molten state both systems are opaque. A vapor bubble was seen in the melt $K\text{-}KBr$; the spectrum of this vapor was that of a mixture of K atoms and K_2 . The melt solidified to a violet crystalline mass, the spectrum of which appears to be that of an R_2 band (derived from F bands) in KBr . The solidified $Na\text{-}NaI$ melt is a blue crystalline mass, the spectrum of which can be ascribed to F bands.

⁴J. P. Young, "Direct Spectrophotometric Studies of Redox Reactions in Molten Fluoride Salts," paper presented at 15th Meeting of the Comité International de Thermodynamique et de Cinétique Electrochimiques, London, England, Sept. 21, 1964.

⁵Chemistry Division.

2.1.e Holder for Use in Obtaining Absorption Spectra of Small Crystals

In cooperation with G. W. Clark,⁶ a special holder for very small crystals (Fig. 2.2) was devised for use in obtaining their spectra. With this holder and the Cary model 14 M recording spectrophotometer, provided with the model 1471200 high-intensity light source, it is possible to obtain spectra of crystals of diameter slightly larger than 0.1 mm in the wavelength range from about 280 to 750 $m\mu$; for crystals of 0.3 mm diameter or larger, spectra can be observed over most of the wavelength range of the Cary spectrophotometer. When the apparatus is properly aligned in the sample compartment, its base-line response is linear and is independent of slit width at slit widths of <0.3 mm. The holder should be generally useful in spectral studies of small crystals, such as those of interest to ceramists, those sometimes obtained from molten salts, and those that are solutes to be dissolved in molten salts.

A detailed description of the holder is being prepared for publication in *Analytical Chemistry*.

2.1.f Absorption Spectrum of UF_6 Gas

Although not directly related to molten-fluoride salts, UF_6 is an important chemical entity and

⁶Metals and Ceramics Division.

Fig. 2.2. Holder for Use in Obtaining Absorption Spectra of Small Crystals.

one that can form if solutions of U^{4+} in molten-fluoride salts are subjected to oxidizing conditions such as those in the Fluoride Volatility Process. Technique and experience in spectral determinations of such gaseous materials as UF_6 and F_2 are therefore of value in spectrophotometric studies of fluoride systems. J. Winnick⁷ was interested in the use of ultraviolet spectrophotometry for in-line determination of UF_6 in gas streams of the Fluoride Volatility Process. Such a gas stream would contain UF_6 , MoF_6 , and F_2 in varying concentrations. A fluorinated-nickel gas cell of 10 cm path length was constructed; it has crystalline Al_2O_3 windows and Teflon gaskets and is vacuum-tight. This cell was used to determine the absorption spectrum of UF_6 . The results show that UF_6 has a complex absorption band in the region from 340 to 420 $m\mu$ with a maximum at 368 $m\mu$, at which wavelength the molar absorptivity of UF_6 is 5.5 liters mole⁻¹ cm⁻¹ $\pm$ 2% over a pressure range from 20 to 100 mm at room temperature. The results from a limited number of spectrophotometric determinations of UF_6 in MoF_6 and F_2 compare favorably with mass spectrometric results. A preliminary report of this work has been written;⁸ the study is being continued.

2.2 VOLTAMMETRY OF MOLTEN-FLUORIDE SALT SYSTEMS

J. M. Dale   D. L. Manning

2.2.a New and Modified Equipment

A vacuum dry box (S. Blickman, Inc., Weehawken, New Jersey) was installed. Leak-rate tests showed that the box conforms to the manufacturer's specification (not $>1 \mu/hr$ at 10 μ pressure). Argon is used inside the box as the inert-gas cover. Traces of moisture and oxygen are removed from the argon by passing it through a trap that contains hot titanium sponge metal. The box is used in the handling and transfer of the various fluoride salts being studied by electroanalytical and spectrophotometric techniques.

⁷Summer research participant (Chemical Technology Division), Department of Chemical Engineering, University of Missouri, Columbia.

⁸J. Winnick, *A Preliminary Investigation of the Use of Ultraviolet Spectrometry for the Analysis of UF_6 - F_2 - MoF_6 Mixtures*, Sept. 14, 1964 (unpublished report).

The apparatus, described earlier,⁹ for containing molten fluorides was modified to provide better control of vacuum or inert-gas cover over the melt. Additional graphite electrolysis cells were fabricated. They were cleaned ultrasonically to minimize the amount of graphite dust that floats on top of the melt. Abnormal amounts possibly could cause an electrical short circuit within the cell.

2.2.b Decomposition Potentials of Pure Metals in Molten-Fluoride Salts

Before the current-voltage characteristics of various electroactive species in melts are investigated, it is desirable to determine the approximate potential at which a particular species undergoes oxidation or reduction. Table 2.1 gives the approximate decomposition potentials of several metals in molten fluorides. If a reasonable degree of reversibility of the $M \rightleftharpoons M^{n+} + ne$ electrode reaction is assumed, the potentials of the various oxidation-reduction waves can be approximated from such values. For example, in molten LiF - NaF - KF the decomposition potentials of iron and nickel are about the same as the half-wave potentials for the reductions of Fe^{2+} and Ni^{2+} at the pyrolytic-graphite indicator electrode. This relationship between potentials also exists for chromium in molten LiF - BeF_2 - ZrF_4 .

For any two particular metals, the difference between decomposition potentials is the only characteristic that should be compared from melt to melt. This limitation is due to the arbitrary zero potential of the platinum quasi-reference electrode. The difference between the decomposition potentials for chromium and iron appears to be larger in LiF - BeF_2 - ZrF_4 than in the other two melts. In both LiF - NaF - KF and LiF - BeF_2 (see Table 2.1) the decomposition potentials of chromium and iron are almost the same; this lack of difference makes their separation difficult, if not impossible.

⁹D. L. Manning, "Voltammetry of Iron in Molten Lithium Fluoride-Potassium Fluoride-Sodium Fluoride," *J. Electroanal. Chem.* 6, 227 (1963).

Table 2.1. Approximate Decomposition Potentials of Pure Metals in Molten Fluorides at 500°C

Metal	Decomposition Potential (v vs platinum quasi-reference electrode)		
	In LiF-NaF-KF (46.5-11.5-42.0 mole %)	In LiF-BeF ₂ ^a (66.0-34.0 mole %)	In LiF-BeF ₂ -ZrF ₄ (65.6-30.7-3.7 mole %)
Zr	-1.3	-1.5	-1.5
Cr	-0.5	-0.6	-0.8
Fe	-0.6	-0.5	-0.3
Ni	-0.2	-0.2	+0.1
Mo	+0.3		
W	+0.5		
Cu			+0.5
Ag	+0.8		
Pt	+1.5	+1.6	

^aG. Mamantov, Reactor Chemistry Division and University of Tennessee, private communication to J. M. Dale and D. L. Manning, July 1964.

2.2.c Voltammetry of Ni²⁺ in Molten LiF-NaF-KF

Rapid-scan and anodic-stripping voltammetry of nickel in molten LiF-NaF-KF (46.5-11.5-42.0 mole %) were studied. The half-wave potential for the reduction $\text{Ni}^{2+} \rightarrow \text{Ni}^0$ occurs at about -0.2 v vs the platinum quasi-reference electrode. Current-voltage curves were recorded with a pyrolytic-graphite indicator electrode at voltage scan rates from 50 mv/min to 10 v/min. At the faster scan rates, peak-shaped curves resulted which indicate that the transport process is mainly diffusion controlled. The diffusion coefficient for Ni²⁺ was calculated to be $\sim 1 \times 10^{-6} \text{ cm}^2/\text{sec}$ at 500°C. Anodic stripping shows promise as a way to determine directly trace concentrations of nickel in the melt; as little as 1 ppm can be detected. An article on this work has been published.¹⁰

2.2.d Voltammetry of the MSR Coolant Salt and MSR Fuel Salt

MSR Coolant Salt. — A sample of LiF-BeF₂ (66.0-34.0 mole %), which is the coolant salt for the MSR, was received from J. H. Shaffer of the

Reactor Chemistry Division. The batch of salt from which the sample was taken had been treated with beryllium metal and then filtered to remove traces of reducible impurities. Current-voltage curves recorded subsequently at a pyrolytic-graphite indicator electrode showed no reduction waves that could be attributed to electroactive impurities such as Fe²⁺ or Ni²⁺. A small rather ill-defined wave is observed at about -1.1 v vs the platinum quasi-reference electrode. This wave is believed to be due to the reduction of Zr⁴⁺, since zirconium in small concentration (700 ppm) was found in the sample by chemical analysis. This wave will be studied further after standard additions of ZrF₄ are made to the melt.

The potential at which the cell current becomes too large to measure (potential limit of the melt) is about -1.7 v vs the platinum quasi-reference electrode. It is believed that at this potential, Be²⁺ is being reduced at the pyrolytic-graphite indicator electrode.

MSR Fuel Salt. — A separate experimental system was set up to permit the study of LiF-BeF₂-ZrF₄ (65.6-30.7-3.7 mole %), which is the fuel salt for the MSR. Cathodic scans of the melt have consistently shown a cathodic peak at about -1.3 v vs the platinum quasi-reference electrode. The peak is too large to be accounted for by the impurities known from initial wet analyses to be present in

¹⁰D. L. Manning, "Voltammetry of Nickel in Molten Lithium Fluoride-Sodium Fluoride-Potassium Fluoride," *J. Electroanal. Chem.* 7, 302 (1964).

the salt. Subsequent spectrographic analysis of the melt indicated the presence of ~ 1800 ppm hafnium. The current-voltage curves were analyzed on the assumption that the peak was due to hafnium. From a plot of peak current vs square root of voltage scan rate, a value for the electron change (n) of 4.2 was obtained as compared with an expected value of 4. Although this result does not prove that the peak is due to hafnium, it does indicate that further experimental work should be done to determine whether or not hafnium is present.

The cathodic limit of the melt occurs at about -1.5 v vs the platinum quasi-reference electrode. It is believed that Zr^{4+} is being reduced at the pyrolytic-graphite indicator electrode at this potential.

The fuel salt was made 2.5 mM in CrF_2 , after which a cathodic wave appeared at about -0.8 v vs the platinum quasi-reference electrode; this is the approximate potential for the oxidation of chromium metal (see Table 2.1). Further study of the chromium system was hindered by difficulties encountered with the pyrolytic-graphite indicating electrode. New methods for fabricating this electrode are being investigated.

2.2.e Reference Electrodes Compatible with Molten-Fluoride Salts

Platinum Quasi-Reference Electrode. — It appears that the platinum quasi-reference electrode is not as well poised in $\text{LiF-BeF}_2\text{-ZrF}_4$ and LiF-BeF_2 as it is in LiF-NaF-KF . This poor behavior was first observed in $\text{LiF-BeF}_2\text{-ZrF}_4$ when the cathodic limit shifted from about -1.2 to -1.5 v vs the platinum quasi-reference electrode after controlled-potential electrolysis was performed in an attempt to remove reducible impurities from the melt. The negative shift also occurred when the system was evacuated. When the cell was allowed to stand under a confined inert-gas cover, the limit drifted in the positive direction. However, the more negative limit could be maintained after evacuation if the cover gas was allowed to flow through the system. Similar results were found subsequently for LiF-BeF_2 .

Ni-NiO Reference Electrode. — Reference electrodes similar to the one used by Steinmetz¹¹ were prepared. These electrodes consist of an

intimate mixture of powdered nickel metal and NiO contained in a ZrO_2 tube. Contact to the Ni-NiO mixture is made with a nickel wire. When the electrode is immersed in the melt, the ZrO_2 becomes a solid ionic conductor (oxide ion membrane) and thus serves as a "salt bridge." The electrode supposedly is a second-order electrode that is stabilized by the oxide ion activity in the solid Ni-NiO mixture at 500°C .

Current-voltage curves from the $\text{LiF-BeF}_2\text{-ZrF}_4$ melt recorded by use of the Ni-NiO electrode did not compare favorably with those obtained with the platinum quasi-reference electrode. The high resistance of the ZrO_2 tube was not the problem, since satisfactory curves were obtained when a 20-kilohm resistor was placed in series with the platinum quasi-reference electrode. The potential of the Ni-NiO reference electrode vs the platinum quasi-reference electrode was followed during a normal voltage scan with the Ni-NiO electrode in the cell circuit. When current started to flow between the working electrode and the counter electrode, the difference in potential between the Ni-NiO and the platinum quasi-reference electrodes varied. Another test was made by using the platinum quasi-reference electrode in the cell circuit and measuring the potential difference between the Ni-NiO electrode and ground during a normal voltage scan. The results showed that the Ni-NiO electrode did not follow the potential of the solution but, in fact, deviated by 0.5 v over a 1.5 -v scan. Tests were also performed in which current-voltage curves from the LiF-BeF_2 melt were recorded with the Ni-NiO electrode in the circuit while the potential of the Ni-NiO electrode vs the platinum quasi-reference electrode was monitored. In this case the difference in potential between the Ni-NiO reference and platinum quasi-reference electrodes did not deviate by more than ± 10 mv throughout the recording of the current-voltage curve.

In an effort to improve the performance of the Ni-NiO reference electrode, the dry Ni-NiO mixture inside the ZrO_2 tube was replaced with LiF-BeF_2 melt that contained an excess of NiO (5 wt %) so as to form a saturated solution of NiO. The resistance of the electrode decreased from ~ 18 to 4-to-6 kilohms, and the general operating characteristics of the electrode improved when it was used in the three-electrode controlled-potential circuit. Over a two-week period the cathodic limit of the $\text{LiF-BeF}_2\text{-ZrF}_4$ melt remained within

¹¹H. Steinmetz, *Development of a Continuous Meter for Oxygen in Sodium*, UNC-5032 (August 1962).

a 0.04-v span with respect to the Ni-NiO electrode, as compared with a 0.3-v span with respect to the platinum quasi-reference electrode. The cathodic limit of the LiF-BeF₂ melt remained constant at -1.85 ± 0.02 v vs the Ni-NiO electrode for a three-week test period. The limits were not affected by static or flowing conditions of the inert-gas cover, as was observed previously for the platinum quasi-reference electrode. It now appears that this type of electrode is a useful reference for molten-salt voltammetry with the three-electrode controlled-potential circuit. However, it could not be used with confidence in a two-electrode circuit, because the cell current that flows through the reference electrode under these conditions could possibly cause polarization and subsequent erratic potential values.

2.3 INSTRUMENTAL APPROACHES TO ANALYSIS OF FUSED SALTS

C. A. Horton

The ability to analyze radioactive molten-fluoride eutectics, either on or off stream, would be helpful in the operation of molten-salt reactors. In addition to absorption spectrophotometry and electroanalytical methods, which are now under study, several other instrumental techniques are being considered on a theoretical basis; some preliminary experimental work was done on a few of these. The determination of minor components of fused alkali-metal fluoride, beryllium fluoride, and uranium(IV) fluoride eutectics has been stressed, prime consideration being given to the effects of high radioactivity. The minor components of importance include oxide, Cr²⁺, Ni²⁺, Fe²⁺, Fe³⁺, and U³⁺.

Electron spin resonance was indicated by Llewellyn¹² to be a possible method for determining Cr²⁺, Ni²⁺, Cu²⁺, Fe²⁺, Fe³⁺, U³⁺, and

U⁴⁺ in solid or liquid fluorides. Others^{13,14} suggest that in liquid samples the possibility exists for iron only but that electron-spin-resonance measurements might be made at liquid-nitrogen or liquid-helium temperatures. Electron-spin-resonance spectra were obtained at 77 and 295°K for the fluorides of U³⁺, U⁴⁺, and both; these fluorides were present in several concentrations in powdered alkaline-earth-metal fluorides that contained impurity ions of various concentrations and in powdered uranium-doped calcium fluoride. The spectra indicate that, at temperatures of 77°K and lower, U³⁺ (~250 ppm) can be determined in the presence of 1% of U⁴⁺ in the molten-fluoride eutectic and very low concentrations of other impurities. At these temperatures, Cr²⁺, Ni²⁺, Fe²⁺, and Fe³⁺ in concentrations from 20 to 50 ppm produce disturbing resonance effects that have not been studied carefully.

Estimation of iron, zirconium, and total uranium in MSRE-type fuels should be possible by x-ray absorption or emission spectroscopy. A special x-ray spectrometer would be necessary. Determination of U³⁺:U⁴⁺ ratios by fine-line effects on absorption or emission spectra would probably fail for melts. Radioactivity effects could be minimized in x-ray methods by the combined use of collimation, shielding, and pulsed-source ac detectors, together with a thin, curved analyzing crystal maintained at a high temperature to avoid radiation damage.

Russian workers^{15,16} indicate that U³⁺-doped crystals of alkaline-earth-metal fluorides fluoresce at four wavelengths: 2151, 2210, 2420, and 2490 mμ; of these the first two are also absorption bands. Likewise, similar crystals have a laser emission in the region from 2.2 to 2.8 μ; such laser emission has not been observed for U⁴⁺. An unsuccessful attempt was made to duplicate the Russian work using fluoride powders. It was found that fluorescence decreases in intensity at higher temperatures; thus a laser operation would be needed for the estimation of U³⁺. The high temperature and the corrosive and radioactive

¹²P. M. Llewellyn, "Some Applications of Paramagnetic Resonance," Ph.D. thesis, St. John's College, Oxford University, Oxford, England, 1956; personal communication, 1963-64.

¹³J. Brown, "Electron Spin Resonance in Solid and Liquid Salt Mixtures," *J. Phys. Chem.* **67**, 2524 (1963).

¹⁴L. Yarnes, M. Kukk, and B. R. Sundheim, "Paramagnetic Resonance Spectrum of Manganese(II) Chloride in Molten Alkali Halides," *J. Chem. Phys.* **40**, 33 (1964).

¹⁵L. N. Galkin and P. P. Feofilov, "Luminescence of Trivalent Uranium," *Soviet Phys. "Doklady" (English Transl.)* **2**, 255 (1957); *Doklady Akad. Nauk SSSR* **114**, 745.

¹⁶P. P. Sorokin and M. J. Stevenson, *Advances in Quantum Electronics* (ed. by J. R. Linger), p. 65, Columbia University Press, New York, 1961.

nature of these samples would make experimental production of simulated emission very difficult.

Infrared and Raman spectroscopy, emission and mass spectrometry, and nuclear magnetic resonance¹⁷ seem less applicable for the determination of minor components in fused salts than the methods just discussed. However, infrared and

Raman spectroscopy have been used for melts.¹⁸⁻²¹

¹⁸G. J. Janz, C. Baddiel, and T. R. Kozlowski, "Vibrational Spectra of Molten Mercuric Halides. IV. $\text{HgCl}_2\text{-KCl-KNO}_3$," *J. Chem. Phys.* **40**, 2055 (1964).

¹⁹G. J. Pontrelli, "The Raman Spectra of Selected Molecules at Elevated Temperatures," Ph.D. thesis, University of Wisconsin, 1963.

²⁰J. Greenberg, "Near-Ultraviolet, Visible, and Infrared Spectra of Molten KSCN and NaSCN ," *J. Chem. Phys.* **39**, 3158 (1963).

²¹J. K. Wilmshurst, "Infrared Spectra of Highly Associated Liquids and the Question of Complex Ions in Fused Salts," *J. Chem. Phys.* **39**, 1779 (1963).

¹⁷S. Hafner and N. H. Nachtrieb, "Nuclear Magnetic Resonance in Molten Salts. I. Chemical Shift of Crystalline and Molten Thallium Salts," *J. Chem. Phys.* **40**, 2891 (1964).

3. Effects of Radiation on Analytical Methods

J. C. White

3.1 EFFECT OF ^{60}Co GAMMA RADIATION ON THE REACTION OF NICKEL WITH DIMETHYLGLYOXIME

H. E. Zittel

Study of the effect of ^{60}Co gamma radiation on the reaction of nickel with dimethylglyoxime (*I*) was completed. The significance of ethyl alcohol concentration, *I* concentration, radiation-dose level, and accumulated radiation was determined. A very important discrepancy exists between the behavior of *I* and the Ni-I complex toward radiation. Spectrophotometric studies of the Ni-I complex made immediately after irradiation showed that a postirradiation effect exists. Data taken earlier indicated that the Ni-I complex is more stable toward radiation than is *I* itself. The new data indicate that radiation has considerable effect on the color of the Ni-I complex but that the color "grows back" after the complex is removed from the radiation source. Extrapolation of the data to zero time (i.e., exact time of removal from the radiation source) shows that the radiation damage to the Ni-I complex is a linear function of radiation dose. This postirradiation effect is not a function of the amount of Ni or *I* present. Possibly the radiation damage to the Ni-I complex is

due to reduction of the Ni(III) in the colored complex.

The results of this study are being prepared for publication.

3.2 EFFECT OF ^{60}Co GAMMA RADIATION ON THE DETERMINATION OF URANIUM(VI) IN PHOSPHORIC ACID SOLUTIONS OF URANIUM(IV) OXIDE

G. L. Kochanny

The effect of ^{60}Co gamma radiation on aerated and deaerated H_3PO_4 solutions of uranium(IV) oxide (UO_2) was studied as a function of temperature, concentration of UO_2 , and radiation dose rate. The effect was measured in terms of the radiolytic yield of U(VI) , $G_{\text{U(VI)}}$. For solutions of high initial UO_2 concentration, $G_{\text{U(VI)}}$ is largest for the aerated solutions at 25°C ; it is lowest for the deaerated solutions at 140°C . The $G_{\text{U(VI)}}$ is lower for solutions of low initial UO_2 concentration than for any of the solutions of high initial UO_2 concentration. At the high starting UO_2 concentration, the initial $G_{\text{U(VI)}}$ values are always higher than the succeeding values; this effect is attributed to the depletion of oxygen

originally present in the solution. Gamma radiation causes an error in the determination of the stoichiometry of UO_2 ; the error is a function of the radiation dose. This error can be minimized by excluding oxygen from solutions of UO_2 and by keeping the initial UO_2 concentration as low as the method of analysis permits. A paper that describes this work is to be published.¹

3.3 EFFECT OF ^{60}Co GAMMA RADIATION ON ARSENAZO III SOLUTIONS

G. L. Kochanny

Studies on the effect of ^{60}Co gamma radiation on solutions of the disodium salt of arsenazo III (*I*) in various aqueous solutions were completed. The rates of radiolytic decomposition of *I* were determined in hydrochloric, sulfuric, phosphoric, and acetic acid solutions as well as in distilled water. For 2.5×10^{-5} and 1×10^{-4} *M* solutions of *I* in 9 *N* HCl, the average rates of decomposition of *I* are 4×10^{-6} and 2×10^{-6} mole/liter per kilorad of absorbed gamma radiation respectively. For a 1×10^{-4} *M* solution of *I* in 1 *N* HCl, the average rate of decomposition of *I* is 9×10^{-7} mole liter⁻¹ kilorad⁻¹. In 9 *N* H_2SO_4 and in 9 *N* H_3PO_4 the initial rate of decomposition is the same as that in 9 *N* HCl, but the rate decreases as the reaction proceeds. In distilled water the average rate of decomposition is about 5×10^{-7} mole liter⁻¹ kilorad⁻¹. The initial and final rates of decomposition of *I* in acetic acid solution are fairly constant at 9×10^{-8} and 2×10^{-6} mole liter⁻¹ kilorad⁻¹ respectively. At a specific absorbed dose, the initial rate of decomposition changes sharply to the final rate of decomposition. The absorbed dose at which this change in rate occurs depends on the acetic acid concentration: for 1 *N* CH_3COOH , 70 kilorads; 2 *N*, 73 kilorads; 4 *N*, 72 kilorads; 9 *N*, 100 kilorads; and 6 *N* CH_3COOH , >180 kilorads. Attempts to identify the products of the radiolytic decomposition of *I* by infrared spectra of solids obtained on evaporation of the solutions were unsuccessful.

¹G. L. Kochanny, Jr., "Effect of Cobalt-60 Gamma Radiation on the Determination of Uranium(VI) in Phosphoric Acid Solutions of Uranium(IV) Oxide," *Anal. Chim. Acta*, in press.

Study of the effects of gamma radiation on the thorium-*I* complex was begun; initial results show that the complex is decomposed by gamma radiation.

3.4 EFFECT OF ^{60}Co GAMMA RADIATION ON 2-THENOYLTRIFLUOROACETONE (TTA) SOLUTIONS

G. L. Kochanny

A study of the effect of gamma radiation on solutions of 2-thenoyltrifluoroacetone (TTA) was initiated. Xylene was used as the solvent. Gamma ray doses as large as 300 kilorads had no effect on the absorption-spectrum maximum of xylene or on xylene solutions of TTA in the region from 320 to 330 $\text{m}\mu$; doses as large as 1800 kilorads did not affect the infrared spectrum. Some variation in the infrared spectrum between 700 and 800 $\text{m}\mu$ did occur, but the absorption in this region is attributed to the ortho and meta substitution of methyl groups on the benzene ring of xylene.

3.5 RADIOLYSIS OF CHLORIDE SOLUTIONS

Hisashi Kubota

Solutions of high chloride concentration are used in many radiochemical procedures; it is therefore desirable to elucidate the radiolytic behavior of such solutions. Sworski reports² that acid chloride solutions react with hydroxyl free radicals in the manner

This reaction indicates that free chlorine is produced at the expense of the hydronium ion. No such oxidation is indicated to occur in neutral or basic solutions. Actual determinations of chlorine were not made by Sworski; the maximum chloride concentration studied was 1 *M*. The 10 *M* lithium chloride solutions used in transuranic separation procedures are known to suffer alpha radiolysis and to give up chlorine while losing acidity.

²T. J. Sworski, "Yields of Hydrogen Peroxide in the Decomposition of Water by Cobalt γ -Radiation. II. Effect of Chloride Ion," *Radiation Res.* 2, 26 (1955).

Studies were made of the radiolysis of chloride solutions prepared without the special precautions required for fundamental radiation chemistry. The results indicate that chlorine is produced at a rate proportional to both chloride and acid concentrations. At fixed acidity, this production varies linearly with total chloride content. The radiolysis of hydrochloric acid solutions gives an exponential response in which both acid and chloride concentrations come into play. The limit of acid and chloride concentrations below

which no chlorine is produced is slightly above 1 M.

This radiolytic reaction to produce chlorine can be eliminated effectively by the addition of methanol; other organic solvents produce the same effect. Scavenging of hydroxyl radicals seems to be the principle involved.

The effect of the products of acid chloride radiolysis on analytical procedures is now under study.

4. Analytical Chemistry for Reactor Projects

J. C. White

L. T. Corbin

The Analytical Chemistry Division continued its programs on analytical chemistry research and development for the Molten-Salt Reactor Experiment (MSRE), Gas-Cooled Reactor (GCR) Program, and Transuranium Element Processing (TRU) Program. Details of these investigations were reported regularly in the following progress reports:

MSRE Semiannual Progress Reports:

ORNL-3626 for Period Ending January 31, 1964

ORNL-3708 for Period Ending July 31, 1964

GCR Semiannual Progress Report:

ORNL-3619 for Period Ending March 31, 1964

TRU Quarterly Progress Reports:

ORNL-3597 for Period Ending November 30, 1963

ORNL-3651 for Period Ending February 29, 1964

ORNL-3739 for Period Ending August 31, 1964

Brief summaries of the analytical programs for these reactor projects are given in the following paragraphs. For details of the work, the reader is referred to the appropriate reactor-project progress reports.

4.1 MOLTEN-SALT REACTOR EXPERIMENT

A. S. Meyer	F. E. Haga
R. F. Apple	F. K. Heacker
D. J. Fisher	J. M. Dale
M. J. Gaitanis	W. L. Maddox
R. W. Stelzner	

The program being carried out by the Analytical Chemistry Division for the MSRE can be classified into two categories: (1) development and evaluation of the methods required for the analysis of the MSR fuel and related problems and (2) investigation of the feasibility of various techniques for in-line monitoring of the fuel.

The first category has occupied the major portion of the program and should be essentially complete by the end of this year. In-line analysis is in the initial stages of investigation. Among the analytical methods being considered for in-line monitoring are: electrochemical analyses of molten materials, electron spin resonance, and x-ray measurements. It is not contemplated to use these in-line measurements on the MSR but to evaluate them for possible future use on molten-salt reactors.

Specially designed equipment was devised and tested for sampling and handling the highly radioactive fluoride-salt fuel mixtures ($\text{LiF-BeF}_2\text{-ZrF}_4\text{-UF}_4$). The maximum expected radioactivity of a sample taken for analysis (~ 10 g) will be ~ 15 curies; thus, cell operations will be performed in the High-Radiation-Level Analytical Laboratory (HRLAL). Methods were established for determining U, Be, Li, Zr, F^- , Cr, Fe, Ni, Mo, and fission products in MSR fuel. The precision to be expected for these methods under remotely controlled operations is currently being established. Methods for determining oxide and the reducing power of the fuel are still being developed. Special equipment that was designed includes a remotely operated filter photometer, a corrosion-resistant servopipetter, and a bottle decapper to accommodate sample bottles of various heights and diameters.

A gas chromatograph equipped with a highly sensitive helium-breakdown detector is being constructed for analysis of the helium carrier gas to be used in the MSR. This chromatograph has the following stable operation detection limits: for permanent gases (H_2 , O_2 , N_2 , CH_4), 5 ppb; for Kr, 3 ppb; for Xe, 5 ppb; and for CF_4 , 30 ppb. The postulated detection limit for H_2O is 10 to 20 ppb.

4.2 GAS-COOLED REACTOR

A. S. Meyer

C. M. Boyd

The Analytical Chemistry Division's effort for the GCR Program has been primarily to evaluate various types of detectors for use in the gas chromatographic determination of impurities in helium. The most promising is the helium-breakdown detector by which voltage changes between electrodes carrying a constant current in the microampere range are measured as a function of changes in the composition of the carrier gas. The detector is sensitive to parts-per-billion concentrations of H_2 , O_2 , N_2 , CH_4 , and CO. The other detector studied was the Lipsky beta ionization detector, which features a 180-mc beta source of titanium tritide. Technetium-99 was also con-

sidered as an alternative source but it is too difficult to plate.

4.3 TRANSURANIUM ELEMENT PROCESSING

P. F. Thomason	T. R. Mueller
F. L. Moore	H. C. Meyer
D. A. Costanzo	R. W. Stelzner
F. E. Haga	W. T. Mullins
W. L. Maddox	A. L. Travaglini

The Analytical Chemistry Division's program for TRU is basically to provide the methods of analysis needed to control the process being carried out at ORNL. In the overall production scheme for the transplutonium elements, ^{239}Pu is irradiated to $> 99.9\%$ burnup and is then processed to separate the ^{242}Pu from Am, Cm, and rare-earth fission products. The Am-Cm actinide fraction is next separated from the rare-earth elements by solvent extraction (Tramex process) with a long-chain tertiary amine. The actinide fraction is formed into oxide targets, which are irradiated at a high neutron flux ($\sim 3 \times 10^{15}$ neutrons $\text{cm}^{-2} \text{sec}^{-1}$) in the High Flux Isotope Reactor (HFIR) at ORNL. The actinides are recovered from the dissolved fuel element by the Tramex process. The Bk, Cf, Es, and Fm produced will be separated by first isolating Bk with 2-ethylhexyl-phenylphosphonic acid and then using cation exchange resins to collect Fm, Es, and Cf. As a different portion of the overall program, $^{242}\text{-}^{244}\text{Cm}$ will be separated from other actinide elements.

Both radiochemical and ionic methods are required; all the operations of these methods must be done in both hot cells and glove boxes (to provide protection against alpha radiation). Radiochemical methods are being evaluated and modified when necessary. Heavy reliance is being placed on instrumental techniques and on alpha and gamma spectrometry in an effort to eliminate chemical operations or reduce them to a minimum. Ionic methods for free acid, lithium, total rare-earth elements, individual actinides, and nitrate are under study. Current work includes the use of a cation-sensitive glass electrode for the determination of lithium in 11 M LiCl, a direct ultraviolet spectrophotometric measurement of

traces of nitrate in 11 M LiCl, potentiometric titration of free acid in Tramex solutions, development of methods for the separation of actinides from lanthanides, and evaluation of methods for determining fission products under operating con-

ditions that simulate actual conditions. In addition, much effort is being given to develop improved remotely operated apparatus such as servopipetters, analytical balances, and solvent-extraction equipment.

5. Chemical Analysis of Advanced Reactor Fuels

J. C. White

A. S. Meyer

P. F. Thomason

5.1 GAS CHROMATOGRAPH FOR THE ANALYSIS OF CORROSIVE GASES

A. D. Horton

A. S. Meyer

A gas chromatograph was designed to minimize the corrosive effects of such gases as nitrogen dioxide, dinitrogen trioxide, chlorine, and nitrosyl chloride. The measuring-and-control system for the carrier gas is conventional. All of the system that comes in contact with the sample, except the supporting stirrups of the thermistors, is constructed of materials highly resistant to corrosion.

The gas-sampling manifold is constructed of glass tubing and Delmar-Urry greaseless needle valves. It contains a Dynisco pressure transducer, which has an absolute pressure range from 0 to 1000 mm Hg. The tantalum diaphragm is the only part of the transducer that comes in contact with the sample.

The detector "block" consists of a cylindrical glass bulb (~2-in. diam, 2½ in. high) that contains two wells for the sample and the reference thermistors. These wells are connected to the appropriate inlet and outlet tubes. The 8000-ohm thermistors are sealed in place with Teflon O-rings and threaded Teflon caps. The detector block is filled with mercury to provide thermal inertia, and a thermocouple well is provided for measuring the temperature of the block. The block is heated with a glass electric heating tape and is insulated with Styrofoam block and quartz wool. The entire system is built into a Micro-Tek model 2500 instrument base; the Micro-Tek column-heating system is used. A Gow-Mac model 9999 D-1

power supply is used to operate the detector. The chromatograph has been leak- and vacuum-tested, but it has not been tested otherwise.

5.2 QUALITATIVE AND QUANTITATIVE ANALYSIS OF ALIPHATIC DILUENTS BY GAS CHROMATOGRAPHY

A. D. Horton

Components of diluents used by the Chemical Technology Division in research on solvent extraction were identified by gas chromatography on

Table 5.1. Results of Qualitative and Quantitative Analyses of Experimental Aliphatic Diluents

Component	Amount of Component Present (vol %)	
	In P-170	In P-185
<i>n</i> -Octane	0.01	0.1
<i>n</i> -Nonane	0.2	0.1
<i>n</i> -Decane	5.0	0.2
<i>n</i> -Undecane	51	9.0
<i>n</i> -Dodecane	29	43
<i>n</i> -Tridecane	12	36
<i>n</i> -Tetradecane	3	10
<i>n</i> -Pentadecane		1.0
Isomeric paraffins	0.3	0.2

a Barber-Colman model 20 gas chromatograph with an argon-beta ionization detector.

Two aliphatic diluents, identified only as P-170 and P-185, were resolved on a 10-ft-long by $\frac{1}{8}$ -in.-OD SE-30 silicone column at 125°C. The argon pressure on the column inlet was 10 psig. Seven normal paraffins were identified in P-170 and eight in P-185 by comparison of the retention times with those of known mixtures of normal paraffins obtained from Micro-Tek Instrument Company and from Phillips Petroleum Company. The above identifications were confirmed by use of a 6-ft-long by $\frac{1}{4}$ -in.-OD Reoplex 400 column. Table 5.1 gives the results of the qualitative and quantitative analyses of the diluent samples.

5.3 COMBUSTION-GAS CHROMATOGRAPHIC DETERMINATION OF CARBON IN AQUEOUS AND NITRIC ACID SOLUTIONS

I. B. Rubin

The combustion-gas chromatographic determination of carbon in aqueous and nitric acid solutions was studied further.¹ Modifications made in the apparatus and procedure gave increased efficiency in the conversion of soluble carbon compounds to carbon dioxide and in the subsequent recovery of this gas. Passage of the combustion gases over hot copper did not affect the quantity of carbon dioxide found. The amount of carbon in distilled concentrated nitric acid was determined, and tests were performed with synthetic samples of sucrose and with nitric acid solutions of various compositions to establish the accuracy and precision of the method.

A slight modification in the combustion procedure for the determination of carbon resulted in increased conversion of carbon to carbon dioxide. By raising the oxygen pressure inside the combustion tube and by decreasing the oxygen flow through the cold trap, the recovery of carbon, as carbon dioxide, was increased from an average of 72.4 to 89.0% over the range from 50 to 400 μ g of carbon. When the combustion gases were passed over copper needles heated to 1025°C, the average recovery was 88.5%. The overall relative standard deviation in each of these two recent tests was

4%. The copper reduction tube, which was heated by means of a platinum wire wound around the tube itself, was replaced by a larger tube heated by a separate combustion furnace. The new tube was designed to be more easily detached for inspection and for replacement of the copper. A batch of freshly prepared copper was not effective in reducing nitrogen oxides until at least several portions of nitric acid had been processed. Therefore, fresh charges of copper were pretreated as follows: the copper oxide needles were reduced with hydrogen at $\sim 450^\circ\text{C}$, ~ 5 ml of concentrated nitric acid was distilled through the copper at 1025°C under vacuum, the oxidation was completed with air at about 450°C, and the copper oxide was re-reduced with hydrogen.

A number of tests were made to determine a nitric acid blank. Concentrated nitric acid was distilled for use in all the tests. When an apparatus blank equivalent to 4.7 μ g of carbon was subtracted, the nitric acid blanks ranged from the equivalent of 7.5 to 25.5 μ g of carbon over a sample range from 0.05 to 0.20 ml of acid. Synthetic samples that contained from 50 to 400 μ g of carbon as sucrose (0.025 to 0.20 ml of solution) were mixed with 0.05- to 0.20-ml portions of concentrated nitric acid. For samples that contained 50 and 400 μ g of carbon, the average net recoveries of the carbon were 79.0 and 81.5% respectively. When the results for all samples were averaged, the relative standard deviation was 17%. Thus, it appears that from 50 to 400 μ g of carbon can be determined in the presence of from 0.05 to 0.20 ml of concentrated nitric acid (0.8 to 3.2 millimoles). The accuracy is about 80% on an absolute basis and about 90% when compared with standards; the relative standard deviation is about 15%.

No future work on this project is contemplated.

5.4 DISSOLUTION OR DECOMPOSITION OF VARIOUS MATERIALS

J. R. Lund Hisashi Kubota P. F. Thomason

Wichers, Schlect, and Gordon² dissolved a variety of oxides, silicates, and ceramic materials in hydrochloric acid by heating the sample,

¹I. B. Rubin, "Determination of Carbon in Aqueous and Nitric Acid Solutions," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 18.

²E. Wichers, W. G. Schlect, and C. L. Gordon, "Preparing Refractory Oxides, Silicates, and Ceramic Materials for Analysis, by Heating with Acids in Sealed Tubes at Elevated Temperatures," Research Paper RP-1621, *J. Res. Natl. Bur. Std.* 33, 451 (1944).

Table 5.2. Results of Attempted Dissolutions and Decompositions by Heating with Acids in Sealed Tubes

Material	Analysis Desired	Acid		Result ^a
		Solvent	Oxidant	
HfO ₂	None	HCl	HClO ₄	S
Fluidized coke	Trace elements	HCl	HClO ₄	F
UO ₂ (graphite-coated)	Trace elements	HCl	HClO ₄	S
ThC ₂ -UC ₂ (graphite-coated)	Trace elements	HCl	HClO ₄	F
HgS	Cl ⁻	HNO ₃	HNO ₃	S
LiF (irradiated)	F	HCl	(KI + AlCl ₃)	F
[(C ₄ H ₉ O) ₂ PSS] ₂	P, S	HNO ₃	HNO ₃	S
Hg[(C ₄ H ₉ O) ₂ PSS] ₂	Hg, P, S	HNO ₃	HNO ₃	S
N-Trimethylborazine	B	HNO ₃	HNO ₃	S
Organic chloride ^b	Cl ⁻	HNO ₃	(AgNO ₃)	S

^aF = failure, did not dissolve; S = success, sufficient dissolution and/or reaction to complete analysis.

^b3,9-Diethyltridecylamine-6-amino-3,9-diethyltridecane hydrochloride.

solvent acid, and an oxidant such as nitric or perchloric acid in a sealed tube at temperatures between 100 and 350°C. The scope of this technique was extended to the use of acids other than hydrochloric acid and is now being modified for hot-cell operation. Table 5.2 summarizes the results obtained to date.

In connection with dissolution problems in general, Smith's "liquid fire" treatments³ have proved more successful for the destruction and dissolution of fluidized coke and graphite-coated materials than has the sealed-tube technique or fusion with sodium peroxide that contains a little potassium nitrate.

Table 5.2 indicates that the dissolution of high-purity refractory hafnium oxide is successful. Although this is true for limited quantities (~0.1 g), the dissolution of as much as 5 g of the material required a preliminary heating with ammonium bifluoride and then a fuming with sulfuric acid.

5.5 POLAROGRAPHY IN HYDROFLUORIC ACID AND OTHER GLASS-CORRODING MEDIA

Helen P. Raaen

Polarography with the Teflon dropping-mercury electrode (D.M.E.)⁴ was continued. Results which show that the horizontal-orifice Teflon D.M.E. is satisfactory for obtaining fundamental polarographic data were given in two articles accepted for open-literature publication. With this D.M.E., polarography of the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ reaction in 1, 4, 8, and 12 N HF was studied in detail, and certain fundamental polarographic data were determined for the first time. This work is being described in an article for open-literature publication. During the measurement of half-wave potentials ($E_{1/2}$) with the horizontal-orifice Teflon D.M.E., the magnitude of junction potentials at the salt bridge was found to be significant. Data that show the effect of such potentials were given

³G. F. Smith, "The Destruction of Viscera in Toxicological Investigations. Determination of Chromium," *Mixed Perchloric, Sulphuric, and Phosphoric Acids and Their Applications in Analysis*, 2d ed., p. 48, G. Frederick Smith Chemical Co., Columbus, Ohio, 1942.

⁴Helen P. Raaen, "Polarography in Hydrofluoric Acid and Other Glass-Corroding Media," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, pp. 35-38.

in a communication accepted for journal publication. Further work was done to improve the procedure for fabricating Smoler-type vertical-orifice Teflon capillaries; the improved procedure is given in a topical report.

This polarographic work with the Teflon D.M.E. is discussed below.

5.5.a Evaluation of the Horizontal-Orifice Teflon D.M.E. for Use in Obtaining Fundamental Polarographic Data

A means of translating from work with the glass D.M.E. in media that do not corrode glass to work with the Teflon D.M.E. in glass-corroding media was provided by taking fundamental polarographic data with the Teflon D.M.E. for two reference redox reactions in noncorroding media.

The $Tl^+ \rightleftharpoons Tl^0$ Reaction. — The polarographic characteristics of the $Tl^+ \rightleftharpoons Tl^0$ reaction in 0.1 M KCl–1 mM HCl were determined with the horizontal-orifice Teflon D.M.E. They are in agreement with those established from studies done with glass D.M.E.'s. The agreement indicates that polarograms obtained with Teflon D.M.E.'s have the same meaning as those taken with glass D.M.E.'s and can be analyzed in the same way. The results show that data taken with the two types of electrodes are, indeed, interchangeable. The results also ensure confidence in the certainty of polarographic measurements made in glass-corroding media with the Teflon D.M.E.; this assurance is needed because reference data for such measurements do not exist. An article⁵ that discusses this work with the $Tl^+ \rightleftharpoons Tl^0$ reaction is tentatively scheduled for publication in December.

The $Pb^{2+} \rightleftharpoons Pb^0$ Reaction. — In a similar way, the $Pb^{2+} \rightleftharpoons Pb^0$ reaction in 1 M HCl was used to evaluate the horizontal-orifice Teflon D.M.E. The results were of the same nature as those obtained in the evaluation with the $Tl^+ \rightleftharpoons Tl^0$ reaction. An article⁶ submitted for publication describes this work.

⁵Helen P. Raaen, "Teflon Dropping-Mercury Electrode for Polarography in Hydrofluoric Acid and Other Glass-Corroding Media. Evaluation with the Thallium(I) $\rightleftharpoons$ Thallium Reaction," *Anal. Chem.* 36, in press.

5.5.b Significance of Junction Potentials in the Measurement of $E_{1/2}$ Values

In the first work on the measurement of $E_{1/2}$ values of the reference redox reactions $Tl^+ \rightleftharpoons Tl^0$ and $Pb^{2+} \rightleftharpoons Pb^0$ in HCl media with the Teflon D.M.E., the test solution was bridged to a saturated calomel electrode (S.C.E.) with a NaF–agar-agar gel, which was thought to be suitable as a bridge to HF media. It was found that for certain media, especially HCl solutions, the magnitude of junction potentials for this bridge, as well as for other types of bridges, can be unexpectedly large and can have a significant effect on the measured value for $E_{1/2}$. From experimental data, it was concluded that the test solution should be bridged to the S.C.E. through a saturated solution of KCl only, the junction potential thereby being only that of the (test solution)/(saturated KCl solution). This work was done with W. L. Belew;⁷ a Short Communication about it was accepted for publication.⁸

For measurement of $E_{1/2}$ values of redox reactions in aqueous hydrofluoric acid media, a bridge was made from Kel-F tubing and disks of sintered Teflon. This bridge is filled with the supporting medium and is connected to the S.C.E. through a solution of saturated KCl. The small differences among the $E_{1/2}$ values for the $Pb^{2+} \rightleftharpoons Pb^0$ reaction in 1, 4, 8, and 12 N HF indicate that the use of this bridge arrangement minimizes junction potentials (see Table 5.3).

5.5.c Polarography of the $Pb^{2+} \rightleftharpoons Pb^0$ Reaction in Aqueous Hydrofluoric Acid with the Horizontal-Orifice Teflon D.M.E.

The broad program of detailed study of individual redox reactions in aqueous hydrofluoric acid media was begun. The polarographic characteristics of

⁶Helen P. Raaen, "Teflon Dropping-Mercury Electrode for Polarography in Hydrofluoric Acid and Other Glass-Corroding Media. Evaluation with the Lead(II) $\rightleftharpoons$ Lead Reaction," submitted for publication in *Analytical Chemistry*.

⁷Analytical Instrumentation Group.

⁸W. L. Belew and Helen P. Raaen, "Effect of Junction Potentials at the Salt Bridge on the Measured Values for the Half-Wave Potential of the $Pb^{2+} \rightleftharpoons Pb^0$ Reduction in Aqueous Solutions of Hydrochloric Acid and Potassium Chloride," *J. Electroanal. Chem.*, in press.

Table 5.3. Polarographic Characteristics of the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ Reaction in Aqueous Hydrofluoric Acid Media

Polarographic Characteristic	HF Concentration, <i>N</i>			
	1.00	4.00	8.00	12.00
Approximate usable range of supporting medium, <i>v</i> vs S.C.E. ^a	+0.4 to -1.25	+0.4 to -1.20	+0.4 to -1.15	+0.4 to -1.10
Number of waves	One	One	One	One
$E_{1/2}$, <i>v</i> vs S.C.E. ^b	-0.380	-0.380	-0.375	-0.370
Reciprocal slope of $\log [\bar{i}_d/(\bar{i}_d - \bar{i})]$ vs $E_{d.e.}$ ^c	0.036	0.035	0.036	0.033
$90.6/W_{1/2}$ ^d	1.90	1.92	1.92	1.94
<i>n</i>	2	2	2	2
Reversibility	Reversible	Reversible	Reversible	Reversible
$[\text{Pb}^{2+}]$ vs $\bar{i}_d$ ^e	Linear	Linear	Linear	Linear
$[\text{Pb}^{2+}]$ vs $(di/dt)_{max}$	Linear	Linear	Linear	Linear

^aFrom dissolution of mercury to evolution of H_2 .

^bDetermined from both average-currents regular and derivative polarograms; the value includes junction potentials.

^cTheoretical value for a reversible 2-electron-change redox reaction = 0.030.

^d $W_{1/2}$ = width of first-derivative peak at half-peak height.

^eOver the range of $[\text{Pb}^{2+}]$ from about 0.03 to 0.8 mM.

the $\text{Pb}^{2+} \rightleftharpoons \text{Pb}^0$ reaction in 1, 4, 8, and 12 *N* HF were determined with the horizontal-orifice Teflon D.M.E. and a bridge of the supporting electrolyte (see Sect. 5.5.b). Table 5.3 summarizes these characteristics, which were determined for the first time.

The Teflon D.M.E. behaved excellently during the study. Undamped regular, average-currents regular, and derivative polarograms were recorded. All these are of the form usual for a glass D.M.E. The undamped polarograms indicate precise drop formation. The shapes of the regular and derivative polarographic waves are excellent; residual-current and limiting-current regions are parallel, and there is no evidence of maxima although maximum suppressors were not used. Diffusion currents were reproducible.

The electrocapillary curve of mercury was determined in each of the HF media. The curves have the usual parabolic shape; the maxima are in the region between -0.40 and -0.55 *v* vs the S.C.E.

The effect of increase in HF concentration on $E_{1/2}$ is not significant; the use of the bridge of supporting medium probably accounts for this small effect, since junction potentials between the test solution and S.C.E. are thus minimized. The slopes of the plots of $[\text{Pb}^{2+}]$ vs $\bar{i}_d$ and of $[\text{Pb}^{2+}]$ vs $(di/dt)_{max}$ decrease with increase in HF concentration.

A paper that describes this complete study is being prepared for open-literature publication.

5.5.d Extension of the Use of the Horizontal-Orifice Teflon D.M.E. by Others

The recent work of Headridge and his associates⁹ indicates that the information given in

⁹J. B. Headridge *et al.*, "Polarographic Investigations in Acidic Fluoride Solutions," Program of the 3rd International Congress of Polarography, The University, Southampton, England, July 19-25, 1964.

ORNL-3344¹⁰ is a satisfactory guide for others who wish to make horizontal-orifice Teflon D.M.E.'s and that the Teflon D.M.E.'s are generally useful for polarographic studies of acid fluoride media. Following the instructions given in ORNL-3344, Headridge and co-workers made Teflon D.M.E.'s and used them to study the polarographic behavior of the ions of 26 elements in HF-NH₄F, HF-HCl, and HF-H₂SO₄ supporting electrolytes. To study complexing effects of fluoride ion, they measured half-wave potentials and other characteristics of the polarographic waves of the ions of 15 metals in 0.1 M HF-0.1 M NH₄F and compared the characteristics with those of the ions in perchlorate media. They state that their results indicate the possibility of determining molybdenum and tungsten polarographically in the presence of Ti, Zr, Nb, and Ta; of determining several common elements in Ti-, Zr-, Nb-, Ta-, and W-base alloys; and of determining tin and lead in alloys by a new polarographic method.

The satisfactory fabrication and use of Teflon D.M.E.'s by Headridge and his associates indicate that this type of electrode is the means of extending the application of both fundamental and applied polarography to glass-corroding media. The potential amount of such polarography is tremendous; it is gratifying to know that others are having success with the fabrication and use of Teflon D.M.E.'s.

5.5.e Vertical-Orifice Rapid Teflon D.M.E.

In work with Ralph L. Clark,¹¹ an improved procedure was developed for fabricating the vertical-orifice Teflon capillary of a rapid Teflon D.M.E. Special tools were designed and built for use in the fabrication. With a micro drill press and a micro drill, the vertical orifice is drilled in a lapped vertical face of the capillary blank. The blank is held in a special jig mounted on the table of the drill press. To form orifices of about 100- μ diameter or larger, a micro twist drill is used; for smaller diameters, a micro pivot drill is used. Several capillaries that have orifice diameters of about 70 and 100 μ were made. Although these capillaries have not yet been evalu-

ated thoroughly, photomicrographs indicate that they have better geometry at the orifice than has a vertical-orifice glass D.M.E. which has performed satisfactorily. The improved fabrication procedure is given in ORNL-3654.¹²

5.6 CHRONOPOTENTIOMETRY OF PLUTONIUM

D. G. Peters¹³ W. D. Shults

A general study of the chronopotentiometric behavior of plutonium in mineral acid media was conducted. The results are presented in a published paper.¹⁴

The chronopotentiometry of Pu³⁺, Pu⁴⁺, and Pu⁶⁺ at a platinum electrode in various media was studied to determine the diffusion coefficients of the different plutonium species, the effects of surface oxidation of the platinum electrode, and the possible analytical usefulness of chronopotentiometry for the determination of plutonium.

The reduction of Pu⁴⁺ $\rightarrow$ Pu³⁺ at a platinum cathode in perchloric, sulfuric, nitric, and hydrochloric acid solutions was investigated. The relatively small diffusion coefficient of Pu⁴⁺ in each of these media plus the spontaneous chemical oxidation of the platinum electrode by Pu⁴⁺ result in a significant positive error in chronopotentiometry with concentrations of Pu⁴⁺ below 0.01 M.

Chronopotentiograms for the Pu³⁺ $\rightarrow$ Pu⁴⁺ oxidation in sulfuric acid show one wave due to oxidation of Pu³⁺ followed by a second wave attributable to the formation of a platinum oxide film. Plutonium(III) in sulfuric acid medium chemically reduces the oxide film. The electro-oxidation of Pu³⁺ in perchloric acid medium gives a well-defined chronopotentiogram at either pre-reduced or preoxidized electrodes.

The chronopotentiometric reduction of Pu⁶⁺ in 1 f perchloric acid proceeds stepwise first to Pu⁵⁺ and then to Pu³⁺. No evidence that Pu⁵⁺ undergoes significant disproportionation in the perchloric acid medium was observed under the experimental conditions.

¹²Helen P. Raaen and Ralph L. Clark, *Fabrication of the Vertical-Orifice Teflon Capillary of a Teflon Dropping-Mercury Electrode*, ORNL-3654 (August 1964).

¹³Assistant Professor, Department of Chemistry, Indiana University, Bloomington.

¹⁴D. G. Peters and W. D. Shults, "Chronopotentiometry of Plutonium in Mineral Acid Media," *J. Electroanal. Chem.* 8, 200 (1964).

¹⁰Helen P. Raaen, R. J. Fox, and V. E. Walker, *Fabrication and Assembly of a Teflon Dropping-Mercury Electrode*, ORNL-3344 (Nov. 30, 1962).

¹¹Plant and Equipment Division.

6. Special Research and Development Problems

J. C. White

P. F. Thomason

6.1 REACTIONS IN CONCENTRATED LITHIUM CHLORIDE SOLUTIONS

Hisashi Kubota

Concentrated solutions of strong acid-strong base salts behave similarly to nonaqueous solvents and can be used as media for titrations of very weak bases.¹ This behavior is especially pronounced in concentrated solutions of lithium chloride and of lithium bromide because of their high solubilities ($\sim 14 M$) and the high affinity of lithium ion for water.

Studies with $10 M$ LiCl solutions have shown that many unique applications are possible with this system. In this medium free acid can be determined in the presence of hydrolyzable cations by direct titration without the need to add a separate complexing agent. This determination is especially useful in the presence of a cation that forms a strong chloro complex. Titration beyond the free-acid end point results in the formation of the hydroxide of the cation, and a sharp end point corresponding to the completion of hydroxide formation is seen.

When a mixture of several hydrolyzable cations is titrated, the cations can be differentiated provided there is a difference of at least seven units between respective pK 's (K = solubility-product constant), the most insoluble hydroxide being titrated first. This is not a precise analytical procedure, but is useful as a rapid semiquantitative method. The results are described in a paper accepted for publication.²

When Al^{3+} or UO_2^{2+} is titrated past the hydroxide end point, another break that corresponds roughly to the formation of aluminate or diuranate is seen. The appearance and stoichiometry of this break seem to be concentration dependent; further work

is necessary to establish conditions for more exact response.

Since lithium chloride is a neutral salt, the titration of weak acids as well as weak bases in this medium seems feasible. Rosenthal and Dwyer³ claim that titrations of weak acids are difficult to carry out with a glass electrode because of alkali errors. Present work using special glass electrodes for highly alkaline solutions and with pyrolytic-graphite electrodes indicates that interaction between lithium and organic acids interferes with titration of weak organic acids; however, weak inorganic acids like boric acid can be readily titrated.

Titration of phosphoric acid in this medium gives rise to one or two breaks, depending on total acid concentration. The breaks correspond to the neutralization of the first and the sum of the second and third hydrogens. These breaks result from precipitation of lithium phosphate. Lithium phosphate is very slightly soluble in $10 M$ LiCl; the solubility is a function of acid concentration. When there is sufficient initial total acidity, the most active acid is titrated before precipitation begins. When the total acidity is small, precipitation sets in before any acid differentiation is possible.

6.2 DISPOSAL OF RADIOACTIVE WASTES IN NATURAL SALT FORMATIONS

Hisashi Kubota

Laboratory studies associated with the disposal of high-level radioactive wastes in natural salt formations are essentially complete. Work of the preceding year established that no detectable chlorine is released from rock salt by ^{60}Co gamma radiation. The field demonstration now under way is being rigged to allow periodic sampling of

¹F. E. Critchfield and J. B. Johnson, "Titration of Weak Bases in Strong Salt Solutions," *Anal. Chem.* **30**, 1247 (1958).

²H. Kubota and D. A. Costanzo, "Reactions in Concentrated Lithium Chloride Solutions. Determination of Free Acid and Hydrolyzable Metal," *Anal. Chem.*, in press.

³D. Rosenthal and J. S. Dwyer, "Acid-Base Equilibria in Concentrated Salt Solutions. Acid-Base Titrations and Measurements of pH and H_0 ," *Anal. Chem.* **35**, 161 (1963).

entrapped air next to the disposal can so that any possible release of chlorine by long-term irradiation can be detected.

One remaining problem is *in situ* dosimetry at various distances in the salt away from the hot can. Glass dosimeters are to be used for this purpose, but it is also desired to use chemical dosimetry as a reference method. Chemical dosimetry is complicated by the expected high temperatures (100 to 250°C) in the surrounding salt.

6.3 SOLID INDICATOR ELECTRODES

F. J. Miller   H. E. Zittel

Evaluation of solid indicator electrodes made of pyrolytic graphite and "glassy" carbon was continued to determine their possible applications and limitations.

6.3.a Glassy-Carbon Indicator Electrode

Glassy carbon is a gas-impermeable electrically conductive material which is highly resistant to chemical attack. From it, an indicator electrode was made in two ways: by molding a piece of glassy carbon into an epoxy rod with a central tube that allows mercury contact and by brazing a platinum wire to the glassy carbon and fitting the assembly into a leak-tight Kel-F stem. The electrode is suitable for use over the potential range from about +1.2 to -0.8 v vs the S.C.E. in acid medium. The voltammetry of solutions of the following was studied: Ce^{3+} , Ce^{4+} , Cr^{6+} , Fe^{2+} , Hg^+ , $\text{Fe}(\text{CN})_6^{4-}$, Ag^+ , Cu^{2+} , and UO_2^{2+} . The E_p and i_p values for these ions are, for the most part, reproducible under the conditions studied and appear to be analytically useful. The results of this study were submitted to *Analytical Chemistry*.

6.3.b Oxide Film Formation on the Pyrolytic-Graphite Electrode

In collaboration with D. E. Freeman⁴ a study was made of the possible existence of an oxide film on the pyrolytic-graphite electrode under

oxidizing conditions. It was shown that an oxide film forms if the electrode is exposed for a long time to a strong oxidant such as Ce^{4+} or is anodized at high positive potentials. The film appears to be temporary; the characteristics of the electrode are unaffected by its formation and removal. The results of this work are being presented by D. E. Freeman as a thesis for the master's degree.

6.3.c Differential Potentiometry

The characteristics of the pyrolytic-graphite and the glassy-carbon electrodes are sufficiently dissimilar that coupling these electrodes for differential titrimetry is possible. The feasibility of doing this was demonstrated by carrying out acid-base and redox titrations. In both cases the differential curve obtained is suitable for end-point detection. The influence of chemical parameters of the system on the quality of the titration is being studied in detail. Such an electrode system would be very useful, especially in hot-cell operations where it could replace electrodes that are fragile, subject to radiation damage, and require frequent maintenance.

6.3.d Voltammetry

The pyrolytic-graphite indicating electrode was used to study the voltammetry of I^- , I_2 , and IO_3^- in H_2SO_4 solution. Change in H_2SO_4 concentration shifts both the E_p and the i_p of the I^- , I_2 , and IO_3^- voltammetric curves. The i_p/C ratio is sufficiently constant for quantitative purposes over the concentration range from 0.005 to 1.000 mM for I^- and 0.060 to 1.200 mM for I_2 . The IO_3^- wave is not reproducible. Absorption of an iodine species on the electrode was demonstrated by tracer experiments.

6.3.e Amperometry

A rapid and precise method for the amperometric titration of Cr^{6+} in mixtures of fluoride salts was developed. The Cr^{6+} is titrated with a standard solution of ferrous sulfate; the cell current is followed with a pyrolytic-graphite electrode. In the range from 1 to 50 μg of Cr^{6+} titrated, the relative standard deviation is less than 2%. This

⁴Graduate student, Department of Chemistry, University of Tennessee, Knoxville.

work, which was done jointly with R. F. Apple, has been published.⁵

6.3.f Chronopotentiometry

The glassy-carbon electrode exhibits characteristics which indicate that it should be extremely useful as an indicator electrode in chronopotentiometry. The chronopotentiometry of U^{6+} and its complexes is being studied with this electrode.

6.3.g Instrumentation

The polarographs now available are not designed for voltammetry; they lack many features that are needed in the voltammetric evaluation of solid electrodes. Accordingly, the Analytical Instrumentation Group was asked to design and construct a prototype voltammeter specifically for use in studying solid electrodes.

6.4 FLAME IONIZATION DETERMINATION OF PARTS-PER-BILLION CONCENTRATIONS OF ORGANIC CONTAMINANTS IN AIR

A. D. Horton

A. S. Meyer

An apparatus utilizing flame ionization detection was developed to measure the total concentration of organic contaminants in the atmosphere of reactor-fuel-burnup test assemblies. Several commercial instruments employing flame ionization detection were tested; the model 109 hydrocarbon analyzer was found to offer the best potential sensitivity. Although the most sensitive range of the Beckman instrument is 3 ppm full scale, the sensitivity was increased about 30-fold by using pure hydrogen as the fuel, by increasing the sample flow to the detector, and by reading the signal of a 1-mv recorder. To exploit the inherent sensitivity, it was necessary to limit the background and noise level by eliminating contamination of the sample and by purifying the burner air.

In the conventional mode of operation recommended by the manufacturer, the sample is drawn

into the instrument and is pressurized for injection into the flame detector by a Dynavac pump. Since the rubber diaphragm in the pump contaminated the sample slightly, an alternative (intermittent) mode of sampling was developed. In this mode, the sample is drawn through an 80-cc loop on a linear gas chromatographic sample valve. The contents of the loop are then injected into a stream of purified air that flows through the detector. The passage of this large sample through the detector is recorded as a plateau of height proportional to the hydrocarbon concentration. By the intermittent-sampling technique, hydrocarbon concentrations equivalent to 5 volumes of methane per billion volumes of air can be detected over a noise level corresponding to 2.5 ppb. Thus, moderate and high concentrations can be monitored continuously in the conventional mode, and more sensitive measurements can be made in the intermittent mode.

The entire apparatus, which includes the hydrocarbon analyzer, the recorder, the air purifier (a $\frac{1}{2}$ -in.-OD by 12-in.-long bed of platinum catalyst heated to 400°C), and the necessary stainless steel valves and connectors to provide the two sampling modes, was assembled in a movable instrument cabinet for making measurements at various sample sources.

Although the instrument is satisfactory for the initial determination of the hydrocarbon concentration in the fuel-burnup test cells, its use during the course of the tests would be complicated by the presence of dispersed oxides of uranium and smaller quantities of the oxides of structural metals. During controlled burnup tests conducted by the Reactor Safety Group, concentrations of oxide aerosols as high as 0.003 mole per cubic meter of air were found. To test for interference by dispersed oxides, aerosols were generated by aspirating measured quantities of solutions of various metallic salts through the hydrogen flame of the burner of a Beckman flame spectrophotometer. The resulting aerosols were mixed with purified air and "analyzed" by sampling them in the intermittent mode. Significantly large and varying amounts of interferences were observed. The signal generated by the iron oxide aerosol from the aspiration of a solution that contained one mole of ferric nitrate was the smallest of those for all the metal oxides tested and was equivalent to that of 0.05 mole of methane. When a solution of uranyl ammonium carbonate was aspirated, the signal due

⁵R. F. Apple and H. E. Zittel, "Amperometric Titration of Chromium in Mixtures of Fluoride Salts," *Anal. Chem.* **36**, 983 (1964).

to the aerosol was the largest obtained and was equivalent to 2 moles of methane per mole of uranium. The aspiration of anions in the form of the corresponding mineral acids did not produce significant detector responses.

These interference data are not suitable for quantitative interpretation, since the efficiency of aerosol formation and the fraction of metal oxide reaching the flame detector could not be determined easily. However, the results indicate that metal oxides must be removed from the samples if hydrocarbon is to be determined accurately. Techniques applicable to the removal of oxides have not been investigated.

6.5 DETERMINATION OF OXYGEN IN ALKALI METALS BY A MODIFICATION OF THE AMALGAMATION METHOD

Gerald Goldberg

To further evaluate the reliability of the amalgamation method for the determination of oxygen in alkali metals,⁶ an experiment was conducted to determine whether a portion of the insoluble oxide is entrained in the amalgam. The first amalgam from a sample of potassium to which ~1000 ppm of oxygen had been added as K_2O was drained under vacuum into a molybdenum capsule that contained a strip of high-purity zirconium metal. This capsule was sealed within a dry box. Samples of triple-distilled mercury and of mercury that had been cleaned with the Bethlehem Oxifier were also sealed in separate molybdenum capsules, which contained similar strips of zirconium metal. After equilibration at an elevated temperature, the zirconium strips were analyzed by vacuum fusion for oxygen pickup. The oxygen contents (ppm) were: amalgam, 34; oxidized mercury, 24; triple-distilled mercury, 38.

As has been the case with almost all oxide additions made to potassium for equilibrium studies, the recovery (by amalgamation) of oxygen from the potassium sample described above was low (420 ppm). However, the result of this gettering experiment, in addition to the good precision obtained between replicate samples of alkali metals

that contained less than 100 ppm of oxygen, indicates that this method is applicable to the determination of oxygen in sodium, potassium, and NaK. Since increase in oxygen concentration enhances corrosion of the containment material, it is possible that part of the oxygen is converted to the metallic oxide of the containment material. The oxygen recovered by amalgamation is that oxygen which remains dissolved in the alkali metal and which is still available to continue to oxidize the containment material.

The calculation of the oxygen content of the alkali metal is based on either the titration of the solution of the residue after amalgamation or the flame photometric analysis of the solution. For each microgram of hydrogen present as hydride in the residue, the result is in error by 8 μg of oxygen. To eliminate this error, any sodium hydride or potassium hydride present is decomposed by refluxing the first amalgam under vacuum for several minutes (see Sect. 6.7). When the hydride concentration is high, a second refluxing may be necessary for complete removal of the hydrogen. This method was proved to be satisfactory by the addition of water in vacuum to the residue after amalgamation of samples to which hydrogen had been added. Less than 2 ppm of hydrogen was recovered from the water addition after refluxing.

Recently, almost continuous discrepancy has existed between the oxygen contents of circulating NaK loops determined by amalgamation and by a plugging meter. In addition, prematurely high plugging temperatures have been recorded. An experiment was conducted to determine whether some compound other than the alkali-metal oxide was causing the erratic behavior of the plugging meter. A valved, crimped, bypass tube was added to the loop, and the crimped area was maintained at a low temperature to form a plug with a large amount of solid. Several such plugs were obtained. The plugged crimped sections were cut from the tubes, and the samples were analyzed by amalgamation.

The first amalgamation did not give rise to any off-gas (hydrogen) after refluxing. The residues were clean white. The oxygen results obtained for those residues that were dissolved and titrated for total alkalinity compared favorably with the results obtained by flame photometric analysis of the solutions after the titrations. There was no evidence of either corrosion products or carbon in the solutions. Carbon dioxide was not evolved

⁶J. C. White, A. S. Meyer, and G. Goldberg, "Determination of Oxygen in Higher Alkali Metals," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1961*, ORNL-3243, p. 41.

from those residues to which dilute acid was added under vacuum, nor was acetylene detected. A small amount of HCN was liberated during the acid addition. These results indicate that a cyanide was formed during the operation of the loop, even though nitrogen is not used as the blanket gas.

The almost pure oxide residues (5 to 6 mg) contained more K_2O than Na_2O . This relationship had been noted also during the analysis of NaK removed from the high-temperature loops by a bucket sampler. Large amounts of K_2O were found, along with larger amounts of Na_2O , in cold traps that were a part of these loops. The residues after amalgamation of samples of NaK from low-temperature systems usually contain 90% or more of Na_2O . At this time it can only be postulated that the erratic behavior of the plugging meter is due to the presence of the mixed oxides of sodium and potassium in the loops, since the solubility curves were based on pure systems.

6.6 DETERMINATION OF CARBON IN ALKALI METALS BY HIGH-TEMPERATURE OXIDATION

Gerald Goldberg

Several modifications were made to the apparatus for the determination of carbon in alkali metals by high-temperature oxidation.⁷ They were necessary because the procedure was changed from ignition in oxygen at reduced pressure to ignition in a mixture of about 10% oxygen in helium at a pressure slightly above atmospheric and at a flow rate of ~100 cc/min. It should now be possible to analyze larger samples with less vaporization during oxidation of the alkali metal. Recovery of carbon will not be affected by this reduction in the amount of oxygen present, since the method depends on the reaction of the carbon impurity with the alkali-metal silicate formed when the metal is converted to the oxide within the quartz boat.

Vacuum-tight low-flow meters were constructed, and the oxygen was metered directly from the gas cylinder. The gases are purified before being added to the ignition tube. The trap that was packed with glass beads was replaced with an

⁷G. Goldberg, "Determination of Carbon in Sodium," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 53.

Anhydrone-filled trap. The flowing gases are passed from the apparatus through a mercury bubbler. The U-tube is evacuated just prior to vaporization of the collected CO_2 for subsequent manometric measurement. The blank is as low as the blank obtained by the reduced pressure method.⁷ The apparatus is now similar to those used at other installations involved in the determination of carbon in alkali metals.

6.7 DETERMINATION OF HYDROGEN IN ALKALI METALS BY AMALGAMATION AND VACUUM EXTRACTION

Gerald Goldberg

The procedure for the determination of hydrogen in alkali metals by amalgamation and vacuum extraction⁸ was modified to compensate for the portion of hydrogen that is liberated as a result of the heat of reaction of the first amalgamation of the sample. Additional heating and refluxing of the first amalgam liberates the hydrogen that is present as the hydrides, and possibly the hydroxides, of sodium and potassium. The Anhydrone and liquid-nitrogen-cooled moisture traps were eliminated, and the hydrogen is now pumped directly into an evacuated sample bulb. In this manner the method is greatly simplified, and it is still possible to determine both oxygen and hydrogen impurities in the same sample.

The recovery of hydrogen from samples of NaK that contained 20 to 30 cc of hydrogen was better than 95%. Lithium added to one sample was converted to the hydride, which remained stable during the refluxing. Controlled addition of hydrogen at low temperature and subsequent filtration of the lithium hydride may be a means to reduce the lithium impurity that sometimes exists in the alkali metals. A paper describing this modified method was presented.⁹

⁸G. Goldberg, "Determination of Hydrogen in the Alkali Metals," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 49.

⁹G. Goldberg, "The Rapid Determination of Low Concentrations of Oxygen and Hydrogen in Alkali Metals by a Modified Amalgamation Technique," presented at the Eighth Conference on Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964.

6.8 NONAQUEOUS TITRIMETRY OF PHENOLS

J. R. Lund

Members of the Chemical Technology Division are investigating the properties of 4-sec-butyl-2(α -methylbenzyl)phenol, referred to as BAMBP. The phenol, dissolved in such diluents as Amsco 125-82, kerosene, or *n*-octane, is used as an extractant for removing cesium from waste water-processing solutions.

A method was developed whereby the concentration of phenol is determined by neutralization of phenol, which is weakly acidic, with a standard solution of tetrabutylammonium hydroxide in a nonaqueous medium. The course of the neutralization is followed with a glass electrode-S.C.E. pair. The nonaqueous pyridine phase, in which the glass electrode is immersed, is separated from the aqueous phase and S.C.E. by an agar-agar plug. Recently, plugs of $\sim 3\%$ agar-agar in 6% lithium chloride solution were substituted for the agar-agar-saturated potassium chloride plugs as salt bridges. Advantages of the new plugs have not been established.

6.9 TITRIMETRY OF ACIDS IN IRRADIATED LIQUIDS

J. R. Lund   Hisashi Kubota

Radiation experiments made in the Chemical Technology Division indicate that certain organic liquids undergo radiolytic decomposition. Free acid and/or carbonyl groups were determined in these irradiated liquids. The free acid was titrated in 10 *M* LiCl with a standard solution of sodium hydroxide. Attempts to determine the carbonyl groups by a similar titration of pyridinium hydrochloride, liberated by the reaction of the carbonyl group with hydroxylamine hydrochloride and pyridine, were unsuccessful.

6.10 DETERMINATION OF SOLIDS IN RADIOACTIVE WASTE-DISPOSAL SLURRIES

J. R. Lund   Hisashi Kubota

A method suitable for field use by the Health Physics Division was developed for determining solids in cement slurries. These slurries are used

in the hydrofracture experiment being made in conjunction with a study of the disposal of intermediate-level radioactive wastes. The method is empirical; the percent of solids is related to the "as is" weight of residue obtained from centrifugation of a weighed test portion of the slurry.

6.11 DETERMINATION OF CHLORIDE WITH A PYROLYTIC-GRAPHITE INDICATOR ELECTRODE

J. R. Lund   F. J. Miller   H. E. Zittel

Dilute solutions of sodium chloride ($\sim 10^{-4}$ *M*) resulted from experiments made by members of the Chemistry Division to determine the amount of sodium chloride held within the lattice of certain ion exchange resins. The sensitivity of the amperometric method of determining the end point of the titration of chloride with a standard solution of Ag^+ was improved by substituting the pyrolytic-graphite indicator electrode for the rotating platinum electrode normally used.

6.12 PYROLYTIC-GRAPHITE CUP AS BOTH VESSEL AND INDICATOR ELECTRODE FOR MICRO REDOX AND ACID-BASE POTENTIOMETRIC TITRATIONS

P. F. Thomason

A microtitration cell that does not require an internal electrode was needed for potentiometric titrations of highly radioactive materials. Such a cell was fabricated and tested for the titration of microliter volumes of acid-base and of Fe^{2+} - Ce^{4+} solutions. These titrations carried out both manually and automatically gave a relative standard deviation of 0.3%. The *Microchemical Journal* has in press a paper that describes this work.¹⁰

¹⁰P. F. Thomason, "Pyrolytic Graphite Cup as Both Vessel and Electrode for Micro Redox and Acid-Base Potentiometric Titrations," *Microchem. J.* 8(3), in press.

6.13 COULOMETRIC DETERMINATION OF ^{99}Tc

A. L. Travaglini

The concentrations of several ^{99}Tc solutions standardized by a radioactivity counting method were checked by coulometric reduction of the ^{99}Tc in a solution of tripolyphosphate as the supporting electrolyte. The method used in this work is that described by Terry and Zittel.¹¹ Results obtained with the two methods were within the limits of experimental error.

8-hydroxyquinoline, ignition of the precipitate at 1000°C for several hours, and weighing the residue as Eu_2O_3 . Molybdenum was determined by precipitation with benzoic α -oxime, ignition of the precipitate at 525°C, and weighing the residue as MoO_3 . The results were 81.5% Eu and 9.8% Mo. The exact composition of the sample was not determined; it appears to be a mixture of Eu_2O_3 and EuMoO_3 .

6.14 COLORIMETRIC DETERMINATION OF SAMARIUM WITH ARSENAZO III

A. L. Travaglini

A series of samples that contained small concentrations of samarium (1 to 5 $\mu\text{g}/\text{ml}$) were analyzed colorimetrically with arsenazo III as the chromogenic reagent. The color developed rapidly in solutions whose pH was adjusted to 2.0 to 2.5 with glacial acetic acid. Sulfate prevented or limited color formation. All solutions were measured at 655 $\text{m}\mu$ on a Beckman model DU spectrophotometer.

6.15 ANALYSIS OF ARC-FUSED EUROPIUM MOLYBDATE

A. L. Travaglini

A sample presumed to be europium molybdate was analyzed for europium by precipitation with

6.16 COULOMETRIC DETERMINATION OF NICKEL

A. L. Travaglini

Accurate determinations of the amount of radioactive nickel in a large number of solutions were required. A coulometric method was used to minimize handling. To determine the chemical factor for nickel, a standard solution was made by dissolving a weighed piece of zone-refined nickel in a minimum of concentrated HNO_3 and diluting the solution to volume in a calibrated 50-ml flask. A calibrated 500- μl pipet was used to withdraw each test portion of standard and unknown. The test portions were titrated in a supporting electrolyte of 1 M NH_4OH –1 M NH_4Cl . The supporting electrolyte was prerduced at -1.20 v vs the S.C.E., the sample was added, and the solution was prerduced at -0.825 v. The final reduction was done at -1.20 v.

Good precision was obtained on duplicate samples.

¹¹A. A. Terry and H. E. Zittel, "Determination of Technetium by Controlled-Potential Coulometric Titration in Buffered Sodium Tripolyphosphate Medium," *Anal. Chem.* **35**, 614 (1963).

7. Analytical Biochemistry

J. C. White

C. A. Horton

I. B. Rubin

A program was initiated in July 1964 with the ultimate objective to establish a biochemistry analytical group in the Analytical Chemistry Division. This effort is being jointly sponsored by the Biology and Chemical Technology Divisions. Two analytical chemists were assigned initially to assist these research divisions in their program to recover and separate the transfer ribonucleic acids (t-RNA's) from *Escherichia coli* bacteria (*E. coli*). The t-RNA's are intermediates in the synthesis of proteins from α -amino acids. The primary objective of this program is to develop methods for obtaining a purified mixture of t-RNA's from *E. coli* and for subsequently fractionating this mixture into the individual t-RNA species. Reverse-phase chromatography is used to fractionate the mixture of t-RNA's into its components. The organic extractant is a quaternary ammonium compound in an organic diluent (0.1 M dimethyldilaurylammonium chloride in amyl acetate) supported on specially treated diatomaceous earth. A sodium chloride solution of increasing concentration is used to elute different t-RNA's. These fractions from the column are assayed by spectral absorbance measurements at 260 m μ and by reacting the fraction with ^{14}C -labeled amino acids. Analytical Chemistry Division personnel are doing these assays. An immense number of assays is required to elucidate the efficiency of the column separation. Initial efforts are thus concerned with modifying the assay procedures to reduce the overall time required for analysis by improving individual steps in the procedure and ultimately to automate the assay insofar as is possible.

Since many pipet operations on small volumes of reagents are required, alternative methods of adding reagents and performing the time reaction

are being investigated.¹ Laing-Levy glass pipets are normally used to take the final aliquot of the mixture to a paper disk, which is washed, dried, and counted for ^{14}C in scintillation fluid. Among a number of others being considered is the Cooke-Takatsy^{2,3} loop, which is a coil of fairly closely wound stainless steel wire with small loops at the sides of the main coil. These loops are sturdy, fairly inexpensive, and easily cleaned; they have adequate precision and accuracy if used properly and permit aliquots to be taken and delivered rapidly. Tests are under way to determine their adequacy as a substitute for the glass pipets in the normal procedure.

The possibility is being considered of depositing final aliquots along a paper strip, which could be washed automatically, dried, and counted by a ^{14}C counter, such as a chromatogram radioactivity scanner. Preliminary test results are encouraging. The possibility of conducting the reaction directly on a paper disk or strip is also under study. Whatman No. 1 and No. 17 and Millipore HAWP papers will not be satisfactory, whereas Whatman 3MM may be. Elevated room temperature ($\sim 37^\circ\text{C}$) and high humidity accelerate the reaction. More studies are needed to determine whether reproducible and complete reaction can be achieved.

Various automatic diluters and pipetters are also being studied to locate one that will increase the number of determinations per day.

¹R. J. Mans and G. D. Novelli, "Measurement of the Incorporation of Radioactive Amino Acids into Protein by a Filter Paper Disc Method," *Arch. Biochem. Biophys.* **94**, 48 (1961).

²J. L. Sever, "Application of a Microtechnique to Viral Serological Investigations," *J. Immunol.* **88**, 320 (1962).

³G. Takatsy, "A New Method for Preparation of Serial Dilutions in a Quick and Accurate Way," *Acta Microbiol. Acad. Sci. Hung.* **3**, 191 (1955).

8. X-Ray and Spectrochemical Analyses

8.1 X-RAY AND SPECTROCHEMICAL ANALYSES (X-10)

M. T. Kelley

Cyrus Feldman

8.1.a X-Ray Analysis

H. W. Dunn

X-Ray Absorption-Edge Analysis of Solids. — Preliminary work was done toward determining the absolute quantity of an element present in a powdered sample by rotating the sample in an x-ray beam and measuring the intensity of the transmitted x ray on each side of the x-ray absorption edge of the element determined. Tests were conducted with mixtures of ZrO_2 and MnO_2 by use of the K_α edge of Zr. Table 8.1 gives the results of these tests.

It is believed that the random nature of the errors is due to imperfect homogenization of the sample. If the homogeneity can be improved, this sample form should be as satisfactory as the liquid form.

Table 8.1. Accuracy of Determination of Zirconium in Powdered Samples by the X-Ray Absorption-Edge Method

Zr (mg)		Error (%)
Present	Found	
0.10	0.072	-28
0.50	0.600	+20
1.0	0.978	-2.2
2.0	2.026	+1.3
5.0	5.24	+4.8
25.0	24.7	-1.4

X-Ray Absorption-Edge Analysis of Radioactive Solutions. — Disposable one-piece polystyrene cells were fabricated for use in the analysis of radioactive solutions by the x-ray absorption-edge method (Fig. 8.1). Both 1.0- and 0.5-cm-thick cells were made.

The cell is filled in a shielded area by remote-handling equipment; the opening is then sealed with tape. The cell is placed in a shielded container and is transferred to the x-ray laboratory for analysis.

Fig. 8.1. Disposable Polystyrene Cell for Holding Radioactive Solutions. Length in direction of x-ray beam, 1 cm; volume, 0.4 cm^3 ; tape seal not shown.

Determination of X-Ray Absorption-Edge Height by Extrapolation. — Heretofore, the height of the x-ray absorption edge has been calculated from intensity measurements made at one point on each side of the edge. In order to minimize the effects of possible shifts in instrumental parameters, it is now proposed to obtain this height more directly by making several measurements of intensity on each side of the edge and then extrapolating to the theoretical wavelength of the edge. An IBM 1604 computer program was written to test the accuracy of various assumed algebraic forms of the x-ray intensity (I) vs wavelength (λ) curve. Thus far, the most successful form appears to be $\log I = \lambda^3$, I being corrected for scattering and resolving-time losses.

Analysis of Solids by X-Ray Fluorescence. — With the help of R. B. Bullock,¹ an IBM 1604 computer program is being developed to use a modified form of Burnham, Hower, and Jones's procedure² for analyzing multicomponent alloys by x-ray fluorescence.

8.1.b Atomic Absorption

Cyrus Feldman

Determination of Ruthenium. — The atomic absorption of solutions of ruthenium in dilute HNO_3 was investigated by use of the 50-cm end-fed absorption tube, hollow cathode, and detection equipment described previously.^{3,4} Study of all variable parameters showed that the best results are obtained under the following operating conditions: spectral line Ru 3498.9 Å (first order); 50- μ slit; Beckman medium-bore $\text{H}_2\text{-O}_2$ burner, fed with 3 lb of H_2 and 20 lb of air; center section of absorption tube surrounded by a 12-in. electric tube furnace operated at 900°C; and hollow cathode charged with compacted Ru metal powder. Under

these conditions, the minimum detectable concentration of Ru is ~ 0.5 $\mu\text{g/ml}$. The slope of the analytical curve ranges from ~ 0.09 optical density unit per $\mu\text{g/ml}$ at 1.5 $\mu\text{g/ml}$ to ~ 0.07 at 4.5 $\mu\text{g/ml}$.

Determination of Selenium. — The chemical state of Se in a flame — and thus the flame absorption coefficient for Se resonance radiation — depends strongly on the oxidizing power of the flame (see previously observed behavior of Sn^3). Experiments in which the absorption tube was used without the furnace showed that Se 1960.3 Å (the resonance line of Se) is not absorbed when a 100- $\mu\text{g/ml}$ solution of Se is aspirated into a $\text{H}_2\text{-O}_2$ flame. However, in a H_2 -air flame, absorption of the line can be detected at a Se concentration of 1 $\mu\text{g/ml}$. A commercial selenium hollow cathode was used in this work.

8.1.c Flame Photometry

T. C. Rains

Cyrus Feldman

Isolation and Flame Photometric Determination of Barium. — In the flame photometric determination of barium at the 0- to 50- $\mu\text{g/g}$ level in salts of alkali metals or alkaline-earth elements, the barium must be isolated from the major component to increase the concentration of the barium and to remove spectral interferences. All the calcium must be removed, since even traces of it (~ 1 $\mu\text{g/ml}$) give intense CaO bands, which interfere with the most sensitive Ba line (553.5 μ).

Korkisch and Tera⁵ indicate that the nitrate form of Dowex 1 retains barium more strongly than it retains alkali metals or other alkaline-earth elements if the solvent is methanol (90 vol %)—5 N HNO_3 (10 vol %). Tests showed that traces of barium can be so retained but that the low solubility of the samples (e.g., KNO_3) in this medium limits the usefulness of the procedure.

The coprecipitation of barium with PbCrO_4 was studied briefly by Reynolds,⁶ although individual results and conditions were not given in detail. This procedure appeared interesting and was

¹Mathematics Division.

²H. D. Burnham, J. Hower, and L. C. Jones, "Generalized X-Ray Emission Spectrographic Calibration Applicable to Varying Compositions and Sample Forms," *Anal. Chem.* **29**, 1827 (1957).

³S. R. Koertyohann and C. Feldman, "Atomic Absorption Analysis," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, pp. 60–62.

⁴S. R. Koertyohann and C. Feldman, "Atomic Absorption Spectroscopy Using Long Absorption Path Lengths and a Demountable Hollow Cathode Lamp," in *Developments in Applied Spectroscopy* (ed. by J. E. Forrette and E. Lanterman), vol. 3, pp. 180–89, Plenum, New York, 1964.

⁵J. Korkisch and F. Tera, "Separation of Thorium by Anion Exchange," *Anal. Chem.* **33**, 1264 (1961).

⁶S. A. Reynolds, "Determination of Alkaline-Earth Elements," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 19 2*, ORNL-3397, pp. 75–78.

investigated further. As much as 300 μg of Ba was coprecipitated quantitatively ($\sim 99\%$) with 10 mg of Pb as PbCrO_4 at $\text{pH} \geq 6.2$; contamination from alkali metals or other alkaline-earth elements was negligible (see Table 8.2). Because of the serious spectral interference of calcium, it probably would be necessary to repeat the coprecipitation if much calcium were present. Under the same conditions, 1 mg of Fe^{3+} or 10 mg of PO_4^{3-} does not affect recovery of the barium, but 1.5 mg of Al^{3+} significantly reduces the recovery.

To circumvent the effect of aluminum, barium was first coprecipitated with calcium oxalate. According to Peters,⁷ precipitation of barium as the oxalate is quantitative from 33 vol % ethyl alcohol solutions. The tracer ^{133}Ba was used to test the coprecipitation as oxalate of 10 μg of Ba with 10 mg of Ca in 30 vol % methanol. The results (Table 8.3) indicate that recovery is essentially complete in this medium at pH 3. The oxalate so obtained is dissolved in a mixture of nitric and perchloric acids, and the solution is subjected to the PbCrO_4 procedure (see above).

The Ba-bearing PbCrO_4 is dissolved in a mixture of nitric acid and hydrogen peroxide, and the solution is diluted to volume with an acetone-water-glycerol solution. The final diluted solution is analyzed for barium with a Jarrell-Ash flame photometer; the 553.6-m μ Ba line is used.

⁷C. A. Peters, "The Estimation of Calcium, Strontium, and Barium as the Oxalates," *Am. J. Sci.* 12 (4), 216 (1901).

Table 8.2. Contamination of PbCrO_4 Precipitate by Various Elements Under Conditions That Give Complete Coprecipitation of Barium

Major Element	Amount Present (mg)	Amount Found in PbCrO_4 Precipitate (μg)
Li	80	<3
Na	200	<3
K	320	50
Mg	60	<8
Ca	180	20
Sr	165	520

Table 8.3. Effect of pH on the Coprecipitation of Barium with Calcium Oxalate in the Presence of 30 vol % Methanol

pH	Recovery of Ba (%)
0.5	77
1	98.4
2	99.2
3	99.5
3 ^a	90.0

^aNo methanol used.

8.2 X-RAY AND SPECTROCHEMICAL ANALYSES (Y-12)

A. E. Cameron

8.2.a Disposable Spectrographic-Excitation Chamber for Radioactive Samples

J. A. Carter

A disposable spectrographic-excitation chamber was designed, tested, and used for determining impurities in ^{147}Pm and ^{151}Sm . Figure 8.2 shows its general design. The body of the chamber is a 1½-in.-ID glass cross. Plexiglas tubes, machined as shown, are slipped onto each of the four glass cross ports to serve as molds for mounting the brass electrode guides and the glass or quartz lenses with epoxy. Excitation chambers used for very long exposures or with high currents must have water-cooled electrode guides, as shown in Fig. 8.2C. Water cooling is not required, however, for exposure durations of 3 min at 5 amp. Air-intake and exhaust connections are provided by sealing ¼-in. copper tubing adjacent to each electrode guide. The chamber is lightweight and compact and is easily fitted to an electrode stand so that the analytical gap may be adjusted during an exposure.

Samples of ^{147}Pm and ^{151}Sm were analyzed successfully for 50 trace elements by use of the disposable excitation chamber and M-11 gas-mask filters for containment. Excitation chambers of this general design may be used for studies in controlled atmospheres.

Fig. 8.2. Disposable Spectrographic Excitation Chamber for Radioactive Samples.

8.2.b Determination of Certain Impurities in Lithium Fluoride Powder by Spark Excitation

J. A. Carter

A rapid technique was developed that utilizes the Paschen Direct Reader for determining Ca, Mg,

Na, Mn, Ni, Ce, Gd, and Lu in lithium fluoride powder. The lithium fluoride is cemented to a $\frac{1}{8}$ -in.-thick by $\frac{1}{2}$ -in.-diam graphite disk with acrylic spray. This disk is mounted on a conventional rotating disk holder, axis horizontal, for excitation by means of a high-voltage ac spark. Calibration standards were prepared by mixing the appropriate weights of the elements to be determined with high-purity lithium fluoride. For the internal standard, the Li 3232.61 Å line is used. Table 8.4 gives the useful concentration range for each element and the analytical lines employed. This technique was used in over 1000 analyses for the Reactor Chemistry Division.

Table 8.4. Element Concentration Range in Lithium Fluoride by a Rotating Disk-AC Spark Technique

Element	Wavelength (Å)	Useful Range (μg per g of LiF)
Na	5889.95	10-2000
Mg	2852.13	10-2000
Ca	4226.73	10-2000
Mn	2593.73	10-2000
Ni	3101.55	50-2000
Ce	4186.60	100-2000
Gd	3646.20	50-2000
Lu	2615.42	10-2000
Li ^a	3232.61	

^aInternal standard.

9. Mass Spectrometry

A. E. Cameron

9.1 TRU MASS SPECTROMETRY

A. E. Cameron

R. E. Eby

The new double-magnetic-deflection mass spectrometer was put in service in Building 9735 on August 1, 1964. The vacuum system is entirely of metal, and pumping is done with VacIon pumps. The magnets and the vacuum-system assembly are in a laboratory arranged for containment of alpha radioactivity (see Fig. 9.1). As with the other two double-stage instruments in use in the Referee

Analysis Laboratory, ion detection is by secondary electron multiplier, and pulse counting is used instead of more conventional current measurement. Spectra are stored in a 400-channel analyzer, from which they are read out on magnetic, printed, or punched tape. The sample size required is of the order of 1 to 2 ng ($0.5 \mu\text{c}$), depending on the radioactivity of the material. In addition to the advantages of small sample size, the equipment also permits the measurement of rare isotopes down to a concentration as low as 1 ppm. All samples of highly radioactive alpha emitters are now being analyzed on this instrument.

Fig. 9.1. TRU Mass Spectrometer in Alpha-Containment Laboratory.

9.2 ISOTOPIC COMPOSITION OF ATMOSPHERIC NEON

A. E. Cameron

J. R. Walton

The published results of several mass spectrometric determinations of the isotopic composition of atmospheric neon are not in good agreement. The ready availability of ^{20}Ne and ^{22}Ne of high isotopic and chemical purity and in adequate quantity makes "calibrated" measurement of the isotopic composition possible by correcting for bias in the mass spectrometer. Several standards were care-

fully prepared from the separated isotopes, and the bias was determined. The results for six samples of neon obtained from commercial suppliers agreed with each other. The agreement indicates either that no fractionation occurred in the preparation of the samples or that the same degree of fractionation occurred in different plants. Results obtained thus far indicate that the isotopic composition (atom percent) of atmospheric neon is: ^{20}Ne , 90.514 ± 0.031 ; ^{21}Ne , 0.266 ± 0.005 ; ^{22}Ne , 9.220 ± 0.029 . The calculated atomic weight is 20.1794 ± 0.0018 ; this value can be compared with the value 20.183, which is based on gas density measurements.

10. Infrared Spectroscopy

Lucy E. Scroggie

Infrared spectroscopy was used to determine the effect of gamma radiation on such compounds as butyl- α -methylbenzylphenol, 2-thenoyltrifluoroacetone, dimethylglyoxime, sodium dimethylglyoxime, *o*-benzylphenol, di-*sec*-butylphenylphosphonate, and ion-exchange resins. Fractions of the products from the nitric acid degradation of diethylbenzene contained alkyl and aryl nitro, ketone carbonyl, and hydroxyl groups, as indicated by infrared absorption spectra.

The hydrolysis of uranium carbides and thorium carbides with water or nitric acid yields mixtures of two types: water-soluble acidic solids and ether-soluble waxes. The infrared spectra of the waxes revealed the alkyl and alkene units of hydrocarbon polymers. The yellow-to-brown solids that were soluble in water and methanol were mixtures of polybasic organic acids, which are difficult to separate by any means. Oxalic acid was identified and removed by vacuum sublimation.

The residue apparently consisted of mellitic acid (benzenehexacarboxylic acid) and minor amounts of benzenepentacarboxylic acid; some samples contained hydroxyl groups and nitrate ions in small quantities. Repeated attempts to separate these acids by paper chromatography with several solvents were unsuccessful.

Table 10.1 lists the various types of samples investigated by infrared spectroscopy. Most studies involved the detection and/or identification of impurities in commercial solvents, process streams, or compounds (inorganic and organic) prepared at ORNL; the identification of commercial products; or the characterization of organic compounds. In addition, semiquantitative or quantitative determinations were made of ethylene glycol-water in engine oil, four isomers of phenylbutanol in reaction mixtures, Cellulube in hexane extracts of air samples, and phenol in di-*sec*-butylphenylphosphonate.

Table 10.1. Types of Samples Examined by Infrared Spectroscopy

Organic	
2-Thenoyltrifluoroacetone-xylene	N,N',N''-Trimethylborazine
Butyl- α -methylbenzylphenol-Amsco	Long-chain tertiary amine
Dimethylglyoxime	Epoxy resin
Sodium dimethylglyoxime	Di-2-ethylhexylphosphoric acid
Diethylbenzenes	Diphenyl ether
Soybean oil-2-ethylhexanol	Alkyl phthalate
o-Benzylphenol-diisopropylbenzene	Tributyl phosphate
Engine oils	Extracts of LiCl solutions
Irradiated ion-exchange-resin effluents	Degraded pump oil
3,9-Diethyltridecanol-6	Di-sec-butylphenylphosphonate
3,9-Diethyltridecanone-6 oxime	Aqueous extract of tributyl phosphate
3,9-Diethyltridecanamine-6	Iodinated-hydrocarbon vapors
Commercial corrosion inhibitor	Methyl isocyanide
Commercial solvents	Trioctylarsine oxide
Commercial odorants	Uranium carbide dissolution products
Phenylbutanol isomers	Thorium carbide dissolution products
Commercial lubricant vapors	Oil smears
Commercial rust remover	
Inorganic	
KCl (single crystals and ingots)	SiF ₄ -SiF ₃ CH ₃ -SiF ₂ (CH ₃) ₂ mixture
NaCl (ingots)	Mg(BrO ₃) ₂
KF·UF ₅	KIO ₄ -KIO ₃ mixtures
LiF·UF ₅	KClO ₄ -KClO ₃ mixtures
RbF·UF ₅	GeO ₂ glass
LiF (single crystals)	

11. Optical and Electron Microscopy

M. T. Kelley

T. E. Willmarth

T. G. Harmon

H. W. Wright

11.1 ELECTRON MICROSCOPY OF RADIOACTIVE MATERIALS

11.1.a Electron Microscope Facility for Studying Radioactive Materials

A contract was let to the H. K. Ferguson Company for modification of room 201, Building 3019,

to house the Philips EM 100B electron microscope. The installation of this microscope and its associated equipment will be the first step toward establishing the much-discussed facility for electron microscopy of radioactive materials of interest in nuclear engineering. Preliminary preparation of radioactive samples will be done in hot cells and will be coordinated with other

uses of the cells by the Analytical Chemistry Division. Final preparation of samples for electron microscopy will be done in the analytical laboratories in Building 3019.

Certain powder samples of 100-r/g radioactivity were prepared and examined successfully,¹ and replica techniques for some radioactive surfaces were developed.² However, each radioactive sample received for the first time presents specific problems and requires special testing and the

¹M. T. Kelley et al., "Optical and Electron Microscopy," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1961*, ORNL-3243, pp. 51-54.

²Staff of the Metallurgy Division, *Technical Function, Operation of the High Radiation Level Examination*, ORNL-3525, ORNL-CF-61-1-75, pp. 49-50

development of certain procedures before it can be examined properly in the electron microscope. The facility will likely be in limited operation by January 1965 and in full operation later that year.

11.2 NUCLEAR SAFETY PROGRAM

Electron microscopy was done for those research groups studying simulated fallout of radioactive particles from possible accidents at experimental or industrial reactors. Studies were made to determine the best procedures for collecting and sampling radioactive particulates. The particulates used in the study were produced on a laboratory scale and in large-scale mockup tests

Fig. 11.1. Representative Particles Collected on Millipore Filter from Simulated Rapid Fuel Burnup. Magnification, 91,500 $\times$.

simulating such accidents. Materials collected on a variety of filters, in electrostatic and thermal precipitators, and in impactors were examined in the electron microscope to determine the size and shape of individual particulates and the nature of agglomeration, if it occurred. Figure 11.1 shows the chainlike agglomerates that form under certain conditions. Selected-area electron diffraction was used to identify the chief constituents of such structures. A technique for electron autoradiography of such radioactive particles and agglomerates is being developed; the technique is similar to that described by Caro, Van Tubergen, and Kolb.³

³L. A. Caro, R. P. Van Tubergen, and J. Kolb, "High Resolution Autoradiography I. Methods," *J. Cell Biol.* 15(2), 173 (1962).

11.3 ELECTRON OPTICAL INSTRUMENTATION

The Philips EM 200 electron microscope discussed earlier⁴ is in operation; resolution better than 6 Å has been achieved with it.

11.4 ELECTRON AND OPTICAL MICROSCOPY AND ELECTRON DIFFRACTION RESEARCH ASSISTANCE TO OTHER LABORATORY DIVISIONS

In their research problems requiring optical and electron microscopy and electron diffraction, assistance was given to the Chemistry, Chemical

⁴M. T. Kelley *et al.*, "Optical and Electron Microscopy," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, pp. 68-70.

2.0 μ

Fig. 11.2. Surface (left) and Internal Structure (right) of Thoria Sol-Gel Beads Formed in the Presence of a Cationic Surfactant. Carbon replica, palladium shadowcast.

Technology, Instrumentation and Controls, Isotopes, Operations, Physics, Reactor Chemistry, Health Physics, and Metals and Ceramics Divisions. Of particular interest was the electron microscopy done relative to the development of thoria-urania sol-gel beads.⁵ Figure 11.2 shows typical results of the studies of the structures of such materials. Other materials of special interest in nuclear science were also studied. These materials included: films formed on cadmium, zinc, indium, silicon, stainless steel (302 and 304), and Y-Al alloys; sintered particles of Al_2O_3 and Fe_3O_4 ; particles of Ce-Al alloy, hydrocarbons, alpha- and gamma-irradiated solutions of AgNO_3 (ref. 6), and pine wax produced in an electric field; molybdenum that contained zirconium oxide and thorium oxide particles; niobium foils that had been exposed to liquid potassium; ammonium tungstate; pyrolytic graphite;

sodium fluoride; cerium oxide; diatomaceous earth; and thoria sols.

The Health Physics and Chemistry Divisions were assisted in the preparation of aluminum semireflectors for use in research spectrophotometers. The Physics Division was aided in preparing and fabricating special (7-cm²) semiconductor (germanium and silicon) radiation detectors for use in experiments on neutron and charged-particle fission and on fission-oriented nuclei.⁷

11.5 ULTRASTRUCTURE STUDIES OF EXCHANGE RESINS

D. H. Freeman,⁸ with T. E. Willmarth's assistance, studied the ultrastructure of certain exchange resins by means of the high resolution of the Philips EM 200 electron microscope.

⁵T. E. Willmarth, "A Microscopic Study of Thoria Sol-Gel Beads," presented at Micro 64 (International Microscopical Society), Chicago, Ill., July 1964 (to be published).

⁶H. A. Mahlman and T. E. Willmarth, "Radiolytic and Photolytic Reduction of Aqueous Silver Nitrate Solutions," *Nature* 202, 590 (1964).

⁷J. W. T. Dabbs, F. J. Walter, and G. W. Parker, "Modification of Cryostat and Associated Equipment," *Phys. Div. Ann. Progr. Rept. Jan. 31, 1964*, ORNL-3582, p. 123.

⁸Summer employee, Washington State University, Pullman.

12. Nuclear and Radiochemical Analyses

J. C. White

W. S. Lyon

12.1 NUCLEAR PROPERTIES OF RADIONUCLIDES

12.1.a Gamma-Ray Branching in the Decay of ^{141}Ce

J. S. Eldridge

An early value for the branching ratio for the 0.145-Mev gamma transition in the decay of ^{141}Ce was 0.43 gamma/dis.¹ However, the adopted value

for the branching of the 0.435-Mev negatron group (70%)² and the total conversion coefficient for the 0.145-Mev gamma ray ($\alpha_T = 0.513$) indicate that the branching ratio should be 0.48 gamma/dis.

Isotopically pure ^{141}Ce was obtained, as described in Sect. 12.2.a, by double neutron capture on ^{139}La followed by negatron decay of the 3.5-hr ^{141}La product. Absolute disintegration rates were determined for several sources with a 4π beta-gamma coincidence counter. Gamma-ray

¹W. S. Lyon, "Isotopic Analysis: Cerium-141 and Cerium-144," *Nucl. Sci. Eng.* 4, 709 (1958).

²" ^{141}Ce , Ground-State Decay," *Nuclear Data Sheets*, vol. 5, Natl. Acad. Sci.—Natl. Res. Council, Washington, D.C., 1962.

intensity was determined with a 3×3 in. NaI(Tl) detector. The branching ratio observed for the 0.145-Mev gamma-ray transition in the decay of ^{141}Ce was 0.493 ± 0.006 gamma/dis. This value is in much better agreement with that predicted from negatron branchings and total conversion coefficients (0.48 gamma/dis) than with the value reported previously (0.43 gamma/dis).

12.1.b Gamma Transitions in the Decay of ^{79}Kr

J. S. Eldridge

Several irradiations of enriched ^{78}Kr were carried out in the ORR to produce ^{79}Kr for use in studies of the nuclear properties of ^{79}Kr and of its

production techniques. Nuclear data obtained previously with a conversion-electron spectrograph indicate that the energy of the highest-energy gamma transition in the decay is 0.833 Mev.²

Gamma-ray spectra collected over a period of several days showed the existence of 1.11- and 1.33-Mev gamma rays in addition to at least one other weak transition; these gamma rays decayed with a 35-hr half-life. Decay measurements taken over a period of 13 days in a high-pressure ionization chamber yielded a preliminary value of 35 hr for the half-life of ^{79}Kr . Figures 12.1 and 12.2 give the high-energy and low-energy portions, respectively, of the gamma-ray spectrum for this nuclide.

Future irradiations are scheduled to obtain decay-scheme parameters necessary for the assay of ^{79}Kr , which has potential applications in engineering and biological experiments. This work was done jointly with R. S. Pressley.³

³Isotopes Division.

Fig. 12.1. High-Energy Gamma-Ray Spectrum of ^{79}Kr .

Fig. 12.2. Low-Energy Gamma-Ray Spectrum of ^{79}Kr .

12.1.c Decay of ^{99}Mo - ^{99m}Tc

Peter Crowther⁴

J. S. Eldridge

The decay parameters of ^{99}Mo - ^{99m}Tc were determined by liquid-liquid extractions, 4π beta-gamma and gamma-gamma coincidence counting, and absolute gamma-spectrometry measurements. Gamma-ray energies and intensities were obtained with a 3×3 in. NaI(Tl) spectrometer. The relative intensities of the 0.74- and 0.78-Mev gamma rays were measured with a lithium-ion-drifted germanium diode detector; these gamma rays were unresolved in the NaI(Tl) spectra. The observed numbers of gamma photons per ^{99}Mo disintegration with energies of 0.142, 0.181, 0.372, 0.740, 0.780, and 0.93 Mev were 0.076, 0.068, 0.013, 0.124, 0.044, and 0.004 respectively. Gamma-gamma coincidence measurements confirmed the existence of the 0.93-Mev gamma ray in the ^{99}Mo decay. A quantitative separation of ^{99m}Tc , followed by determinations of x- and gamma-ray emission rates, gave the sum of the internal conversions of the 0.140- and 0.142-Mev gamma rays as $\alpha_T = 0.099 \pm 0.015$. At equilibrium, the radioactivity of the ^{99m}Tc daughter was determined to be 0.964 that of the ^{99}Mo radioactivity. A paper on this work was submitted to *Nuclear Physics* for publication.⁵

12.1.d New Isomer of Bromine: ^{82m}Br

J. F. Emery

The decays of ^{82m}Br were studied by gamma-ray scintillation spectroscopy and beta proportional counting. This new isomer decays with a half-life of 6.20 ± 0.05 min and excites a highly converted gamma-ray transition of 46 ± 2 kev in ^{82}Br ; α_K is 268. The total combined beta branching is 2.4%.

The thermal-neutron activation cross section and resonance integral for ^{82m}Br are 3.0 and 34 barns, respectively, and the corresponding values for the total production of ^{82}Br are 3.23 ± 0.2 and 41.3 ± 1 barns. This work was discussed,⁶ and a paper was accepted for publication in the *Journal of Inorganic and Nuclear Chemistry*.

⁴P. Crowther, temporary alien employee, South African Atomic Energy Board, Pelindaba, Pretoria, South Africa.

⁵P. Crowther and J. S. Eldridge, "Decay of ^{99}Mo - ^{99m}Tc ," submitted for publication in *Nuclear Physics*.

12.1.e Studies of Rare-Earth-Element Alpha Emitters

T. H. Handley

A study of rare-earth-element alpha emitters and a search for new alpha emitters, especially of low branching ratio, were made. The radionuclides were produced in either the ORIC or the 86-in. cyclotron by bombarding selected enriched stable isotopes with 75-Mev alpha particles or 20-Mev protons. The radionuclides were separated by ion exchange on Dowex 50 and were eluted with α -hydroxyisobutyric acid. A new alpha emitter with a decay energy of 2.63 ± 0.03 Mev was discovered and was assigned to the nuclide ^{148}Eu . The measured ratio of alpha to electron capture branching was $(9.4 \pm 2.8) \times 10^{-9}$, which corresponds to a partial alpha half-life of $(1.6 \pm 0.5) \times 10^7$ years. By use of a Coulomb barrier penetration formula and the measured alpha decay energy, a half-life of $(6.2^{+6.7}_{-3.3}) \times 10^6$ years was calculated. The agreement, within experimental error, between the measured and calculated partial alpha half-lives indicates that the ground-state spin and parity assignments are probably the same for ^{148}Eu as for its daughter ^{144}Pm . A paper on this subject is scheduled for publication in the December issue of *The Physical Review*.⁷

This work was done jointly with K. S. Toth, I. R. Williams, and E. Newman.⁸

12.1.f Properties of Nuclear Levels in a Number of Even-A Nuclei ($184 \leq A \leq 192$)

Benjamin Harmatz⁹

T. H. Handley

A large accumulation of internal-conversion-electron data has made possible the study of the properties of high-energy nuclear levels in the transition region of mass numbers 184 to 192. Reasonably detailed schemes that show the nuclear levels were constructed from these measurements and led to the following even-even

⁶J. F. Emery, " ^{82m}Br : A New Bromine Isomer," presented at the 148th National American Chemical Society Meeting, Chicago, Ill., Aug. 30-Sept. 4, 1964.

⁷K. S. Toth et al., "New Rare Earth Alpha Emitter, ^{148}Eu ," *Phys. Rev.*, in press (1964).

⁸Each from the Electronuclear Division.

⁹Electronuclear Division.

nuclei: $^{184m}\text{Re} \rightarrow ^{184}\text{W}$, $^{186}\text{Ir} \rightarrow ^{186}\text{Os}$, $^{188}\text{Ir} \rightarrow ^{188}\text{Os}$, $^{190}\text{Ir} \rightarrow ^{190}\text{Os}$, and $^{192}\text{Ir} \rightarrow ^{192}\text{Os}$.

Parameters relevant to rotational configurations and branching ratios of the de-exciting transitions were evaluated. The low-energy spectra, with their associated vibrational and rotational modes of excitation, were confirmed and extended. Triple isomerism was observed in ^{190}Ir including isomeric transitions of $M3$ (26 keV) and $M4$ (148 keV) character. The metastable state of ^{184}Re is partially de-excited by an 83-keV isomeric transition of $M4$ multipolarity. A paper on this subject was published.¹⁰

12.1.g Studies of Neutron-Deficient Hafnium Radionuclides

T. H. Handley

The decays of neutron-deficient hafnium radionuclides ($168 \leq A \leq 173$) produced in ORIC by (α, xn) reactions on ytterbium stable isotopes were studied with high-resolution spectrographs and gamma scintillation spectrometers. The hafnium radionuclides were separated from the ytterbium target by solvent extraction with thenoyltrifluoroacetone (TTA). The carrier-free radionuclides were electroplated onto fine platinum wire. Over 60 transitions in the 100-keV energy range were resolved. Assignment of the resolved decay schemes to particular radionuclides will be based on relative activation yield, determined by use of enriched isotopes of ytterbium plus bombarding energies, and on decay rates of conversion lines in a series of photographic exposures. The detailed analysis of conversion spectral lines and of relative gamma scintillation spectra will make possible a study of the properties of nuclear-energy levels in lutetium isotopes.

This work was a continuation of previous work done with the 86-in. cyclotron. Bombarding with 75-MeV alpha particles produces radionuclides previously unavailable with 20-MeV proton bombardment. These studies were done jointly with B. Harmatz.⁹

¹⁰B. Harmatz and T. H. Handley, "Properties of Nuclear Levels in a Number of Even-Mass Nuclei ($184 \leq A \leq 192$)," *Nucl. Phys.* **56**, 1 (1964).

12.1.h Half-Life Measurements

S. A. Reynolds

Unpublished decay data for ^{140}La were analyzed according to the least-squares method both by the IBM 7090 computer with the CLSQ code and by hand calculation.¹¹ The half-life values determined were 40.2 ± 0.1 and 40.1 ± 0.1 hr respectively. The former result was chosen because the CLSQ program weights the early high-precision points more than the later ones, and the hand calculation involves taking logarithms, which appears to simulate a weighting in the reverse sense. Literature values are 40.0 to 40.3 hr, with a weighted mean of 40.2 hr.¹²

Direct measurement of the gamma decay of four ^{137}Cs sources has been in progress for five years. The data acquired thus far have been treated by the CLSQ code, and the half-life value so obtained, which is the present tentative value, is 30.6 ± 0.7 years (95% C.L.). A recent value based on specific activity is 30.8 ± 0.3 years.¹³

12.1.i Redetermination of the Half-Life of ^{232}U

W. S. Lyon

The value 71.4 ± 0.6 years was determined for the half-life of ^{232}U by measuring the heat evolution of a weighed sample of uranium oxide whose uranium content was 99.24% mass 232. The value 72.1 ± 0.5 years was obtained by counting the alpha disintegration rate. A mean between these values, 71.7 ± 0.9 years, at an estimated 95% confidence level is proposed for the half-life of ^{232}U . A paper on this subject was published.¹⁴ This work was done jointly with J. M. Chilton,¹⁵ R. E. Leuze,¹⁵ and R. A. Gilbert.¹⁶

¹¹J. B. Cumming, "CLSQ, the Brookhaven Decay Curve Analysis Program," pp. 25-33 in *Radiochemical Techniques. Applications of Computers to Nuclear and Radiochemistry* (ed. by G. D. O'Kelley), NAS-NS-3107 (March 1963).

¹² ^{140}La , Ground-State Decay, Sheet 1," *Nuclear Data Sheets*, vol. 5, Natl. Acad. Sci.-Natl. Res. Council, Washington, D.C., 1962.

¹³R. E. Lewis, ORNL Isotopes Division, personal communication to S. A. Reynolds, July 1964.

¹⁴J. M. Chilton *et al.*, "A Redetermination of the Half-Life of Uranium-232," *J. Inorg. Nucl. Chem.* **26**, 395 (1964).

¹⁵Chemical Technology Division.

¹⁶Chemistry Division.

12.1.j Half-Life of ^{76}As

J. F. Emery

The half-life of ^{76}As was recalculated by use of computer programs to analyze the decay data. The new value for the half-life of ^{76}As is 26.05 ± 0.10 hr; values reported in the literature range from 26.1 to 26.8 hr.¹⁷

12.2 MEASUREMENT OF RADIOACTIVITY

12.2.a Epithermal Neutron Irradiation of Lanthanum to Produce ^{136}Cs

J. S. Eldridge

High-purity lanthanum was irradiated in a high epithermal neutron flux facility of the ORR to produce ^{136}Cs by the (n, α) reaction. Cerium-141 and ^{140}Ba were produced in addition to ^{136}Cs . The ^{141}Ce could have been produced by two paths:

Since an appreciable quantity of ^{141}Ce was produced and the (n, γ) cross section of ^{140}Ce is only 0.5 barn, one concludes that ^{140}La has a high cross section. The ^{141}Ce was isolated in high radiochemical purity and in carrier-free form by thenoyltrifluoroacetone (TTA) extraction.

It was not expected that ^{140}Ba would be produced in detectable quantities, as it can be made by only an (n, p) reaction on ^{140}La ; its production here indicates a high (n, p) as well as a high (n, γ) cross section for ^{140}La .

This work will be repeated to measure cross sections of some of the radioactive species involved and to study the feasibility of producing ^{141}Ce by these two paths.

This work was done jointly with H. A. O'Brien.¹⁸

¹⁷D. Strominger, J. M. Hollander, and G. T. Seaborg, "Table of Isotopes," *Rev. Mod. Phys.* 30 (2), pt. 2, 585 (1958); esp. p. 644.

¹⁸Isotopes Division.

12.2.b Gamma-Ray Spectroscopy with Lithium-Drifted Germanium Diode Detectors

J. S. Eldridge

A lithium-drifted germanium diode detector of the type described by Tavendale and Ewan¹⁹ was used in several analytical applications. The high resolution inherent in this device separates gamma rays of closely similar energies, which are unresolved in conventional NaI(Tl) spectroscopy. A study of the decay of ^{99}Mo - ^{99m}Tc (see Sect. 12.1.c) required a means of determining the abundance of 0.78-Mev gamma rays in ^{99}Mo . Figure 12.3 indicates the gamma-ray spectrum of this radionuclide and shows that the 0.74- and 0.78-Mev gamma rays are unresolved. Figure 12.4 shows the gamma-ray spectrum of this nuclide obtained with a germanium diode detector. The

¹⁹A. J. Tavendale and G. T. Ewan, "A High Resolution Lithium-Drifted Germanium Gamma-Ray Spectrometer," *Nucl. Instr. Methods* 25, 185 (1963).

Fig. 12.3. Gamma-Ray Spectra of ^{99}Mo (upper curve) and ^{99m}Tc .

Fig. 12.4. Gamma-Ray Spectrum of ^{99}Mo - ^{99m}Tc Obtained with a High-Resolution Lithium-Drifted Germanium Diode Detector.

0.74- and 0.78-Mev photopeaks are clearly resolved. Determination of the branchings in ^{99}Mo through the 0.74- and 0.78-Mev transitions per-

mitted the calculation of equilibrium concentrations of ^{99m}Tc .

Figure 12.5 is a gamma-ray spectrum of 35-hr ^{79}Kr obtained with a lithium-ion-drifted germanium detector. Because of its high resolution, this detector permits the determination of precise energy values more easily than does NaI(Tl) spectroscopy. Comparison of Fig. 12.5 with Fig. 12.1 illustrates the utility of the high-resolution detector; in Fig. 12.1 the 1.1-Mev photopeak is only partly resolved, whereas in Fig. 12.5 it is resolved into three gamma rays.

Mixtures of ^{95}Zr - ^{95}Nb and ^{59}Fe - ^{60}Co that are unresolved in conventional NaI(Tl) spectroscopy were successfully separated with the germanium diode detector.

Fig. 12.5. Gamma-Ray Spectrum of ^{79}Kr Obtained with a High-Resolution, Lithium-Drifted Germanium Diode Detector.

12.2.c Effect of Gamma Spectrometer Live Time on Precision of Measurements

S. A. Reynolds

The effect of live time on the performance of a typical 256-channel analyzer was studied briefly.

The study required three ^{137}Cs sources (A, B, and C, provided by J. F. Emery) that had precisely known ratios of radioactivity (1:2.5:5). Spectra of these sources were taken at four different distances, and the spectra of B and C were compared with that of A. The correction for random-summing loss was estimated as follows. It was assumed that, in the region of the sum spectrum up to twice the energy of the Compton maximum, every second count represented the loss of a count from the primary peak (peak/total is ~ 0.5). Above this energy level, every sum count indicated the loss of a peak count. Thus, the correction was found to be +0.2% per 1000 counts/sec in the peak. The data were grouped and averaged in order to show the effects of different parameters or operating conditions. None of these have much effect; the results are reasonably accurate even at live time as small as 10%, although making measurements at such a small live time is not recommended.

12.2.d International Atomic Energy Agency (IAEA) Intercomparison of Determinations of ^{137}Cs

J. S. Eldridge   Peter Crowther⁴

To clarify existing discrepancies among several laboratories in which different assay methods are used to determine ^{137}Cs , the International Atomic Energy Agency (IAEA) Division of Research and Laboratories conducted an interlaboratory intercomparison. Results from ORNL by three assay methods were 8.91, 8.99, and 9.04 $\mu\text{C/g}$; the mean of the results from all the participating laboratories was 9.06 $\mu\text{C/g}$. Participation in this intercomparison has helped to improve the assay methods used to measure this important radionuclide.

12.2.e Absolute Determination of ^{125}I in Clinical Applications

J. S. Eldridge   Peter Crowther⁴

A sum-coincidence method for the absolute determination of ^{125}I was studied with several detectors. Four detector types gave absolute disintegration-rate values that were accurate to better than 1%. Effects of distance, sample volume, and detector resolution on the absolute method were studied. Detection efficiencies were

measured in six measurement systems and gave values ranging from 18 to 47%. Surface effects in NaI(Tl) detectors that cause distorted spectra were explained. A paper on this subject was published.²⁰

12.2.f Determinations of ^{232}U by Gamma Spectrometry

S. A. Reynolds

The gamma spectra were taken for a number of samples of ^{233}U that had been enriched in a calutron. Most of the gamma radiations were of low energy and arose in the decay of ^{233}U . The high-energy gammas were of major interest; they are associated with the ^{208}Tl daughter of contaminant ^{232}U ,²¹ measured through the 2.6-Mev radiation of ^{208}Tl .²² The peaks characteristic of ^{208}Tl were seen, as well as those of ^{209}Tl and ^{213}Bi which are daughters of ^{233}U . The samples were enclosed in a variety of containers, principally shipping cans ~ 7 in. high and metal chambers. A simple estimate of the effective distance h of a source was made by counting its container both while upright and while inverted. Uranium-232 in concentrations from one to several hundred parts per billion was measured in ^{233}U samples that were 0.1 g to many grams in size.

Uranium-232 was found in each of several samples of enriched ^{235}U ; levels of ^{232}U of ~ 0.1 to 0.7 ppb were measured in ^{235}U . Thus, a hitherto unreported finding²³ by ORGDP personnel in 1960 was confirmed. Uranium-232 is not formed in significant quantity in nature, but on irradiation of uranium it is produced both from thorium impurity and from the ^{231}Pa daughter of ^{235}U .

²⁰J. S. Eldridge and P. Crowther, "Absolute Determination of ^{125}I in Clinical Applications," *Nucleonics* 22(6), 56 (1964).

²¹S. A. Reynolds, "Radioactivity Associated with Uranium, Thorium, and Plutonium," pp. 562-72 in vol. 2 of *Progress in Nuclear Energy, Series III, Process Chemistry*, ed. by F. R. Bruce, J. M. Fletcher, and H. H. Hyman, Pergamon, New York, 1958.

²²S. A. Reynolds, "Determination of U^{232} in U^{233} ," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1958*, ORNL-2662, p. 57.

²³C. A. Kienberger, ORGDP, personal communication to S. A. Reynolds, July 1964.

12.3 RADIOCHEMICAL STUDIES

12.3.a Trialkyl- and Hexaalkylphosphorothioic Triamides as Extractants for Metal Ions. Selective Extraction of Hg^{2+} , Ag^+ , and Cu^+

T. H. Handley

N,N',N''-Trihexylphosphorothioic triamide (thio-THPA) and N,N',N''-hexabutylphosphorothioic triamide (thio-HBPA), which are nitrogen analogs of the neutral esters of phosphorothioic acid, were evaluated as reagents for extracting metal ions from solutions of aqueous mineral acids. Of 33 metal ions studied, only Cu^+ , Hg^{2+} , Ag^+ , Pd^{2+} , and Au^{3+} are extracted in significant amounts. The extracted species are formed rapidly. From aqueous solutions 0.1 to 6 M in acid and with a 2.62 mM solution of thio-THPA or thio-HBPA in CHCl_3 , the metal ions Hg^{2+} , Ag^+ , and Cu^+ are extracted quantitatively. The D_{Hg} (distribution ratio of Hg) is independent of the concentration of HNO_3 or H_2SO_4 in the aqueous phase; the D_{Ag} depends on NO_3^- concentration. Mercury(II) combines with thio-THPA in a mole ratio of 2 to 1. The metal-ion concentration, the type of organic solvent, and the substituent group of the trialkylphosphorothioic triamides are significant variables. Structures are postulated for the complex species formed between the extractant and the metal ions. A paper²⁴ on this subject is scheduled for publication in the December issue of *Analytical Chemistry*.

12.3.b Metal Di-n-butyl Phosphorodithioates as Extractants for Metals

T. H. Handley

The metal dialkyl phosphorodithioates have greater chemical stability than the corresponding acids and, accordingly, are less subject to oxidation and hydrolysis. Therefore, they were considered as possible extractants and were found to show the following definite order of replacement with respect to one another: $\text{Pd}^{2+} > \text{Au}^{3+} > \text{Cu}^+ > \text{Hg}^{2+} > \text{Ag}^+ > \text{Cu}^{2+} > \text{Bi}^{3+} > \text{Pb}^{2+} > \text{Cd}^{2+} > \text{In}^{3+} > \text{Zn}^{2+}$. When one metal ion is to be separated from

²⁴T. H. Handley, "Trialkyl- and Hexaalkylphosphorothioic Triamides as Extractants for Metal Ions. Selective Extraction of Mercury(II), Silver(I), and Copper(I)," *Anal. Chem.* **36**, in press (1964).

another, selectivity is improved by the proper choice and use of a metal dialkyl phosphorodithioate as the extractant. However, the behavior of the dialkyl phosphorodithioates of certain metal ions, for example, Hg^{2+} , Ag^+ , and Pd^{2+} , is more complicated than the simple replacement of one metal ion for another. At high loading, a complex species is formed that may contain two different metal ions or a quantity of a single metal ion which is greater than that represented by a hydrogen atom replacement reaction. Therefore, the use of the dialkyl phosphorodithioate of Hg^{2+} , Ag^+ , or Pd^{2+} as an extractant may not always improve selectivity.

Experimental evidence of the complicated behavior of the alkyl phosphorodithioates of certain metal ions was obtained in studies of the extraction of Ag^+ . A series of experiments was made in which a CCl_4 solution of $[(\text{C}_4\text{H}_9\text{O})_2\text{P}(\text{S})\text{S}]_2\text{Hg}$ or $(\text{C}_4\text{H}_9\text{O})_2\text{P}(\text{S})\text{S}\text{Ag}$ was used to extract Ag^+ from an acid aqueous phase. A Scientific Communication²⁵ on this subject is to be published in *Analytical Chemistry*.

12.3.c A New Approach to the Separation of Trivalent Actinide Elements from Lanthanide Elements. Selective Liquid-Liquid Extraction with Tricaprylmethylammonium Thiocyanate

F. L. Moore

Preferential liquid-liquid extraction of the anionic thiocyanate complexes of the trivalent actinide elements with tricaprylmethylammonium thiocyanate dissolved in xylene or other solvents affords a new improved method for their separation from the lanthanide elements. The order of extractability is $\text{Cf} > \text{Be} > \text{Am}, \text{Cm} \gg \text{Yb} > \text{Tm} > \text{Eu} > \text{Pm} > \text{Y} > \text{Ce} > \text{La}$. Various dilute acids markedly enhance the separation factors. Among the advantages of this method are the high single-stage separation factors possible and the elimination of the neutron hazard and the corrosion problems associated with lithium chloride-hydrochloric acid systems. The method has several useful analytical and process

²⁵T. H. Handley, "Use of Metal Di-n-butyl Phosphorodithioates as Extractants for Metals," *Anal. Chem.* **36**, in press (1964).

applications. A paper on this subject was published.²⁶

12.3.d Rapid Separation and Determination of Technetium

Gerald Goldstein

Extraction with cyclohexanone, first suggested by Boyd and Larson,²⁷ was applied to the determination of technetium in fission products. About 98% of the technetium can be extracted from 0.1 to 6 *N* H₂SO₄ solutions. There are very few interferences. Reducing agents can prevent the complete extraction of TcO₄⁻; a few elements, notably rhenium in the form of ReO₄⁻, are also extractable.

Recently, considerable interest has been shown in the use of technetium as a burnup monitor because of its low rate of diffusion and volatility and because of the high fission yield of the mass-99 chain (6.06% for ²³⁵U fission). For short neutron irradiations (a few minutes) the number of fissions occurring in a uranium sample was determined by allowing the sample to cool for 20 to 24 hr, during which time ^{99m}Tc grows in from its ⁹⁹Mo parent. The ^{99m}Tc is then separated by cyclohexanone extraction, and its disintegration rate is determined by gamma spectrometry. From this value, the number of atoms of ⁹⁹Mo present at the end of the irradiation and, consequently, the number of fissions can be calculated. Gamma spectra of the fission product solution and of the extract (Fig. 12.6) demonstrate that the 140-kev ^{99m}Tc transition is easily measured in the extract. Results for several irradiations of natural uranium are shown in Table 12.1.

Technetium can also be separated rapidly and efficiently from long-lived fission products (^{141,144}Ce, ¹⁴⁰Ba-¹⁴⁰La, ⁹⁵Zr-⁹⁵Nb, ^{103,106}Ru, and ¹³⁷Cs) by a single extraction from 2.5 *N* H₂SO₄, followed by one wash with a volume of 2.5 *N* H₂SO₄ equal to the volume of the extract. The decontamination factor is 10⁵ to 10⁶; about

²⁶F. L. Moore, "A New Approach to Separation of Trivalent Actinide Elements from Lanthanide Elements. Selective Liquid-Liquid Extraction with Tricaprylmethylammonium Thiocyanate," *Anal. Chem.* **36**, 2158 (1964).

²⁷G. E. Boyd and Q. V. Larson, "Solvent Extraction of Heptavalent Technetium," *J. Phys. Chem.* **64**, 988 (1960).

Fig. 12.6. Gamma Spectra of Short-Lived Fission Product Solution and Separated ^{99m}Tc. (~10 kev per channel.)

Table 12.1. Results of Determination of Number of Fissions

1.00 mg of natural uranium irradiated

Duration of Irradiation (min)	^{99m} Tc ^a (dis/sec)	^{99m} Mo ^b (atoms)	Fissions ^c (number/min)
	× 10 ⁻³	× 10 ⁻⁹	× 10 ⁻⁹
1	2.35	1.17	1.17
2	4.83	2.39	1.19
3	6.89	3.41	1.14

^aCorrected to time of separation.

^bAt end of irradiation.

^c1.16 × 10⁹ calculated from average flux value.

Table 12.2. Results of Separation of ^{99}Tc from Long-Lived Fission Products

^{99}Tc (μg)		Recovery (%)	Relative Standard Deviation of Recovery (%)
Added	Recovered ^a		
0	~ 0.01		
5.84	5.47	93.7	0.6
14.6	13.6	93.2	1.2
29.2	27.0	92.5	1.4
29.2 ^b	26.9	92.3	0.7

^aAverage of four determinations.

^bNo fission product activity added.

93% of the technetium is recovered. Table 12.2 shows the results of extractions of technetium spikes added to 10 μC of fission product radionuclides. In this case, ^{99}Tc was measured by the liquid-scintillation method.

12.3.e Separation of Trace Metals from Uranium by Cellulose Column Chromatography

L. C. Bate

R. A. A. Muzzarelli²⁸

By cellulose column chromatography, sub-microgram quantities of 13 metal ions were separated from 50 g of uranyl nitrate dissolved in ethyl ether (95%)–nitric acid (5%) solution. The absorption and elution of the trace metals was followed with radioisotopes. A KCNS–ethyl ether (60%)–methanol (40%) eluent removed In, Zn, Co, Cu, Cr, Mn, Ba, Fe, and Ag; a KCNS–acetone eluent removed Sr and Cd; and KCNS–HCl (30%)–acetone (70%) eluted Sb and Cs. All these ions except barium were completely removed by the eluents.

²⁸Alien guest. Present address: Université de Sherbrooke, Faculté des Sciences, Sherbrooke, Quebec, Canada.

12.3.f Chemical Effects of Isomeric Transitions. Separation of Tellurium Isomers in Different Chemical Media

R. L. Hahn

Study of the chemical changes that follow isomeric transitions in some tellurium radionuclides was continued.²⁹ The chemical separation of the nuclear isomers of ^{127}Te and ^{129}Te in different media was investigated. The variation of f_j (^{127}Te) with pH in aqueous solutions of HCl, HNO_3 , HClO_4 , and NaOH was measured; f_j is the probability that, if the parent metastable-state radionuclide is in the form of telluric acid, the daughter ground-state radionuclide will be found as tellurous acid because of chemical interactions in substance j . The relation between f_j and pH is essentially the same for the different acids. For 6 N acid solutions, f_j is close to unity; it decreases with increase in pH, and at pH 6.0 it approaches the value for H_2O (0.760 ± 0.017). For NaOH solutions, f_j increases with a decrease in pH and also approaches the value for H_2O (see Fig. 12.7). The variation of f_j with pH can be expressed by the relation

$$f_j = \exp(x_j) / [1 + \exp(x_j)] ,$$

with

$$x_j = m_j(\text{pH}) + b_j ;$$

m_j and b_j are parameters obtained from the data. Also, relative f_j values for ^{127}Te and ^{129}Te were determined in solid telluric acid, water, and 6 N solutions of HCl, HClO_4 , and NaOH. Although the absolute f_j values for these nuclides change from substance to substance, the ratios of the f_j 's remain fairly constant (~ 1). Thus, f_j appears to be mainly a function of the chemical – not the nuclear – properties of the isomer-separation process. A paper on this subject was published.³⁰

²⁹R. L. Hahn, "Chemical Effects of Isomeric Transitions: Separation of the Isomers of ^{127}Te , ^{129}Te , and ^{121}Te ," *J. Chem. Phys.* **39**, 3482 (1963).

³⁰R. L. Hahn, "Chemical Effects of Isomeric Transitions: The Separation of Tellurium Isomers in Different Chemical Media," *J. Chem. Phys.* **41**, 1986 (1964).

Fig. 12.7. Variation of f_j (^{127}Te) with pH for Various Substances j . The solid curves are fits to the data calculated with the equations: $f_j = \exp(x_j) / [1 + \exp(x_j)]$. For the acids, $x = -0.404 (\text{pH}) + 3.59$; for NaOH, $x = -0.129 (\text{pH}) + 2.25$.

12.3.g Yields of Krypton and Xenon from Fission of Uranium

R. L. Hahn

Work on the determination of yields of krypton and xenon from fission of uranium was continued.³¹ Changes were made in the vacuum system so that 10-year ^{85}Kr could be used to determine the chemical yield of the gas-handling procedure for krypton. Auxiliary studies were carried out to check calculations of the solid angle subtended by a sphere with respect to a right circular cylinder; agreement to within 3% was obtained between the theoretical and experimental results.

12.3.h Ore Selection for Project Coach

S. A. Reynolds

Exploratory studies were made to acquire analytical data relevant to methods of ore selection for Project Coach,³² which is concerned with recovery of transplutonium elements formed by an explosion of a nuclear device in a salt bed.

³¹R. L. Hahn, "Determination of the Yields of Krypton and Xenon Nuclides in Uranium Fission," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 76.

³²"Project Coach," *Chem. Tech. Div. Ann. Progr. Rept. May 31, 1964*, ORNL-3627, pp. 256-58.

Initially, it was assumed that a simple external reading of the gross gamma radiation from ore would suffice to select the material to be processed. A more complicated method involving measurement of spontaneous-fission gammas or neutrons would be feasible but was shown to be unnecessary.

The early part of the experimental program included the taking of gamma spectra of samples from the Gnome underground test presumed to be reasonably representative of Coach "ore." Spectra of a typical aqueous leach solution and water-insoluble solid are shown in Fig. 12.8. All the samples contained the same radionuclides, but in different proportions; and all included both fission products and neutron-induced nuclides. Although the levels of radioactivity of the various samples were very different, the spectra did not show meaningful differences in the behavior of the elements present. This observation was substantiated by consideration of earlier radiochemical analytical results.

Fig. 12.8. Gamma Spectra of Samples from the Gnome Underground Test.

The analyses consisted primarily in determining gross gamma radioactivity, plutonium, and gross transplutonic elements (TrPu) in 48 samples of Gnome material. After exhaustive leaching with dilute HCl, the acidity was adjusted to $\sim 1.5 M$, and Pu was determined by double TTA extraction under the usual conditions. The TrPu, as a group, were determined by oxidizing the raffinates from the Pu extraction and performing $\text{La}(\text{OH})_3$ and LaF_3 precipitations. The Pu and TrPu values were corrected according to ^{144}Ce recovery, based on gamma spectra.

Various correlations were explored. Thus, good correlation was observed between TrPu and Pu radioactivities and between TrPu and Ce. Correlation between TrPu and gross gamma, though not so good, was real, as shown by computation of correlation coefficients. The ratio of TrPu to Pu alpha radioactivities increased during a period of a few months, and both the magnitude of the ratio and its increase were consistent with $\sim 1\%$ ^{241}Pu being present in the post-shot Pu. Decay of the gross gamma radioactivity fitted reasonably well the equation³³

$$A = Kt^{-1.5},$$

said to be applicable from 100 days to 3 years post-shot.

The TrPu-Ce correlation was used as the basis for a field method for ore selection. A gamma spectrometer could be used to screen batches of ore, but a less expensive device could also serve. A mockup of such a "gamma probe" was made from a scintillation counter in a lead shield with a hole, ~ 2 in. in diameter, in the top. A 1.8-g/cm^2 Al absorber (to absorb betas) was placed over the hole, and 1-g portions of ten selected samples were counted. Next, a 0.9-g/cm^2 Pb absorber (~ 3 half-thicknesses for ^{144}Ce gamma rays) was added, and the samples were re-counted. The difference between the two counts of each sample is proportional to its soft-gamma content, largely ^{144}Ce . The differences were compared with TrPu values; the correlation was very good. Therefore, it is concluded that TrPu content can be estimated in the field by use of a simple scintillation device with a lead filter.

³³J. E. Watson, *An Analysis of Calculated and Measured Fission Product Activities*, BRL-1239 (February 1964).

12.3.i Search for Natural Transuranic Radioactivity

S. A. Reynolds

A small-scale study, related to a problem in cosmology, is of inherent interest and possible significance in low-level work. A "surplus" alpha radioactivity was reported in some natural materials. The surplus was ascribed to ^{247}Cm (ref. 34) and to ^{244}Pu by other investigators,³⁵ who reported detecting it in a mineral fraction of Conway (New Hampshire) granite. A solution resulting from leaching Conway granite with dilute nitric acid was furnished by F. J. Hurst.¹⁵ A TTA extraction for Pu was made and none was found. The limit of detection was such that the finding does not contradict that of Cherdyntsev and Mikhailov,³⁴ who reported the mysterious activity as only a few percent of that of ^{238}U , but the finding is inconsistent with the second report.³⁵ The ^{247}Cm postulate was shown to be invalid because the half-life of ^{247}Cm is too short,³⁶ and the ^{244}Pu postulate was retracted.

12.3.j Low-Level Analyses

S. A. Reynolds

C. L. Burros³⁷

Required cooperative effort in low-level analyses has continued as previously reported,³⁸ and results appear to be very satisfactory; a few examples follow. The study of air-filter samples included identification of the radionuclides in an April "dustfall" as old fission products. In several coal samples, the upper-limit radioactivity levels of gross beta, Ra, U, Th, and K and the ash content were determined. Comparison of these data

³⁴V. V. Cherdyntsev and V. F. Mikhailov, "A Primordial Transuranium Isotope in Nature," *Geochem. (USSR)* (English Transl.) 1, 1 (1963).

³⁵R. D. Cherry, K. A. Richardson, and J. A. S. Adams, "Unidentified Excess Alpha-Activity in the 4.4-MeV Region in Natural Thorium Samples," *Nature* 202, 639 (1964).

³⁶P. R. Fields *et al.*, "Possible Existence of Curium in Nature. II," *Phys. Rev.* 131, 1249 (1963).

³⁷Radioisotopes-Radiochemistry Group.

³⁸S. A. Reynolds and C. L. Burros, "Low-Level Radiochemical Studies," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 81.

with published values³⁹ showed that the level of radioactivity correlates with the percentage of ash. Four 50-g disks of metallic lead were analyzed by gamma spectrometry and low-background beta counting; the Ra, Th, and U contents were negligible, but one of the samples contained $80 \text{ dis min}^{-1} \text{ g}^{-1}$ of ^{210}Pb .

12.4 LIQUID SCINTILLATORS

12.4.a Liquid Scintillators That Contain 1-Methylnaphthalene

Gerald Goldstein   W. S. Lyon

Liquid scintillators containing 1-methylnaphthalene were prepared, and their properties were determined. Commercially available 1-methylnaphthalene was purified by chromatography on acidic-grade activated alumina. Solutions that contain 1 g of POPOP per liter of the purified 1-methylnaphthalene have a relative pulse height (gamma excitation) equal to that of conventional xylene- or toluene-based scintillators. Pulse height is proportional to the Compton recoil energy. Possibly 1-methylnaphthalene can be used in large-volume scintillators, because of its high flash point (112°C) and high density (1.02 g/cc), as a secondary solvent in xylene- and *p*-dioxane-based scintillators, in studies of energy-transfer processes, and in distinguishing particles of different kinds by the pulse-shape discrimination method. A paper on this subject was published.⁴⁰

12.4.b N,N',N'' -Trimethylborazine as a Liquid-Scintillator Solvent for Thermal Neutron Detection

H. H. Ross   H. L. Holsopple

The formulation of an efficient liquid detector for thermal neutrons, with the neutron target as an integral part of the system, is often a difficult problem. Practical systems should have a high detection efficiency, low gamma sensitivity, fast

response time, large pulse-height outputs from thermal-neutron reactions, and good chemical stability. Also, it is desirable that the solutions be easy to prepare.

Because neutrons are uncharged, they cannot be detected in a liquid scintillator as a result of primary ionization. However, advantage can be taken of various neutron interactions to produce light output from these systems. Fast and epithermal neutrons are observed in conventional liquid scintillators as a result of neutron-proton recoil reactions with the solvent. Thermal neutrons are detected by allowing them to undergo an exoergic nuclear reaction with a suitable target; the resulting reaction fragments can then interact with the liquid scintillator to produce a measurable output pulse.

The compound, N,N',N'' -trimethylborazine, is an efficient solvent in the liquid-scintillation process. Additionally, the natural ^{10}B content of the compound enables the system to be used for the detection of thermal neutrons according to the reaction $^{10}\text{B}(n,\alpha)^7\text{Li}$. The system is unusual in that the compound serves as both the neutron target and the scintillator solvent. When compared with conventional boron-loaded scintillators, the borazine system exhibits a number of significant advantages. An article on this work was accepted for publication in *Nuclear Instruments and Methods*.⁴¹

12.4.c Absolute Counting of Beta Emitters by the Liquid-Scintillation Method

Gerald Goldstein

Extrapolation methods for absolute counting of beta emitters in liquid scintillators have been reported from time to time in the past ten years and have now been examined in some detail with the Packard Tri-Carb liquid-scintillation spectrometer. In this method, the integral counting rate is measured at various pulse-height-discriminator settings. The logarithm of the count rate is plotted vs the discriminator setting, and the line obtained

³⁹M. Eisenbud and H. G. Petrow, "Radioactivity in the Atmospheric Effluents of Power Plants That Use Fossil Fuels," *Science* **144**, 288 (1964).

⁴⁰G. Goldstein and W. S. Lyon, "Liquid Scintillators Using 1-Methylnaphthalene," *Intern. J. Appl. Radiation Isotopes* **15**, 133 (1964).

⁴¹H. H. Ross and H. L. Holsopple, " N,N,N' -Trimethylborazine as a Liquid Scintillator Solvent for Thermal Neutron Detection," to be published in *Nuclear Instruments & Methods*.

Fig. 12.9. Results of Extrapolation Method Applied to ^{99}Tc .

Fig. 12.10. Efficiency of the Extrapolation Method.

is extrapolated to zero discriminator setting (Fig. 12.9) to obtain the absolute disintegration rate. By counting radioisotopes previously standardized by other methods, it was found that the efficiency is 100% if the maximum beta energy is greater than 200 kev (Fig. 12.10). The instrumental and sample-solution variables were evaluated; the results will be reported in detail elsewhere.

This method has some significant advantages. If the maximum beta energy is greater than 200 kev, quenching agents have virtually no effect on the extrapolated value, as shown for ^{99}Tc in Table 12.3. They do, however, increase the slope of the straight line. If two beta groups, or beta emitters, are present, the sum of both can be determined by using instrument settings suitable for the lower-energy group. Initial experiments with a beta-gamma emitter (^{60}Co) indicate that the gamma radiation does not cause any difficulty.

If one uses a computer program⁴² to establish the best straight line and the intercept, the relative standard deviation of replicate measurements is usually about 1%.

Potential applications of the method include decay-scheme studies and standardization of radionuclide preparations. As an example of the former, the half-life of ^{99}Tc was remeasured⁴³ by

⁴²M. H. Lietzke, *A Generalized Least-Squares Program for the IBM-7090 Computer*, ORNL-3259 (Apr. 4, 1962).

⁴³G. Goldstein, "Specific Activity of ^{99}Tc by Liquid Scintillation Counting," *Chem. Div. Ann. Progr. Rept.* June 20, 1964, ORNL-3679, pp. 19-21.

Table 12.3. Effect of Quenching Agents on ^{99}Tc Measurements

Quencher Added ^a	Intercept (counts/min)	Standard Deviation of the Intercept (counts/min)	Slope
	$\times 10^{-4}$	$\times 10^{-4}$	$\times 10^3$
None	4.34	0.03	-3.00
Chloroform	4.28	0.02	-4.31
Cyclohexanone	4.25	0.03	-4.20
Pyridine	4.27	0.02	-3.13
Tetraphenylarsonium chloride ^b	4.25	0.03	4.13

^a1 v/v %.

^b0.1 M solution in CHCl_3 .

the specific activity method, the disintegration rate being determined by the extrapolation technique, and was found to be $(2.14 \pm 0.05) \times 10^5$ years.

Further studies of this technique and additional applications of it are in progress.

12.5 APPLICATION OF COMPUTERS

12.5.a Electronic Resolution of Gamma-Ray Spectra

J. S. Eldridge

Standard-response curves from 42 radionuclides were collected for the "library."⁴⁴ A computer program was written to recall the pooled master spectra in a variety of paper-tape formats. Plans are under way for the dissemination of the standard data in paper-tape and graphical forms. It is anticipated that other laboratories will be able to use the spectral data as well as the spectral resolution program⁴⁵ by requesting a copy of the library from a distribution center.

Final validation of the spectral data will be made by independent analysis of each radionuclide cataloged in the library. This validation will make use of the program for spectral resolution.⁴⁵

12.5.b Computer Program for Accumulating Standard Gamma-Ray Spectra and for Quality-Control Measurements

F. F. Dyer

Efforts were redirected from the program previously mentioned⁴⁶ to writing a program for the accumulation of standard gamma-ray spectra. This

⁴⁴J. S. Eldridge, "Electronic Resolution of Gamma-Ray Spectra," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 85.

⁴⁵J. S. Eldridge, "Computer Applications in Nuclear Analyses," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 85.

⁴⁶F. F. Dyer and E. Ricci, "Computer Program for the Calculation of Absolute Activities, Fluxes, and Cross Sections," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 86.

program, written in FORTRAN 63 for the CDC 1604-A, is similar to the one reported by Eldridge⁴⁷ but is tailored for activation-analysis problems and is designed to be used with other programs that run on the 1604-A. Three spectra of each of four standards (12 total spectra) can be summed by the program. The resulting spectrum, which contains a much larger number of counts per channel than the original separate spectra, is very precise. Before summation, each spectrum is changed to a standard pulse-height scale (gain). The method reported by Heath⁴⁸ is used; the position of a well-resolved photopeak is found, and the spectrum is then shifted so that the photopeak appears in a preselected position. Alternatively, the program can be used to compute values of chi-square for each channel for a total of ten spectra. Used in this manner, the program permits quality-control checks to be made on gamma-ray spectrometers.

12.6 APPLICATION OF RADIOISOTOPES TO ANALYTICAL CHEMISTRY

12.6.a Radio-Release Method for the Evaluation of Atmospheric Pollution. Sulfur Dioxide

H. H. Ross

Atmospheric pollution has recently become a problem of national concern. Therefore, the determination of sulfur-bearing air pollutants, primarily sulfur dioxide, is being studied carefully. The high-sensitivity radio-release method was chosen as a new approach to the determination of sulfur dioxide. This method is based on the selective reaction of the sought constituent with a radioactive reagent of known specific activity. During the reaction, radioactivity is released as a gas or as an easily separable chemical species. The amount of the sought constituent is then calculated from the amount of radioactivity released, the specific activity of the reagent, and the stoichiometry of the reaction. Alternatively, the calculations can be avoided by use of standard samples.

⁴⁷J. S. Eldridge, "Electronic Resolution of Gamma-Ray Spectra," *Anal. Chem. Div. Ann. Progr. Rept.* Dec. 31, 1962, ORNL-3397, p. 88.

⁴⁸R. L. Heath, *Data Analysis Techniques for Gamma-Ray Scintillation Spectrometry*, IDO-16784 (May 29, 1962).

The method is potentially one of the most useful radioisotopic analytical techniques. In addition to sensitivity, it has the advantages of selectivity and speed and it readily lends itself to automated systems.

The new method for sulfur dioxide determination is based on the release of radioiodine according to the reaction

The reaction is carried out in solution by forcing air through a bubbler train that contains a basic solution of potassium iodate. After the sample has reacted, the solution is acidified, and the liberated radioiodine is extracted. The radioactivity of this solution is determined, and the amount of sulfur dioxide is calculated.

A paper on this work was given^{49,50} and will be published.⁵⁰

12.6.b Application of Radioisotopes to the Determination of Sodium, Lithium, and Phosphorus

W. J. Ross

Sodium. — The standard gravimetric method for determining sodium as sodium zinc uranyl acetate was evaluated with the help of ²⁴Na tracer. A modified and accelerated version was developed whereby sodium tracer is included for yield correction, and the reagent is preheated to improve the purity of the precipitate and to increase the recovery of sodium. The time per analysis is decreased significantly, and the accuracy is increased, thereby enhancing the usefulness of this method for routine analyses.

Lithium. — A similar attempt was made to accelerate the determination of lithium by incorporating ¹³¹I in the KIO₄ reagent used in the classical gravimetric method. Such a radioactive

reagent has been useful in determining yield and in verifying that the Li/I mole ratio in the precipitate is 4.2 ± 0.2 . However, the routine use of such a radioreagent cannot be recommended, because it is difficult to maintain complete dissolution of KIO₄.

Phosphorus. — Phosphorus-32 was used to establish the degree of recovery of small amounts (<10 mg) of phosphorus as Mg₂P₂O₇ in the standard gravimetric method. By elimination of the need for quantitative recovery, this usually lengthy procedure was performed in less than 8 hr without loss of precision or accuracy.

12.6.c Separation of Sodium

W. J. Ross

A program was initiated to develop a rapid and efficient method for removing gross amounts of ²⁴Na from neutron-activated samples, especially biological and geological materials, so that minor gamma radionuclides can be identified and measured. Essentially quantitative retention of sodium has been achieved from ammoniacal and slightly acid solutions by such solid ion exchangers as zirconium phosphate, zirconium antimonate, and Dowex 50, even in the presence of complexing agents such as fluoride, tartrate, and EDTA. Inasmuch as many other elements are absorbed under the same conditions, these exchangers do not effectively isolate sodium.

The most promising method for removing ²⁴Na is by isotopic exchange. In batch-type equilibrations, essentially quantitative exchange of ²⁴Na in 80 to 90% HCl has been achieved with solid NaCl. Exchange occurs during the dissolution and recrystallization of NaCl and is decreased in very dilute or very concentrated HCl systems. Initial experiments with 38 elements showed that only Cl, Mn, Cd, and Ba are retained on the solid NaCl to an extent that exceeds 7%. For the removal of sodium from solutions, this approach, as well as other possibilities, will be studied during the coming year in an effort to broaden the scope of usefulness of neutron activation analysis.

⁴⁹H. H. Ross, "Radio-Release Methods for the Evaluation of Atmospheric Pollution," presented at the 12th Anachem Conference, Detroit, Mich., Oct. 21-23, 1964.

⁵⁰H. H. Ross and W. S. Lyon, "Radio-Release Methods for the Evaluation of Atmospheric Pollution: SO₂," presented at the International Atomic Energy Agency Symposium on Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964 (to be published in the proceedings of the Symposium).

12.7 ACTIVATION ANALYSIS

12.7.a Study of Precision in Activation Analysis

F. F. Dyer

J. F. Emery

Activation analysis is often used to compare the trace-element concentrations of a number of samples, for example, samples taken to ascertain homogeneity of a standard or those that pertain to criminal investigation. The correct interpretation and the general utility of the results depends markedly on experimental errors. Because experimental errors in activation analyses have not been studied adequately, it seemed worth while to begin a study of the precision of these methods. Thus far in this study, measurements have been made only on elements that produce radionuclides with half-lives of a few minutes or less. Samples that contained known amounts of selenium and silver, which give 17- and 24-sec activities, respectively, are typical of those studied. For these samples, the relative standard errors are usually about $\pm 1\%$ at the 95% confidence level. Some of the findings have been described.⁵¹

⁵¹F. F. Dyer and J. F. Emery, "Precision of Activation Analysis of Short-Lived Nuclides," presented at the Eighth Conference on Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964.

12.7.b Application of Activation Analysis to Forensic Science

F. F. Dyer

J. F. Emery

Ammunition Primers. — Ammunition primers contain large amounts of compounds of barium and antimony. These elements usually deposit in detectable amounts on the hands of one who fires a gun.⁵²⁻⁵⁴ However, the total deposit per firing, as well as the ratio of barium to antimony, is variable. If the ratio were constant, it could be used to indicate the type or brand of ammunition fired. Since this ratio has not been measured for unfired primers, a limited study was made to determine it. The primers used in several brands of .38-caliber ammunition were analyzed, and the residues left in some of the primer caps after firing were analyzed. Table 12.4 gives the results. The data indicate that the barium-to-antimony ratio varies with brand of ammunition

⁵²J. D. Buchanan and R. R. Ruch, "Applications of Neutron-Activation Analysis in Scientific Crime Detection," *Quarterly Report for Period Ending October 31, 1962*, GA-3664 (Oct. 31, 1962).

⁵³V. P. Guinn, R. R. Ruch, and S. C. Bellanca, "Application of Neutron-Activation Analysis in Scientific Crime Detection," *Quarterly Report for Period Ending January 31, 1963*, GA-4041 (Jan. 31, 1963).

⁵⁴R. R. Ruch, S. B. Madigan, and V. P. Guinn, "Applications of Neutron-Activation Analysis in Scientific Crime Detection," *Quarterly Report for Period Ending July 31, 1963*, GA-4576 (July 31, 1963).

Table 12.4. Ratio of Barium to Antimony in Primer Material Before and After Firing

Type of Sample	Brand of Ammunition	Number of Cartridges Analyzed	Measured Ba/Sb Ratio ^{a,b}
Primer	Federal	5	2.42 ± 0.17^c
Primer	Federal	5	1.37 ± 0.34^c
Primer	Remington-Peters	5	3.45 ± 0.50
Burned primer	Western	3	1.57 ± 0.55^d
Burned primer	Remington-Peters	3	4.46 ± 0.90^d

^aThe errors given are 95% confidence limits.

^bNo measurements were made of burned Federal primer.

^cThree measurements were made for each cartridge.

^dOne measurement was made for each cartridge.

and that this ratio is smaller in the original primer than in the residue left in the cap after the firing.

Because cartridges from only a few boxes of ammunition were analyzed, it is not known how constant the ratio remains from one batch to another of a given brand. The second conclusion is tentative because of the overlap of the 95% confidence intervals for burned and unburned primers. Additional analyses should show definite differences.

Gunshot Residues. — A preliminary study of the firing of a .38-caliber revolver showed that in many instances visible particles are deposited on the shooter's hand. A few of these particles contained significant quantities of barium and antimony. A total of 21 additional firings were made to determine whether the barium-to-antimony ratio of the particles and that of the unfired primer could be correlated. Of 50 particles analyzed, only five contained barium and/or antimony, and their barium-to-antimony ratios did not correspond to that of the primers.

This work was done in cooperation with J. F. Gallagher.⁵⁵

12.7.c Analysis of Bond Paper

J. F. Emery   F. F. Dyer

The aluminum and titanium contents of 27 sheets from eleven brands of bond paper were measured. Five samples from each sheet were analyzed, determinations were made nondestructively, and gamma-ray spectra were resolved with a least-squares computer program. The results indicate that each sheet of paper is homogeneous, but differences among some brands are very pronounced. Elements that produce longer-lived radionuclides will be measured subsequently.

12.7.d Wool Analysis

L. C. Bate   W. B. Healy⁵⁶

The trace-element content was determined on wool from twin wethers raised in two areas on pastures whose trace-element compositions reflect

⁵⁵Federal Bureau of Investigation, Laboratory Division, Washington 25, D.C.

⁵⁶Soil Bureau, Department of Scientific and Industrial Research, Lower Hutt, New Zealand.

soil differences.^{57,58} Nine elements (Mn, Cu, Zn, Al, Se, Mo, W, V, and Au) were measured quantitatively, and four others (Ag, Hg, Sb, and Cr) were detected. The amounts of five of the elements (Mn, Zn, Cu, Se, and W) present in the wool depended on which soil area the animal was raised on. The trace-element content of the wool was compared with that of the internal organs; the results indicate the possibility of following the animal's nutrition by monitoring the trace-element content of the wool. This work was discussed,⁵⁹ and a paper was submitted to the *New Zealand Journal of Agricultural Research*.⁶⁰

12.7.e Absorption of Trace Elements by Hair

L. C. Bate

Certain elements (Au, Se, and Hg) are absorbed by hair and cannot be removed subsequently by a detergent wash. It seemed possible that significant fractions of the elements normally found on hair might be surface contaminants and that washing with a detergent might not remove them. Therefore, a thorough study of this possibility seemed necessary.

The absorption of Au^{3+} , Zn^{2+} , Se^{2+} , Cr^{3+} , Cr^{6+} , I^- , As^{3+} , As^{5+} , Br^- , Cu^{2+} , Na^+ , Ag^+ , Hg^{2+} , Sb^{3+} , Co^{2+} , Fe^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+} , Mn^{2+} , K^+ , Cl^- , and P^{5+} was investigated. Some of the cations are believed to be absorbed as anionic species. Most of them are normally found by activation analysis of hair. In most experiments, 100 mg of hair was placed in 15 ml of an aqueous solution that contained the element to be absorbed. The amount of absorption was measured by radioactive tracers. The composition of the solution approximated the chemical composition of perspiration, and all the absorptions were made at a number of pH values

⁵⁷W. B. Healy, T. G. Ludwig, and F. L. Losee, "Soils and Dental Caries in Hawke's Bay, New Zealand," *Soil Sci.* **92**, 359 (1962).

⁵⁸L. C. Bate and W. B. Healy, "Wool Analysis," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 98.

⁵⁹L. C. Bate and W. B. Healy, "Determination of Trace Elements in Wool," presented at the Eighth Conference on Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964.

⁶⁰W. B. Healy, L. C. Bate, and T. G. Ludwig, "Neutron Activation Analysis of Wool," submitted for publication, *New Zealand Journal of Agricultural Research*.

similar to those of perspiration. All the elements are absorbed except the alkali metals. The extent of absorption depends on the element as well as on the pH of the solution.

Removal of the absorbed elements with complexing agents is now being tried; EDTA appears to be effective in removing some of the absorbed elements.

12.7.f Hair Analysis

L. C. Bate   W. B. Healy⁵⁶

Analysis of three groups of hair samples was completed.⁶¹ The samples were from local people, from residents of Hasting and Napier, New Zealand, and from children and pigs that had kwashiorkor (before- and after-recovery samples). In general, the results are similar, and most of the differences apparently are due to differences in diets. All the hair samples were analyzed after being cleaned with a nonionic detergent.⁶²

A paper⁶² on washing of hair with nonionic detergents was accepted for publication in the *Journal of Forensic Science*.

12.7.g Applied Neutron Activation Analysis

J. F. Emery

A number of samples were analyzed by neutron activation analysis for the Botany Department of the University of Florida. Some 30 solutions of $(\text{NH}_4)_2\text{CO}_3$, enriched to various degrees in ^{18}O , and about 20 CO_2 -filled capsules were analyzed for ^{18}O by the reaction $^{18}\text{O}(n,\gamma)^{19}\text{O}$ ($t_{1/2} = 29$ sec). Mercury residues from the vacuum system used to prepare the samples complicated the analysis of the liquid samples, and ^{41}Ar ($t_{1/2} = 110$ min) masked the ^{19}O radioactivity in the gas samples.

Other materials analyzed were: ORR fuel elements for surface contamination by ^{235}U , air

filters for selenium, crystalline ZrO_2 for ^{238}U , ^{58}Ni metal for cobalt, solutions of BeSO_4 for aluminum, and a germanium oxide crystal for aluminum, vanadium, and chloride.

The fluoride contents of K_2TaF_7 and CsTaF_6 were determined by neutron activation analysis; the results were 33.95 ± 0.52 and 26.50 ± 0.28 wt % respectively.

12.7.h Activation Analysis of Uranyl Nitrate Solutions

W. J. Ross

Activation analysis was used successfully to determine 0.1 to 10 ppm of Cd, Cr, Co, Mo, Cu, and Mn in an IAEA round-robin sample that contained 50 mg of U per milliliter. A method was developed whereby these trace constituents could be determined by gamma spectrometry after "preseparation" of uranium, neutron activation of the residual components, and chemical separation of the individual nuclides. The preseparation was required to prevent the formation of dangerous and overshadowing amounts of gamma activity in uranium during activation; it consisted in the extraction of uranium from 0.5 M HNO_3 with a cyclohexane solution of tri-*n*-octylphosphine oxide (TOPO). Essentially none (10% of Mo) of the trace elements were removed from the aqueous phase during this extraction. An amount of arsenic equivalent to 1 ppm of the sample was detected in the cadmium fraction and represented the only extraneous element that may have been added with the reagents before activation. The results obtained by this method were in excellent agreement with those obtained by other methods used in this program.

12.7.i Activation Analysis of High-Purity Materials

W. J. Ross

Samples of high-purity beryllium, aluminum, and iron were analyzed for trace amounts of 62 possible elemental impurities by measuring the gamma activities of the radionuclides produced by neutron activation. Ten elements were determined by non-destructive techniques after neutron bombardment of a portion of the sample for 10 sec and rapid

⁶¹L. C. Bate and W. B. Healy, "Hair Analysis," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 96.

⁶²L. C. Bate, "The Use of Activation Analysis in Procedures for the Removal and Characterization of the Surface Contaminants of Hair," presented at the meeting of the American Academy of Forensic Science, Chicago, Ill., Feb. 28-29, 1964 (to be published in the proceedings of the Meeting).

measurement of the induced short-lived radionuclides. A second portion of the sample was activated for 20 min and was analyzed for the gamma-emitting radionuclides of chlorine, bromine, and iodine. Forty-nine elements were determined in a third portion of the sample after a 16-hr irradiation. The induced radionuclides were divided into six groups by a series of rapid chemical separations, and each gamma activity was identified, counted, and compared with that of a standard radionuclide. A paper on this subject was published.⁶³

12.7.j Neutron-Absorption Analysis with Isotopic Sources

J. E. Strain   W. J. Ross

The neutron-absorption analysis of synthesized organo-boron compounds for boron was demonstrated on compounds in which the boron is so tightly bound that the conventional pyrolytic analysis for boron is impossible.

Total neutron-absorption cross section of reactor construction materials was determined by use of a large sample ($\sim 7000 \text{ cm}^3$) and two 2-curie ^{241}Am -Be neutron sources. The limit of cross-section measurement was found to be equivalent to $\pm 2 \mu\text{g}$ equivalents of B per cm^3 . This concentration is within the purity limits presently imposed in reactor material acceptance criteria for beryllium and aluminum. The total cross-section analysis was proved to be practical for determining H_2O , D_2O , Be, graphite, and Al. The analysis is non-destructive and requires less than 30 min.

12.7.k Helium-3 Activation Analysis

E. Ricci   R. L. Hahn

Markowitz and Mahony⁶⁴ and Demildt⁶⁵ have shown that ^3He -activation analysis for oxygen in

⁶³W. J. Ross, "Activation Analysis of High Purity Materials," *Anal. Chem.* **36**, 1114 (1964).

⁶⁴S. S. Markowitz and J. D. Mahony, "Activation Analysis for Oxygen and Other Elements by Helium-3-Induced Nuclear Reactions," *Anal. Chem.* **34**, 329 (1964).

⁶⁵A. C. Demildt, "Microactivation Analysis for Oxygen in the Actinide Metals," *Anal. Chem.* **35**, 1228 (1963).

beryllium, thorium, Mylar, and actinide elements is not only feasible but is also very sensitive (fractions of ppb). Extension of the technique to other elements of low atomic weight by the use of short-lived as well as long-lived radionuclides is being attempted. The problem is complicated by the possibility of interferences; that is, the same radionuclide may be produced from two or more different elements. When excitation functions are known, however, it should be possible to reduce interferences by selectively varying the energy of the ^3He ions.

About 80 irradiations were performed at the 5.5-Mev Van de Graaff accelerator with ^3He ions of energies from 3 to 10 Mev on foils of Mylar (C, O, H), nylon (C, O, H, N), Teflon (C, F), and beryllium. Data were obtained for the excitation functions of reactions leading to the following radionuclides: ^{11}C (20.5 min), ^{13}N (10 min), ^{14}O (72 sec), ^{15}O (124 sec), ^{17}F (66 sec), and ^{18}F (111 min). Thick targets of SiO_2 and ZrO_2 were irradiated with 10-Mev ^3He ions to establish sensitivities for the oxygen determination. The results indicate that ultimate sensitivities of about $2 \times 10^{-10} \text{ g}$ may be obtained if ^{15}O or ^{17}F is counted with the foil 10 cm from the detector. These data are taken with a 1-min irradiation in a $^3\text{He}^{2+}$ current of $25 \mu\text{a}$. Analogously, for an irradiation of 110 min, a sensitivity of about $3 \times 10^{-11} \text{ g}$ of oxygen may be obtained with ^{18}F . Thick-target neutron yields were also determined; Table 12.5 shows the results. A fraction of the

Table 12.5. Neutron Yields for Reactions Induced on Thick Targets by ^3He Ions of 5 and 10 Mev

^3He current = $25 \mu\text{a}$

Target	Neutron Yield (10^{10} neutrons/sec)	
	5 Mev	10 Mev
Be	1.4	9.5
Li	1.0	5.0
B	0.70	5.3
C	0.098	0.93
O	0.016	0.58

neutron output (10-Mev ^3He) from Be, Li, and B targets had energies greater than 20 Mev, as determined by the $^{12}\text{C}(n,2n)^{11}\text{C}$ reaction. The above data show that a ^3He -beam generating machine could also be used as an effective neutron source for activation analysis. Results are encouraging, and work is being continued in this field.

12.8 14-Mev NEUTRON GENERATOR

12.8.a Output Spectrum from 14-Mev Neutron Generators; Its Rapid Estimation and Its Influence on Cross-Section Measurements and Activation Analysis

E. Ricci

Neutron generators that use the reaction $^3\text{H}(d,n)^4\text{He}$ are being employed extensively in 14-Mev neutron cross-section determinations and in activation analysis. The frequent assumption that the generated neutrons are monoenergetic is not always valid; consequently, the nuclear chemist must know the neutron spectrum to appraise his results and conclusions. A simple approximate method to estimate such spectra was developed. The neutrons impinging on a sample are divided into four groups, and the energy range of each of these groups is obtained from calculations of scattering; the corresponding neutron percentages result from probability considerations. The influence of the 14-Mev neutron spectrum on flux measurements, cross-section determinations, and activation analysis was studied. From these studies, means to appraise irradiation geometries and to calculate and correct for experimental errors were developed. A paper on this work was accepted for publication in the *Journal of Inorganic and Nuclear Chemistry*.⁶⁶

⁶⁶E. Ricci, "Output Spectrum from 14-MeV Neutron Generators: Rapid Estimation and Influence in Cross-Section Measurements and Activation Analysis," to be published in the *Journal of Inorganic & Nuclear Chemistry*.

12.8.b Catalog of 14-Mev Neutron Reactions

J. E. Strain   W. J. Ross

The gamma-ray spectra and reaction cross sections for the $Z = 3$ through $Z = 30$ elements were published.⁶⁷ Work is continuing on the remaining elements ($Z > 30$).

12.8.c Titanium Irradiations at the 14-Mev Neutron Generator

E. Ricci

Work on (n,p) and $(n,np) + (n,d)$ cross sections of titanium isotopes⁶⁸ was resumed after the neutron spectrum produced by the new stainless steel target assembly of the generator was estimated. The calculation of the neutron spectrum was made by using the modified method reported in Sect. 12.8.a of this report. A suitable irradiation geometry was found at which 92% of the neutrons have energies of 14.8 ± 0.1 Mev. A test irradiation showed that enough data for the cross-section calculations can be obtained by running three successive 2-hr irradiations of double samples (natural Ti- ^{47}Ti , natural Ti- ^{49}Ti , and ^{47}Ti - ^{49}Ti) sandwiched between aluminum flux monitors. This work is in progress.

12.8.d Determination of Oxygen with 14-Mev Neutrons

J. E. Strain

To increase the sensitivity of the determination of oxygen in metals with 14-Mev neutrons, an inert-gas system was fabricated. This system prevents sample contamination, reduces background, and permits the use of larger samples. It is possible to prepare the sample, irradiate it, and count the induced radioactivity without exposing the sample to either oxygen or moisture. The totally inert system makes possible the analysis of alkali metals without using sealed irradiation

⁶⁷J. E. Strain and W. J. Ross, *14-Mev Neutron Reactions*, ORNL-3672 (in press, 1964).

⁶⁸E. Ricci, "Irradiation of Titanium with 14-Mev Neutrons," *Anal. Chem. Div. Ann. Progr. Rept. Nov. 15, 1963*, ORNL-3537, p. 100.

containers. The sensitivity expected for an 18-g sample is ≤ 10 ppm.

12.8.e Miscellaneous Uses of the 14-Mev Neutron Generator

J. E. Strain

Fast-neutron activation analysis was performed on a variety of samples for O₂, N, P, Mn, As, and Se. By the technique of delayed-neutron counting, the analysis of highly radioactive reactor fuel elements for residual fissionable materials was demonstrated. In this evaluation of the technique, the neutron generator is pulsed on for 10 sec and then is turned off; next, a high-efficiency ¹⁰BF₃

neutron counter is turned on to count delayed neutrons. The paraffin moderator, in which the counting tubes are embedded, serves to moderate the 14-Mev neutrons for activation and to thermalize the delayed neutrons for counting. The limit of detection was 0.1 mg of ²³⁵U.

In cooperation with the Health Physics Division and the Isotopes Division, a program of evaluating tritium targets for neutron production was initiated. To date, Ti-³H targets have been studied extensively. The optimum target of this type contains 4 mg of Ti per square centimeter and about 20 curies of ³H in a 3.17-cm diameter. This combination produces a half-life of 1400 μ a-hr and an initial neutron yield of 9×10^7 neutrons sec⁻¹ μ a⁻¹ at a deuteron energy of 150 kev. Targets in which Y, Er, and Zr are used separately to absorb the ³H are now being evaluated.

13. Inorganic Preparations

M. T. Kelley

D. E. LaValle

R. B. Quincy

The preparation of anhydrous fused or sublimed salts continued, but on a reduced scale. For the Ion Spectroscopy Laboratory of the Metals and Ceramics Division, MgCl₂, SnCl₂, SbCl₃, NiCl₂, NaCl, KCl, and RbCl were prepared in 100-g quantities, and some in multiple batches. For use in these solvent media, the following salts were provided: V₂(SO₄)₃·xH₂O, LiBF₄, Ni(BF₄)₂·8H₂O, V(BF₄)₃·xH₂O, and Li₃PO₄. These compounds were prepared by either known methods or those described in previous reports.

Other anhydrous, fused, or sublimed salts were prepared for the High Temperature and Structural Chemistry Group of the Chemistry Division; they were SrI₂, BaI₂, YCl₃, LaCl₃, and KCl-LiCl eutectic. In other work for this group, K₂S in 30-g quantities was prepared by two different methods involving reaction of the elements. In one method, the vapors of sulfur were allowed to react with molten potassium at 200°C in a double-

chambered, evacuated, sealed tube. In the other, finely ground sulfur was caused to drop in small portions into liquid potassium at 200°C in a tube whose outlet opened to a stream of inert gas. The products of both methods were essentially the same; their melting points (~945°C) were about 35°C higher than that previously reported for the product from the liquid ammonia method.¹ For the Inorganic and Physical Chemistry Group, pound quantities of high-purity KCl and LiCl were prepared, and for the Radiation Chemistry Group solid lithium hypobromite, stable at room temperature, was prepared successfully.

Series of preparations were made for the Salt Separation Chemistry of Protactinium from Ir-radiated Thorium Group of the Reactor Chemistry Division. These included multiple 100-g batches

¹G. Brauer, ed. (R. F. Riley, translation ed.), *Handbook of Preparative Inorganic Chemistry*, 2d ed., vol. 1, p. 360, Academic, New York, 1963.

of AlCl_3 . Fusion of this salt without explosion was finally achieved through the removal of all absorbed, extraneous, volatile materials such as chlorine and CCl_4 by sublimation through aluminum chips at 450°C . Like amounts of ThCl_4 and ZrCl_4 were prepared by repeated sublimations of commercially obtained materials. Also, 100 g of anhydrous MgCl_2 was prepared by the reaction of NH_4Cl on MgO and subsequent sublimation of the resultant product. Also for this group several preparations of UCl_3 were made by the reaction of HCl gas on UH_3 . Purification of the products by the iodine sublimation method of Gregory² was attempted but was only partly successful. Finally, a product of 98% purity was obtained by use, with some refinements, of the apparatus described by Johnson, Butler, and Newton.³

In work for the Neutron Diffraction Studies Group of the Solid State Division, 20 g of DyP of practically 100% purity was made by a new⁴ method

²N. W. Gregory, *Preparation and Properties of the Uranium Halides*, MDDC-1755 (declassified Feb. 18, 1948).

³O. Johnson, T. Butler, and A. S. Newton, "Preparation, Purification, and Properties of Anhydrous Uranium Chlorides," paper 1, p. 2, in *Chemistry of Uranium. Collected Papers* (ed. by J. J. Katz and E. Rabinowitch), TID-5290, Book 1 (1958).

⁴M. T. Kelley and D. E. LaValle, "Inorganic Preparations," *Anal. Chem. Div. Ann. Progr. Rept. Dec. 31, 1961*, ORNL-3243, pp. 77-78.

in which dysprosium metal at 750°C in an alundum boat is exposed to phosphorus vapors in a sealed system. Preparatory to making pure HoS, an investigation of the holmium-sulfur system is under way because of the lack of information on this system in the literature. In other work for the Solid State Division, high-purity KCl is being produced on an almost routine basis for the Research and Development on Pure Materials Group.

For the High-Temperature Materials Group of the Metals and Ceramics Division, several more 10-g preparations of K_2O were made and like amounts of the niobates of lithium and potassium.

The work for the Physics Division was limited to the preparation of more alloys of the rare-earth metals and the treatment of various alloys of manganese with chromium, vanadium, and iron at 1000°C in highly purified hydrogen. Both types of work were for the Neutron Diffraction Group.

Miscellaneous preparations included: 50 g of MoCl_5 for the Physical Metallurgy Laboratory of the Metals and Ceramics Division, 5 g of IBr for the Tandem Routine Operations Group of the Physics Division, 10 g of ICl for the Characterization, Control, and Simulation of Accident-Released Fission Products Group of the Reactor Chemistry Division, and 10 g of Li_3Sb for the Radiation Detection Group of the Instrumentation and Controls Division.

14. Organic Preparations

J. C. White

P. F. Thomason

H. L. Holsopple

Several organic compounds were custom synthesized to fill research needs of the Chemical Technology, Chemistry, and Analytical Chemistry Divisions. These compounds, prepared and purified on request, were not readily available from commercial sources.

14.1 COMPOUNDS PREPARED

14.1.a Methyl Isocyanide

Methyl isocyanide (25 g) was synthesized for the Chemical Separation of Isotopes Group of the

Chemistry Division. The compound was prepared by decomposing a solid complex of methyl iodide and silver cyanide with an aqueous solution of potassium cyanide. Methyl isocyanide was separated by distillation through a packed column and was purified by passing the vapors, under vacuum, through appropriate contaminant-removing reagents. Infrared spectroscopy showed that the synthesized material is essentially pure methyl isocyanide. This work is reported in detail elsewhere.¹

14.1.b N,N',N''-Trimethylborazine

A quantity of N,N',N''-trimethylborazine was prepared as a new liquid-scintillator solvent to be used in thermal-neutron detection. The reaction of monomethylammonium chloride and lithium borohydride gives N,N',N''-trimethylborazine according to the reaction

1,2-Bis-(2-methoxyethoxy)ethane was used uniquely as the solvent in which this reaction occurred. Elemental analysis of the product gave the following results (in weight percent):

Component	Theoretical	Found
Carbon	29.4	29.3
Hydrogen	9.87	9.67
Boron ^a	26.5	25.1

^aDetermined by neutron absorption.

The product was further characterized by its refractive index (1.4396) and boiling point (134°C), which agree closely with the values 1.4404 and 133°C, respectively, that are given in the literature.² The details of this preparation are given elsewhere.^{3,4}

¹H. L. Holsopple, *Synthesis of Methyl Isocyanide*, ORNL-TM-777 (Jan. 27, 1964).

²W. V. Hough et al., "The Preparation, Identification and Characterization of N-Trialkylborazoles," *J. Am. Chem. Soc.* 77, 864 (1955).

14.1.c 6-Amino-3,9-diethyltridecane

A long branched-chain primary amine was needed by the Chemical Technology Division in their extraction studies. To provide this, first a C₁₇ alcohol, 3,9-diethyltridecanol-6, was oxidized to the corresponding ketone with chromic anhydride according to the general method of Mosher and Langerak.⁵ Then this ketone was reacted with hydroxylamine hydrochloride and sodium carbonate to give 6-oxime-3,9-diethyltridecane (1.5 kg); the reaction was

Vigorous refluxing of reactants for 1 hr was necessary to complete the preparation.

6-Amino-3,9-diethyltridecane was then prepared by submitting the oxime to hydrogenation over Raney nickel catalyst for ~1 hr at 125°C under 90 atm of hydrogen. The product was purified by fractional vacuum distillation and characterized by elemental analysis.

The hydrogenation apparatus consists primarily of an American Instrument Company shaker assembly and a bomb assembly cold-tested at 12,000 psi. High-pressure valves, tubing, and fittings were required to transmit hydrogen from the cylinder to the bomb assembly and back through a transducer to a continuous pressure recorder. Thermocouples linked the bomb assembly to a continuous temperature recorder. Power to heat the shaker assembly was supplied through a 20-amp Variac and was maintained by a single-set Wheelco temperature controller. Figure 14.1 is a photograph of the bomb assembly and its parts.

The shaker assembly rocks the bomb through an angle of ~30°, that is, the bomb placed on its side is rocked in such a way that one end is alternately 15° above and 15° below horizontal.

³H. L. Holsopple and L. E. Scroggie, *Synthesis and Infrared Absorption Spectra of N,N',N''-Trimethylborazine*, ORNL-TM-860 (May 8, 1964).

⁴H. H. Ross and H. L. Holsopple, "N,N',N''-Trimethylborazine as a Liquid Scintillator Solvent for Thermal Neutron Detection," *Nucl. Instr. Methods*, in press.

⁵W. A. Mosher and E. O. Langerak, "Oxidation of Some Aliphatic Alcohols with Chromic Acid," *J. Am. Chem. Soc.* 71, 286 (1949).

Fig. 14.1. Bomb Assembly and Its Parts.

Fig. 14.2. Apparatus for Pressure Reactions.

The rate of oscillation varies from 36 to 38 oscillations/min. Movement is obtained from an $\frac{1}{8}$ -hp 1725-rpm electric motor. The heater receptacle is integral with the shaker assembly, the temperature being controlled from the instrument panel. Figure 14.2 shows the apparatus ready for operation.

14.1.d Monoacid Esters

A new monoacid ester, monoheptyldecyltetrapropenylsuccinate, was prepared for the Chemical Technology Division. Heptyldecyl alcohol (0.5 mole) and tetrapropenylsuccinic anhydride (0.5 mole) were reacted to give 260 g of the ester. Monoheptyldecylmaleate (550 g) was prepared for the Chemical Technology Division by an analogous reaction between heptyldecyl alcohol and maleic anhydride.

14.1.e α,α' -Dipiperidyl

α,α' -Dipiperidyl (15 g) was synthesized for the Isotope Separations Group of the Chemistry Division. α,α' -Dipyridyl was reduced with hydrogen (platinum oxide as catalyst) in a 250-ml hydrogenation bomb at 100 atm and 150°C. A moderate excess of 5 *N* HCl was used to dissolve the dipyridyl. The quantity of hydrogen used agreed with the absorption of 12 hydrogen atoms. The solution that remained after the reduction was separated from the platinum and made basic; the dipiperidyl was extracted into diethyl ether. The ether was removed at reduced pressure, and the liquid α,α' -dipiperidyl was filtered through a fine-fritted funnel.

The phenyl isothiocyanate addition product, $C_{10}H_{20}N_2 \cdot 2C_6H_5NCS$, of α,α' -dipiperidyl was crystallized from ethyl alcohol and had a melting point of 178°C, which is the same as the literature value.⁶ Elemental analysis of the α,α' -dipiperidyl gave the following results (in weight percent):

Component	Theoretical	Found
Carbon	71.4	71.4
Nitrogen	16.6	16.0

⁶C. R. Smith, "Dipiperidyls," *J. Am. Chem. Soc.* **50**, 1936 (1928).

14.2 DETERMINATION OF ALDEHYDES AND KETONES

An acidimetric method for the determination of aldehydes and ketones with hydroxylamine hydrochloride and pyridine as reagents was used successfully on carbonyl samples from the Chemical Technology Division. Pyridine forces the formation of oxime to completion and renders the initial reaction mixture neutral to bromophenol blue, thus eliminating the need of a blank titration.

14.3 PURIFICATION OF α -METHYLNAPHTHALENE

α -Methylnaphthalene was purified by fractional distillation for use in studies being made by the Radiochemistry Group of the Analytical Chemistry Division.

14.4 CURRENT PROGRAMS

High-purity ^{10}B diborane is needed by the Physics Division. Boron trifluoride enriched to 96% ^{10}B will be reacted with lithium aluminum hydride in 1,2-bis-(2-methoxyethoxy)ethane as solvent; the ^{10}B diborane will be collected by fractional condensation.

Octyldecyl sulfoxide may be prepared by treating an aqueous alcoholic solution of octyldecyl chloride with sodium sulfide to form octyldecyl sulfide, which can then be oxidized to the sulfoxide with 30% hydrogen peroxide or chromic anhydride.

Preliminary studies have been made of the feasibility of preparing a quantity of chlorophosphonazo III. This reagent, a structural analog of arsenazo III, is of interest to the analytical service groups for possible use in the photometric determination of calcium and magnesium. The possibility of synthesizing other azo-type chromogenic reagents such as dibromoarsenazo II and lumogallion will be investigated.

Syntheses of tetra(perfluorovinyl) tin and perfluoroacrylic acid are being attempted. The

vinyltin compound is being prepared by reacting bromotrifluoroethylene with tin chloride and magnesium in tetrahydrofuran. The Grignard reagent prepared from bromotrifluoroethylene reacts according to the equation

Perfluoroacrylic acid will be prepared from the same Grignard reagent.

Part B. Service Analyses

A summary of the service analyses made by the laboratories of the Analytical Chemistry Division is given in the table below.

Summary of Analytical Service Work

Group Making Analyses	Average Number in Group		Number of Results Reported																											
	For ORNL																					For Others								
	Scientists	Technicians	Analytical Chemistry	Biology	Chemical Technology	Chemistry	Electronuclear	Finance and Materials	Health	Health Physics	Inspection Engineering	Instrumentation and Controls	Isotopes	Metals and Ceramics	Neutron Physics	Operations	Physics	Plant and Equipment	Reactor	Reactor Chemistry	Solid State	Thermonuclear	Armour	General Electric	Miscellaneous	Savannah River Laboratory	Special Projects	Westinghouse	Y-12	Total
Mass Spectrometry Analyses	2	4	12	50	2,484	440	4	1610		50		120	7,400	1,851	4	18	230		4,579	4,158	10	34			972				454	24,486
Optical and Electron Microscopy	3	2	18		176	73				41		5	21	110		3	193		114	340	6								24	1,129
Process Analyses																														
General Analyses Laboratory	9	17	15	93	29,604	891	33		467	733		4	212	7,365	85	643	34	285	2,129	3,182	402	82			14					46,299
General Hot Analyses Laboratory	11	13			14,774					55			876	58		3230			223	1,472			9					101		20,822
High-Level Alpha Radiation Laboratory	3	4			9,902					5			545							25						12		47	21	10,564
Materials Testing Laboratory	5	10	45	1	11,497	695	2		20	211	3		118	1,204	25	28	19	138	1,228	4,620	18									19,887
Radioisotopes-Radiochemistry Laboratory	9	18	164	39	7,559	26			28	3,838			11,736	1,828	153	5861			2,848	13,042	505			1019	51					48,724
Reactor Engineering Services Analytical Chemistry Laboratory	1	3	6		114	30				258	16	9	12	519		25			3,404	1,185		6							116	5,704
Spectrochemical Laboratory	2	2	200		625	85	59		430				10,856	327	50		518		1,130	2,177	976	50							614	18,101
X-Ray and Spectrochemical Analyses	9	6	142	5	5,451	861			4094	15,076	30		654	1,666		16	76	30	714	1,344	464									30,638
Total	54	79	602	188	82,186	3101	98	1610	5039	20,267	49	138	32,430	14,928	317	9824	1070	453	16,369	31,545	2381	172	9	1019	1037	12		148	1229	226,354

15. Quality Control

C. K. Talbott   Bobby G. Eblen   G. R. Wilson

An improvement occurred in the overall quality level of the analytical work for the 12-month period July 1963 through June 1964. The overall quality level increased from 94% to 96.5%; the number of control results increased 15%. The marked improvement in the quality level in the General Hot Analyses Laboratory is due mostly to the increase in the number of coulometric determinations of uranium. The 2S, or 95% confidence, limit for this determination is

now at 1% and should be reduced to 0.5%. The number of control programs decreased by one as a result of the discontinuation of the colorimetric determinations of chloride and copper and the addition of the volumetric determination of cadmium. Table 15.1 shows the distribution of these control tests by laboratories. The number of control tests and their specific characteristics are shown more appropriately in Table 15.2.

Table 15.1. Distribution by Laboratories of Control Tests for July 1963 Through June 1964

Laboratory	Number of Control Results		Quality Level (%) ^a	
	Total	Outside Fixed Limits	1963	1964
General Hot Analyses	1395	61	88	95.6
Materials Testing	1262	49	97	96.1
General Analyses	2149	69	94	96.8
Reactor Engineering Services	379	10	96	97.4
Total	5185	Total 189	Av 94	Av 96.5

^aControl results within prescribed 2S limits.

Table 15.2. Distribution by Methods of Control Results for July 1963 Through June 1964

Type of Method	Constituent	Number of Control Programs	Number of Control Results	Type of Method	Constituent	Number of Control Programs	Number of Control Results
Colorimetric (spectrophotometric)	Aluminum	1	173	Gravimetric	Carbon	3	589
					Molybdenum	1	27
	Chromium	2	158		Nickel	1	56
	Iron	2	261		Silicon	1 6	4 676
	Manganese	1	53	Potentiometric	Uranium	1 1	21 21
	Mercury	1	8	Volumetric	Aluminum	1	132
	Molybdenum	1	85		Cadmium	1	3
	Nickel	3	200		Chromium	1	60
	Niobium	1	174		Nitrate	2	117
	Thorium	4	473		Phosphorus	1	54
Uranium	3 19	720 2305	Sulfate		1	69	
			Sulfur		1 8	50 485	
Coulometric	Uranium	2 2	1228 1228				
Fluorometric	Uranium	3 3	470 470	Total		39	5185

16. Mass Spectrometric Analysis

A. E. Cameron

J. R. Sites

The Mass Spectrometry Laboratory continued to analyze sweep gas from experiments in the ORR, helium from trailers for the liquid-helium plant and the Reactor Chemistry Division, special argon from cylinders for ORNL Stores, fission product off-gases for the Solid State Division, rare-gas products of the thermal-diffusion plant, argon-helium mixtures for the Kilord Program, and special gas mixtures for several divisions. The enriched ^{14}C content of some CH_4 was determined for the Isotopes Division, as were the chemical purity and isotopic composition of young fission product Kr and Xe. The accelerator tank gas for three Van de Graaff generators was analyzed for the High Voltage Laboratory. The ^{18}O content of CO_2 samples was measured for the Biology Division. The CF_4 , Kr, and Xe contents of radioactive trapped off-gases from a reactor capsule test in Idaho were determined. Various phases of the SNAP program were supported by certifying the

purity of gas from cylinders and by analyzing the gaseous products of experiments. The carbon isotope ratios in acetylene and benzene samples were determined for ORINS.

The relative isotopic abundances were determined for uranium-inventory samples, uranium-burnup experiments, uranium fuel-element certification, and separated stable-isotope cyclotron targets. Radioactive samples of ^{10}Be , ^{36}Cl , ^{59}Ni , ^{90}Sr , ^{131}I , ^{147}Pm , and ^{151}Sm were analyzed. The Yb contaminant present at the parts-per-million level in a separated-calcium-isotope crystal was characterized.

A total of 950 samples were analyzed for the Stable Isotope Separation program. This work included the isotopic analysis of the following 34 elements: B, Ba, Ca, Cd, Cr, Cu, Er, Fe, Ga, Gd, Ge, Hf, Hg, Ir, K, Mg, Mo, Ni, Pb, Rb, Ru, S, Se, Si, Sm, Sn, Ta, Te, Ti, U, W, Yb, Zn, and Zr.

---

17. Spectrochemical Analysis Laboratory

A. E. Cameron

J. A. Carter

Zell Combs

About 1200 samples were analyzed in the Spectrochemical Analysis Laboratory, and over 18,000 results were reported. Thirty-three percent of the samples originated in the Isotopes Division; they included the radioisotopes ^{147}Pm and ^{151}Sm and the stable isotopes of B, Ba, Ca, Cd, Cl, Cr, Cu, Dy, Er, Ga, Gd, Hf, Ir, Fe, K, Pb, Li, Mg, Mo, Rb, Ru, Sm, Se, Si, S, Ta, Te, Tl, Sn, Ti, W, Yb, Zn, and Zr. Lithium fluoride accounted for 208 sam-

ples, 162 samples were metals for identification or specification testing, and over 100 samples contained beryllium.

The Wadsworth and Ebert spectrographs were relocated; as a result, one arc-spark stand serves both instruments. This arrangement provides wavelength coverage sufficient to determine 60 to 65 trace elements with one exposure; previously, three exposures were required.

18. Process Analyses

L. T. Corbin

18.1 HIGH-LEVEL ALPHA RADIATION LABORATORY

J. H. Cooper

The High-Level Alpha Radiation Laboratory reported 10,557 results during the past year. Of these, 95% were for the Chemical Technology Division and 5% were for the Isotopes Division.

The usual procedure for determining ^{231}Pa alpha radioactivity is to measure the gross alpha activity and to determine the percent of ^{231}Pa alpha activity by alpha pulse-height analysis. Whenever dissolved solids prevent the preparation of good counting plates or whenever high ^{232}U content masks the ^{231}Pa alpha peak in alpha spectrometry, an alternative procedure must be followed. Uranium and iron are extracted from 9 M HCl into either diisobutylcarbinol or tributyl phosphate and are separated from the Pa if the Pa is first complexed with fluoride ion. If no solids are present, an aliquot of the aqueous phase can then be counted and pulsed for ^{231}Pa . If solids are present, fluoride can be complexed with borate and the Pa extracted into diisobutylcarbinol, counted, and pulsed.

The Savannah River Laboratory was assisted in a study of the penetration of plutonium into the aluminum cladding of fuel elements. Small chips of the aluminum were analyzed by extracting the plutonium into TTA and counting the alpha radioactivity. Anion exchange separation of the plutonium did not give quantitative recovery, but two successive extractions with TTA did.

Samples of plutonium sols were analyzed for ammonia and nitrate. A micro Kjeldahl distillation apparatus was installed in a glove box, and the nitrogen was distilled from samples of plutonium that contained several microcuries of alpha activity.

18.2 GENERAL ANALYSES LABORATORY

W. R. Laing

A total of 46,273 results were reported during the past year. Several new or modified methods

were placed in service. A Leco inert-gas-fusion apparatus was used to determine oxygen in uranium nitride. Cesium was extracted from a solution of its ores into 4-sec-butyl-2-(α -methylbenzyl)phenol (BAMBP), stripped with 0.25 N HCl,¹ and measured by flame spectrophotometry. A WO_3 (40%)– Na_2WO_4 (60%) flux was used to determine F^- in solids and solutions that contained Ta. Gas-release tests were made on sol-gel thoria at temperatures up to 2200°C. The upper pressure for permeability measurements was extended from 1.5 atm to 6.0 atm. Work continued on the determination of free HF in solutions that contain $\text{H}_4\text{NbO}_2\text{F}_5$ and HF; thorium was used as the titrant, but the trisodium salt of 4,5-dihydroxy-3-(*p*-sulfophenylazo)-2,7-naphthalenedisulfonic acid (SPADNS) was found to be a better indicator than Thoron.

Several methods recently put into service have resulted in considerable cost savings. A Technicon AutoAnalyzer was used to determine both uranium and the synthetic detergent, ABS. For the determination of uranium, it was operated at a rate of 60 samples/hr, with a relative standard deviation slightly less than that obtained by standard spectrophotometry. The operating rate for the ABS determination was 20 samples/hr, compared with 4 samples/hr when done by hand. The relative standard deviation was the same in both cases.

In many samples, a volumetric EDTA titration was used in place of gravimetry to determine thorium; use of the volumetric method resulted in a 50% saving of time.

Location of another vendor of crucibles, funnels, and stoppers for the vacuum-fusion apparatus has resulted in a 45% reduction in the cost of these supplies.

A more rapid method for the measurement of coating densities of AVR fuel particles was developed. The density of the coated particle is measured; then the particle is burned in oxygen, and the CO_2 and oxide residue are weighed. From

¹W. J. Ross and J. C. White, "Determination of Cesium and Rubidium After Extraction with 4-sec-Butyl-2-(α -methylbenzyl)phenol," *Anal. Chem.* **36**, 1998 (1964).

a knowledge of the density of the core material, the density of the coating is calculated.

Computer programs were coded for pycnometer density, total anion, permeability, and porosity measurements. The coding of programs for quality control and surface-area measurements is planned.

18.3 GENERAL HOT ANALYSES LABORATORY

C. E. Lamb

The preparation for handling, treating, and analyzing radioactive materials originating from new programs was continued as one of the major efforts by the General Hot Analyses Laboratory. Special programs requiring such work exist in the Reactor Chemistry, Reactor, and Chemical Technology Divisions. The programs include Curium Recovery, Power Reactor Fuel Processing, $^{231}\text{Protactinium}$ Cleanup from $^{232}\text{Uranium}$ Production, and Close-Coupled Process Development.

The initial phase of the development of methods and equipment for the MSRE program was completed. The work and prototype equipment were moved from the mockup area to the High-Radiation-Level Analytical Laboratory (HRLAL), and the training of personnel was started concurrently with the fabrication of equipment for use in the hot cells.

For analysis of samples from the Curium Recovery Program, several new methods with related equipment were selected and tested in a hot cell. They included the determination of aluminum² in the presence of rare-earth elements by titration with EDTA to a mixed-indicator (bromocresol-methyl red) end point, free acid³ by potentiometric titration with LiOH in LiCl solution, chloride^{4,5} by titration with AgNO_3 and by spectrophotometric

measurement using mercuric chloranilate ($\text{HgC}_6\text{Cl}_2\text{O}_4$) as the chromogenic agent, nitrate⁶ by spectrophotometric measurement using sulfanilic acid and α -naphthylamine, and rare-earth elements⁷ in the presence of aluminum by EDTA titration to a xylenol orange end point.

At the request of the Power Reactor Fuel Processing Group, a quartz tube furnace⁸ (Fig. 18.1) to be used within a hot cell was fabricated for the determination of carbon in graphite, pyrolytic-carbon-coated fuel particles, and solutions of dissolved carbon. The samples were burned in an oxygen atmosphere, and the gas was passed through a solution of KMnO_4 (when samples contained nitrates) and a trap of Drierite, and then absorbed in an Ascarite trap. The carbon content was calculated from the increased weight of the trap. The method was unsatisfactory for samples of low carbon content; the lower limit was not established.

In cooperation with the Metals and Ceramics and the Reactor Chemistry Divisions, a glass-and-platinum electrolysis assembly, supplied by J. L. Cook,⁹ was tested in a hot cell for the disintegration of irradiated graphite spheres that contain particles of pyrolytic-carbon-coated uranium fuels. The spheres were electrolytically disintegrated in 8 M HNO_3 at 4 to 5 amp and 4 to 5 v; the disintegration required 12 to 24 hr. An analysis for the uranium in the supernatant liquid then made possible the calculation of the number of fractured particles leached by the nitric acid solution. Also for the Reactor Chemistry Division, graphite was dissolved completely in a hot cell under reflux conditions using fuming nitric-perchloric acid.

Materials submitted by organizations outside ORNL were analyzed; these included $\text{UO}_2\text{-ThO}_2$ and $\text{UO}_2\text{-ZrO}_2$ pellets from Westinghouse and a UO_2SO_4 solution from the I.I.T. Research Institute.

An Alpha Facility that consists of 65 lin ft of glove boxes was constructed in Building 3019. The Facility was designed for use in handling alpha-emitting materials removed from the hot

²H. Flaschka et al., "The EDTA Titration: Applications II," *Chemist-Analyst* 47, 22 (1958).

³H. Kubota and D. A. Costanzo, "Reactions in Concentrated Lithium Chloride Solution: Determination of Free Acid and Hydrolyzable Cation," *Anal. Chem.* 36, in press (1964).

⁴F. J. Miller, "Chlorine (Chloride), Potentiometric Silver Nitrate Titration Method," Method Nos. 1 212020 and 9 00712020 (1-29-59), *ORNL Master Analytical Manual*; TID-7015, suppl. 2.

⁵J. E. Barney II and R. J. Bertolacini, "Colorimetric Determination of Chloride with Mercuric Chloranilate," *Anal. Chem.* 29, 1187 (1957).

⁶L. Procházková, "Bestimmung der Nitrate im Wasser," *Z. Anal. Chem.* 167, 254 (1959).

⁷H. Flaschka et al., "The EDTA Titration: Applications IV," *Chemist-Analyst* 47, 78 (1958).

⁸L. M. Ferris et al., *Combustion-Dissolution Experiments with Irradiated Graphite-Base Reactor Fuel Containing Carbon-Coated Thorium-Uranium Dicarbidic Particles*, ORNL-TM-688 (Sept. 20, 1963).

⁹Metals and Ceramics Division.

Fig. 18.1. Quartz Tube Furnace for Combustion of Carbon Samples.

cells after the radiation level had been reduced to a safe limit and also other samples low in total radiation but relatively high in alpha emitters.

Four alien guests (two from Germany, one from Italy, and one from France) were trained in analytical chemistry hot-cell operations.

18.4 MATERIALS TESTING LABORATORY

L. J. Brady

The Materials Testing Laboratory, with a staff of 15 employees, reported the results of about 19,900 analyses during the past year. Of this total, about 58% were for the Chemical Technology Division, 23% for the Reactor Chemistry Division, 6% for the Metals and Ceramics Division, and 6% for the Reactor Division.

Specification tests of the flush salts and charge material for the MSRE included the determination of major components as well as traces of iron, chromium, and nickel. In addition, oxygen and total sulfur were determined in many fused fluoride salt samples.

The determination of the thorium content of granite samples and of acid leach solutions was continued.

The rare-earth-element content of samples derived from extraction studies was determined, with arsenazo as the chromogenic agent. Calibration curves were prepared after solutions were tested that contained known amounts of the same mixture of rare-earth elements as those that were being tested in the extraction process. No preferential extraction of specific rare-earth elements was expected during the process.

Samples of potassium nitrate were analyzed for nitrite. They had been subjected to radiation in

the Van de Graaff generator, and the quantity of nitrite produced was used to estimate the energy input to the salts being tested.

Nitrogen was determined in refractory samples of uranium nitride and boron nitride. After the sample was dissolved in aqueous solution or by fusion with sodium hydroxide, the ammonia was distilled into a solution of boric acid and then titrated.

The carbonate content of samples of thorium oxide and rare-earth slurries or sols that contained less than 0.1% carbonate was determined by gas chromatography. The carbon dioxide was evolved from an acid solution of the sample and was swept into a sampling loop with helium. The loop was maintained at liquid-nitrogen temperature, and the solid carbon dioxide was retained in the capillary loop by a section of powdered glass held in place with small plugs of glass wool. After the carbon dioxide was collected, the stopcocks on the sampling loop were closed, and the loop was allowed to warm to room temperature. The gaseous carbon dioxide was then measured with a gas chromatograph.

A number of samples of tellurium that had been collected on nickel-wool filters were analyzed to determine their tellurium content. The entire sample was dissolved in acid under reflux. The tellurium was precipitated from solution by reducing it to the metal with sulfur dioxide and hydrazine hydrochloride. The tellurium metal was filtered from the solution, dried, and weighed. Precautions were necessary to prevent loss of tellurium during the dissolution.

For the Plant and Equipment Division, a series of compatibility tests was conducted. They were designed to determine the tendency of various lubricating oils to form highly viscous sludge when kept in contact with antifreeze mixtures based on ethylene glycol. Attempts were being made to circumvent difficulties encountered in the past when antifreeze was allowed to come in contact with the oils lubricating engines used to drive air compressors. Some of these engines had been damaged as the result of abnormal wear on the bearings.

The carbon and nitrogen contents of a number of dietary foods and of plant materials were determined for the Health Physics Division; macro-combustion methods were used.

18.5 RADIOISOTOPES-RADIOCHEMISTRY LABORATORY

E. I. Wyatt

The Radioisotopes-Radiochemistry Laboratory had an increase in personnel and in the volume and variety of analytical work. All the intermediate-level radiochemical work is now performed in Building 9204-1 instead of Building 3550. The field of low-level radiochemical analysis now includes tritium determinations. Gamma-ray spectrometric analysis was expanded to include the hot-cell work in Building 3525. The use of computer programs to resolve spectrometer data was increased, the objective being to resolve complex gamma-ray spectra from the Curium, the TRU, and the Nuclear Safety Pilot Plant Programs. A second anticoincidence beta proportional counter and an additional multichannel analyzer were acquired. The latter is being used in conjunction with a lithium-drifted germanium diode detector to obtain better resolution of gamma spectra than is given by NaI detectors.

The mass distribution of the fission products formed by the epicadmium-induced fission of ^{237}Np was measured. The fission products were determined radiochemically. A report of this work is being prepared for publication. The half-lives of ^{141}Ce and ^{144}Ce were measured by means of a beta proportional counter; values of 31.9 ± 0.3 and 284.2 ± 1.0 days, respectively, were obtained.

18.6 HIGH-RADIATION-LEVEL ANALYTICAL FACILITY (HRLAF)

L. G. Farrar

In the High-Radiation-Level Analytical Facility (HRLAF) contamination difficulties in handling dilutions removed from the cells for hot-laboratory work made necessary the use of rigid monitoring techniques for all materials removed from the hot cells. The number of radiation-monitoring instruments used in the HRLAF has almost doubled over the past year.

Two hot cells sealed in glove-box fashion for work with high-level alpha-emitting materials were

operated successfully, with minor modifications for access and viewing. The two containment cells were used to separate ^{233}U from its daughter nuclides, to separate americium and curium from fission products, and to clean up 45 g of ^{231}Pa . These operations involved the use of ion exchange, solvent extraction, precipitation, and filtration under hot-cell and glove-box conditions.

The radioactivity of samples received in the HRLAF over the past year has increased by a factor of at least 10. Because of the unusual nature of recent samples, longer storage of hotter samples has caused the breakdown of the gasket material in the viewing window of the storage cell. Under irradiation, the gasket material yields a phosphate compound that precipitates as lead phosphate in the oil of the viewing window and thus causes cloudiness. The oil has been changed twice to reduce cloudiness, but it is expected that a complete cleaning of the window will soon be necessary.

High-level contamination has been experienced in cells used to check MSRE analytical procedures with irradiated salt samples. Additional contain-

ment of crushed salt samples is being used in an effort to decrease general contamination in the cell.

More frequent changes of manipulator boots resulted in a decrease in the alpha contamination of manipulators. A manipulator-decontamination facility was completed; it will greatly facilitate the repair of contaminated manipulators. During routine maintenance of manipulators, all units were fitted with quick-disconnect replaceable master-slave hands and relays to decrease manipulator repair time. Routine maintenance in the HRLAF has included repairs to 123 manipulators and the decontamination of 11 work cells.

Greater use is being made of transfer carriers to decrease contamination of carriers shipped to other hot facilities at ORNL. An effort has been made to standardize transfer carriers as much as possible.

Spread of fission products as a result of the operation of a flame photometer in cell 6 of the HRLAF was diminished by separating the fission products from the samples before the sample is burned in the cell.

19. Reactor Engineering Service Laboratory

A. E. Cameron

C. K. Talbott

The Reactor Engineering Service Analytical Chemistry Laboratory made ~5700 analyses on about 1160 samples. Of these, about 50% were submitted by the Reactor Division, 30% by the Reactor Chemistry Division, 8% from the Metals and Ceramics Division, and the remainder were derived from ten other sources. The samples consisted principally of water; high-alloy steel; solutions of HCl , HNO_3 , KOH , CdSO_4 , CdCl_2 , $\text{Cd}(\text{NO}_3)_2$, $\text{Sm}_2(\text{SO}_4)_3$, and low-level waste; Al; bromates of Ba, Ca, and Sr; and corrosion scale samples. Analyses were made less frequently on a variety

of materials such as ThO_2 , UO_2 , gas samples, plant material, and plastic and insulation products. About 160 cylinders of mixed gases were prepared during this period. Methods of analyses included volumetric analysis, spectrophotometric and potentiometric titrations, gravimetry, thermogravimetry, spectrophotometry, and gasometric analysis. Physical measurements were made on many of the samples; the measurements included pH, conductance, particle-size distribution, specific gravity, and zeta potential.

Part C. ORNL Master Analytical Manual

20. ORNL Master Analytical Manual

M. T. Kelley

Helen P. Raaen

20.1 CUMULATIVE INDEXES TO THE ORNL MASTER ANALYTICAL MANUAL

Cumulative indexes to the *ORNL Master Analytical Manual* were first issued in 1963. The purpose of the indexes and the arrangement of their content has been explained.¹ The indexes were updated to indicate the changes made in the content of the *Manual* during 1963. The updated cumulative indexes are entitled "Indexes to the *Oak Ridge National Laboratory Master Analytical Manual* (1953-1963), TID-7015 (Indexes), Revision 1." The document is available from the Office of Technical Services, United States Department of Commerce, Washington, D.C. 20230; the price is \$2.50. The indexes were issued as a companion document to Supplement 6 of TID-7015.

The computer work required for the preparation of the updated indexes was supervised by Ann S. Klein.²

20.2 MAINTENANCE OF THE ORNL MASTER ANALYTICAL MANUAL

The sixth supplement to the reprinted form of the *ORNL Master Analytical Manual* was published.

¹Helen P. Raaen, "Cumulative Indexes to the *ORNL Master Analytical Manual*," *Anal. Chem. Div. Ann. Progr. Rept.* Nov. 15, 1963, ORNL-3537, p. 129.

²Technical Information Division.

It contains the new methods and the revisions issued in 1963. This supplement, designated TID-7015 (Suppl. 6), is available from the Office of Technical Services, Department of Commerce, Washington, D.C. 20230, at a price of \$5.00.

The new Section 4, "Mass Spectrometric Methods," and also the Subsections 9 02, "Molten-Salt Reactor Experiment (MSRE) Methods," and 9 06, "Transuranium (TRU) Process Methods," were added to the *Manual*. Section 4 is a reprinted form of ORNL-3528, *Isotopic Mass Spectrometry of the Elements*, by E. J. Spitzer and J. R. Sites; it consists primarily of one-page guide sheets for the mass spectrometric analysis of 64 elements. Subsections 9 02 and 9 06 contain four and ten methods, respectively, that are being evaluated for use in the MSRE and TRU work.

Altogether, 106 new methods were added to the *Manual*; 4 of these were for the purpose of record only. Revisions were made to 46 methods; 1 obsolete method was discontinued. Also, the Table of Contents for the *Manual* was updated. (See "Presentation of Research Results.")

A survey was made to determine what methods now contained in the *Manual* are no longer used, what revisions to existing methods are needed, and what new methods are required for current or anticipated analytical work. On the basis of the survey, methods-writing assignments were made to persons in the Analytical Chemistry Division.

Presentation of Research Results

Several of the presentations listed below were made jointly with members of other divisions. In these cases the member(s) of the other division(s) is indicated by a single asterisk.

PUBLICATIONS

Books, Theses, Monographs

AUTHOR(S)	TITLE	PUBLISHER
1 Belew, W. L.	<i>Application of Controlled-Potential and Derivative Polarography to the Determination of Metal Complexes in Organic Extracts and Compensation of Polarographic Cell Resistance in High Specific Resistance Solutions</i> (M.S. thesis)	University of Tennessee, December 1963
2 Dyer, F. F.	"Reactor Neutron Flux: Characteristics and Uses," pp. 14-32 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964
3 Eldridge, J. S.	"Scintillation Counting Techniques," pp. 80-107 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964
4 Hahn, R. L.	"Radiation Detectors and Counting Statistics," pp. 67-79 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964
5 Koirtzohann, S. R., C. Feldman	"Atomic Absorption Spectroscopy Using Long Absorption Path Lengths and a Demountable Hollow Cathode Lamp," pp. 180-89 in <i>Developments in Applied Spectroscopy</i> , vol. 3, ed. by J. E. Forrette and E. Lanterman	Plenum, New York, 1964
6 Lyon, W. S. (ed.)	<i>Guide to Activation Analysis</i>	Van Nostrand, Princeton, N.J., 1964
7 Lyon, W. S.	"Present Byways and Future Trends in Activation Analysis," pp. 108-15 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964
8 Ricci, E.	"Practical Examples of Activation Analysis," pp. 116-42 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964
9 Ross, H. H.	"Basic Nuclear Properties and Activation Analysis," pp. 1-13 in <i>Guide to Activation Analysis</i> , ed. by W. S. Lyon, Jr.	Van Nostrand, Princeton, N.J., 1964

- 10 Ross, H. H. "Radiochemical Separations," pp. 55-61 in *Guide to Activation Analysis*, ed. by W. S. Lyon, Jr. Van Nostrand, Princeton, N.J., 1964
- 11 Strain, J. E. "Nonreactor Neutron Sources," pp. 33-54 in *Guide to Activation Analysis*, ed. by W. S. Lyon, Jr. Van Nostrand, Princeton, N.J., 1964

Articles

AUTHOR(S)	TITLE	PUBLICATION
12 Apple, R. F., H. E. Zittel	"Amperometric Titration of Chromium in Mixtures of Fluoride Salts"	<i>Anal. Chem.</i> 36 , 983 (1964)
13 Attrill, J. E., L. B. Yeatts, Jr.,* W. T. Rainey, Jr.	"Retention Data for Polyphenyl Compounds"	<i>J. Gas Chromatog.</i> 2 (1), 46 (1964)
14 Bate, L. C., J. F. Emery, G. W. Leddicotte, ¹ W. S. Lyon, M. J. Pro ²	"Application of Activation Analysis to Forensic Science. I. Physical Evidence"	<i>Intern. J. Appl. Radiation Isotopes</i> 14 , 549 (1963)
15 Bate, L. C., M. J. Pro ²	"Application of Activation Analysis to Forensic Science. II. Drugs"	<i>Intern. J. Appl. Radiation Isotopes</i> 15 , 111 (1964)
16 Bate, L. C., M. M. Tuckerman, ³ G. W. Leddicotte ¹	"Determination of Trace Elements in Drugs by Neutron Activation Analysis"	<i>J. Pharm. Sci.</i> 53 (8), 983 (1964)
17 Burns, J. F.	"Auto-Ionizing Processes in the Rare Gases"	<i>Bull. Am. Phys. Soc.</i> 9 (3), 353 (1964)
18 Corbin, L. T., W. R. Winsbro,* C. E. Lamb, M. T. Kelley	"Design and Construction of ORNL High-Radiation-Level Analytical Laboratory"	<i>Trans. Am. Nucl. Soc.</i> 6 (2), 440 (1963)
19 Costanzo, D. A.	"Determination of Europium(II) and Total Europium - Europium-Activated Lithium Iodide Scintillation Crystals"	<i>Anal. Chem.</i> 36 , 2042 (1964)
20 Crowther, P., ⁴ J. S. Eldridge	"Decay of Molybdenum-99-Techneium-99m"	<i>Trans. Am. Nucl. Soc.</i> 7 (1), 87 (1964)
21 Crowther, P., ⁴ F. L. Moore	"Liquid-Liquid Extraction of Cesium with 2-Thenoyltrifluoroacetone"	<i>Anal. Chem.</i> 35 , 2081 (1963)
22	"Liquid-Liquid Extraction of Cesium with Thenoyl Trifluoroacetone"	<i>Trans. Am. Nucl. Soc.</i> 6 (1), 184 (1963)
23 Dale, J. M.	"Study of Metal-1,10-Phenanthroline Complex Equilibria by Potentiometric Measurement"	<i>Inorg. Chem.</i> 2 (3), 591 (1963)

¹Present address: Union Carbide Corp., Nuclear Division, Tuxedo, N.Y.

²Alcohol and Tax Unit, Treasury Department, Washington, D.C.

³Chemistry Department, Temple University, Philadelphia, Pa.

⁴Temporary alien employee, South African Atomic Energy Board, Pretoria, South Africa.

- 24 Eldridge, J. S.,
P. Crowther⁴ "Absolute Determination of I^{125} in Clinical Applications" *Nucleonics* **22**(6), 56 (1964)
- 25 Eldridge, J. S., F. L. Moore "Direct Non-Destructive Method for Determination of Californium-252" *Anal. Chem.* **36**, 808 (1964)
- 26 Feldman, C., T. C. Rains "The Collection and Flame Photometric Determination of Cesium" *Anal. Chem.* **36**, 405 (1964)
- 27 Fisher, D. J. Book review of: *Electronic Circuits and Instrumentation Systems*, J. J. Studer, Wiley, New York, 1963 *Anal. Chem.* **35**, 81A (Oct. 1963)
- 28 Folsom, T. R.,⁵ C. Feldman, T. C. Rains "Variation of Cesium in the Ocean" *Science* **144**, 538 (1964)
- 29 Goldstein, G. "Equilibrium Distribution of Metal-Fluoride Complexes" *Anal. Chem.* **36**, 243 (1964)
- 30 Goldstein, G., W. S. Lyon "Liquid Scintillators Using 1-Methylnaphthalene" *Intern. J. Appl. Radiation Isotopes* **15**, 133 (1964)
- 31 Hahn, R. L. "Chemical Effects of Isomeric Transitions: Separation of the Isomers of ^{127}Te , ^{129}Te , and ^{121}Te " *J. Chem. Phys.* **39**, 3482 (1963)
- 32 "Chemical Effects of Isomeric Transitions: The Separation of Tellurium Isomers in Different Chemical Media" *J. Chem. Phys.* **41**, 1986 (1964)
- 33 Handley, T. H. "Selective Determination of Mercury by Isotopic Exchange with Mercuric Di-*n*-Butyl Phosphorothioate in an Extraction System" *Anal. Chem.* **36**, 153 (1964)
- 34 Harmatz, B.,* T. H. Handley "Properties of Nuclear Levels in a Number of Even-Mass Nuclei ($184 \leq A \leq 192$)" *Nucl. Phys.* **56**, 1 (1964)
- 35 Horton, A. D., J. L. Botts "Gas Chromatography as Applied to Nuclear Technology - II. Analysis of the Hydrolysis Products of Uranium Carbides and Thorium Carbides" *Nucl. Sci. Eng.* **18**, 97 (1964)
- 36 Horton, C. A., B. C. Pal⁶ "The Structure of 3-Methyladenine, and Methylation of 6-Dimethylaminopurine" *J. Chem. Soc.* **1964**, 400
- 37 Kelley, M. T., C. D. Susano, J. S. Eldridge, C. Feldman, D. J. Fisher, W. S. Lyon, D. L. Manning, R. W. Stelzner, P. F. Thomson "Analytical Chemistry in Nuclear Technology" *Science* **144**, 570 (1964)

---

⁵Scripps Institute of Oceanography, LaJolla, Calif.

⁶Research participant in the Biology Division from Chemistry Department, Tuskegee Institute, Tuskegee, Ala.

- 38 Kelley, M. T., C. D. Susano, J. S. Eldridge, C. Feldman, D. J. Fisher, W. S. Lyon, D. L. Manning, R. W. Stelzner, P. F. Thomason "A Resume of the Seventh Conference on Analytical Chemistry in Nuclear Technology — Analytical Instrumentation: Molten Salt Systems, Radioactivity Standards, Nuclear Analysis, Spectroscopy, Gas Chromatography, Automation, Electroanalytical Techniques" *J. Electroanal. Chem.* 7, 165 (1964)
- 39 Lyon, W. S. "Report for Analytical Chemists: Availability and Use of Radioactivity Standards" *Anal. Chem.* 36, 31A (February 1964)
- 40 "180° Compton-Scattered-Annihilation Gamma-Ray Sum Peak Observed in Gamma-Ray Spectrometry" *Anal. Chem.* 36, 682 (1964)
- 41 Book review of: *Radioactive Tracers in Physical Metallurgy*, C. Leymonie, trans. by V. Griffiths, Wiley, New York, 1963 *Mater. Res. Std.* 4, 148 (1964)
- 42 Book review of: *International Directory of Radioisotopes*, 2d ed., IAEA, Vienna, 1962 *Health Phys.* 9, 87 (1963)
- 43 Lyon, W. S., J. M. Chilton,* R. A. Gilbert,* R. E. Leuze* "A Redetermination of the Half-Life of Uranium-232" *J. Inorg. Nucl. Chem.* 26, 395 (1964)
- 44 Mahlman, H. A.,* T. E. Willmarth "Radiolytic and Photolytic Reduction of Aqueous Silver Nitrate Solutions" *Nature* 202, 590 (1964)
- 45 Manning, D. L. "Voltammetry of Nickel in Molten Lithium Fluoride-Sodium Fluoride-Potassium Fluoride" *J. Electroanal. Chem.* 7, 302 (1964)
- 46 Manning, D. L., G. Mamantov⁷ "Rapid Scan Voltammetry. Chronopotentiometric Studies of Iron in Molten Fluoride" *J. Electroanal. Chem.* 7, 102 (1964)
- 47 "Current-Voltage Curves for Zirconium and Uranium in Molten Fluorides" *J. Electroanal. Chem.* 6, 328 (1963)
- 48 Miller, F. J., H. E. Zittel "Amperometric Titration of Uranium(IV) with Cerium(IV) Utilizing Pyrolytic Graphite Electrodes" *Anal. Chem.* 36, 45 (1964)
- 49 "Voltammetry of Ce(IV), Mn(VII), Cr(VI) and V(V) with the Pyrolytic Graphite Electrode" *J. Electroanal. Chem.* 7, 116 (1964)
- 50 Moore, F. L. "A New Approach to the Separation of Trivalent Actinide Elements — Selective Liquid-Liquid Extraction with Tricaprylmethylammonium Thiocyanate" *Anal. Chem.* 36, 2158 (1964)
- 51 Moore, F. L., J. S. Eldridge "Direct Nondestructive Method for Determination of Californium-252. Application of Prompt Gamma Rays from Spontaneous Fission" *Anal. Chem.* 36, 808 (1964)
- 52 Morton, J. E., H. A. Parker, E. I. Wyatt, L. T. Corbin "Shielded Facility for Use in the Analysis of Radioisotopes" *Trans. Am. Nucl. Soc.* 6(2), 446 (1963)

⁷Chemistry Department, University of Tennessee, Knoxville.

- 53 Peters, D. G.,⁸ W. D. Shults "Chronopotentiometry of Plutonium in Mineral Acid Media" *J. Electroanal. Chem.* 8, 200 (1964)
- 54 Reynolds, S. A. "Choosing Optimum Counting Methods and Radio-tracers" *Nucleonics* 22(8), 104 (1964)
- 55 Ricci, E. "Nomographs for Calculating Induced Radio-activity and Decay" *Nucleonics* 22(8), 105 (1964)
- 56 Ricci, E., F. F. Dyer "Second-Order Interference in Activation Analysis" *Nucleonics* 22(6), 45 (1964)
- 57 Rickard, R. R., C. F. Goeking, Jr., E. I. Wyatt "A Study of Fission Yields of Americium-241" *Trans. Am. Nucl. Soc.* 6(2), 261 (1963)
- 58 Ross, H. H. "Liquid Scintillation Counting of C¹⁴ Using a Balanced Quenching Technique" *Intern. J. Appl. Radiation Isotopes* 15, 273 (1964)
- 59 Ross, H. H., R. P. Gardner,⁹ J. W. Dunn III⁹ "Wear Rates in Automotive Engines by Liquid Scintillation Counting of Fe-55" *Trans. Am. Nucl. Soc.* 6(2), 401 (1963)
- 60 Ross, H. H., R. E. Yerick¹⁰ "A New Scintillator for Thermal Neutron Detection" *Nucl. Sci. Eng.* 20, 23 (1964)
- 61 Ross, W. J. "Activation Analysis of High Purity Materials" *Anal. Chem.* 36, 1114 (1964)
- 62 Ross, W. J., J. C. White "Determination of Cesium and Rubidium After Extraction with 4-sec-Butyl-2(α -methylbenzyl)-phenol" *Anal. Chem.* 36, 1998 (1964)
- 63 Spronk, N.¹¹ "Sodium Separation from Biological Material" *Trans. Am. Nucl. Soc.* 6(2), 398 (1963)
- 64 Stokely, J. R.,¹² F. L. Moore "Selective Liquid-Liquid Extraction of Radiotin with 2-Thenoyltrifluoroacetone" *Anal. Chem.* 36, 1203 (1964)
- 65 Strain, J. E., J. H. Shaffer,* W. R. Grimes,* G. M. Watson,* D. R. Cuneo,* M. J. Kelly* "Recovery of Protactinium and Uranium from Molten Fluoride Systems by Precipitation as Oxides" *Nucl. Sci. Eng.* 18, 177 (1964)
- 66 Thomason, P. F. "Pyrolytic Graphite Cup as Both Vessel and Electrode for Micro Redox and Acid-Base Potentiometric Titrations" *J. Microchem.* 8, 234 (1964)
- 67 Weekley, R. E.,¹³ J. A. Norris¹³ "A Versatile Electronic Computer for Photo-electric Spectrochemical Analysis" *Appl. Spectry.* 18, 21 (1964)
- 68 Young, J. P. "Windowless Spectrophotometric Cell for Use with Corrosive Liquids" *Anal. Chem.* 36, 390 (1964)

⁸Department of Chemistry, Indiana University, Bloomington.

⁹Measurement and Controls Laboratory, Research Triangle Institute, Durham, N.C.

¹⁰Department of Chemistry, Lamar State College of Technology, Beaumont, Tex.

¹¹Permanent address: Zoological Laboratory, Free University, Amsterdam, Netherlands.

¹²NDEA (National Defense Education Act) Fellow, Clemson University, Clemson, S.C.

¹³Present address: Jarrell-Ash Company, Waltham, Mass.

- 69 "Spectrometric Study of Molten Lithium Metal—Lithium Chloride Solutions" *J. Phys. Chem.* **67**, 2507 (1963)
- 70 Young, J. P., G. P. Smith* "Coordination of Fluoride Ions About Nickel(II) Ions in the Molten LiF-NaF-KF Eutectic" *J. Chem. Phys.* **40**, 913 (1964)
- 71 Zittel, H. E., Louise B. Dunlap "Controlled Potential Coulometric Titration of Uranium(IV) and Uranium(VI) in Sodium Tri-polyphosphate Medium" *Anal. Chem.* **35**, 125 (1963)

Reports

AUTHOR(S)	TITLE	REPORT NO.
72 Barton, C. J.,* D. R. Cuneo,* M. J. Kelly,* J. E. Strain	"Protactinium Stability in Thorium Nitrate—Nitric Acid Solutions" in <i>Proceedings of the Protactinium Chemistry Symposium, Gatlinburg, Tenn., April 25–26, 1963</i>	TID-7675, p. 35 (February 1964)
73 Burns, J. F.	<i>Trip Report, July 16–Aug. 15, 1963</i>	Sept. 12, 1963 (unpublished report)
74 Cameron, A. E.	<i>Report of Foreign Travel – July 1–30, 1963</i>	Aug. 19, 1963 (unpublished report)
75 Carter, J. A., W. S. Pappas, ¹⁴ R. R. Wright, ¹⁴ C. W. Weber ¹⁴	"Preparation and Recovery of Cesium Compounds" in <i>The Joint National Institutes of Health—Atomic Energy Commission Zonal Centrifuge Development Program Semiannual Report for Period July 1–December 31, 1963</i>	ORNL-3656, p. 49 (August 1964)
76 Eldridge, J. S., P. Crowther ⁴	"Evaluation of I ¹²⁵ Measurement Techniques for Clinical Applications of Radioiodine" in <i>Second Annual Oak Ridge Radioisotope Conference, April 19–22, 1964</i>	TID-7689, p. 15 (April 1964)
77 Goldstein, G.	<i>Equilibrium Distribution of Metal-Ion Complexes</i>	ORNL-3620 (November 1964)
78 Holsopple, H. L.	<i>Synthesis of Methyl Isocyanide</i>	ORNL-TM-777 (Jan. 27, 1964)
79 Holsopple, H. L., Lucy E. Scroggie	<i>Synthesis and Infrared Absorption Spectra of N,N',N''-Trimethylborazine</i>	ORNL-TM-860 (May 8, 1964)
80 Horton, C. A., J. C. White	<i>Separation of Uranium by Solvent Extraction with Tri-n-Octylphosphine Oxide and Its Direct Colorimetric Determination with Dibenzoylmethane</i>	ORNL-TM-866 (May 18, 1964)
81 Jones, H. C.	<i>Check Out and Test Procedure for High-Sensitivity Coulometric Titrator, ORNL Model Q-2564</i>	ORNL Test Specification ST-260 (Dec. 10, 1963)
82 Jones, R. J. (ed.),* S. Katz,* J. A. Carter	"Spectrochemical Determination of Volatile Fluoride Impurities in Uranium Compounds Using the Rotating-Disk Spark Technique" in <i>Selected Measurement Methods for Plutonium and Uranium in the Nuclear Fuel Cycle</i>	TID-7029, p. 383 (December 1963)

¹⁴ORGDP, Oak Ridge, Tenn.

- 83 "Spectrochemical Determination of Impurities in Uranium Compounds Using the Gallium Oxide Carrier Distillation Technique" in *Selected Measurement Methods for Plutonium and Uranium in the Nuclear Fuel Cycle* TID-7029, p. 389 (December 1963)
- 84 Kelley, M. T. *Report on Foreign Travel of Myron T. Kelley, March 21, 1964, to April 11, 1964* May 11, 1964 (unpublished report)
- 85 *Statistical Quality Control Report, Analytical Chemistry Division, January Through March 1964* June 8, 1964 (unpublished report)
- 86 *Statistical Quality Control Report, January Through June, 1964* Aug. 12, 1964 (unpublished report)
- 87 *Statistical Quality Control Report, Analytical Chemistry Division, January Through September, 1963* Nov. 11, 1963 (unpublished report)
- 88 *January Through December, 1963 - Statistical Quality Control Report, Analytical Chemistry Division* Feb. 18, 1964 (unpublished report)
- 89 Lyon, W. S. "Research on Activation Analysis Problems" in *Isotopes Technology Development Program* TID-7681, p. 13 (February 1964)
- 90 "Electronic Resolution of Gamma-Ray Spectra" in *Isotopes Technology Development Program* TID-7681, p. 17 (February 1964)
- 91 Manning, D. L. *Report of Foreign Travel* Oct. 26, 1964 (unpublished report)
- 92 Raaen, Helen P. (ed.) *Annual Progress Report for Period Ending November 15, 1963, Analytical Chemistry Division* ORNL-3537 (Feb. 10, 1964)
- 93 *Oak Ridge National Laboratory Master Analytical Manual, Supplement 6* TID-7015, suppl. 6 (June 1964)
- 94 Raaen, Helen P. *Report on Foreign Travel* Jan. 17, 1964 (unpublished report)
- 95 Raaen, Helen P., R. P. Clark* *Fabrication of the Vertical-Orifice Teflon Capillary of a Teflon Dropping-Mercury Electrode* ORNL-3654 (August 1964)
- 96 Raaen, Helen P., Ann S. Klein* (eds.) *Indexes to the Oak Ridge National Laboratory Master Analytical Manual (1953-1963)* TID-7015, Indexes, revision 1
- 97 Reynolds, S. A. "Radioisotopes in Alkaline-Earth Analysis" in *Second Annual Oak Ridge Radioisotope Conference, April 19-22, 1964* TID-7689, p. 81 (April 1964)
- 98 Ross, H. H. "A Unique Scintillator for Neutron Detection Using Lithium-6 Enriched Isotope" in *Isotope Technology Development Program* TID-7681, p. 15 (February 1964)
- 99 Ross, H. H., R. E. Yerick¹⁰ "A Unique Scintillator for Neutron Detection" in *Second Annual Oak Ridge Radioisotope Conference, April 19-22, 1964* TID-7689, p. 103 (April 1964)
- 100 Scroggie, Lucy E. *A Literature Survey of Sensitive Methods for the Determination of Dissolved Gases and Impurities in Reactor Coolant Water* ORNL-TM-724 (Nov. 11, 1963)

101	Shaffer, J. H.,* W. R. Grimes,* G. M. Watson,* D. R. Cuneo,* J. E. Strain, M. J. Kelly*	"Recovery of Uranium and Protactinium from Molten Fluoride Systems by Precipitation as Oxides" in <i>Proceedings of the Protactinium Chemistry Symposium, Gatlinburg, Tenn., April 25-26, 1963</i>	TID-7675, p. 86 (February 1964)
102	Strain, J. E., A. P. Litman*	<i>Trip Report to General Atomic, September 28, 1964</i>	Oct. 30, 1964 (unpublished report)
103	Spitzer, E. J., J. R. Sites	<i>Isotopic Mass Spectrometry of the Elements</i>	ORNL-3528 (Dec. 3, 1963)
104	White, J. C.	<i>Determination of Traces of Iron(III) in NaF-LiF-KF-UF₄ with Thiocyanate</i>	ORNL-TM-742 (Sept. 20, 1955)
105		<i>Analytical Chemistry Research and Development Group Monthly Summary - December, 1963</i>	Jan. 9, 1964 (unpublished report)
106		<i>Analytical Chemistry Research and Development Group Monthly Summary - January, 1964</i>	Feb. 7, 1964 (unpublished report)
107		<i>Monthly Summary - February, 1964, Analytical Chemistry Research and Development Group</i>	Mar. 17, 1964 (unpublished report)
108		<i>Analytical Chemistry Research and Development Group Monthly Summary - March, 1964</i>	Apr. 17, 1964 (unpublished report)
109		<i>Monthly Summary - April, 1964, Analytical Chemistry Research and Development Group</i>	May 11, 1964 (unpublished report)
110		<i>Analytical Chemistry Research and Development Group Monthly Summary - May, 1964</i>	June 16, 1964 (unpublished report)
111		<i>Analytical Chemistry Research and Development Group Monthly Summary - June, 1964</i>	July 10, 1964 (unpublished report)
112		<i>Analytical Chemistry Research and Development Group Monthly Summary - July, 1964</i>	Aug. 7, 1964 (unpublished report)
113		<i>Monthly Summary - August, 1964, Analytical Chemistry Research and Development Group</i>	Sept. 8, 1964 (unpublished report)
114		<i>Analytical Chemistry Research and Development Group Monthly Summary - September/October 1964</i>	Nov. 6, 1964 (unpublished report)
115	Young, J. P.	<i>Report of Foreign Travel</i>	Oct. 28, 1964 (unpublished report)

New Methods Issued to ORNL Master Analytical Manual

AUTHOR(S)	TITLE	NUMBER(S)	DATE
116 Apple, R. F.	"Dissolution of Irradiated, High-Fired, Refractory Nuclear Materials"	1 0902 9 00902	4-16-64
117	"Zirconium in MSRE Fuel, Amperometric Cupferron Titration Method"	9 021201	4-15-64
118	"Chromium in MSRE Fuel, Amperometric Ferrous Sulfate Titration Method"	9 021202	6-24-64
119	"Fluoride in MSRE Fuel, Pyrolysis Method"	9 021203	7-6-64

120		"Uranium in MSRE Fuel, Polarographic Method"	9 021204	7-13-64
121	Brady, L. J.	"Nitrate (Nitrogen), Volumetric Ferrous Ammonium Sulfate Method"	1 215671	10-14-63
122	Hill, F. M., F. L. Layton	"Carbon in Metals and Metallic Oxides, Leco Conductometric Method"	1 211793 9 00711793	6-27-63
123	Horton, A. D.	"C ₂ Through C ₅ Paraffins and Olefins, Gas Chromatographic Method"	1 221003 9 00721003	10-7-63
124		"C ₄ Through C ₈ Paraffins and Olefins, Gas Chromatographic Method"	1 221004 9 00721004	10-3-63
125	Kubota, H.	"Niobium, Spectrometric Hydroquinone Method"	1 215510 9 00715510	3-24-64
126	Layton, F. L.	"Sulfur (Sulfide and Nonsulfide), Indirect Polarographic Method"	1 218123 9 00718123	10-10-63
127	Lynn, E. C., F. M. Hill	"Aluminum and Thorium, Volumetric Disodium Dihydrogen Ethylenediaminetetraacetate (EDTA) Method"	1 210272 1 218772 9 00710272 9 00718772	4-22-64
128	Lyon, W. S.	"Aluminum Absorption Studies"	2 0915 5 10105 9 0733004	9-10-63
129		"Gamma Ionization Chamber"	2 00360 5 00360 9 00360	9-12-63
130		"Geiger-Mueller Counter"	2 00355 5 00355 9 00355	9-10-63
131	Manning, D. L.	"Thorium, Amperometric Disodium Dihydrogen Ethylenediaminetetraacetate-Iron(II) Indicator Method"	1 218773 9 00718773	7-13-64
132	Moore, F. L.	"Gross Alpha Radioactivity in Transuranium (TRU) Process Solutions, Direct-Measurement Method"	9 062301	6-30-64
133		"Gross Alpha Radioactivity in Transuranium (TRU) Process Solutions, Lanthanum Fluoride Precipitation-Proportional Alpha Counting Method"	9 062302	6-30-64
134		"Gross Alpha Radioactivity in Transuranium (TRU) Process Solutions, Triisooctylamine (or Tricaprylamine) Extraction-Proportional Alpha Counting Method"	9 062303	6-30-64
135		"Alpha Spectrometry of Transuranium (TRU) Process Solutions, Silicon Diode Detector Method"	9 062304	7-1-64
136		"Americium in Transuranium (TRU) Process Solutions, Ammonium Persulfate Oxidation-Proportional Alpha Counting Method"	9 062305	7-1-64
137		"Plutonium Alpha Radioactivity in Transuranium (TRU) Process Solutions, Lanthanum Fluoride Precipitation-Proportional Alpha Counting Method"	9 062306	7-1-64

138		"Plutonium Alpha Radioactivity in Transuranium (TRU) Process Solutions, Thenoyltrifluoroacetone (TTA) Extraction-Proportional Alpha Counting Method"	9 062307	7-2-64
139		"Transplutonium Alpha Radioactivity in Transuranium (TRU) Process Solutions, Triisooctylamine Extraction-Proportional Alpha Counting Method"	9 062308	7-2-64
140		"Transplutonium Alpha Radioactivity in Transuranium (TRU) Process Solutions, Lanthanum Fluoride Precipitation-Proportional Alpha Counting Method"	9 062309	7-2-64
141	Morton, J. E.	"Mercury-197m ₂ , 197, Product Analysis Guide"	9 0733492	6-22-64
142		"Strontium-89 and Strontium-90 in Aqueous Solutions, Di-2-Ethylhexylphosphoric Acid-Amsco Extraction Method"	9 0733804	4-13-64
143	Parker, H. A.	"Bismuth-210, Product Analysis Guide"	9 0733111	6-19-64
144		"Thulium-170, Product Analysis Guide"	9 0733882	6-22-64
145	Parker, H. A., J. E. Morton	"Calcium-47, Product Analysis Guide"	9 0733152	6-19-64
146	Raaen, Helen P.	"Preparation of Computer Input Information for Annual Revision to Cumulative Indexes for the ORNL Master Analytical Manual"	07	4-10-64
147	Reynolds, S. A.	"Gamma Scintillation Counter"	2 00365 5 00365 9 00365	5-17-63
148		"Decay Studies"	2 0914 5 10104 9 0733003	5-22-63
149	Rickard, R. R.	"Iodine Adsorbed on Charcoal, Neutron Activation Analysis (Isotopic Carrier) Method"	5 11391	9-20-63
150		"Ruthenium Radioactivity in Aqueous Solutions, Pyridine Extraction-Gamma Counting Method"	2 21734 9 062310	7-20-64
151		"Nickel, Neutron Activation Analysis (Fast Neutron-Isotopic Carrier) Method"	5 115450	7-21-64
152	Rubin, I. B.	"Separation of Krypton and Xenon from Contaminating Gases, Molecular Sieve Absorption Method"	1 00710 9 00654	10-9-63
153	Spitzer, E. J., J. R. Sites	"General Operating Conditions for Isotopic Mass Spectrometry of the Elements"	4 0001	2-20-64
154		"Aluminum, Isotopic Mass Spectrometry"	4 0102	2-20-64
155		"Antimony, Isotopic Mass Spectrometry"	4 0104	2-20-64
156		"Barium, Isotopic Mass Spectrometry"	4 0108	2-20-64
157		"Boron, Isotopic Mass Spectrometry"	4 0112	2-20-64
158		"Bromine, Isotopic Mass Spectrometry"	4 0113	2-20-64
159		"Cadmium, Isotopic Mass Spectrometry"	4 0114	2-20-64

160	"Calcium, Isotopic Mass Spectrometry"	4 0115	2-20-64
161	"Cerium, Isotopic Mass Spectrometry"	4 0118	2-20-64
162	"Cesium, Isotopic Mass Spectrometry"	4 0119	2-20-64
163	"Chlorine, Isotopic Mass Spectrometry"	4 0120	2-20-64
164	"Chromium, Isotopic Mass Spectrometry"	4 0121	2-20-64
165	"Copper, Isotopic Mass Spectrometry"	4 0123	2-20-64
166	"Dysprosium, Isotopic Mass Spectrometry"	4 0125	2-20-64
167	"Erbium, Isotopic Mass Spectrometry"	4 0126	2-20-64
168	"Europium, Isotopic Mass Spectrometry"	4 0127	2-20-64
169	"Gadolinium, Isotopic Mass Spectrometry"	4 0130	2-20-64
170	"Gallium, Isotopic Mass Spectrometry"	4 0131	2-20-64
171	"Germanium, Isotopic Mass Spectrometry"	4 0132	2-20-64
172	"Hafnium, Isotopic Mass Spectrometry"	4 0134	2-20-64
173	"Holmium, Isotopic Mass Spectrometry"	4 0136	2-20-64
174	"Indium, Isotopic Mass Spectrometry"	4 0138	2-20-64
175	"Iodine, Isotopic Mass Spectrometry"	4 0139	2-20-64
176	"Iridium, Isotopic Mass Spectrometry"	4 0140	2-20-64
177	"Iron, Isotopic Mass Spectrometry"	4 0141	2-20-64
178	"Lanthanum, Isotopic Mass Spectrometry"	4 0143	2-20-64
179	"Lead, Isotopic Mass Spectrometry"	4 0144	2-20-64
180	"Lithium, Isotopic Mass Spectrometry"	4 0145	2-20-64
181	"Lutetium, Isotopic Mass Spectrometry"	4 0146	2-20-64
182	"Magnesium, Isotopic Mass Spectrometry"	4 0147	2-20-64
183	"Mercury, Isotopic Mass Spectrometry"	4 0149	2-20-64
184	"Molybdenum, Isotopic Mass Spectrometry"	4 0150	2-20-64
185	"Neodymium, Isotopic Mass Spectrometry"	4 0151	2-20-64
186	"Neptunium, Isotopic Mass Spectrometry"	4 0153	2-20-64
187	"Nickel, Isotopic Mass Spectrometry"	4 0154	2-20-64
188	"Osmium, Isotopic Mass Spectrometry"	4 0157	2-20-64
189	"Palladium, Isotopic Mass Spectrometry"	4 0159	2-20-64
190	"Platinum, Isotopic Mass Spectrometry"	4 0161	2-20-64
191	"Potassium, Isotopic Mass Spectrometry"	4 0164	2-20-64
192	"Praseodymium, Isotopic Mass Spectrometry"	4 0165	2-20-64
193	"Rhenium, Isotopic Mass Spectrometry"	4 0170	2-20-64
194	"Rubidium, Isotopic Mass Spectrometry"	4 0172	2-20-64
195	"Ruthenium, Isotopic Mass Spectrometry"	4 0173	2-20-64
196	"Samarium, Isotopic Mass Spectrometry"	4 0174	2-20-64
197	"Selenium, Isotopic Mass Spectrometry"	4 0176	2-20-64
198	"Silicon, Isotopic Mass Spectrometry"	4 0177	2-20-64

199	"Silver, Isotopic Mass Spectrometry"	4 0178	2-20-64
200	"Sodium, Isotopic Mass Spectrometry"	4 0179	2-20-64
201	"Strontium, Isotopic Mass Spectrometry"	4 0180	2-20-64
202	"Sulfur, Isotopic Mass Spectrometry"	4 0181	2-20-64
203	"Tantalum, Isotopic Mass Spectrometry"	4 0182	2-20-64
204	"Technetium, Isotopic Mass Spectrometry"	4 0183	2-20-64
205	"Tellurium, Isotopic Mass Spectrometry"	4 0184	2-20-64
206	"Terbium, Isotopic Mass Spectrometry"	4 0185	2-20-64
207	"Thallium, Isotopic Mass Spectrometry"	4 0186	2-20-64
208	"Thorium, Isotopic Mass Spectrometry"	4 0187	2-20-64
209	"Thulium, Isotopic Mass Spectrometry"	4 0188	2-20-64
210	"Tin, Isotopic Mass Spectrometry"	4 0189	2-20-64
211	"Titanium, Isotopic Mass Spectrometry"	4 0190	2-20-64
212	"Tungsten, Isotopic Mass Spectrometry"	4 0191	2-20-64
213	"Uranium, Isotopic Mass Spectrometry"	4 0192	2-20-64
214	"Vanadium, Isotopic Mass Spectrometry"	4 0193	2-20-64
215	"Ytterbium, Isotopic Mass Spectrometry"	4 0195	2-20-64
216	"Zinc, Isotopic Mass Spectrometry"	4 0197	2-20-64
217	"Zirconium, Isotopic Mass Spectrometry"	4 0198	2-20-64

Revised Methods Issued to *ORNL Master Analytical Manual*

	AUTHOR(S)	TITLE	NUMBER(S)	DATE
218	Bate, L. C., G. W. Leddicotte ¹	"Particle-Size Distribution in Thorium Oxide, Neutron Activation-Sedimentation Method"	5 10200	R. 5-22-63
219	Canada, D. C.	"Total Plutonium, Thenoyltrifluoroacetone Extraction Method"	2 31621 9 008621	R. 3-24-64
220	Connelly, M. V.	"Boron (Borate), Potentiometric Mannitol-Sodium Hydroxide Titration Method"	1 211220 9 00711220	R. 5-15-63
221		"Ion-Exchange Separation of Boron from Other Elements"	1 00701	R. 5-16-63
222	Corbin, L. T., G. W. Leddicotte, ¹ S. A. Reynolds, P. F. Thomason	"Safety"	1 0020 2 0050 5 0050 9 0055	R. 5-16-63
223	Lynn, E. C.	"Magnesium, Volumetric Versene Method"	1 214770 9 00714770	R. 6-26-64
224	Raaen, Helen P.	"Organization of the <i>ORNL Master Analytical Manual</i> and Numbering of the Methods"	00	R. 2-20-64
225		"Typing and Printing Methods for the <i>ORNL Master Analytical Manual</i> "	03	R. 8-1-63

226	"Writing Instrumental Methods for the ORNL Master Analytical Manual"	05	R. 10-16-63
227	"Use and Care of Polyethylene"	1 001005	R. 10-16-63
228 Reynolds, S. A.	"Apparatus, General"	2 0010 5 10110	R. 5-16-63
229	"Reagents"	2 0040 5 10140	R. 5-16-63
230 Wyatt, E. I.	"Antimony-125 CF, Product Analysis Guide"	9 0733042	R. 6-14-63
231	"Arsenic-77, Product Analysis Guide"	9 0733064	R. 6-14-63
232	"Barium-131, Product Analysis Guide"	9 0733085	R. 6-14-63
233	"Bromine-82, Product Analysis Guide"	9 0733131	R. 7-1-63
234	"Cadmium-115m HSA, Product Analysis Guide"	9 0733141	R. 7-1-63
235	"Cerium-141,144, Product Analysis Guide"	9 0733181	R. 3-1-64
236	"Cesium-134, Product Analysis Guide"	9 0733193	R. 4-23-64
237	"Chromium-51, Product Analysis Guide"	9 0733211	R. 8-15-63
238	"Cobalt-58, Product Analysis Guide"	9 0733225	R. 8-15-63
239	"Copper-64, Product Analysis Guide"	9 0733231	R. 8-15-63
240	"Gold-198, Product Analysis Guide"	9 0733331	R. 8-20-63
241	"Gold-199, Product Analysis Guide"	9 0733332	R. 6-22-64
242	"Iodine-131, Product Analysis Guide"	9 0733391	R. 8-20-63
243	"Iridium-194, Product Analysis Guide"	9 0733402	R. 8-20-63
244	"Iron-55,59, Product Analysis Guide"	9 0733411	R. 8-22-63
245	"Mercury-203, Product Analysis Guide"	9 0733491	R. 8-22-63
246	"Molybdenum-99, Product Analysis Guide"	9 0733501	R. 8-23-63
247	"Neodymium-147-Promethium-147, Product Analysis Guide"	9 0733511	R. 9-9-63
248	"Osmium-191, Product Analysis Guide"	9 0733571	R. 9-10-63
249	"Palladium-109, Product Analysis Guide"	9 0733591	R. 9-10-63
250	"Potassium-42, Product Analysis Guide"	9 0733641	R. 9-10-63
251	"Praseodymium-142, Product Analysis Guide"	9 0733650	R. 9-11-63
252	"Praseodymium-143, Product Analysis Guide"	9 0733651	R. 9-11-63
253	"Promethium-147, Product Analysis Guide"	9 0733661	R. 9-11-63
254	"Rubidium-86, Product Analysis Guide"	9 0733721	R. 9-12-63
255	"Ruthenium-103,106, Product Analysis Guide"	9 0733731	R. 9-12-63
256	"Samarium-153, Product Analysis Guide"	9 0733741	R. 9-12-63
257	"Scandium-56, Product Analysis Guide"	9 0733751	R. 9-12-63
258	"Selenium-75, Product Analysis Guide"	9 0733761	R. 9-12-63
259	"Silver-110m, Product Analysis Guide"	9 0733781	R. 7-1-63
260	"Silver-111, Product Analysis Guide"	9 0733783	R. 7-7-63
261	"Sodium-24, Product Analysis Guide"	9 0733792	R. 7-1-63

262		"Tin-113, Product Analysis Guide"	9 0733891	R. 7-1-63
263	Wyatt, E. I., R. R. Rickard	"Iodine Activity in Aqueous Solutions"	2 21391 9 0733391	R. 8-20-63

Record Copies Issued to *ORNL Master Analytical Manual*

	AUTHOR(S)	TITLE	NUMBER(S)	DATE
264	Farrar, L. G.	"Uranium, Copper, and Nickel in Homogeneous Reactor Fuel, Coulometric Titration Method"	9 082228	6-4-63
265	Kubota, H.	"Monobutylphosphoric Acid, Dibutylphosphoric Acid, and Orthophosphoric Acid in Tributyl Phosphate, Volumetric Sodium Hydroxide Titration Method"	1 221006 9 00721006	4-21-64
266	Laing, W. R., H. G. Davis	"Total Gases in Solids -- Release Measurement and Collection for Mass Spectrometric Analysis"	1 106 9 00606	2-6-64
267	Rubin, I. B.	"Carbon in Aqueous and Nitric Acid Solutions"	1 211794	11-15-64

ORAL PRESENTATIONS

Eighth Conference on Analytical Chemistry in Nuclear Technology

More than 300 scientists, including 21 representatives from 8 foreign countries, attended the Eighth Conference on Analytical Chemistry in Nuclear Technology, which was held October 6-8, 1964, in Gatlinburg, Tennessee. The ORNL Analytical Chemistry Division continued its sponsorship of this annual event.

The Conference Committee for this meeting was comprised of nine ORNL staff members: M. T. Kelley, Director of the Division; C. D. Susano, Associate Director; and L. J. Brady, Cyrus Feldman, H. L. Holsopple, W. R. Laing, W. S. Lyon, A. S. Meyer, and J. R. Sites.

Fifty-six papers were presented at the meeting, nine of which were presented by members of the ORNL staff.

In addition to the usual program, meetings were also held simultaneously by a Subcommittee of the National Research Council on Radioactivity Standards, by a group on beryllium exchange analysis, by another group on the exchange of analyses on uranium, and by a large number of participants in an impromptu meeting on the analysis of alkali metals.

The emphasis on the determination of trace constituents of nuclear and reactor materials was by far the most important aspect of the conference. This emphasis, in addition to giving consideration to the determination of a wide range of constituents in many materials, extended to the important problem of determining impurities in alkali metals commonly used as reactor coolants and to a serious discussion of the problems involved in the determination of the degree of burnup in reactor fuels.

The Ninth Conference in this series is tentatively scheduled to be held at the Mountain View Hotel, Gatlinburg, Tennessee, on October 12-14, 1965.

At Meetings of Professional Societies

AUTHOR(S)	TITLE	PRESENTED AT
268 Bate, L. C.	"Individual Identification by Activation Analysis of Hair and Its Surface Contamination"	American Academy of Forensic Science, Chicago, Ill., Feb. 28-29, 1964
269 Bate, L. C., ¹⁵ W. B. Healy ¹⁶	"Determination of Trace Elements in Wool"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
270 Belew, W. L., ¹⁵ D. J. Fisher, M. T. Kelley	"Second Derivative DC Polarography as a Technique in Quantitative Polarographic Measurements"	12th Anachem Conference and Instrument Exhibit, Wayne State University, Detroit, Mich., Oct. 21-23, 1964
271 Biggers, R. E., ¹⁵ D. A. Costanzo	"A Generalized Computer Program to Obtain Reaction Rate Data by the Analysis of Spectrometric Absorption Data from Dynamic Multi-component Systems"	Symposium on Molecular Structure and Spectroscopy, Department of Physics and Astronomy, Ohio State University, Columbus, June 15-19, 1964
272 Cameron, A. E.	"Commentary on ORNL Double-Magnet Mass Spectrometer"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
273 Crowther, P., ^{4,15} J. S. Eldridge	"Decay of Molybdenum-99-Technetium-99m"	10th Annual Meeting, American Nuclear Society, Philadelphia, Pa., June 15-17, 1964
274 Dyer, F. F., ¹⁵ L. C. Bate, J. F. Emery	"Application of Nuclear Analysis to Forensic Science"	6th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Nov. 9-10, 1964
275 Dyer, F. F., ¹⁵ J. F. Emery	"Precision of Activation Analysis of Short-Lived Nuclides"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
276 Eldridge, J. S.	"Electronic Resolution of Gamma-Ray Spectra"	6th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Nov. 9-10, 1964
277 Eldridge, J. S., ¹⁵ P. Crowther ⁴	"Evaluation of I ¹²⁵ Measurement Techniques for Clinical Applications"	2d Annual Meeting, Oak Ridge Radioisotope Conference, Gatlinburg, Tenn., Apr. 19-22, 1964
278 Emery, J. F.	"Br ^{82m} : A New Bromine Isomer"	148th Meeting, American Chemical Society, Chicago, Ill., Aug. 30-Sept. 4, 1964
279 Feldman, C.	"Atomic Absorption Analysis"	Research Committee Meeting, Union Carbide Nuclear Corp., Buffalo, N.Y., May 25-26, 1964

¹⁵Speaker.¹⁶Soil Bureau, Department of Scientific and Industrial Research, Lower Hutt, New Zealand.

280		"The Place of Atomic Absorption in Tissue Analysis"	12th Anachem Conference and Instrument Exhibit, Wayne State University, Detroit, Mich., Oct. 21-23, 1964
281	Feldman, C., T. C. Rains, ¹⁵ N. Marion Ferguson	"Chemical Isolation and Flame Photometric Determination of Barium"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
282	Fisher, D. J.	Discussion following Chapter III	Robert A. Welch Foundation Conference on Chemical Research, VII. Modern Developments in Analytical Chemistry, Houston, Tex., Nov. 18-20, 1963
283		"Controlled Potential D.C. Polarography"	The Society for Analytical Chemistry and the Polarographic Society, London, England, July 28, 1964
284		"Circumventions of Chemical Measurement Difficulties Through Systems Design"	147th Meeting, American Chemical Society, Philadelphia, Pa., Apr. 5-10, 1964
285	Fisher, D. J., ¹⁵ W. L. Belew, M. T. Kelley	"Recent Developments in DC Polarography"	Third International Congress of Polarography, Southampton, England, July 19-25, 1964
286		"A Simple Quasi Reference Electrode... Applications in Controlled-Potential Polarography and Voltammetry and in Chronopotentiometry"	Third International Congress of Polarography, Southampton, England, July 19-25, 1964
287	Goldberg, G.	"The Rapid Determination of Low Concentrations of Oxygen in Potassium and NaK by a Modified Amalgamation Technique"	15th Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Pittsburgh, Pa., Mar. 2-6, 1964
288		"The Rapid Determination of Low Concentrations of Oxygen and Hydrogen in Alkali Metals by a Modified Amalgamation Technique"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
289	Goldstein, G.	"Absolute Counting of Beta Emitters by the Liquid Scintillation Method"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
290	Kelley, M. T.	"The Accurate and Precise Determination of Uranium, with Special Reference to Coulometry"	International Atomic Energy Agency Panel on Analytical Chemistry of Nuclear Materials, Vienna, Austria, Mar. 23-26, 1964
291	Kubota, H., ¹⁵ D. A. Costanzo	"Reactions in Concentrated Lithium Chloride Solutions: Determination of Free Acid and Hydrolyzable Metal"	12th Anachem Conference and Instrument Exhibit, Wayne State University, Detroit, Mich., Oct. 21-23, 1964
292	Lyon, W. S.	"Research on Activation Analysis Problems"	5th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Dec. 2-3, 1963

- 293 "Electronic Resolution of Gamma-Ray Spectra" 5th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Dec. 2-3, 1963
- 294 Lyon, W. S.,¹⁵ "Experimental Study of Artifacts and Errors Encountered in Gamma-Ray Spectrometry for Radiochemistry and Activation Analysis" International Atomic Energy Agency's Symposium on Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964
J. S. Eldridge,
P. Crowther⁴
- 295 Mamantov, G.,^{7,15} D. L. "Voltammetry and Chronopotentiometry of Iron in Molten Fluorides" Southeastern Regional American Chemical Society Meeting, Charlotte, N.C., Nov. 14-16, 1963
Manning
- 296 Manning, D. L., J. M. "Polarography in Molten Fluorides" Third International Congress of Polarography, Southampton, England, July 19-23, 1964
Dale, G. Mamantov^{7,15}
- 297 Manning, D. L.,¹⁵ J. M. "Voltammetric Measurements in Molten Fluoride Salt Systems" 15th Meeting, Comite International de Thermodynamique et de Cinetique Electrochimiques, London, England, Sept. 21-26, 1964
Dale, G. Mamantov⁷
- 298 Morton, J. E.,¹⁵ H. A. "Shielded Facility for Use in the Analysis of Radioisotopes" 11th Hot Laboratory and Equipment Conference, New York, Nov. 18-22, 1963
Parker, E. I. Wyatt,
L. T. Corbin
- 299 Perone, S. P.,^{15,17} T. R. "The Application of Derivative Techniques to Stationary Electrode Polarography" 148th Meeting, American Chemical Society, Chicago, Ill., Aug. 30-Sept. 4, 1964
Mueller
- 300 Peters, D. G.,^{8,15} W. D. "Chronopotentiometry of Plutonium in Mineral Acid Media" 148th Meeting, American Chemical Society, Chicago, Ill., Aug. 30-Sept. 4, 1964
Shults
- 301 Reynolds, S. A. "Current Work at ORNL" Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio, Apr. 8, 1964
- 302 "Radioisotopes in Alkaline-Earth Analysis" 2d Annual Oak Ridge Radioisotope Conference, Gatlinburg, Tenn., Apr. 19-22, 1964
- 303 "Recent Radiochemical Work at ORNL" Seminar, Northeastern Radiological Health Laboratory, Public Health Service, Winchester, Mass., Aug. 27, 1964
- 304 "Nondestructive Determination of Uranium-232 and Thorium-228 by Gamma Spectrometry" 8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
- 305 Reynolds, S. A.,¹⁵ C. L. "Some Experiences in Environmental Analyses at ORNL" 9th Annual Meeting, Health Physics Society, Cincinnati, Ohio, June 14-18, 1964
Burros
- 306 Ricci, E. "Output Spectra of 14-Mev Neutron Generators. Rapid Estimation and Influence in Activation Analysis" 10th Annual Meeting, American Nuclear Society, Philadelphia, Pa., June 15-17, 1964

¹⁷Department of Chemistry, Purdue University, Lafayette, Ind.

307	Ross, H. H.	"Radioisotopes in Chemical Analysis"	Annual Lecture Series, Rochester Section, American Chemical Society, Rochester, N.Y., Nov. 12, 1964
308		"Radio-Release Methods for the Evaluation of Atmospheric Pollution"	12th Anachem Conference and Instrument Exhibit, Wayne State University, Detroit, Mich., Oct. 21-23, 1964
309		"A Unique Liquid Scintillator for Neutron Detection Using Lithium-6 Enriched Isotope"	5th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Dec. 2-3, 1963
310	Ross, H. H., ¹⁵ T. H. Handley, W. J. Ross	"Application of Isotopes to Analytical Chemistry"	6th Annual Contractor's Meeting, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington, D.C., Nov. 9-10, 1964
311	Ross, H. H., ¹⁵ R. E. Yerick ¹⁰	"A Unique Scintillator for Neutron Detection"	2d Annual Meeting, Oak Ridge Radioisotope Conference, Gatlinburg, Tenn., Apr. 19-22, 1964
312	Ross, H. H., ¹⁵ W. S. Lyon	"Radio-Release Methods for the Evaluation of Atmospheric Pollution: SO ₂ "	International Atomic Energy Agency's Symposium on Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964
313	Ross, W. J., ¹⁵ J. E. Strain	"Reactions Observed with 14-Mev Neutrons"	8th Annual Conference, Analytical Chemistry in Nuclear Technology, Gatlinburg, Tenn., Oct. 6-8, 1964
314	Strain, J. E.	"Explanation and Demonstration of Neutron Activation Analysis"	AEC Exhibit, National Science Fair, Baltimore, Md., May 6-8, 1964
315		"Isotopic and Accelerator Neutron Sources"	ORINS, Activation Analysis Course, Oak Ridge, Tenn., Apr. 8 and 10, 1964
316	Strain, J. E., ¹⁵ W. S. Lyon	"The Use of Isotopic Neutron Sources for Chemical Analysis"	International Atomic Energy Agency's Symposium on Radiochemical Methods of Analysis, Salzburg, Austria, Oct. 19-23, 1964
317	Willmarth, T. E.	"A Microscopical Study of the Structure of Spherical Thoria Sol-Gel Beads"	"Micro 64" (International Electron Microscopy Society), Chicago, Ill., July 1964
318		"Analytical Electron Microscopy - Past and Present at Oak Ridge National Laboratory"	Louisiana Electron Microscopy Society, New Orleans, La., Oct. 2, 1964
319	Young, J. P.	"Direct Spectrophotometric Studies of Redox Reactions in Molten Fluoride Salts"	15th Meeting, Comite International de Thermodynamique et de Cinetique Electrochimiques, London, England, Sept. 21-26, 1964

320		Seminar, Dept. de Physico-Chimie, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France, Sept. 1, 1964
321	"Spectrophotometric Observations of the Re- action of Molten Lithium Fluoride-Sodium Fluoride-Potassium Fluoride with Several Active Metals"	145th Meeting, American Chemical Society, New York, N.Y., Sept. 8-13, 1963
322	"The Role of Serendipity in Research"	King's College Chemical Society, King's College, Wilkes-Barre, Pa., May 14, 1964

Under the ORNL Traveling Lecture Program

	LECTURER	LECTURE TITLE	PRESENTED AT
323	Cameron, A. E.	"Geological Age Determination by Isotope Meas- urements"	Western Carolina College, Cul- lowhee, N.C., Jan. 6, 1964
324			North Carolina State College, Raleigh, Jan. 8, 1964
325			Tennessee Polytechnic Institute, Cookeville, Feb. 13, 1964
326			Appalachian State Teachers College, Boone, N.C., Apr. 30, 1964
327			Rice University, Houston, Tex., May 6, 1964
328			Stephen F. Austin State College, Nacogdoches, Tex., May 7, 1964
329	Raaen, Helen P.	"How a Sewing Needle and Teflon Are Ad- vancing Polarography"	Texas Woman's University, Denton, Tex., Mar. 20, 1964
330	Ross, H. H.	"Modern Methods in Liquid Scintillator Tech- nology"	Georgia Institute of Technology, Atlanta, Oct. 15, 1964
331	Thomason, P. F.	"Controlled-Potential Coulometry: New Ana- lytical Tool in the Nuclear Energy Program"	Birmingham-Southern College, Birmingham, Ala., Apr. 21, 1964
332	White, J. C.	"The New Image of Analytical Chemistry in Science"	Purdue University, Lafayette, Ind., Nov. 11, 1964

Patents

	AUTHOR(S)	TITLE	PATENT NO(S).	ISSUED
333	Shaffer, J. H.,* J. E. Strain, D. R. Cuneo,* M. J. Kelly*	"Separation of Protactinium from Molten Salt Reactor Fuel Composition"	3,110,555	Nov. 12, 1963

Indexes

Helen P. Raaen

Ann S. Klein¹

Indexes are a part of the Analytical Chemistry Division annual report for the first time this year. The numbering system used will make possible the preparation of cumulative indexes to this and future annual progress reports from the Division. This section of the report contains a key-word index and an author index.

The Key Word Index is prepared both from the numbered headings that appear within the report and from the titles of the entries in the Presentation of Research Results. To increase the depth of indexing of the work reported, supplementary

precedes that author's name. If, for any of a number of reasons, an author is not a permanent member of ORNL, the symbol = appears before his name.

An example of the numbering system used to refer to material in the main body of the report is 64B-12-8E, where 64 indicates the year of publication of the annual report, B designates a major part or division of the report, 12 is the chapter number, 8 is a primary section within the chapter, and E is a subsection (designated in the subsection heading with e instead of E); for example,

words were added to some of the headings. These words appear in parentheses, together with the heading, in the key-word index; they do not appear elsewhere in the report.

The Author Index is an alphabetical listing of authors, together with number entries that specify the material to which each author contributed. This index includes both the authors of material in the body of the report and the authors of the entries listed in the Presentation of Research Results. In the cases of co-authorships, the member of another ORNL division is so indicated by an asterisk which

In the use of the Index to locate material in the body of the report, only the last two groups of numbers are needed, because the chapters are numbered consecutively.

For reference to the Presentation of Research Results, the numbering system is of the type 64-PRR-25, where 64 designates the year in which the entry was listed in the annual report, PRR identifies the authored work as being listed in the Presentation of Research Results part of the annual report, and 25 is the number of the entry listed in that part of the report; for example,

¹Technical Information Division.

In the use of the Index to locate an entry in the Presentation of Research Results part of the report, only the last group of numbers is needed, because the entries are numbered consecutively.

Machine limitations necessitate that some entries be in an unusual form. Because special type cannot be used, entries that otherwise would require it are written out; for example, chemical symbols, chemical formulas, Greek letters, *o*-, *m*-, *p*-, etc. Superscript and subscript numbers cannot be printed; hence, valence is designated by a

Roman numeral following the name of the element or ion, and an isotope mass number is indicated by a hyphen and an Arabic number following the name of the element. The lower-case *m*, used with an isotope mass number to designate a metastable state, appears as a capital *M* in the listing.

Additional useful entries are provided by dividing certain words; for example, ethylenediamine is divided into ethylene, di, and amine. *Chemical Titles* is used as a guide in making such divisions.

Key Word Index

SCINTILLATION METHOD	ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID	64A-12-04C
SCINTILLATION METHOD	ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID	64PRR-289
APPLICATIONS	ABSOLUTE DETERMINATION OF IODINE-125 IN CLINICAL	64A-12-02E
APPLICATIONS	ABSOLUTE DETERMINATION OF IODINE-125 IN CLINICAL	64PRR-024
	ATOMIC ABSORPTION (RUTHENIUM / SELENIUM)	64A-08-01B
	ATOMIC ABSORPTION ANALYSIS	64PRR-279
	NEUTRON ABSORPTION ANALYSIS WITH ISOTOPIC SOURCES	64A-12-07J
M OF URANIUM(VI) FLUORIDE GAS (NICKEL SPECTROPHOTOMETRIC	ABSORPTION CELL)	64A-02-01F
/TAIN REACTION RATE DATA BY THE ANALYSIS OF SPECTROMETRIC	ABSORPTION DATA FROM DYNAMIC MULTICOMPONENT SYS/	64PRR-271
	THE PLACE OF ATOMIC ABSORPTION IN TISSUE ANALYSIS	64PRR-280
YPTON AND XENON FROM CONTAMINATING GASES, MOLECULAR SIEVE	ABSORPTION METHOD	64PRR-152
	SEPARATION OF KR	64A-12-07E
	ABSORPTION OF TRACE ELEMENTS BY HAIR	64PRR-005
CATHODE LAMP ATOMIC ABSORPTION SPECTROSCOPY USING LONG	ABSORPTION PATH LENGTHS AND A DEMOUNTABLE HOLLOW	64A-02-01D
LI METAL HALIDE SYSTEMS	ABSORPTION SPECTRA OF MOLTEN ALKALI METAL - ALKA	64PRR-079
NE	ABSORPTION SPECTRA OF N,N',N'' TRI METHYL BORAZI	64A-02-01E
	ABSORPTION SPECTRA OF SMALL CRYSTALS	64A-02-01C
UORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN /	ABSORPTION SPECTRA OF URANIUM(III) IN LITHIUM FL	64A-02-01
MOLTEN SALT SYSTEMS	ABSORPTION SPECTROPHOTOMETRIC STUDIES RELATED TO	64PRR-005
TH LENGTHS AND A DEMOUNTABLE HOLLOW CATHODE LAMP ATOMIC	ABSORPTION SPECTROSCOPY USING LONG ABSORPTION PA	64A-02-01F
(NICKEL SPECTROPHOTOMETRIC ABSORPTION CELL)	ABSORPTION SPECTRUM OF URANIUM(VI) FLUORIDE GAS	64PRR-128
	ALUMINUM ABSORPTION STUDIES	64A-08-01A
CTIVE SOLUTIONS / MEASUREMENT OF ABSORP/ X-RAY ANALYSIS (	ABSORPTION-EDGE ANALYSIS OF SOLIDS AND OF RADIOA	64A-08-01A
/ OF SOLIDS AND OF RADIOACTIVE SOLUTIONS / MEASUREMENT OF	ABSORPTION-EDGE HEIGHT / COMPUTER CODE FOR X-RAY/	64PRR-315
	ISOTOPIC AND ACCELERATOR NEUTRON SOURCES	64A-12-05B
QUALITY CONTROL MEASUREMENTS	COMPUTER PROGRAM FOR ACCUMULATING STANDARD GAMMA-RAY SPECTRA AND FOR	64PRR-290
ITH SPECIAL REFERENCE TO COULOMETRY	THE ACCURATE AND PRECISE DETERMINATION OF URANIUM, W	64PRR-131
MPEROMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA	ACETATE - IRON(II) INDICATOR METHOD THORIUM, A	64PRR-127
VOLUMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA	ACETATE (EDTA) METHOD ALUMINUM AND THORIUM,	64PRR-022
LIQUID-LIQUID EXTRACTION OF CESIUM WITH THENOYL TRI FLUORO	ACETONE	LIQ 64PRR-021
UID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO	ACETONE	SELECTIVE LIQUI 64PRR-064
D-LIQUID EXTRACTION OF RADIOTIN WITH 2 THENOYL TRI FLUORO	ACETONE	64PRR-138
/ANSURIUM (TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO	ACETONE (ITA) EXTRACTION - PROPORTIONAL ALPHA/	EF 64A-03-04
EFFECT OF COBALT-60 GAMMA RADIATION ON 2 THENOYL TRI FLUORO	ACETONE (ITA) SOLUTIONS	64PRR-219
TOTAL PLUTONIUM, THENOYL TRI FLUORO	ACETONE EXTRACTION METHOD	64PRR-142
TIUM-90 IN AQUEOUS SOLUTIONS, DI 2 ETHYL HEXYL PHOSPHORIC	ACID - AMSCO EXTRACTION METHOD /IUM-89 AND STRON	64A-06-12
/ BOTH VESSEL AND INDICATOR ELECTRODE FOR MICRO REDOX AND	ACID - BASE POTENTIOMETRIC TITRATIONS (PLATINU/	64PRR-066
HITE CUP AS BOTH VESSEL AND ELECTRODE FOR MICRO REDOX AND	ACID - BASE POTENTIOMETRIC TITRATIONS /YTIC GRAP	65A-06-01
/CTIONS IN CONCENTRATED LITHIUM CHLORIDE SOLUTIONS (FREE	ACID / HYDROLYZABLE CATION / BORIC ACID / WEAK /	65A-06-01
ORIDE SOLUTIONS (FREE ACID / HYDROLYZABLE CATION / BORIC	ACID / WEAK BASES) /IN CONCENTRATED LITHIUM CHL	64PRR-291
TRATED LITHIUM CHLORIDE SOLUTIONS - DETERMINATION OF FREE	ACID AND HYDROLYZABLE METAL REACTIONS IN CONCEN	64A-05-05
	POLAROGRAPHY IN HYDROFLUORIC	64A-14-01D
	MONO ACID ESTERS	64PRR-265
/RIC ACID, DI BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPHORIC	ACID IN TRI BUTYL PHOSPHATE, VOLUMETRIC SODIUM /	64PRR-053
CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL	ACID MEDIA	64PRR-300
CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL	ACID MEDIA	64PRR-072
PROTACTINIUM STABILITY IN THORIUM NITRATE - NITRIC	ACID SOLUTIONS	64PRR-267
CARBON IN AQUEOUS AND NITRIC	ACID SOLUTIONS	64A-05-03
MATOGRAPHIC DETERMINATION OF CARBON IN AQUEOUS AND NITRIC	ACID SOLUTIONS	64A-03-02
DICATION ON THE DETERMINATION OF URANIUM(VI) IN PHOSPHORIC	ACID WITH THE HORIZONTAL ORIFICE TEFLON DROPPIN/	64A-05-05C
/EAD TO LEAD METAL REDOX REACTION IN AQUEOUS HYDROFLUORIC	ACID, AND ORTHO PHOSPHORIC ACID IN TRI BUTYL PHO	64PRR-265
SPHATE, / MONO BUTYL PHOSPHORIC ACID, DI BUTYL PHOSPHORIC	ACID, DI BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPH	64PRR-265
ORIC ACID IN TRI BUTYL PHOSPHATE, / MONO BUTYL PHOSPHORIC	ACIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RI	64A-07
BO NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LABELED AMINO	ACIDS / TAKATSY LOOP / CARBON-14 LABELED AMINO A	64A-07
CIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RIBO NUCLEIC	ACIDS IN IRRADIATED LIQUIDS	64A-06-09
TITRIMETRY OF	ACTINIDE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTR	64PRR-050
ACTION WIT/ A NEW APPROACH TO THE SEPARATION OF TRIVALENT	ACTINIDE ELEMENTS FROM LANTHANIDE ELEMENTS - SEL	64A-12-03C
ECTIVE LIQ/ A NEW APPROACH TO THE SEPARATION OF TRIVALENT	ACTIVATED LITHIUM IODIDE SCINTILLATION CRYSTALS	64PRR-019
TERMINATION OF EUROPIUM(III) AND TOTAL EUROPIUM - EUROPIUM	ACTIVATION - SEDIMENTATION METHOD	64PRR-218
PARTICLE SIZE DISTRIBUTION IN THORIUM OXIDE, NEUTRON	ACTIVATION ANALYSIS	64A-12-07
	ACTIVATION ANALYSIS	64A-12-07A
	ACTIVATION ANALYSIS	64A-12-07K
	ACTIVATION ANALYSIS	64PRR-006
	ACTIVATION ANALYSIS	64PRR-007
	ACTIVATION ANALYSIS	64PRR-008
	ACTIVATION ANALYSIS	64PRR-009
	ACTIVATION ANALYSIS	64PRR-016
	ACTIVATION ANALYSIS	64PRR-056
	ACTIVATION ANALYSIS	64PRR-314
	ACTIVATION ANALYSIS	64PRR-306
EV NEUTRON GENERATORS - RAPID ESTIMATION AND INFLUENCE IN	OUTPUT SPECTRA OF I4-M	64PRR-151
ARRIER) METHOD	NICKEL, NEUTRON ACTIVATION ANALYSIS (FAST NEUTRON - ISOTOPIC CA	64PRR-149
	IODINE ADSORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSIS (ISOTOPIC CARRIER) METHOD	64A-12-07G
ENIUM)	APPLIED NEUTRON ACTIVATION ANALYSIS (OXYGEN-18 / FLUORIDE / SEL	64A-12-08A
ATION AND ITS INFLUENCE ON CROSS SECTION MEASUREMENTS AND	GENERATORS - ITS RAPID ESTIM	64PRR-294
COUNTERED IN GAMMA-RAY SPECTROMETRY FOR RADIOCHEMISTRY AND	ACTIVATION ANALYSIS /OF ARTIFACTS AND ERRORS ENC	

AMINATION	INDIVIDUAL IDENTIFICATION BY	ACTIVATION ANALYSIS OF HAIR AND ITS SURFACE CONT	64PRR-268
		ACTIVATION ANALYSIS OF HIGH PURITY MATERIALS	64A-12-071
		ACTIVATION ANALYSIS OF HIGH PURITY MATERIALS	64PRR-061
	PRECISION OF	ACTIVATION ANALYSIS OF SHORT-LIVED NUCLIDES	64PRR-275
		ACTIVATION ANALYSIS OF URANYL NITRATE SOLUTIONS	64A-12-07H
	RESEARCH ON	ACTIVATION ANALYSIS PROBLEMS	64PRR-089
	RESEARCH ON	ACTIVATION ANALYSIS PROBLEMS	64PRR-292
	APPLICATION OF	ACTIVATION ANALYSIS TO FORENSIC SCIENCE	64A-12-078
ICAL EVIDENCE	APPLICATION OF	ACTIVATION ANALYSIS TO FORENSIC SCIENCE I. PHYS	64PRR-014
GS	APPLICATION OF	ACTIVATION ANALYSIS TO FORENSIC SCIENCE II. DRU	64PRR-015
NEW ISOMER OF BROMINE - BROMINE-82M (HALF LIFE / NEUTRON		ACTIVATION CROSS SECTION)	64A-12-010
ORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE WITH SEVERAL		ACTIVE METALS /HE REACTION OF MOLTEN LITHIUM FLU	64PRR-321
RINE		ADSORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSI	64PRR-036
S (ISOTOPIC CARRIER) METHOD	IODINE	ADVANCED REACTOR FUELS	64PRR-149
	CHEMICAL ANALYSIS OF	ADVANCING POLAROGRAPHY	64A-05
	HCW A SEWING NEEDLE AND TEFLON ARE	AGE DETERMINATION BY ISOTOPIC MEASUREMENTS	64PRR-329
	GEOLOGICAL	AGENCY (IAEA) INTERCOMPARISON OF DETERMINATION	64PRR-323
S OF CESIUM-137	INTERNATIONAL ATOMIC ENERGY	AIR FLAME IONIZATION DETERMINATION OF PA	64A-12-020
RTS PER BILLION CONCENTRATIONS OF ORGANIC CONTAMINANTS IN		ALDEHYDES AND KETONES	64A-06-04
	DETERMINATION OF	ALIPHATIC DILUENTS BY GAS CHROMATOGRAPHY (SOLVE	64A-14-02
NT EXTRACTANTS / QUALITATIVE AND QUANTITATIVE ANALYSIS OF		ALKALI METAL - ALKALI METAL HALIDE SYSTEMS	64A-05-02
STUDIES OF THE ABSORPTION SPECTRA OF MOLTEN		ALKALI METAL HALIDE SYSTEMS	64A-02-010
TUDIES OF THE ABSORPTION SPECTRA OF MOLTEN ALKALI METAL -		ALKALI METALS AND ALKALINE EARTH ELEMENTS)	S 64A-02-010
FLAME PHOTOMETRY (SEPARATION OF BARIUM FROM		ALKALI METALS BY A MODIFICATION OF THE AMALGAMAT	64A-08-01C
ION METHOD	DETERMINATION OF OXYGEN IN	ALKALI METALS BY A MODIFIED AMALGAMATION TECHNI/	64A-06-05
/MINATION OF LOW CONCENTRATIONS OF OXYGEN AND HYDROGEN IN	DETERMINATION OF HYDROGEN IN	ALKALI METALS BY AMALGAMATION AND VACUUM EXTRACT	64PRR-288
ION	DETERMINATION OF CARBON IN	ALKALI METALS BY HIGH TEMPERATURE OXIDATION	64A-06-07
	RADIOISOTOPES IN	ALKALINE EARTH ANALYSIS	64A-06-06
	RADIOISOTOPES IN	ALKALINE EARTH ANALYSIS	64PRR-097
	ALKALINE EARTH ELEMENTS)	FLAME	64PRR-302
PHOTOMETRY (SEPARATION OF BARIUM FROM ALKALI METALS AND		ALKYL AND HEXA ALKYL PHOSPHORO THIOIC TRI AMIDES	64A-08-01C
AS EXTRACTANTS FOR METAL IONS - SELECTIVE EXTRACTIO/ TRI		ALKYL PHOSPHORO THIOIC TRI AMIDES AS EXTRACTANTS	64A-12-03A
FOR METAL IONS - SELECTIVE EXTRACTIO/ TRI ALKYL AND HEXA		ALLOYS) /ENT OF ABSORPTION-EDGE HEIGHT / COMPUT	64A-12-03A
ER CODE FOR X-RAY FLUORESCENCE ANALYSIS OF MULTICOMPONENT		ALPHA COUNTING METHOD /) PROCESS SOLUTIONS, THE	64A-08-01A
NOYL TRI FLUORO ACETONE (ITA) EXTRACTION - PROPORTIONAL		ALPHA COUNTING METHOD /NSURANIUM (TRU) PROCESS	64PRR-138
SOLUTIONS, AMMONIUM PER SULFATE OXIDATION - PROPORTIONAL		ALPHA COUNTING METHOD /NSURANIUM (TRU) PROCESS	64PRR-136
SOLUTIONS, TRI ISO OCTYL AMINE EXTRACTION - PROPORTIONAL		ALPHA COUNTING METHOD /S SOLUTIONS, TRI ISO OCTY	64PRR-139
L AMINE (OR TRI CAPRYL AMINE) EXTRACTION - PROPORTIONAL		ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS S	64PRR-134
SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL		ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS S	64PRR-133
OLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL		ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS S	64PRR-137
OLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL		ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS S	64PRR-140
	STUDIES OF RARE EARTH ELEMENT	ALPHA EMITTERS (EUROPIUM)	64A-12-01E
CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 (		ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL AMMON	64PRR-062
IUM H/ NONAQUEOUS TITRIMETRY OF PHENOLS (4 SEC BUTYL 2 (		ALPHA METHYL NAPHTHALENE	64A-06-08
	PURIFICATION OF	ALPHA RADIATION LABORATORY	64A-14-03
	HIGH LEVEL	ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64B-18-01
ESS SOLUTIONS, DIRECT MEASUREMENT METHOD	GROSS	ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-132
ESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - / GROSS		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-133
ESS SOLUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL / GROSS		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-134
ESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATIO/ PLUTONIUM		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-137
ESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (IT/ PLUTONIUM		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-138
ESS SOLUTIONS, TRI ISO OCTYL AMINE EXTRACT/ TRANSPLUTONIUM		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-139
ESS SOLUTIONS, LANTHANUM FLUORIDE PRECIP/ TRANSPLUTONIUM		ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU) PROC	64PRR-140
SS SOLUTIONS, SILICON DIODE DETECTOR METHOD		ALPHA SPECTROMETRY OF TRANSURANIUM (TRU) PROCE	64PRR-135
		ALPHA,ALPHA/ DI PIPERIDYL	64A-14-01E
CADMIUM / CALCIUM / CERIUM/ ISOTOPIC MASS SPECTROMETRY /	ALUMINUM / ANTIMONY / BARIUM / BORON / BROMINE /	ALUMINUM ABSORPTION STUDIES	64PRR-154
DROGEN ETHYLENE DI AMINE TETRA ACETATE (EDTA) METHOD		ALUMINUM AND THORIUM, VOLUMETRIC DI SODIUM DI HY	64PRR-128
/E / POTASSIUM SULFIDE / LITHIUM HYPO BROMITE / ANHYDROUS		ALUMINUM CHLORIDE / THORIUM TETRA CHLORIDE / ZI/	64PRR-127
DETERMINATION OF HYDROGEN IN ALKALI METALS BY		AMALGAMATION AND VACUUM EXTRACTION	64A-13
ATION OF OXYGEN IN ALKALI METALS BY A MODIFICATION OF THE		AMALGAMATION METHOD	64A-06-07
NCENTRATIONS OF OXYGEN IN POTASSIUM AND NAK BY A MODIFIED		AMALGAMATION TECHNIQUE / DETERMINATION OF LOW CO	64A-06-05
ONS OF OXYGEN AND HYDROGEN IN ALKALI METALS BY A MODIFIED		AMALGAMATION TECHNIQUE /ATION OF LOW CONCENTRATI	64PRR-287
ONS, AMMNIOUM PER SULFATE OXIDATION - PROPORTIONAL ALPHA/		AMERICIUM IN TRANSURANIUM (TRU) PROCESS SOLUTI	64PRR-288
A STUDY OF FISSION YIELDS OF	AMERICIUM-241	AMIDES AS EXTRACTANTS FOR METAL IONS - SELECTIVE	64PRR-136
EXTRACTIO/ TRI ALKYL AND HEXA ALKYL PHOSPHORO THIOIC TRI		AMINE) EXTRACTION - PROPORTIONAL ALPHA COUNTIN/	64A-12-03A
/I) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL		AMINE (OR TRI CAPRYL AMINE) EXTRACTION - PROP/	64PRR-134
/IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL		AMINE EXTRACTION - PROPORTIONAL ALPHA COUNTING /	64PRR-139
/IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL		AMINE TETRA ACETATE - IRON(II) INDICATOR METHOD	64PRR-131
THORIUM, AMPERMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI		AMINE TETRA ACETATE (EDTA) METHOD ALUMINUM	64PRR-127
AND THORIUM, VOLUMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI		AMINO 6 AMINO 3,9 DI ETHYL TRI DECANE HYDRO CHL/	64A-05-04
/ORO DI THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL TRI DECYL		AMINO ACIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRI	64A-07
CAL RIBO NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LABELED		AMINO PURINE	64PRR-036
CTURE OF 3 METHYL ADENINE, AND METHYLATION OF 6 DI METHYL		6 AMINO 3,9 DI ETHYL TRI DECANE	64A-14-01C
	6 AMINO 3,9 DI ETHYL TRI DECANE	AMMONIUM HYDROXIDE / LITHIUM CHLORIDE SALT BRID/	64A-05-04
THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL TRI DECYL AMINE 6		AMMONIUM PER SULFATE OXIDATION - PROPORTIONAL AL	64A-06-08
/SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL		AMMONIUM SULFATE METHOD	64PRR-136
PHA/ AMERICIUM IN TRANSURANIUM (TRU) PROCESS SOLUTIONS,		AMMONIUM THIO CYANATE /LENT ACTINIDE ELEMENTS -	64PRR-121
NITRATE (NITROGEN) VOLUMETRIC FERROUS		AMMONIUM THIO CYANATE /OM LANTHANIDE ELEMENTS -	64PRR-050
SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL		AMPEROMETRIC CUPFERRON TITRATION METHOD	64A-12-03C
SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL		AMPEROMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI A	64PRR-117
ZIRCONIUM IN MSRE FUEL,		AMPEROMETRIC FERROUS SULFATE TITRATION METHOD	64PRR-131
MINE TETRA ACETATE - IRON(III) INDICATOR METHOD THORIUM,		AMPEROMETRIC TITRATION OF CHROMIUM IN MIXTURES O	64PRR-118
CHROMIUM IN MSRE FUEL,		AMPEROMETRIC TITRATION OF URANIUM(IV) WITH CERIU	64PRR-012
F FLUORIDE SALTS		AMPEROMETRY	64PRR-048
M(IV) UTILIZING PYROLYTIC GRAPHITE ELECTRODES		AMSCO EXTRACTION METHOD /IUM-89 AND STRONTIUM-90	64A-06-03E
		ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RIBO NUCLE	64PRR-142
IN AQUEOUS SOLUTIONS, DI 2 ETHYL HEXYL PHOSPHORIC ACID -		ANALYTICAL CHEMISTRY	64A-07
IC ACIDS / TAKATSY LOOP / CARBON-14 LABELED AMINO ACIDS)		ANALYTICAL CHEMISTRY	64A-12-06
APPLICATION OF RADIOISOTOPES TO		ANALYTICAL CHEMISTRY	64PRR-310
APPLICATION OF ISOTOPES TO		ANALYTICAL CHEMISTRY DIVISION	64PRR-088
JAN.-DEC.,1963 - STATISTICAL QUALITY CONTROL REPORT,			

ANNUAL PROGRESS REPORT FOR PERIOD ENDING NOV.15,1963, STATISTICAL QUALITY CONTROL REPORT, STATISTICAL QUALITY CONTROL REPORT,	ANALYTICAL CHEMISTRY DIVISION ANALYTICAL CHEMISTRY DIVISION, JAN.-MAR.,1964 ANALYTICAL CHEMISTRY DIVISION, JAN.-SEPT.,1963 ANALYTICAL CHEMISTRY FOR REACTOR PROJECTS ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY - ANA ANALYTICAL CHEMISTRY IN SCIENCE ANALYTICAL CHEMISTRY RESEARCH AND DEVELOPMENT GR ANALYTICAL CHEMISTS - AVAILABILITY AND USE OF RA ANALYTICAL ELECTRON MICROSCOPY - PAST AND PRESEN ANALYTICAL FACILITY (HRLAF) ANALYTICAL INSTRUMENTATION ANALYTICAL INSTRUMENTATION - MOLTEN SALT SYSTEM/ ANALYTICAL LABORATORY ANALYTICAL MANUAL ANALYTICAL MANUAL ANALYTICAL MANUAL ANALYTICAL MANUAL ANALYTICAL MANUAL (1953-1963) ANALYTICAL MANUAL /MPUTER INPUT INFORMATION FOR ANALYTICAL MANUAL AND NUMBERING OF THE METHODS ANALYTICAL MANUAL, SUPPLEMENT 6 ANALYTICAL METHODS ANALYTICAL RESEARCH ANALYTICAL STUDIES OF MOLTEN SALT SYSTEMS ANALYTICAL TOOL IN THE NUCLEAR ENERGY PROGRAM ANHYDROUS ALUMINUM CHLORIDE / THORIUM TETRA CHL/ ANNIHILATION GAMMA-RAY SUM PEAK OBSERVED IN GAMM ANNUAL PROGRESS REPORT FOR PERIOD ENDING NOV.15, ANNUAL REVISION TO CUMULATIVE INDEXES FOR THE OR ANTIMONIDE) /HLORIDE / DYSPROSIUM PHOSPHIDE / H ANTIMONY / BARIUM / BORON / BROMINE / CADMIUM / ANTIMONY-125 CF / ARSENIC-77 / BARIUM-131 / BROM APPARATUS, GENERAL APPROACHES TO ANALYSIS OF FUSED SALTS (ELECTRON APR.,1964 / MAY,1964 / JUNE,1964 / JULY,1964 / / AQUEOUS AND NITRIC ACID SOLUTIONS AQUEOUS AND NITRIC ACID SOLUTIONS AQUEOUS HYDROFLUORIC ACID WITH THE HORIZONTAL O/ AQUEOUS SILVER NITRATE SOLUTIONS AQUEOUS SOLUTIONS AQUEOUS SOLUTIONS, DI 2 ETHYL HEXYL PHOSPHORIC A AQUEOUS SOLUTIONS, PYRIDINE EXTRACTION - GAMMA C ARC FUSED EUROPIUM MOLYBDATE ARSENATO-III ARSENATO-III SOLUTIONS ARSENIC-76 ARSENIC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-I ARTIFACTS AND ERRORS ENCOUNTERED IN GAMMA-RAY SP ASSEMBLY ATMOSPHERIC NEON ATMOSPHERIC POLLUTICN ATMOSPHERIC POLLUTION - SULFUR DI OXIDE ATMOSPHERIC POLLUTION - SULFUR DI OXIDE ATMOSPHERIC POLLUTION - SULFUR DI OXIDE ATOMIC ABSORPTION (RUTHENIUM / SELENIUM) ATOMIC ABSORPTION ANALYSIS ATOMIC ABSORPTION IN TISSUE ANALYSIS ATOMIC ABSORPTION SPECTROSCOPY USING LONG ABSORP ATOMIC ENERGY AGENCY (IAEA) INTERCOMPARISON OF ATOMIC, SEPT.28,1964 AUG.,1964 / SEPT.-OCT.,1964 /964 / FEB.,1964 / M AUTO IONIZING PROCESSES IN THE RARE GASES AUTOMATION, ELECTROANALYTICAL TECHNIQUES / STAND AUTOMOTIVE ENGINES BY LIQUID SCINTILLATION COUNT AVAILABILITY AND USE OF RADIOACTIVITY STANDARDS BALANCED QUENCHING TECHNIQUE BARIUM BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / C BARIUM FROM ALKALI METALS AND ALKALINE EARTH ELE BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CER BASE POTENTIOMETRIC TITRATIONS (PLATINUM IN-BU/ BASE POTENTIOMETRIC TITRATIONS /YTIC GRAPHITE CU BASES) /IN CONCENTRATED LITHIUM CHLORIDE SOLUTI BASIC NUCLEAR PROPERTIES AND ACTIVATION ANALYSIS BEADS A MICROSC BENZOYL METHANE /CTION WITH TRI N OCTYL PHOSPHIN BENZYL) PHENOL DETERMINATION OF CESIUM AND RU BENZYL) PHENOL / TETRA BUTYL AMMONIUM HYDROXID/ BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN L BERYLLIUM FLUORIDE (PREPARATION OF SOLUTIONS) BERYLLIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLI/ BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / PYROL/ BETA EMITTERS BY THE LIQUID SCINTILLATION METHOD BETA EMITTERS BY THE LIQUID SCINTILLATION METHOD BILLION CONCENTRATIONS OF ORGANIC CONTAMINANTS I BIOCHEMISTRY (SYMMETRICAL RIBO NUCLEIC ACIDS / BIOLOGICAL MATERIAL BIS (OXYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORY/ BISMUTH-210, PRODUCT ANALYSIS GUIDE BOND PAPER	64PRR-092 64PRR-085 64PRR-087 64A-04 64PRR-037 64PRR-038 64PRR-332 64PRR-105 64PRR-039 64PRR-318 64B-18-06 64A-01 64PRR-038 64PRR-018 64C-20 64C-20-01 64C-20-02 64C 64PRR-225 64PRR-226 64PRR-096 64PRR-146 64PRR-224 64PRR-093 64A-03 64A 64A-02 64PRR-331 64A-13 64PRR-040 64PRR-092 64PRR-146 64A-13 64PRR-154 64PRR-230 64PRR-228 64A-02-03 64PRR-105 64A-05-03 64PRR-267 64A-05-05C 64PRR-044 64PRR-263 64PRR-142 64PRR-150 64A-06-15 64A-06-14 64A-03-03 64A-12-01J 64PRR-230 64PRR-294 64A-02-01A 64A-09-02 64PRR-308 64A-12-06A 64PRR-312 64A-08-01B 64PRR-279 64PRR-280 64PRR-005 64A-12-02D 64PRR-103 64PRR-105 64PRR-017 64PRR-038 64PRR-059 64PRR-039 64PRR-058 64PRR-281 64PRR-154 64A-08-01C 64PRR-230 64A-06-12 64PRR-066 65A-06-01 64PRR-009 64PRR-317 64PRR-080 64PRR-062 64A-06-08 64A-02-01C 64A-02-01C 64A-02-02 64A-02-02 64A-12-04C 64PRR-289 64A-06-04 64A-07 64PRR-063 64A-05-04 64PRR-143 64A-12-07C
LYTICAL INSTRUMENT/ A RESUME OF THE SEVENTH CONFERENCE ON THE NEW IMAGE OF OUP MONTHLY SUMMARY - DEC.,1963 / JAN.,1964 / FEB.,1964 / DIOACTIVITY STANDARDS T AT ORNL HIGH RACIATION LEVEL /NFERENCE ON ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY - DESIGN AND CCNSTRUCTION OF ORNL HIGH RADIATION LEVEL ORNL MASTER CUMULATIVE INDEXES TO THE ORNL MASTER MAINTENANCE OF THE ORNL MASTER ORNL MASTER TYPING AND PRIATING METHODS FOR THE ORNL MASTER WRITING INSTRUMENTAL METHODS FOR THE ORNL MASTER INDEXES TO THE ORNL MASTER ANNUAL REVISION TO CUMULATIVE INDEXES FOR THE ORNL MASTER ORGANIZATION OF THE ORNL MASTER ORNL MASTER EFFECTS OF RADIATION ON CONTROLLED POTENTIAL COULOMETRY - NEW /FLUO BORATE / POTASSIUM SULFIDE / LITHIUM HYPO BROMITE / A-RAY SPECTRMETRY 180 DEGREE COMPTON SCATTERED 1963, ANALYTICAL CHEMISTRY DIVISION NL MASTER / PREPARATION OF COMPUTER INPUT INFORMATION FOR IGH PURITY POTASSIUM CHLORIDE / POTASSIUM OXIDE / LITHIUM CALCIUM / CERIUM/ ISOTOPIC MASS SPECTROMETRY / ALUMINUM / INE-82 / CADMIUM-115M HSA / CER/ PRODUCT ANALYSIS GUIDE - SPIN RESONANCE) /UMMARY - DEC.,1963 / JAN.,1964 / FEB.,1964 / MAR.,1964 / COMBUSTION GAS CHRMATOGRAPHIC DETERMINATION OF CARBON IN CARBON IN /PHY OF THE DIVALENT LEAD TO LEAC METAL REDOX REACTION IN RADIOLYTIC AND PHOTOLYTIC REDUCTION OF IODINE ACTIVITY IN CID - AMSCC EXTRACTION / STRONTIUM-89 AND STRONTIUM-90 IN OUNTING METHOD RUTHENIUM RADIOACTIVITY IN ANALYSIS OF COLCRIMETRIC DETERMINATION OF SAMARIUM WITH EFFECT OF COBALT-60 GAMMA RADIATION ON HALF-LIFE OF ISM HSA / CER/ PRDUCT ANALYSIS GUIDE - ANTIMONY-125 CF / ECTROMETRY FOR RADIOCHEMISTRY AND / EXPERIMENTAL STUDY OF NICKEL HIGH TEMPERATURE SPECTROPHOTOMETRIC CELL ISOTOPIC COMPOSITION OF RADIO RELEASE METHODS FOR THE EVALUATION OF RADIO RELEASE METHOD FOR THE EVALUATION OF RADIO RELEASE METHODS FOR THE EVALUATION OF THE PLACE OF TION PATH LENGTHS AND A DEMOUNTABLE HOLLOW CATHODE LAMP DETERMINATIONS OF CESIUM-137 INTERNATIONAL TRIP REPORT TO GENERAL AR.,1964 / APR.,1964 / MAY,1964 / JUNE,1964 / JULY,1964 / ARDS, NUCLEAR ANALYSIS, SPECTROSCOPY, GAS CHROMATOGRAPHY, ING OF IRCN-55 WEAR RATES IN REPORT FOR ANALYTICAL CHEMISTS - LIQUID SCINTILLATION COUNTING OF CARBON-14 USING A CHEMICAL ISCLATION AND FLAME PHOTOMETRIC DETERMINATION OF ERIUM/ ISOTOPIC MASS SPECTROMETRY / ALUMINUM / ANTIMONY / MENTS) FLAME PHOTOMETRY (SEPARATION OF / PRODUCT ANALYSIS GUIDE - ANTIMONY-125 CF / ARSENIC-77 / /ESSEL AND INDICATOR ELECTRODE FOR MICRO REDOX AND ACID - P AS BOTH VESSEL AND ELECTRODE FOR MICRO REDOX AND ACID - ONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID / WEAK OPICAL STUDY OF THE STRUCTURE OF SPHERICAL FLUORIDE SOL-GEL E OXIDE AND ITS DIRECT COLORIMETRIC DETERMINATION WITH DI BIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 (ALPHA METHYL /OUS TITRIMETRY OF PHENOLS (4 SEC BUTYL 2 (ALPHA METHYL ABSORPTION SPECTRA OF URANIUM(III) IN LITHIUM FLUORIDE M FLUORIDE - ZIRCONIUM FLUORIDE AND IN LITHIUM FLUORIDE - /ODIUM FLUORIDE - POTASSIUM FLUORIDE / LITHIUM FLUORIDE - /THIUM FLUORIDE - BERYLLIUM FLUORIDE / LITHIUM FLUORIDE - ABSOLUTE COUNTING OF ABSOLUTE COUNTING OF N AIR FLAME IONIZATION DETERMINATION OF PARTS PER TAKATSY LCCP / CARBON-14 LABELED AMINO ACIDS) ANALYTICAL SODIUM SEPARATION FROM /I) SULFIDE / URANIUM(IV) OXIDE / N TRI METHYL BORAZINE / ANALYSIS OF	ORNL MASTER OR	

IDE TITRATION METHOD BORON (BORATE) POTENTIOMETRIC MANNITOL - SODIUM HYDROX 64PRR-220
 /ARATIONS (HYDRATED VANADIUM(III) SULFATE / LITHIUM FLUO BORATE / HYDRATED NICKEL FLUO BORATE / HYDRATED/ 64A-13
 /II) SULFATE / LITHIUM FLUO BORATE / HYDRATED NICKEL FLUO BORATE / HYDRATED VANADIUM(III) FLUO BORATE / P/ 64A-13
 /YDRATED NICKEL FLUO BORATE / HYCRATED VANADIUM(III) FLUO BORATE / POTASSIUM SULFIDE / LITHIUM HYPO BROMI/ 64A-13
 N,N,N,N// TRI METHYL BORAZINE 64A-14-018
 IS AND INFRARED ABSORPTION SPECTRA OF N,N,N,N// TRI METHYL BORAZINE SYNTHES 64PRR-079
 // MERCURY(III) SULFIDE / URANIUM(IV) OXIDE / N TRI METHYL BORAZINE / BIS (OXYGEN, OXYGEN DI BUTYL DI THIO/ 64A-05-04
 ERMAL NEUTRON DETECTION N,N,N,N// TRI METHYL BORAZINE AS A LIQUID SCINTILLATOR SOLVENT FOR TH 64A-12-048
 UM CHLORIDE SOLUTIONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID / WEAK BASES) /IN CONCENTRATED LITHI 65A-06-01
 M HYDROXIDE TITRATION METHOD BORON (BORATE) POTENTIOMETRIC MANNITOL - SODIU 64PRR-220
 /TOPIC MASS SPECTROMETRY / ALUMINUM / ANTIMONY / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / / 64PRR-154
 ION EXCHANGE SEPARATION OF BORON FROM OTHER ELEMENTS 64PRR-221
 GAMMA-RAY BRANCHING IN THE DECAY OF CERIUM-141 64A-12-01A
 / TETRA BUTYL AMMONIUM HYDROXIDE / LITHIUM CHLORIDE SALT BRIDGE) /BUTYL 2 (ALPHA METHYL BENZYL) PHENOL 64A-06-08
 VATION CROSS SECTION) NEW ISOMER OF BROMINE - BROMINE-82M (HALF LIFE / NEUTRON ACTI 64A-12-010
 /SS SPECTROMETRY / ALUMINUM / ANTIMONY / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM // 64PRR-154
 BROMINE-82M - A NEW BROMINE ISOMER 64PRR-278
 /YSIS GUIDE - ANTIMONY-125 CF / ARSENIC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CERIUM-141, CER/ 64PRR-230
 BROMINE-82M - A NEW BROMINE ISOMER 64PRR-278
 BROMINE-82M (HALF LIFE / NEUTRON ACTIVATION CRO 64A-12-010
 SS SECTION) NEW ISOMER OF BROMINE - BROMITE / ANHYDROUS ALUMINUM CHLORIDE / THORIUM/ 64A-13
 /DIUM(III) FLUO BORATE / POTASSIUM SULFIDE / LITHIUM HYPO BUTYL AMMONIUM HYDROXIDE / LITHIUM CHLORIDE SAL/ 64A-06-08
 /S (4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERCURY/ 64A-05-04
 / OXIDE / N TRI METHYL BORAZINE / BIS (OXYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERCURY/ 64PRR-265
 / BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, VOLUMETRIC SODIUM HYDROXIDE TI/ 64PRR-265
 IN TRI BUTYL PHOSPHATE, / MONO BUTYL PHOSPHORIC ACID, DI BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPHORIC ACID, 64PRR-265
 AND ORTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, / MONO BUTYL PHOSPHORIC ACID, DI BUTYL PHOSPHORIC ACID, 64PRR-265
 /BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERCURY(II) DI N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED COKE / 3/ 64A-05-04
 ETALS METAL DI N BUTYL PHOSPHORO DI THIOATES AS EXTRACTANTS FOR M 64A-12-038
 NATION OF MERCURY BY ISOTOPIC EXCHANGE WITH MERCURIC DI N BUTYL PHOSPHORO THIOATE IN AN EXTRACTION SYSTEM 64PRR-033
 NATION OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL DETERMI 64PRR-062
 UTYL AMMONIUM H/ NONAQUEOUS TITRIMETRY OF PHENOLS (4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / TETRA B 64A-06-08
 PRESENT BYWAYS AND FUTURE TRENDS IN ACTIVATION ANALYSIS 64PRR-007
 /METRY / ALUMINUM / ANTIMONY / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM / CHLORINE / 64PRR-154
 /ANTIMONY-125 CF / ARSENIC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CERIUM-141, CERIUM-144 / CES/ 64PRR-230
 /UMINUM / ANTIMONY / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM / CHLORINE / CHROMIUM/ 64PRR-154
 /CALCIUM-47, PRODUCT ANALYSIS GUIDE 64PRR-145
 NCMOGRAPHS FOR CALCULATING INDUCED RADIOACTIVITY AND DECAY 64PRR-055
 UTECKY EQUATION (COMPUTER PROGRAM DIFFUSE) CALCULATION OF DIFFUSION COEFFICIENT FROM THE KO 64A-01-04
 DIRECT NON-DESTRUCTIVE METHOD FOR DETERMINATION OF CALIFORNIUM-252 64PRR-025
 YS FRO/ DIRECT NONDESTRUCTIVE METHOD FOR DETERMINATION OF CALIFORNIUM-252 - APPLICATION OF PROMPT GAMMA-RA 64PRR-051
 FABRICATION OF THE VERTICAL ORIFICE TEFLON CAPILLARY OF A TEFLON DROPPING MERCURY ELECTRODE 64PRR-095
 / (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL AMINE) EXTRACTION - PROPORTIONAL ALPHA / 64PRR-134
 DE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /LENT ACTINI 64PRR-050
 DE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /OM LANTHAN 64A-12-03C
 F THE HYDROLYSIS PRODUCTS OF URANIUM CARBIDES AND THORIUM CARBIDES / TO NUCLEAR TECHNOLOGY II. ANALYSIS O 64PRR-035
 OLOGY II. ANALYSIS OF THE HYDROLYSIS PRODUCTS OF URANIUM CARBIDES AND THORIUM CARBIDES / TO NUCLEAR TECHN 64PRR-035
 SOLID INDICATOR ELECTRODES (PYROLYTIC GRAPHITE / GLASSY CARBON) 64A-06-03
 ATION DETERMINATION OF CARBON IN ALKALI METALS BY HIGH TEMPERATURE OXID 64A-06-06
 COMBUSTION GAS CHROMATOGRAPHIC DETERMINATION OF CARBON IN AQUEOUS AND NITRIC ACID SOLUTIONS 64A-05-03
 CARBON IN AQUEOUS AND NITRIC ACID SOLUTIONS 64PRR-267
 CARBON IN METALS AND METALLIC OXIDES, LECO CONDU 64PRR-122
 CTOMETRIC METHOD CARBON INDICATOR ELECTRODE 64A-06-03A
 C METHOD TWO CARBON THROUGH FIVE CARBON PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHI 64PRR-123
 C METHOD FOUR CARBON THROUGH EIGHT CARBON PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHI 64PRR-124
 S, GAS CHROMATOGRAPHIC METHOD FOUR CARBON THROUGH EIGHT CARBON PARAFFINS AND OLEFIN 64PRR-124
 , GAS CHROMATOGRAPHIC METHOD TWO CARBON THROUGH FIVE CARBON PARAFFINS AND OLEFINS 64PRR-123
 EMISTRY (SYMMETRICAL RIBO NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LABELED AMINO ACIDS) ANALYTICAL BIOCH 64A-07
 LIQUID SCINTILLATION COUNTING OF CARBON-14 USING A BALANCED QUENCHING TECHNIQUE 64PRR-058
 USE AND CARE OF POLY ETHYLENE 64PRR-227
 EL, NEUTRON ACTIVATION ANALYSIS (FAST NEUTRON - ISOTOPIC CARRIER) METHOD NICK 64PRR-151
 ORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSIS (ISOTOPIC CARRIER) METHOD IODINE ADS 64PRR-149
 F IMPURITIES IN URANIUM COMPOUNDS USING THE GALLIUM OXIDE CARRIER DISTILLATION TECHNIQUE / DETERMINATION O 64PRR-083
 CATALOG OF 14-MEV NEUTRON REACTIONS 64A-12-088
 ING LONG ABSORPTION PATH LENGTHS AND A DEMOUNTABLE HOLLOW CATHODE LAMP ATOMIC ABSORPTION SPECTROSCOPY US 64PRR-005
 TED LITHIUM CHLORIDE SOLUTIONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID / WEAK BASES) /IN CONCENTRA 65A-06-01
 M(VI) FLUORIDE GAS (NICKEL SPECTROPHOTOMETRIC ABSORPTION CELL) ABSORPTION SPECTRUM OF URANIU 64A-02-01F
 NICKEL HIGH TEMPERATURE SPECTROPHOTOMETRIC CELL ASSEMBLY 64A-02-01A
 WINDOWLESS SPECTROPHOTOMETRIC CELL FOR USE WITH CORROSIVE LIQUIDS 64PRR-068
 /ROGRAPHY (POTENTIOSTATIC COMPENSATION FOR POLAROGRAPHIC CELL RESISTANCE / TIME DERIVATIVE DC POLAROGRAPH/ 64A-01-01
 /ES IN ORGANIC EXTRACTS AND COMPENSATION OF POLAROGRAPHIC CELL RESISTANCE IN HIGH SPECIFIC RESISTANCE SOL/ 64PRR-001
 SEPARATION OF TRACE METALS FROM URANIUM BY CELLULOSE COLUMN CHROMATOGRAPHY 64A-12-03E
 /NTIMONY / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM / CHLORINE / CHROMIUM / COPPER / 64PRR-154
 GAMMA-RAY BRANCHING IN THE DECAY OF CERIUM-141 64A-12-01A
 /RSENIC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CERIUM-141, CERIUM-144 / CESIUM-134 / CHROMIUM-/ 64PRR-230
 /BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CERIUM-141, CERIUM-144 / CESIUM-134 / CHROMIUM-51 / COBALT-/ 64PRR-230
 ES CERIUM(IV) UTILIZING PYROLYTIC GRAPHITE ELECTROD 64PRR-048
 NADIUM(V) WITH THE PYROLYTIC GRAPHITE ELE/ VOLTAMMETRY OF CERIUM(IV), MANGANESE(VII), CHROMIUM(VII), AND VA 64PRR-049
 THE COLLECTION AND FLAME PHOTOMETRIC DETERMINATION OF CESIUM 64PRR-026
 / BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM / CHLORINE / CHROMIUM / COPPER / DYSPROS/ 64PRR-154
 BUTYL 2 (ALPHA METHYL BENZYL) PHENOL DETERMINATION OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC 64PRR-062
 PREPARATION AND RECOVERY OF CESIUM COMPOUNDS 64PRR-075
 VARIATION OF CESIUM IN THE OCEAN 64PRR-028
 LIQUID-LIQUID EXTRACTION OF CESIUM WITH THENOYL TRI FLUORO ACETONE 64PRR-022
 LIQUID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO ACETONE 64PRR-021
 /BROMINE-82 / CADMIUM-115M HSA / CERIUM-141, CERIUM-144 / CESIUM-134 / CHROMIUM-51 / COBALT-58 / COPPER-6/ 64PRR-230
 EPITHERMAL NEUTRON IRRADIATION OF LANTHANUM TO PRODUCE CESIUM-136 64A-12-02A
 ERGY AGENCY (IAEA) INTERCOMPARISON OF DETERMINATIONS OF CESIUM-137 INTERNATIONAL ATOMIC EN 64A-12-02D
 IUM-115M HSA / CER/ PRODUCT ANALYSIS GUIDE - ANTIMONY-125 CF / ARSENIC-77 / BARIUM-131 / BROMINE-82 / CADM 64PRR-230
 GAMMA IONIZATION CHAMBER 64PRR-129
 DISPOSABLE SPECTROGRAPHIC EXCITATION CHAMBER FOR RADIOACTIVE SAMPLES 64A-08-02A
 CARRIER) METHOD IODINE ADSORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSIS (ISOTOPIC 64PRR-149
 Y COULOMETRIC TITRATOR, CRNL MODEL Q-2564 CHECK OUT AND TEST PROCEDURE FOR HIGH SENSITIVIT 64PRR-081

RADIOISOTOPES IN THE USE OF ISOTOPIC NEUTRON SOURCES FOR	CHEMICAL ANALYSIS	64PRR-307
TIVE WASTES IN NATURAL SALT FORMATIONS (HIGH TEMPERATURE	CHEMICAL ANALYSIS	64PRR-316
ATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL MEDIA	CHEMICAL ANALYSIS OF ADVANCED REACTOR FUELS	64A-05
ATION OF THE ISOMERS OF TELLURIUM-127, TELLURIUM-129, AN/	CHEMICAL DOSIMETERS) DISPOSAL OF RADIOAC	64A-06-02
EPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL MED/	CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS - SEPAR	64A-12-03F
NATION OF BARIUM	CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS - SEPAR	64PRR-031
S DESIGN	CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS - THE S	64PRR-032
CIRCUMVENTIONS OF	CHEMICAL ISOLATION AND FLAME PHOTOMETRIC DETERM	64PRR-281
RANSITIONS - SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT	CHEMICAL MEASUREMENT DIFFICULTIES THROUGH SYSTEM	64PRR-284
ITIONS - THE SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT	CHEMICAL MEDIA CHEMICAL EFFECTS OF ISOMERIC T	64A-12-03F
APPLICATION OF RADIOISOTOPES TO ANALYTICAL	CHEMICAL MEDIA /EMICAL EFFECTS OF ISOMERIC TRANS	64PRR-032
APPLICATION OF ISOTOPES TO ANALYTICAL	CHEMISTRY	64A-12-06
EC., 1963 - STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL	CHEMISTRY	64PRR-310
PROGRESS REPORT FOR PERIOD ENDING NOV. 15, 1963, ANALYTICAL	CHEMISTRY DIVISION	JAN.-D 64PRR-088
STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL	CHEMISTRY DIVISION	ANNUAL 64PRR-092
STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL	CHEMISTRY DIVISION, JAN.-MAR., 1964	64PRR-085
STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL	CHEMISTRY DIVISION, JAN.-SEPT., 1963	64PRR-087
	CHEMISTRY FOR REACTOR PROJECTS	64A-04
	CHEMISTRY IN NUCLEAR TECHNOLOGY	64PRR-037
TRUMENT/ A RESUME OF THE SEVENTH CONFERENCE ON ANALYTICAL	CHEMISTRY IN NUCLEAR TECHNOLOGY - ANALYTICAL INS	64PRR-038
THE NEW IMAGE OF ANALYTICAL	CHEMISTRY IN SCIENCE	64PRR-332
SUMMARY - DEC., 1963 / JAN., 1964 / FEB., 1964 / ANALYTICAL	CHEMISTRY RESEARCH AND DEVELOPMENT GROUP MONTHLY	64PRR-105
STANDARDS	CHEMISTS - AVAILABILITY AND USE OF RADIOACTIVITY	64PRR-039
EN DI OXIDE / DI NITROGEN TRI OXIDE / CHLORINE / NITROSYL	CHLORIDE) / ANALYSIS OF CORROSIVE GASES (NITROG	64A-05-01
HYL TRI DECYL AMINE 6 AMINO 3,9 DI ETHYL TRI DECANE HYDRO	CHLORIDE) / THIOATE / FLUIDIZED COKE / 3,9 DI ET	64A-05-04
/ TETRA CHLORIDE / ZIRCONIUM TETRA CHLORIDE / URANIUM TRI	CHLORIDE / DYSPROSIUM PHOSPHIDE / HIGH PURITY P/	64A-13
/ CHLORIDE / DYSPROSIUM PHOSPHIDE / HIGH PURITY POTASSIUM	CHLORIDE / POTASSIUM OXIDE / LITHIUM ANTIMONIDE/	64A-13
/SIUM SULFIDE / LITHIUM HYPO BROMITE / ANHYDROUS ALUMINUM	CHLORIDE / THORIUM TETRA CHLORIDE / ZIRCONIUM T/	64A-13
/INUM CHLORIDE / THORIUM TETRA CHLORIDE / ZIRCONIUM TETRA	CHLORIDE / URANIUM TRI CHLORIDE / DYSPROSIUM PH/	64A-13
/PO BROMITE / ANHYDROUS ALUMINUM CHLORIDE / THORIUM TETRA	CHLORIDE / ZIRCONIUM TETRA CHLORIDE / URANIUM T/	64A-13
ENZYL) PHENCL / TETRA BUTYL AMMONIUM HYDROXIDE / LITHIUM	CHLORIDE SALT BRIDGE) / BUTYL 2 (ALPHA METHYL B	64A-06-08
SPECTROMETRIC STUDY OF MOLTEN LITHIUM METAL - LITHIUM	CHLORIDE SOLUTIONS	64PRR-069
AND HYDROLYZABLE METAL REACTIONS IN CONCENTRATED LITHIUM	CHLORIDE SOLUTIONS - DETERMINATION OF FREE ACID	64PRR-291
TION / BORIC ACID / WE/ REACTIONS IN CONCENTRATED LITHIUM	CHLORIDE SOLUTIONS (FREE ACID / HYDROLYZABLE CA	65A-06-01
RADICAL WITH METHANOL)	CHLORIDE SOLUTIONS (SCAVENGING OF HYDROXYL FREE	64A-03-05
RADIOLYSIS OF	CHLORIDE WITH A PYROLYTIC GRAPHITE INDICATOR ELE	64A-06-11
CTRODE	CHLORINE / CHROMIUM / COPPER / DYSPROSIUM / ERB/	64PRR-154
/ BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / CESIUM /	CHLORINE / NITROSYL CHLORIDE) / ANALYSIS OF CORR	64A-05-01
OSIVE GASES (NITROGEN DI OXIDE / DI NITROGEN TRI OXIDE /	CHOOSING OPTIMUM COUNTING METHODS AND RADIOTRACE	64PRR-054
RS	CHROMATOGRAPH FOR THE ANALYSIS OF CORROSIVE GASE	64A-05-01
S (NITROGEN DI OXIDE / DI NITROGEN TRI OXIDE / CHLO/ GAS	CHROMATOGRAPHIC DETERMINATION OF CARBON IN AQUEO	64A-05-03
US AND NITRIC ACID SOLUTIONS	CHROMATOGRAPHIC METHOD	64PRR-123
TWO CARBON THROUGH FIVE CARBON PARAFFINS AND OLEFINS, GAS	CHROMATOGRAPHIC METHOD	FO 64PRR-124
UR CARBON THROUGH EIGHT CARBON PARAFFINS AND OLEFINS, GAS	CHROMATOGRAPHY	SE 64A-12-03E
PARATION OF TRACE METALS FROM URANIUM BY CELLULOSE COLUMN	CHROMATOGRAPHY (SOLVENT EXTRACTANTS / PARAFFIN/	64A-05-02
/E AND QUANTITATIVE ANALYSIS OF ALIPHATIC DIUENTS BY GAS	CHROMATOGRAPHY, AUTOMATION, ELECTROANALYTICAL T/	64PRR-038
/OACTIVITY STANDARDS, NUCLEAR ANALYSIS, SPECTROSCOPY, GAS	CHROMIUM / COPPER / DYSPROSIUM / ERBIUM / EUROPI/	64PRR-154
/OMINE / CADMIUM / CALCIUM / CERIUM / CESIUM / CHLORINE /	CHROMIUM IN MIXTURES OF FLUORIDE SALTS	64PRR-012
AMPEROMETRIC TITRATION OF	CHROMIUM IN MSRE FUEL, AMPEROMETRIC FERROUS SULF	64PRR-118
ATE TITRATION METHOD	CHROMIUM-51 / COBALT-58 / COPPER-64 / GOLD-198 /	64PRR-230
/CADMIUM-115M HSA / CERIUM-141, CERIUM-144 / CESIUM-134 /	CHROMIUM(VI), AND VANADIUM(V) WITH THE PYROLYTIC	64PRR-049
GRAPHITE ELE/ VOLTAMMETRY OF CERIUM(IV), MANGANESE(IV),	CHROMOTOPGRAPHY AS APPLIED TO NUCLEAR TECHNOLOGY	64PRR-035
II. ANALYSIS OF THE HYDROLYSIS PRODUCTS OF URANIUM / GAS	CHRONOPOTENTIOMETRIC STUDIES OF IRON IN MOLTEN F	64PRR-046
LUORIDE	CHRONOPOTENTIOMETRY	64A-06-03F
CONTROLLED POTENTIAL POLAROGRAPHY AND VOLTAMMETRY AND IN	CHRONOPOTENTIOMETRY /ELECTRODE - APPLICATIONS IN	64PRR-286
NITIAL POLAROGRAPHY, CONTROLLED POTENTIAL VOLTAMMETRY, AND	CHRONOPOTENTIOMETRY /ICATIONS IN CONTROLLED POTE	64A-01-02
VOLTAMMETRY AND	CHRONOPOTENTIOMETRY OF IRON IN MOLTEN FLUORIDES	64PRR-295
	CHRONOPOTENTIOMETRY OF PLUTONIUM	64A-05-06
MEDIA	CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL ACID	64PRR-053
MEDIA	CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL ACID	64PRR-300
MODEL VII FLAME SPECTROPHOTOMETER	CIRCUIT FOR THE MULTIPLIER PHOTOTUBE OF THE ORNL	64A-01-07
	CIRCUITS AND INSTRUMENTATION SYSTEMS	64PRR-027
IES THROUGH SYSTEMS DESIGN	CIRCUMVENTIONS OF CHEMICAL MEASUREMENT DIFFICULT	64PRR-284
ABSOLUTE DETERMINATION OF IODINE-125 IN	CLINICAL APPLICATIONS	64A-12-02E
ABSOLUTE DETERMINATION OF IODINE-125 IN	CLINICAL APPLICATIONS	64PRR-024
EVALUATION OF IODINE-125 MEASUREMENT TECHNIQUES FOR	CLINICAL APPLICATIONS	64PRR-277
EVALUATION OF IODINE-125 MEASUREMENT TECHNIQUES FOR	CLINICAL APPLICATIONS OF RADIO IODINE	64PRR-076
ORE SELECTION FOR PROJECT	COACH (TRANSPLUTONIUM / GNOME)	64A-12-03H
LOW LEVEL ANALYSES (RADIUM-226 / THORIUM /	COAL / FALLOUT / LEAD-210)	64A-12-03J
/SA / CERIUM-141, CERIUM-144 / CESIUM-134 / CHROMIUM-51 /	COBALT-58 / COPPER-64 / GOLD-198 / GOLD-199 / I/	64PRR-230
ONS	COBALT-60 GAMMA RADIATION ON ARSENATO-III SOLUTI	64A-03-03
F URANIUM(VI) IN PHOSPHORIC ACID SOLUTIONS OF / EFFECT OF	COBALT-60 GAMMA RADIATION ON THE DETERMINATION O	64A-03-02
KEL WITH DI METHYL GLYOXIME	COBALT-60 GAMMA RADIATION ON THE REACTION OF NIC	64A-03-01
O ACETONE (TTA) SOLUTIONS	COBALT-60 GAMMA RADIATION ON 2 THENOYL TRI FLUOR	64A-03-04
/TIONS / MEASUREMENT OF ABSORPTION-EDGE HEIGHT / COMPUTER	CODE FOR X-RAY FLUORESCENCE ANALYSIS OF MULTICO/	64A-08-01A
R PROGRAM DIFFUSE)	COEFFICIENT FROM THE KOUTECKY EQUATION (COMPUTE	64A-01-04
/ MERCURY(II) DI N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED	COKE / 3,9 DI ETHYL TRI DECYL AMINE 6 AMINO 3,9/	64A-05-04
F CESIUM	COLLECTION AND FLAME PHOTOMETRIC DETERMINATION O	64PRR-026
TOTAL GASES IN SOLIDS - RELEASE MEASUREMENT AND	COLLECTION FOR MASS SPECTROMETRIC ANALYSIS	64PRR-266
NAZO-III	COLORIMETRIC DETERMINATION OF SAMARIUM WITH ARSE	64A-06-14
TRACTION WITH TRI N OCTYL PHOSPHINE OXIDE AND ITS DIRECT	COLORIMETRIC DETERMINATION WITH DI BENZOYL METH/	64PRR-080
SEPARATION OF TRACE METALS FROM URANIUM BY CELLULOSE	COLUMN CHROMATOGRAPHY	64A-12-03E
CARBON IN AQUEOUS AND NITRIC ACID SOLUTIONS	COMBUSTION GAS CHROMATOGRAPHIC DETERMINATION OF	64A-05-03
ER	COMMENTARY ON ORNL DOUBLE MAGNET MASS SPECTROMET	64PRR-272
QUASI REFERENCE ELECTRODE / NICKEL/ REFERENCE ELECTRODES	COMPATIBLE WITH MOLTEN FLUORIDE SALTS (PLATINUM	64A-02-02E
/ RECENT DEVELOPPMENTS IN DC POLAROGRAPHY (POTENTIOSTATIC	COMPENSATION FOR POLAROGRAPHIC CELL RESISTANCE /	64A-01-01
/DETERMINATION OF METAL COMPLEXES IN ORGANIC EXTRACTS AND	COMPENSATION OF POLAROGRAPHIC CELL RESISTANCE I/	64PRR-001
STUDY OF METAL I, I O PHENANTHROLINE	COMPLEX EQUILIBRIA BY POTENTIOMETRIC MEASUREMENT	64PRR-023
EQUILIBRIUM DISTRIBUTION OF METAL - FLUORIDE	COMPLEXES	64PRR-029
EQUILIBRIUM DISTRIBUTION OF METAL - ION	COMPLEXES	64PRR-077
/ND DERIVATIVE POLAROGRAPHY TO THE DETERMINATION OF METAL	COMPLEXES IN ORGANIC EXTRACTS AND COMPENSATION /	64PRR-001
SEPARATION OF PROCTACTINIUM FROM MOLTEN SALT REACTOR FUEL	COMPOSITION	64PRR-333

K OBSERVED IN GAMMA-RAY SPECTROMETRY 180 DEGREE COMPOSITION OF ATMOSPHERIC NEON 64A-09-02
 /TIVE SOLUTIONS / MEASUREMENT OF ABSORPTION-EDGE HEIGHT / COMPUTER SCATTERED ANNIHILATION GAMMA-RAY SUM PEAK 64PRR-040
 SIS A VERSATILE ELECTRONIC COMPUTER CODE FOR X-RAY FLUORESCENCE ANALYSIS OF 64A-08-01A
 O CUMULATIVE INDEXES FOR THE ORNL MASTER / PREPARATION OF COMPUTER FOR PHOTOELECTRIC SPECTROCHEMICAL ANALY 64PRR-067
 ION OF DIFFUSION COEFFICIENT FROM THE KOUTECKY EQUATION (COMPUTER INPUT INFORMATION FOR ANNUAL REVISION T 64PRR-146
 -RAY SPECTRA AND FOR QUALITY CONTROL MEASUREMENTS COMPUTER PROGRAM DIFFUSE) CALCULAT 64A-01-04
 THE ANALYSIS OF SPECTROMETRIC ABSORPTION / A GENERALIZED COMPUTER PROGRAM FOR ACCUMULATING STANDARD GAMMA 64A-12-058
 APPLICATION OF COMPUTERS 64PRR-271
 CARBON IN METALS AND METALLIC OXIDES, LECO CONDUCTOMETRIC METHOD 64A-12-05
 CHNOLOGY - ANALYTICAL INSTRUMENT/ A RESUME OF THE SEVENTH CONFERENCE ON ANALYTICAL CHEMISTRY IN NUCLEAR TE 64PRR-122
 ICAL LABORATORY DESIGN AND CONSTRUCTION OF ORNL HIGH RADIATION LEVEL ANALYT 64PRR-038
 CONTAINERS FOR MOLTEN FLUORIDE SALTS 64PRR-018
 64A-02-01B
 ERMINATION OF PARTS PER BILLION CONCENTRATIONS OF ORGANIC FLAME IONIZATION DET 64A-06-04
 METHOD SEPARATION OF KRYPTON AND XENON FROM CONTAMINATING GASES, MOLECULAR SIEVE ABSORPTION 64PRR-152
 TIFICATION BY ACTIVATION ANALYSIS OF HAIR AND ITS SURFACE CONTAMINATION INDIVIDUAL IDEN 64PRR-268
 QUALITY CONTROL 64B-15
 R ACCUMULATING STANDARD GAMMA-RAY SPECTRA AND FOR QUALITY CONTROL MEASUREMENTS COMPUTER PROGRAM FO 64A-12-058
 JAN.-DEC., 1963 - STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIVISION 64PRR-088
 AN.-MAR., 1964 STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIVISION, J 64PRR-085
 AN.-SEPT., 1963 STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIVISION, J 64PRR-087
 STATISTICAL QUALITY CONTROL REPORT, JAN.-JUNE, 1964 64PRR-086
 TO THE DETERMINATION OF METAL COMPLEXES / APPLICATION OF CONTROLLED POTENTIAL AND DERIVATIVE POLAROGRAPHY 64PRR-001
 ANIUM(IV) AND URANIUM(VI) IN SODIUM TRI POLY PHOSPHATE M/ CONTROLLED POTENTIAL COULOMETRIC TITRATION OF UR 64PRR-071
 SIGNIFICANCE OF PLACEMENT OF THE REFERENCE ELECTRODE IN CONTROLLED POTENTIAL COULOMETRY 64A-01-08
 TOOL IN THE NUCLEAR ENERGY PROGRAM CONTROLLED POTENTIAL COULOMETRY - NEW ANALYTICAL 64PRR-331
 - DESIGN AND EVALUATION CONTROLLED POTENTIAL DC POLAROGRAPHY VOLTAMMETER 64A-01-03
 CONTROLLED POTENTIAL DC POLAROGRAPHY 64PRR-283
 Y A/ A SIMPLE QUASI REFERENCE ELECTRODE - APPLICATIONS IN CONTROLLED POTENTIAL POLAROGRAPHY AND VOLTAMMETR 64PRR-286
 / (Q.R.E.) A SIMPLE REFERENCE ELECTRODE APPLICATIONS IN CONTROLLED POTENTIAL POLAROGRAPHY, CONTROLLED P/ 64A-01-02
 /RODE APPLICATIONS IN CONTROLLED POTENTIAL POLAROGRAPHY, CONTROLLED POTENTIAL VOLTAMMETRY, AND CHRONOPOT/ 64A-01-02
 VOLTAMMETRY OF THE MSR COOLANT SALT AND MSR FUEL SALT 64A-02-020
 DETERMINATION OF DISSOLVED GASES AND IMPURITIES IN REACTOR COOLANT WATER /EY OF SENSITIVE METHODS FOR THE D 64PRR-100
 ONS IN THE MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - P/ COORDINATION OF FLUORIDE IONS ABOUT NICKEL(II) I 64PRR-070
 /MIUM / CALCIUM / CERIUM / CESIUM / CHLORINE / CHROMIUM / COPPER / DYSPROSIUM / ERBIUM / EUROPIUM / GADOL/ 64PRR-154
 COULOMETRIC TITRATION METHOD URANIUM, COPPER, AND NICKEL IN HOMOGENEOUS REACTOR FUEL, 64PRR-264
 /141, CERIUM-144 / CESIUM-134 / CHROMIUM-51 / COBALT-58 / COPPER-64 / GOLD-198 / GOLD-199 / IODINE-131 / / 64PRR-230
 ONS - SELECTIVE EXTRACTION OF MERCURY(II), SILVER(II), AND COPPER(II) /TRI AMIDES AS EXTRACTANTS FOR METAL I 64A-12-03A
 POLAROGRAPHY IN HYDROFLUORIC ACID AND OTHER GLASS CORRODING MEDIA 64A-05-05
 N TRI OXIDE / CHLO/ GAS CHROMATOGRAPH FOR THE ANALYSIS OF CORROSIVE GASES (NITROGEN DI OXIDE / DI NITROGE 64A-05-01
 WINDOWLESS SPECTROPHOTOMETRIC CELL FOR USE WITH CORROSIVE LIQUIDS 64PRR-068
 URANIUM, COPPER, AND NICKEL IN HOMOGENEOUS REACTOR FUEL, COULOMETRIC DETERMINATION OF NICKEL 64A-06-16
 (VI) IN SODIUM TRI POLY PHOSPHATE M/ CONTROLLED POTENTIAL COULOMETRIC DETERMINATION OF TECHNETIUM-99 64A-06-13
 ST SPECIFICATIONS / T/ ORNL MODEL Q-2564 HIGH SENSITIVITY COULOMETRIC TITRATION METHOD 64PRR-264
 CHECK OUT AND TEST PROCEDURE FOR HIGH SENSITIVITY COULOMETRIC TITRATION OF URANIUM(IV) AND URANIUM 64PRR-071
 CEMENT OF THE REFERENCE ELECTRODE IN CONTROLLED POTENTIAL COULOMETRIC TITRATOR (ENGINEERING DRAWINGS / TE 64A-01-05
 ECISE DETERMINATION OF URANIUM, WITH SPECIAL REFERENCE TO COULOMETRIC TITRATOR, ORNL MODEL Q-2564 64PRR-081
 ENERGY PROGRAM COULOMETRY SIGNIFICANCE OF PLA 64A-01-08
 COULOMETRY THE ACCURATE AND PR 64PRR-290
 COULOMETRY - NEW ANALYTICAL TOOL IN THE NUCLEAR 64PRR-331
 GEIGER-MUELLER COUNTER 64PRR-130
 GAMMA SCINTILLATION COUNTER 64PRR-147
 CTIVITY IN AQUEOUS SOLUTIONS, PYRIDINE EXTRACTION - GAMMA COUNTING METHOD RUTHENIUM RADIOA 64PRR-150
 RI FLUORO ACETONE (TTA) EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD /) PROCESS SOLUTIONS, THENOYL T 64PRR-138
 IONS, AMPONIUM PER SULFATE OXIDATION - PROPORTIONAL ALPHA COUNTING METHOD /NSURANIUM (TRU) PROCESS SOLUT 64PRR-136
 IONS, TRI ISO OCTYL AMINE EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD /NSURANIUM (TRU) PROCESS SOLUT 64PRR-139
 E (OR TRI CAPRYL AMINE) EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD /S SOLUTIONS, TRI ISO OCTYL AMIN 64PRR-134
 NS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS SOLUTIO 64PRR-133
 NS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS SOLUTIO 64PRR-137
 NS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TRU) PROCESS SOLUTIO 64PRR-140
 CHOOSING OPTIMUM COUNTING METHODS AND RADIOTRACERS 64PRR-054
 ATION METHCO ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID SCINTILL 64A-12-04C
 ATION METHCO ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID SCINTILL 64PRR-289
 TECHNIQUE LIQUID SCINTILLATION COUNTING OF CARBON-14 USING A BALANCED QUENCHING 64PRR-058
 WEAR RATES IN AUTOMOTIVE ENGINES BY LIQUID SCINTILLATION COUNTING OF IRON-55 64PRR-059
 RADIATION DETECTORS AND COUNTING STATISTICS 64PRR-004
 SCINTILLATION COUNTING TECHNIQUES 64PRR-003
 OF BROMINE - BROMINE-82M (HALF LIFE / NEUTRON ACTIVATION CROSS SECTION) NEW ISOMER 64A-12-01D
 /N GENERATORS - ITS RAPID ESTIMATION AND ITS INFLUENCE ON CROSS SECTION MEASUREMENTS AND ACTIVATION ANALY/ 64A-12-08A
 HOLDER FOR USE IN OBTAINING ABSORPTION SPECTRA OF SMALL CRYSTALS 64A-02-01E
 EUROPIUM - EUROPIUM ACTIVATED LITHIUM IODIDE SCINTILLATION CRYSTALS /ERMINATION OF EUROPIUM(III) AND TOTAL E 64PRR-019
 /ION OF COMPUTER INPUT INFORMATION FOR ANNUAL REVISION TO CUMULATIVE INDEXES FOR THE ORNL MASTER ANALYTIC/ 64PRR-146
 MANUAL CUMULATIVE INDEXES TO THE ORNL MASTER ANALYTICAL 64C-20-01
 AND ACID - BASE POTENTIOMETRIC TITRA/ PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND ELECTRODE FOR MICRO REDOX 64PRR-066
 MICRO REDOX AND ACID - BASE POTENTIOMETRIC PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND INDICATOR ELECTRODE FOR M 64A-06-12
 ZIRCONIUM IN MSRE FUEL, AMPEROMETRIC CUPFERRON TITRATION METHOD 64PRR-117
 SEARCH FOR NATURAL TRANSURANIC RADIOACTIVITY (CURIUM-247 / PLUTONIUM-244) 64A-12-031
 UM IN MOLTEN FLUORIDES CURRENT - VOLTAGE CURVES FOR ZIRCONIUM AND URANI 64PRR-047
 CURRENT PROGRAMS 64A-14-04
 CURRENT WORK AT ORNL 64PRR-301
 IDES CURRENT - VOLTAGE CURVES FOR ZIRCONIUM AND URANIUM IN MOLTEN FLUOR 64PRR-047
 IDE - POTASSIUM FLUORIDE - URANIUM(IV) FLUORIDE WITH THIO CYANATE /III) IN SODIUM FLUORIDE - LITHIUM FLUOR 64PRR-104
 ID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /LENT ACTINIDE ELEMENTS - SELECTIVE LIQU 64PRR-050
 ID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /OM LANTHANIDE ELEMENTS - SELECTIVE LIQU 64A-12-03C
 METHYL ISO CYANIDE 64A-14-01A
 SYNTHESIS OF METHYL ISO CYANIDE 64PRR-078
 ELECTRODE FOR USE IN OBTAINING FUNDAMENTAL POLAROGRAPHIC DATA /HORIZONTAL ORIFICE TEFLON DROPPING MERCURY 64A-05-05A
 / A GENERALIZED COMPUTER PROGRAM TO OBTAIN REACTION RATE DATA BY THE ANALYSIS OF SPECTROMETRIC ABSORPTION 64PRR-271
 RETENTION DATA FOR POLY PHENYL COMPOUNDS 64PRR-013
 ION RATE DATA BY THE ANALYSIS OF SPECTROMETRIC ABSORPTION DATA FROM DYNAMIC MULTICOMPONENT SYSTEMS / REACT 64PRR-271
 ON CONTROLLED POTENTIAL DC POLAROGRAPH VOLTAMMETER - DESIGN AND EVALUATI 64A-01-03
 CONTROLLED POTENTIAL DC POLAROGRAPHY 64PRR-283

RECENT DEVELOPMENTS IN DC POLAROGRAPHY	64PRR-285
R POLAROGRAPHIC CELL RESISTANCE // RECENT DEVELOPMENTS IN DC POLAROGRAPHY (POTENTIOSTATIC COMPENSATION FOR	64A-01-01
UTION FOR POLAROGRAPHIC CELL RESISTANCE / TIME DERIVATIVE DC POLAROGRAPHY / FIRST DERIVATIVE DC POLAROGRA	64A-01-01
/ATIVE DC POLAROGRAPHY / SIGNAL TO NOISE RATIO (S/N) IN DC POLAROGRAPHY / RESOLUTION OF POLAROGRAPHIC W/	64A-01-01
/NCE / TIME DERIVATIVE DC POLAROGRAPHY / FIRST DERIVATIVE DC POLAROGRAPHY / SECOND DERIVATIVE DC POLAROGRA	64A-01-01
/Y / SECOND DERIVATIVE DC POLAROGRAPHY / THIRD DERIVATIVE DC POLAROGRAPHY / SIGNAL TO NOISE RATIO (S/N) /	64A-01-01
/Y / FIRST DERIVATIVE DC POLAROGRAPHY / SECOND DERIVATIVE DC POLAROGRAPHY / THIRD DERIVATIVE DC POLAROGRA	64A-01-01
OLAROGRAPHIC MEASUREMENTS SECOND DERIVATIVE DC POLAROGRAPHY AS A TECHNIQUE IN QUANTITATIVE P	64PRR-270
EMISTRY RESEARCH AND DEVELOPMENT GROUP MONTHLY SUMMARY - DEC.,1963 / JAN.,1964 / FEB.,1964 / MAR.,1964 //	64PRR-105
6 AMINO 3,9 DI ETHYL TRI DECA	64A-14-01C
TRACTANTS / PARAFFINS NORMAL OCTANE THROUGH NORMAL PENTA	64A-05-02
E / 3,9 DI ETHYL TRI DECYL AMINE 6 AMINO 3,9 DI ETHYL TRI	64A-05-04
NOMOGRAPHY FOR CALCULATING INDUCED RADIOACTIVITY AND	64PRR-055
GAMMA-RAY BRANCHING IN THE	64A-12-01A
GAMMA TRANSITIONS IN THE	64A-12-01B
DECAY OF KRYPTON-79	64A-12-01C
DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-020
DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-273
DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-148
DECAY STUDIES	64A-05-04
DECOMPOSITION OF VARIOUS MATERIALS (HAFNIUM OXI	64A-02-02B
DECOMPOSITION POTENTIALS OF PURE METALS IN MOLTE	64A-05-04
DECYL AMINE 6 AMINO 3,9 DI ETHYL TRI DECA	64A-12-01G
DEFICIENT HAFNIUM RADIONUCLIDES	64PRR-005
DEMOUNTABLE HOLLOW CATHODE LAMP ATOMIC ABSORPT	64A-01-01
DERIVATIVE DC POLAROGRAPHY / FIRST DERIVATIVE D/	64A-01-01
DERIVATIVE DC POLAROGRAPHY / SECOND DERIVATIVE /	64A-01-01
DERIVATIVE DC POLAROGRAPHY / SIGNAL TO NOISE RA/	64A-01-01
DERIVATIVE DC POLAROGRAPHY / THIRD DERIVATIVE D/	64PRR-270
DERIVATIVE DC POLAROGRAPHY AS A TECHNIQUE IN QUA	64A-01-06
DERIVATIVE METHOD TO STATIONARY ELECTRODE VOLTAM	64PRR-001
DERIVATIVE POLAROGRAPHY TO THE DETERMINATION OF	64PRR-299
DERIVATIVE TECHNIQUES TO STATIONARY ELECTRODE PO	64PRR-284
DESIGN CIRCUMVENT	64PRR-018
DESIGN AND CONSTRUCTION OF ORNL HIGH RADIATION L	64A-01-03
DESIGN AND EVALUATION	64PRR-060
DETECTION	64PRR-099
DETECTION	64PRR-311
DETECTION	64A-12-04B
DETECTION USING LITHIUM-6 ENRICHED ISOTOPE	64PRR-098
DETECTION USING LITHIUM-6 ENRICHED ISOTOPE	64PRR-309
DETECTOR METHOD ALPHA SPECTROMETRY	64PRR-135
DETECTORS GA	64A-12-02B
DETECTORS AND COUNTING STATISTICS	64PRR-004
DI AMINE TETRA ACETATE - IRON(II) INDICATOR METH	64PRR-131
DI AMINE TETRA ACETATE (EDTA) METHOD ALUMIN	64PRR-127
DI BENZOYL METHANE /CTION WITH TRI N OCTYL PHOSP	64PRR-080
DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERC/	64A-05-04
DI BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPHORIC A	64PRR-265
DI ETHYL TRI DECA	64A-14-01C
DI ETHYL TRI DECA	64A-05-04
DI ETHYL TRI DECYL AMINE 6 AMINO 3,9 DI ETHYL T/	64A-05-04
DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE - IR	64PRR-131
DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE (ED	64PRR-127
DI METHYL AMINO PURINE	64PRR-036
DI METHYL GLYOXIME	64A-03-01
DI N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED COK/	64A-05-04
DI N BUTYL PHOSPHORO DI THIOATES AS EXTRACTANTS	64A-12-03B
DI N BUTYL PHOSPHORO THIOATE IN AN EXTRACTION S/	64PRR-033
DI NITROGEN TRI OXIDE / CHLORINE / NITROSYL CHL/	64A-05-01
DI OXIDE	64A-12-06A
DI OXIDE	64PRR-312
DI OXIDE / DI NITROGEN TRI OXIDE / CHLORINE / N/	64A-05-01
DI PIPERIDYL	64A-14-01E
DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA AC	64PRR-127
DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA AC	64PRR-131
DI SULFIDE / MERCURY(II) DI N BUTYL PHOSPHORO D/	64A-05-04
DI THIO PHOSPHORYL) DI SULFIDE / MERCURY(II) D/	64A-05-04
DI THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL TRI /	64A-05-04
DI THIOATES AS EXTRACTANTS FOR METALS	64A-12-03B
DI 2 ETHYL HEXYL PHOSPHORIC ACID - AMSCO EXTRACT	64PRR-142
DIFFERENTIAL POTENTIOMETRY	64A-06-03C
DIFFICULTIES THROUGH SYSTEMS DESIGN	64PRR-284
DIFFRACTION RESEARCH ASSISTANCE TO OTHER LABORAT	64A-11-04
DIFFUSE) CALCULATION OF DIFFUSION	64A-01-04
DIFFUSION COEFFICIENT FROM THE KOUBECKY EQUATION	64A-01-04
DILUENTS BY GAS CHROMATOGRAPHY (SOLVENT EXTRACT	64A-05-02
DIODE DETECTOR METHOD ALPHA SPECTR	64PRR-135
DIODE DETECTORS	64A-12-02B
DIRECTORY OF RADIOISOTOPES	64PRR-042
DISK SPARK TECHNIQUE /TERMINATION OF VOLATILE FL	64PRR-082
DISPOSABLE SPECTROGRAPHIC EXCITATION CHAMBER FOR	64A-08-02A
DISPOSAL OF RADIOACTIVE WASTES IN NATURAL SALT F	64A-06-02
DISPOSAL SLURRIES	64A-06-10
DISSOLUTION OF IRRADIATED, HIGH FIRED, REFRACTOR	64PRR-116
DISSOLUTION OR DECOMPOSITION OF VARIOUS MATERIAL	64A-05-04
DISSOLVED GASES AND IMPURITIES IN REACTOR COOLA/	64PRR-100
DISTILLATION TECHNIQUE / DETERMINATION OF IMPURI	64PRR-083
DIVALENT LEAD TO LEAD METAL REDOX REACTION IN AQ	64A-05-05C
DIVISIONS /ECTRON AND OPTICAL MICROSCOPY AND ELE	64A-11-04
DOSIMETERS) DISPOSAL OF RADIOACTIVE WAST	64A-06-02
DOUBLE MAGNET MASS SPECTROMETER	64PRR-272

/2564 HIGH SENSITIVITY CULOMETRIC TITRATOR (ENGINEERING	DRAWINGS / TEST SPECIFICATIONS / TROUBLE-SHOOTI/	64A-01-05
GAMMA-RAY SPECTROSCOPY WITH LITHIUM	DRIFTED GERMANIUM DIODE DETECTORS	64A-12-02B
VERTICAL ORIFICE RAPID TEFLON	DROPPING MERCURY ELECTRODE	64A-05-05E
TION OF THE VERTICAL ORIFICE TEFLON CAPILLARY OF A TEFLON	DROPPING MERCURY ELECTRODE	64PRR-095
EOUS HYDROFLUORIC ACID WITH THE HORIZONTAL ORIFICE TEFLON	DROPPING MERCURY ELECTRODE /EDOX REACTION IN AQU	64A-05-05C
EXTENSION OF THE USE OF THE HORIZONTAL ORIFICE TEFLON	DROPPING MERCURY ELECTRODE BY OTHERS	64A-05-05D
FUNDAMENTAL / EVALUATION OF THE HORIZONTAL ORIFICE TEFLON	DROPPING MERCURY ELECTRODE FOR USE IN OBTAINING	64A-05-05A
PLICATION OF ACTIVATION ANALYSIS TO FORENSIC SCIENCE II.	DRUGS	AP 64PRR-015
DETERMINATION OF TRACE ELEMENTS IN	DRUGS BY NEUTRON ACTIVATION ANALYSIS	64PRR-016
ATA BY THE ANALYSIS OF SPECTROMETRIC ABSORPTION DATA FROM	DYNAMIC MULTICOMPONENT SYSTEMS / REACTION RATE D	64PRR-271
/LCIUM / CERIUM / CESIUM / CHLORINE / CHROMIUM / COPPER /	DYSPROSIUM / ERBIUM / EUROPIUM / GADOLINIUM / G/	64PRR-154
/RIDE / ZIRCONIUM TETRA CHLORIDE / URANIUM TRI CHLORIDE /	DYSPROSIUM PHOSPHIDE / HIGH PURITY POTASSIUM CH/	64A-13
RADIOISOTOPES IN ALKALINE	EARTH ANALYSIS	64PRR-097
RADIOISOTOPES IN ALKALINE	EARTH ANALYSIS	64PRR-302
STUDIES OF RARE	EARTH ELEMENT ALPHA EMITTERS (EUROPIUM)	64A-12-01E
RY (SEPARATION OF BARIUM FROM ALKALI METALS AND ALKALINE	EARTH ELEMENTS)	64A-08-01C
C DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE (	EDTA) METHOD ALUMINUM AND THORIUM, VOLUMETRI	64PRR-127
R ANALYSIS, SPECTROSCOPY, GAS CHROMATOGRAPHY, AUTOMATION,	ELECTROANALYTICAL TECHNIQUES / STANDARDS, NUCLEA	64PRR-038
VERTICAL ORIFICE RAPID TEFLON DROPPING MERCURY	ELECTRODE	64A-05-05E
GLASSY CARBON INDICATOR	ELECTRODE	64A-06-03A
OXIDE FILM FORMATION ON THE PYROLYTIC GRAPHITE	ELECTRODE	64A-06-03B
RMINATION OF CHLORIDE WITH A PYROLYTIC GRAPHITE INDICATOR	ELECTRODE	64A-06-11
CAL ORIFICE TEFLON CAPILLARY OF A TEFLON DROPPING MERCURY	ELECTRODE	64PRR-095
/ QUASI REFERENCE ELECTRODE (Q.R.E.) A SIMPLE REFERENCE	ELECTRODE APPLICATIONS IN CONTROLLED POTENTIAL/	64A-01-02
ORIDE - ZIRCONIUM FLUORIDE / PYROLYTIC GRAPHITE INDICATOR	ELECTRODE) / LITHIUM FLUORIDE - BERYLLIUM FLU	64A-02-02
TIAL (POLAROGRAPHY / ELECTROLYSIS / HANGING MERCURY DROP	ELECTRODE) /AMMETRY WITH LINEARLY VARYING POTEN	64A-01-06
REFERENCE ELECTRODE / NICKEL - NICKEL(II) OXIDE REFERENCE	ELECTRODE) /EN FLUORIDE SALTS (PLATINUM QUASI	64A-02-02E
E POTENTIOMETRIC TITRATIONS (PLATINUM IN-BURET REFERENCE	ELECTRODE) /RODE FOR MICRO REDOX AND ACID - BAS	64A-06-12
POLAROGRAPHY AND VOLTAMMETRY A/ A SIMPLE QUASI REFERENCE	ELECTRODE - APPLICATIONS IN CONTROLLED POTENTIAL	64PRR-286
E APPLICATIONS IN CONTRLLED POTENT/ THE QUASI REFERENCE	ELECTRODE (Q.R.E.) A SIMPLE REFERENCE ELECTROD	64A-01-02
/LE WITH MOLTEN FLUORIDE SALTS (PLATINUM QUASI REFERENCE	ELECTRODE / NICKEL - NICKEL(II) OXIDE REFERENCE/	64A-02-02E
ACID WITH THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY	ELECTRODE /EDOX REACTION IN AQUEOUS HYDROFLUORIC	64A-05-05C
CHROMIUM(VI), AND VANADIUM(V) WITH THE PYROLYTIC GRAPHITE	ELECTRODE /METRY OF CERIUM(IV), MANGANESE(VII),	64PRR-049
THE USE OF THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY	ELECTRODE BY OTHERS	64A-05-05D
HOME/ PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND INDICATOR	ELECTRODE FOR MICRO REDOX AND ACID - BASE POTENT	64A-06-12
IOMETRIC TITRA/ PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND	ELECTRODE FOR MICRO REDOX AND ACID - BASE POTENT	64PRR-066
UATION OF THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY	ELECTRODE FOR USE IN OBTAINING FUNDAMENTAL POLA/	64A-05-05A
SIGNIFICANCE OF PLACEMENT OF THE REFERENCE	ELECTRODE IN CONTROLLED POTENTIAL COULOMETRY	64A-01-08
/Y AND APPLICATION OF THE DERIVATIVE METHOD TO STATIONARY	ELECTRODE POLAROGRAPHY	64PRR-299
URANIUM(IV) WITH CERIUM(IV) UTILIZING PYROLYTIC GRAPHITE	ELECTRODE VOLTAMMETRY WITH LINEARLY VARYING POT/	64A-01-06
)	ELECTRODES	64PRR-048
(PLATINUM QUASI REFERENCE ELECTRODE / NICKEL/ REFERENCE	ELECTRODES (PYROLYTIC GRAPHITE / GLASSY CARBON	64A-06-03
TAMMETRY WITH LINEARLY VARYING POTENTIAL (POLAROGRAPHY /	ELECTRODES COMPATIBLE WITH MOLTEN FLUORIDE SALTS	64A-02-02E
FRACTION RESEARCH ASSISTANCE TO OTHER LABORATORY DIVISIO/	ELECTROLYSIS / HANGING MERCURY DROP ELECTRODE)	64A-01-06
R LABORATORY DIVISIO/ ELECTRON AND OPTICAL MICROSCOPY AND	ELECTRON AND OPTICAL MICROSCOPY AND ELECTRON DIF	64A-11-04
CTIVE MATERIALS	ELECTRON DIFFRACTION RESEARCH ASSISTANCE TO OTHE	64A-11-04
	ELECTRON MICROSCOPE FACILITY FOR STUDYING RADIOA	64A-11-01A
	ELECTRON MICROSCOPY	64A-11
	ELECTRON MICROSCOPY - PAST AND PRESENT AT ORNL	64PRR-318
	ELECTRON MICROSCOPY OF RADIOACTIVE MATERIALS	64A-11-01
	ELECTRON OPTICAL INSTRUMENTATION	64A-11-03
	ELECTRON SPIN RESONANCE)	64A-02-03
INSTRUMENTAL APPROACHES TO ANALYSIS OF FUSED SALTS (	ELECTRONIC CIRCUITS AND INSTRUMENTATION SYSTEMS	64PRR-027
MICAL ANALYSIS	ELECTRONIC COMPUTER FOR PHOTOELECTRIC SPECTROCHE	64PRR-067
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64A-12-05A
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-090
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-276
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-293
STUDIES OF RARE EARTH ELEMENT ALPHA	EMITTERS (EUROPIUM)	64A-12-01E
ABSOLUTE COUNTING OF BETA	EMITTERS BY THE LIQUID SCINTILLATION METHOD	64A-12-04C
ABSOLUTE COUNTING OF BETA	EMITTERS BY THE LIQUID SCINTILLATION METHOD	64PRR-289
HEMISTRY AND / EXPERIMENTAL STUDY OF ARTIFACTS AND ERRORS	ENCOUNTERED IN GAMMA-RAY SPECTROMETRY FOR RADIOC	64PRR-294
INATIONS OF CESIUM-137	ENERGY AGENCY (IAEA) INTERCOMPARISON OF DETERM	64A-12-02D
POTENTIAL CULOMETRY - NEW ANALYTICAL TOOL IN THE NUCLEAR	ENERGY PROGRAM	64PRR-331
/ORNL MODEL Q-2564 HIGH SENSITIVITY CULOMETRIC TITRATOR (	ENGINEERING DRAWINGS / TEST SPECIFICATIONS / TR/	64A-01-05
-55	ENGINEERING SERVICE LABORATORY	64B-19
UNIQUE SCINTILLATOR FOR NEUTRON DETECTION USING LITHIUM-6	ENGINES BY LIQUID SCINTILLATION COUNTING OF IRON	64PRR-059
LIQUID SCINTILLATOR FOR NEUTRON DETECTION USING LITHIUM-6	ENRICHED ISOTOPE	64PRR-098
	ENRICHED ISOTOPE	64PRR-309
	ENVIRONMENTAL ANALYSES AT ORNL	64PRR-305
PRODUCE CESIUM-136	EPITHERMAL NEUTRON IRRADIATION OF LANTHANUM TO P	64A-12-02A
CALCULATION OF DIFFUSION COEFFICIENT FROM THE KOUBECKY	EQUATION (COMPUTER PROGRAM DIFFUSE)	64A-01-04
STUDY OF METAL ,1,10 PHENANTHROLINE COMPLEX	EQUILIBRIA BY POTENTIOMETRIC MEASUREMENT	64PRR-023
PLEXES	EQUILIBRIUM DISTRIBUTION OF METAL - FLUORIDE COM	64PRR-029
S	EQUILIBRIUM DISTRIBUTION OF METAL - ION COMPLEXE	64PRR-077
	EQUIPMENT	64A-02-02A
/M / CESIUM / CHLORINE / CHROMIUM / COPPER / DYSPROSIUM /	ERBIUM / EUROPIUM / GADOLINIUM / GALLIUM / GERM/	64PRR-154
RADIOCHEMISTRY AND / EXPERIMENTAL STUDY OF ARTIFACTS AND	ERRORS ENCOUNTERED IN GAMMA-RAY SPECTROMETRY FOR	64PRR-294
MONO ACID	ESTERS	64A-14-01D
OUTPUT SPECTRA OF 14-MEV NEUTRON GENERATORS - RAPID	ESTIMATION AND INFLUENCE IN ACTIVATION ANALYSIS	64PRR-306
/TPUT SPECTRUM FROM 14-MEV NEUTRON GENERATORS - ITS RAPID	ESTIMATION AND ITS INFLUENCE ON CROSS SECTION M/	64A-12-08A
STRONTIUM-89 AND STRONTIUM-90 IN AQUEOUS SOLUTIONS, DI 2	ETHYL HEXYL PHOSPHORIC ACID - AMSO EXTRACTION M	64PRR-142
6 AMINO 3,9 DI	ETHYL TRI DECA	64A-14-01C
IDIZED COKE / 3,9 DI ETHYL TRI DECYL AMINE 6 AMINO 3,9 DI	ETHYL TRI DECA	64A-05-04
/I N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED COKE / 3,9 DI	ETHYL TRI DECA	64A-05-04
USE AND CARE OF POLY	ETHYLENE	64PRR-227
ATOR METHOD THORIUM, AMPEROMETRIC DI SODIUM DI HYDROGEN	ETHYLENE DI AMINE TETRA ACETATE - IRON(III) INDIC	64PRR-131
ALUMINUM AND THORIUM, VOLUMETRIC DI SODIUM DI HYDROGEN	ETHYLENE DI AMINE TETRA ACETATE (EDTA) METHOD	64PRR-127
STUDIES OF RARE EARTH ELEMENT ALPHA EMITTERS (	EUROPIUM)	64A-12-01E
NTILLATION CRYST/ DETERMINATION OF EUROPIUM(II) AND TOTAL	EUROPIUM - GADOLINIUM ACTIVATED LITHIUM IODIDE SCI	64PRR-019
/M / CHLORINE / CHROMIUM / COPPER / DYSPROSIUM / ERBIUM /	EUROPIUM / GADOLINIUM / GALLIUM / GERMANIUM / H/	64PRR-154
CRYST/ DETERMINATION OF EUROPIUM(II) AND TOTAL EUROPIUM -	EUROPIUM ACTIVATED LITHIUM IODIDE SCINTILLATION	64PRR-019

ANALYSIS OF ARC FUSED EUROPIUM MOLYBDATE
 ATED LITHIUM IODIDE SCINTILLATION CRYST/ DETERMINATION OF EUROPIUM(III) AND TOTAL EUROPIUM - EUROPIUM ACTIV 64A-06-15
 N LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE EUROPEAN JOURNAL OF PURE AND APPLIED PHYSICS 64PRR-019
 /PROPERTIES OF NUCLEAR LEVELS IN A NUMBER OF EVEN-A NUCLEI EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM 18/ 64PRR-070
 THROUGH 192/ PROPERTIES OF NUCLEAR LEVELS IN A NUMBER OF EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM 184 64PRR-034
 NGING FROM 1/ PROPERTIES OF NUCLEAR LEVELS IN A NUMBER OF EVEN-A NUCLEI EVEN MASS NUCLEI (MASS NUMBERS RA 64A-12-01F
 OF CERTAIN IMPURITIES IN LITHIUM FLUORIDE POWDER BY SPARK EXCITATION DETERMINATION 64A-08-02B
 DISPOSABLE SPECTROGRAPHIC SOME EXCITATION CHAMBER FOR RADIOACTIVE SAMPLES 64A-08-02A
 EFLON DROPPING MERCURY ELECTRODE BY OTHERS EXPERIENCES IN ENVIRONMENTAL ANALYSES AT ORNL 64PRR-305
 /IS OF ALIPHATIC DILUENTS BY GAS CHROMATOGRAPHY (SOLVENT EXTENSION OF THE USE OF THE HORIZONTAL ORIFICE T 64A-05-050
 / TRI ALKYL AND HEXA ALKYL PHOSPHORO THIOIC TRI AMIDES AS EXTRACTANTS / PARAFFINS NORMAL OCTANE THROUGH N/ 64A-05-02
 METAL DI N BUTYL PHOSPHORO DI THIOATES AS EXTRACTANTS FOR METAL IONS - SELECTIVE EXTRACTIO 64A-12-03A
 N OF HYDROGEN IN ALKALI METALS BY AMALGAMATION AND VACUUM EXTRACTANTS FOR METALS 64A-12-03B
 RUTHENIUM RADIOACTIVITY IN AQUEOUS SOLUTIONS, PYRIDINE EXTRACTION - GAMMA COUNTING METHOD 64A-06-07
 SS SOLUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL AMINE) EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD 64PRR-150
 U) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (TTA) EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD 64PRR-134
 ANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD 64PRR-138
 TOTAL PLUTONIUM, THENOYL TRI FLUORO ACETONE EXTRACTION - PROPORTIONAL ALPHA COUNTING METHOD 64PRR-139
 AQUEOUS SOLUTIONS, DI 2 ETHYL HEXYL PHOSPHORIC ACID - AMSCO EXTRACTION METHOD /IUM-89 AND STRONTIUM-90 IN AQ 64PRR-219
 TONE LIQUID-LIQUID EXTRACTION METHOD /IUM-89 AND STRONTIUM-90 IN AQ 64PRR-142
 CETONE LIQUID-LIQUID EXTRACTION OF CESIUM WITH THENOYL TRI FLUORO ACE 64PRR-022
 /OIC TRI AMIDES AS EXTRACTANTS FOR METAL IONS - SELECTIVE EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO A 64PRR-021
 ACETONE SELECTIVE LIQUID-LIQUID EXTRACTION OF MERCURY(II), SILVER(II), AND COPPE/ 64A-12-03A
 EXCHANGE WITH MERCURIC DI N BUTYL PHOSPHORO THIOATE IN AN EXTRACTION OF RADIOTIN WITH 2 THENOYL TRI FLUORO 64PRR-064
 /MENTS FROM LANTHANIDE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION SYSTEM /ATION OF MERCURY BY ISOTOPIC 64PRR-033
 /OF TRIVALENT ACTINIDE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO/ 64A-12-03C
 ITS DIRECT COLORIMETRIC/ SEPARATION OF URANIUM BY SOLVENT EXTRACTION WITH TRI N CCTYL PHOSPHINE OXIDE AND 64PRR-050
 ZYL) PHENOL DETERMINATION OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 (ALPHA METHYL BEN 64PRR-080
 C WAVES / POLAROGRAPHY IN NONAQUEOUS SOLVENTS AND SOLVENT EXTRACTS) /OGRAPHY / RESOLUTION OF POLAROGRAPHI 64PRR-062
 /RAPHY TO THE DETERMINATION OF METAL COMPLEXES IN ORGANIC EXTRACTS AND COMPENSATION OF POLAROGRAPHIC CELL/ 64A-01-01
 LARY OF A TEFLON DROPPING MERCURY ELECTRODE FABRICATION OF THE VERTICAL ORIFICE TEFLON CAPIL 64PRR-001
 LOW LEVEL ANALYSES (RADIUM-226 / THORIUM / COAL / FALLOUT / LEAD-210) 64A-12-03J
 /ELOPMENT GROUP MONTHLY SUMMARY - DEC., 1963 / JAN., 1964 / FEB., 1964 / MAR., 1964 / APR., 1964 / MAY, 1964 / / 64PRR-105
 NITRATE (NITROGEN) VOLUMETRIC FERROUS AMMONIUM SULFATE METHOD 64PRR-121
 CHROMIUM IN MSRE FUEL, AMPEROMETRIC FERROUS SULFATE TITRATION METHOD 64PRR-118
 DE OXIDE FILM FORMATION ON THE PYROLYTIC GRAPHITE ELECTRO 64A-06-03B
 DISSOLUTION OF IRRADIATED, HIGH FIRED, REFRACTORY NUCLEAR MATERIALS 64PRR-116
 M-252 - APPLICATION OF PROMPT GAMMA-RAYS FROM SPONTANEOUS FISSION / METHOD FOR DETERMINATION OF CALIFORNIU 64PRR-051
 YIELDS OF KRYPTON AND XENON FROM FISSION OF URANIUM 64A-12-03G
 A STUDY OF FISSION YIELDS OF AMERICIUM-241 64PRR-057
 ION CONCENTRATIONS OF ORGANIC CONTAMINANTS IN AIR FLAME IONIZATION DETERMINATION OF PARTS PER BILL 64A-06-04
 CHEMICAL ISOLATION AND FLAME PHOTOMETRIC DETERMINATION OF BARIUM 64PRR-281
 THE COLLECTION AND FLAME PHOTOMETRIC DETERMINATION OF CESIUM 64PRR-026
 FLAME PHOTOMETRY (SEPARATION OF BARIUM FROM ALK 64A-08-01C
 ALL METALS AND ALKALINE EARTH ELEMENTS) FLAME SPECTROPHOTOMETER SAFETY C 64A-01-07
 IRCUIT FOR THE MULTIPLIER PHOTOTUBE OF THE ORNL MODEL VII FLUIDIZED COKE / 3,9 DI ETHYL TRI DECYL AMINE 6/ 64A-05-04
 / SULFIDE / MERCURY(II) DI N BUTYL PHOSPHORO DI THIOATE / FLUO BORATE / HYDRATED NICKEL FLUO BORATE / HYD/ 64A-13
 / PREPARATIONS (HYDRATED VANADIUM(III) SULFATE / LITHIUM FLUO BORATE / HYDRATED VANADIUM(III) FLUO BORAT/ 64A-13
 /IUM(III) SULFATE / LITHIUM FLUO BORATE / HYDRATED NICKEL FLUO BORATE / POTASSIUM SULFIDE / LITHIUM HYPO / 64A-13
 /E / HYDRATED NICKEL FLUO BORATE / HYDRATED VANADIUM(III) FLUORESCENCE ANALYSIS OF MULTICOMPONENT ALLOYS / 64A-08-01A
 /MENT OF ABSORPTION-EDGE HEIGHT / COMPUTER CODE FOR X-RAY RAPID SCAN VOL 64PRR-046
 TAMMETRY - CHRONOPOTENTIOMETRIC STUDIES OF IRON IN MOLTEN FLUORIDE - VOLTAMMETRY OF NICKEL 64PRR-045
 IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE - VOLTAMMETRY OF NICKEL(II) 64A-02-02C
 IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORID 64A-02-01C
 DE AND IN / ABSORPTION SPECTRA OF URANIUM(III) IN LITHIUM FLUORIDE - BERYLLIUM FLUORIDE (PREPARATION OF / 64A-02-01C
 /- BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN LITHIUM FLUORIDE - SODIUM FLUORIDE / LITHIUM FLUORID/ 64A-02-02
 /UORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUOR/ 64A-02-02
 /UORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE / LITHIUM FLUORIDE - LITHIUM FLUORIDE - POTASSIUM FLUORIDE 64PRR-104
 - URANIUM/ DETERMINATION OF TRACES OF IRON(III) IN SODIUM FLUORIDE - POTASSIUM FLUORIDE 64PRR-045
 VOLTAMMETRY OF NICKEL IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE VOLT 64A-02-02C
 AMMETRY OF NICKEL(II) IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE - URANIUM(IV) FLU/ 64PRR-104
 /TION OF TRACES OF IRON(III) IN SODIUM FLUORIDE - LITHIUM FLUORIDE - POTASSIUM FLUORIDE / LITHIUM FLUORID/ 64A-02-02
 /MOLTEN FLUORIDE SALT SYSTEMS (LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE EUCTIC /ONS ABOU 64PRR-070
 T NICKEL(II) IONS IN THE MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE WITH SEVERAL ACTI/ 64PRR-321
 /IONS OF THE REACTION OF MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE 64A-02-02
 / / VOLTAMMETRY OF MOLTEN FLUORIDE SALT SYSTEMS (LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE 64A-02-02C
 VOLTAMMETRY OF NICKEL(II) IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE 64PRR-045
 VOLTAMMETRY OF NICKEL IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE/ 64PRR-070
 /UORIDE IONS ABOUT NICKEL(III) IONS IN THE MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE/ 64PRR-321
 /OTOMETRIC OBSERVATIONS OF THE REACTION OF MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE/ 64A-02-01C
 /N(III) IN SODIUM FLUORIDE - LITHIUM FLUORIDE - POTASSIUM FLUORIDE - URANIUM(IV) FLUORIDE WITH THIO CYANA/ 64PRR-104
 / SPECTRA OF URANIUM(III) IN LITHIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN LITHIUM FL/ 64A-02-01C
 - ZIRCONIUM FLUORIDE AND IN LITHIUM FLUORIDE - BERYLLIUM FLUORIDE (PREPARATION OF SOLUTIONS) / FLUORIDE 64A-02-01C
 /SYSTEMS (LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORID/ 64A-02-02
 /RIDE - POTASSIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORID/ 64A-02-02
 /RIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / PYROLYTIC GRAPHITE INDICATOR ELECTRO/ 64A-02-02
 APPLIED NEUTRON ACTIVATION ANALYSIS (OXYGEN-18 / FLUORIDE / SELENIUM) 64A-12-07G
 /RIDE - BERYLLIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / PYROLYTIC GRAPH/ 64A-02-02
 /II) IN LITHIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN LITHIUM FLUORIDE - BERYLLIUM FL/ 64A-02-01C
 EQUILIBRIUM DISTRIBUTION OF METAL - FLUORIDE COMPLEXES 64PRR-029
 THE MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE EUCTIC /ONS ABOUT NICKEL(II) IONS IN 64PRR-070
 ION CELL) ABSORPTION SPECTRUM OF URANIUM(VI) GAS (NICKEL SPECTROPHOTOMETRIC ABSORPT 64A-02-01F
 HE ROTATING DI/ SPECTROCHEMICAL DETERMINATION OF VOLATILE FLUORIDE IMPURITIES IN URANIUM COMPOUNDS USING T 64PRR-082
 FLUORIDE IN MSRE FUEL, PYROLYSIS METHOD 64PRR-119
 N LITHIUM FLUORIDE - SODIUM FLUORIDE - P/ COORDINATION OF FLUORIDE IONS ABOUT NICKEL(III) IONS IN THE MOLTE 64A-08-02B
 DETERMINATION OF CERTAIN IMPURITIES IN LITHIUM FLUORIDE POWDER BY SPARK EXCITATION 64PRR-070
 /ITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COU/ 64PRR-133
 /ITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COU/ 64PRR-137
 /ITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - PROPORTIONAL ALPHA COU/ 64PRR-140
 VOLTAMMETRIC MEASUREMENTS IN MOLTEN FLUORIDE SALT SYSTEMS 64PRR-297
 M FLUORIDE - POTASSIUM FLUORIDE / / VOLTAMMETRY OF MOLTEN FLUORIDE SALT SYSTEMS (LITHIUM FLUORIDE - SODI 64A-02-02
 CONTAINERS FOR MOLTEN FLUORIDE SALTS 64A-02-01B

DECOMPOSITION POTENTIALS OF PURE METALS IN MOLTEN FLUORIDE SALTS	64A-02-02B
AMPEROMETRIC TITRATION OF CHROMIUM IN MIXTURES OF FLUORIDE SALTS	64PRR-012
Y SPECTROPHOTOMETRIC STUDIES OF REDOX REACTIONS IN MOLTEN FLUORIDE SALTS	DIRECT 64PRR-319
ODE / NICKEL / REFERENCE ELECTRODES COMPATIBLE WITH MOLTEN FLUORIDE SALTS (PLATINUM QUASI REFERENCE ELECTRODES)	64A-02-02E
RECOVERY OF PROTACTINIUM AND URANIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS OXIDES	64PRR-065
RECOVERY OF URANIUM AND PROTACTINIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS OXIDES	64PRR-101
OF MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE WITH SEVERAL ACTIVE METALS / THE REACTION	64PRR-321
IDE - LITHIUM FLUORIDE - POTASSIUM FLUORIDE - URANIUM(IV) FLUORIDE WITH THIO CYANATE / (III) IN SODIUM FLUORIDE	64PRR-104
VOLTAMMETRY AND CHRONOPOTENTIOMETRY OF IRON IN MOLTEN FLUORIDES	64PRR-295
POLAROGRAPHY IN MOLTEN FLUORIDES	64PRR-296
RENT - VOLTAGE CURVES FOR ZIRCONIUM AND URANIUM IN MOLTEN FLUORIDES	CUR 64PRR-047
LIQUID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO ACETONE	64PRR-021
LIQUID-LIQUID EXTRACTION OF CESIUM WITH THENOYL TRI FLUORO ACETONE	64PRR-022
E LIQUID-LIQUID EXTRACTION OF RADIOTIN WITH 2 THENOYL TRI FLUORO ACETONE	SELECTIV 64PRR-064
Y IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (TTA) EXTRACTION - PROPORTIONA/	64PRR-138
EFFECT OF COBALT-60 GAMMA RADIATION ON 2 THENOYL TRI FLUORO ACETONE (TTA) SOLUTIONS	64A-03-04
TOTAL PLUTONIUM, THENOYL TRI FLUORO ACETONE EXTRACTION METHOD	64PRR-219
REACTOR NEUTRON FLUX - CHARACTERISTICS AND USES	64PRR-002
REPORT OF FOREIGN TRAVEL	64PRR-091
REPORT ON FOREIGN TRAVEL	64PRR-094
REPORT OF FOREIGN TRAVEL	64PRR-115
REPORT OF FOREIGN TRAVEL JULY-1-30, 1963	64PRR-074
REPORT ON FOREIGN TRAVEL MAR. 21-APR. 11, 1964	64PRR-084
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC SCIENCE	64A-12-07B
APPLICATION OF NUCLEAR ANALYSIS TO FORENSIC SCIENCE	64PRR-274
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC SCIENCE I. PHYSICAL EVIDENCE	64PRR-014
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC SCIENCE II. DRUGS	64PRR-015
S) DISPOSAL OF RADIOACTIVE WASTES IN NATURAL SALT FORMATIONS (HIGH TEMPERATURE CHEMICAL DOSIMETER	64A-06-02
E / REACTIONS IN CONCENTRATED LITHIUM CHLORIDE SOLUTIONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID / W	65A-06-01
CONCENTRATED LITHIUM CHLORIDE SOLUTIONS - DETERMINATION OF FREE ACID AND HYDROLYZABLE METAL REACTIONS IN C	64PRR-291
RADIOLYSIS OF CHLORIDE SOLUTIONS (SCAVENGING OF HYDROXYL FREE RADICAL WITH METHANOL)	64A-03-05
SEPARATION OF PROTACTINIUM FROM MOLTEN SALT REACTOR FUEL COMPOSITION	64PRR-333
VOLTAMMETRY OF THE MSR COOLANT SALT AND MSR FUEL SALT	64A-02-02D
ZIRCONIUM IN MSRE FUEL, AMPEROMETRIC CUPFERRON TITRATION METHOD	64PRR-117
CHROMIUM IN MSRE FUEL, AMPEROMETRIC FERROUS SULFATE TITRATION MET	64PRR-118
URANIUM, COPPER, AND NICKEL IN HOMOGENEOUS REACTOR FUEL, COULOMETRIC TITRATION METHOD	64PRR-264
URANIUM IN MSRE FUEL, POLAROGRAPHIC METHOD	64PRR-120
FLUORIDE IN MSRE FUEL, PYROLYSIS METHOD	64PRR-119
CHEMICAL ANALYSIS OF ADVANCED REACTOR FUELS	64A-05
CE TEFLON DROPPING MERCURY ELECTRODE FOR USE IN OBTAINING FUNDAMENTAL POLAROGRAPHIC DATA / HORIZONTAL ORIFI	64A-05-05A
ANALYSIS OF ARC FUSED EUROPIUM MOLYBDATE	64A-06-15
INSTRUMENTAL APPROACHES TO ANALYSIS OF FUSED SALTS (ELECTRON SPIN RESONANCE)	64A-02-03
PRESENT BYWAYS AND FUTURE TRENDS IN ACTIVATION ANALYSIS	64PRR-007
/E / CHROMIUM / COPPER / DYSPROSIUM / ERBIUM / EUROPIUM / GADOLINIUM / GALLIUM / GERMANIUM / HAFNIUM / HO/	64PRR-154
// COPPER / DYSPROSIUM / ERBIUM / EUROPIUM / GADOLINIUM / GALLIUM / GERMANIUM / HAFNIUM / HOLMIUM / INDIU/	64PRR-154
ETERMINATION OF IMPURITIES IN URANIUM COMPOUNDS USING THE GALLIUM OXIDE CARRIER DISTILLATION TECHNIQUE / D	64PRR-083
RADIOACTIVITY IN AQUEOUS SOLUTIONS, PYRIDINE EXTRACTION - GAMMA COUNTING METHOD RUTHENIUM	64PRR-150
EFFECT OF COBALT-60 GAMMA IONIZATION CHAMBER	64PRR-129
VII) IN PHOSPHORIC ACID SOLUTIONS OF / EFFECT OF COBALT-60 GAMMA RADIATION ON ARSENATO-III SOLUTIONS	64A-03-03
I METHYL GLYOXIME GAMMA RADIATION ON THE DETERMINATION OF URANIUM	64A-03-02
(TTA) SOLUTIONS EFFECT OF COBALT-60 GAMMA RADIATION ON THE REACTION OF NICKEL WITH D	64A-03-01
GAMMA RADIATION ON 2 THENOYL TRI FLUORO ACETONE	64A-03-04
GAMMA SCINTILLATION COUNTER	64PRR-147
GAMMA SPECTROMETER LIVE TIME ON PRECISION OF MEA	64A-12-02C
GAMMA SPECTROMETRY	64A-12-02F
GAMMA SPECTROMETRY NONDE	64PRR-304
GAMMA TRANSITIONS IN THE DECAY OF KRYPTON-79	64A-12-01B
GAMMA-RAY BRANCHING IN THE DECAY OF CERIUM-141	64A-12-01A
ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64A-12-05A
ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-090
ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-276
ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-293
EMENTS COMPUTER PROGRAM FOR ACCUMULATING STANDARD GAMMA-RAY SPECTRA AND FOR QUALITY CONTROL MEASUR	64A-12-05B
TON SCATTERED ANNIHILATION GAMMA-RAY SUM PEAK OBSERVED IN 180 DEGREE COMP	64PRR-040
/XPERIMENTAL STUDY OF ARTIFACTS AND ERRORS ENCOUNTERED IN GAMMA-RAY SPECTROMETRY FOR RADIOCHEMISTRY AND A/	64PRR-294
ANIUM DIODE DETECTORS GAMMA-RAY SPECTROSCOPY WITH LITHIUM DRIFTED GERM	64A-12-02B
METRY 180 DEGREE COMPTON SCATTERED ANNIHILATION GAMMA-RAY SUM PEAK OBSERVED IN GAMMA-RAY SPECTRO	64PRR-040
DETERMINATION OF CALIFORNIUM-252 - APPLICATION OF PROMPT GAMMA-RAYS FROM SPONTANEOUS FISSION / METHOD FOR	64PRR-051
) ABSORPTION SPECTRUM OF URANIUM(VI) FLUORIDE GAS (NICKEL SPECTROPHOTOMETRIC ABSORPTION CELL	64A-02-01F
GASES (NITROGEN DI OXIDE / DI NITROGEN TRI OXIDE / CHLO/ GAS CHROMATOGRAPH FOR THE ANALYSIS OF CORROSIVE	64A-05-01
QUEOUS AND NITRIC ACID SOLUTIONS COMBUSTION GAS CHROMATOGRAPHIC DETERMINATION OF CARBON IN A	64A-05-03
TWO CARBON THROUGH FIVE CARBON PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHIC METHOD	64PRR-123
FOUR CARBON THROUGH EIGHT CARBON PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHIC METHOD	64PRR-124
/ATIVE AND QUANTITATIVE ANALYSIS OF ALIPHATIC DILUENTS BY GAS CHROMATOGRAPHY (SOLVENT EXTRACTANTS / PARA/	64A-05-02
/RADIOACTIVITY STANDARDS, NUCLEAR ANALYSIS, SPECTROSCOPY, GAS CHROMATOGRAPHY, AUTOMATION, ELECTROANALYTIC/	64PRR-038
OGY II. ANALYSIS OF THE HYDROLYSIS PRODUCTS OF URANIUM / GAS CHROMATOGRAPHY AS APPLIED TO NUCLEAR TECHNOL	64PRR-035
GAS-COOLED REACTOR	64A-04-02
GASES	64PRR-017
GASES (NITROGEN DI OXIDE / DI NITROGEN TRI OXID	64A-05-01
GASES AND IMPURITIES IN REACTOR COOLANT WATER / E	64PRR-100
GASES IN SOLIDS - RELEASE MEASUREMENT AND COLLEC	64PRR-266
GASES, MOLECULAR SIEVE ABSORPTION METHOD	64PRR-152
GEIGER-MUELLER COUNTER	64PRR-130
GENERALIZED COMPUTER PROGRAM TO OBTAIN REACTION	64PRR-271
GENERATOR	64A-12-08
GENERATOR	64A-12-08C
GENERATOR	64A-12-08E
GENERATORS - ITS RAPID ESTIMATION AND ITS INFLUE	64A-12-08A
GENERATORS - RAPID ESTIMATION AND INFLUENCE IN A	64PRR-306
GEOLOGICAL AGE DETERMINATION BY ISOTOPIC MEASURE	64PRR-323
GERMANIUM / HAFNIUM / HOLMIUM / INDIUM / IODINE/	64PRR-154
GERMANIUM DIODE DETECTORS	64A-12-02B

POLAROGRAPHY IN HYDROFLUORIC ACID AND OTHER SOLID INDICATOR ELECTRODES (PYROLYTIC GRAPHITE /	GLASS CORRODING MEDIA	64A-05-05
GAMMA RADIATION ON THE REACTION OF NICKEL WITH DI METHYL ORE SELECTION FOR PROJECT COACH (TRANSPLUTONIUM /	GLASSY CARBON)	64A-06-03
/144 / CESIUM-134 / CHROMIUM-51 / COBALT-59 / COPPER-64 /	GLASSY CARBON INDICATOR ELECTRODE	64A-06-03A
/M-134 / CHROMIUM-51 / COBALT-58 / COPPER-64 / GOLD-198 /	GLYOXIME EFFECT OF COBALT-60	64A-03-01
SOLID INDICATOR ELECTRODES (PYROLYTIC	GNOME)	64A-12-03H
CRO REDOX AND ACID - BASE POTENTIOMETRIC TITRA/ PYROLYTIC	GOLD-198 / GOLD-199 / IODINE-131 / IRIIDIUM-194 /	64PRR-230
ODE FOR MICRO REDOX AND ACID - BASE POTENTIOME/ PYROLYTIC	GOLD-199 / IODINE-131 / IRIIDIUM-194 / IRON-55, /	64PRR-230
OXIDE FILM FORMATION ON THE PYROLYTIC	GRAPHITE / GLASSY CARBON)	64A-06-03
SEI(II), CHROMIUM(VI), AND VANADIUM(IV) WITH THE PYROLYTIC	GRAPHITE CUP AS BOTH VESSEL AND ELECTRODE FOR MI	64PRR-066
RATION OF URANIUM(IV) WITH CERIUM(IV) UTILIZING PYROLYTIC	GRAPHITE CUP AS BOTH VESSEL AND INDICATOR ELECTR	64A-06-12
DETERMINATION OF CHLORIDE WITH A PYROLYTIC	GRAPHITE ELECTRODE	64A-06-03B
IDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / PYROLYTIC	GRAPHITE ELECTRODE /METRY OF CERIUM(IV), MANGANE	64PRR-049
) PROCESS SOLUTIONS, DIRECT MEASUREMENT METHOD	GRAPHITE ELECTRODES	64PRR-048
) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION - /	GRAPHITE INDICATOR ELECTRODE	64A-06-11
) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL/	GRAPHITE INDICATOR ELECTRODE) / / LITHIUM FLUOR	64A-02-02
// ERBIUM / EUROPIUM / GADOLINIUM / GALLIUM / GERMANIUM /	GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU	64PRR-132
) OX/ DISSOLUTION OR DECOMPOSITION OF VARIOUS MATERIALS (	GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU	64PRR-133
STUDIES OF NEUTRON DEFICIENT	GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU	64PRR-134
ABSORPTION OF TRACE ELEMENTS BY	HAFFNIUM / HOLMIUM / INDIUM / IODINE / IRIIDIUM /	64PRR-154
INDIVIDUAL IDENTIFICATION BY ACTIVATION ANALYSIS OF	HAFFNIUM OXIDE / MERCURY(II) SULFIDE / URANIUM(IV	64A-05-04
NEW ISOMER OF BROMINE - BROMINE-82M (	HAFFNIUM RADIONUCLIDES	64A-12-01G
REDETERMINATION OF THE	HAIR	64A-12-07E
A REDETERMINATION OF THE	HAIR ANALYSIS	64A-12-07F
SIGNIFICANCE OF JUNCTION POTENTIALS IN THE MEASUREMENT OF	HAIR AND ITS SURFACE CONTAMINATION	64PRR-268
ABSORPTION SPECTRA OF MOLTEN ALKALI METAL - ALKALI METAL	HALF-LIFE / NEUTRON ACTIVATION CROSS SECTION)	64A-12-01D
INEARLY VARYING PCTENTIAL (POLAROGRAPHY / ELECTROLYSIS /	HALF-LIFE MEASUREMENTS (LANTHANUM-140)	64A-12-01H
/F RADIOACTIVE SOLUTIONS / MEASUREMENT OF ABSORPTION-EDGE	HALF-LIFE OF ARSENIC-76	64A-12-01J
TIUM-89 AND STRONTIUM-90 IN AQUEOUS SOLUTIONS, DI 2 ETHYL	HALF-LIFE OF URANIUM-232	64A-12-01I
DISSOLUTION OF IRRADIATED,	HALF-LIFE OF URANIUM-232	64PRR-043
ACTIVATION ANALYSIS OF	HALF-WAVE POTENTIAL VALUES	64A-05-05B
ACTIVATION ANALYSIS OF	HALIDE SYSTEMS	64A-02-01D
/CHLORIDE / URANIUM TRI CHLORIDE / DYSPROSIUM PHOSPHIDE /	HANGING MERCURY DROP ELECTRODE) /AMETRY WITH L	64A-01-06
)	HEIGHT / COMPUTER CODE FOR X-RAY FLUORESCENCE A/	64A-08-01A
DESIGN AND CONSTRUCTION OF ORNL	HELIUM-3 ACTIVATION ANALYSIS	64A-12-07K
ING DRAWINGS / TEST SPECIFICATIONS / T/ ORNL MODEL Q-2564	HEXYL PHOSPHORIC ACID - AMSCO EXTRACTION METHOD	64PRR-142
L Q-2564	HIGH FIRED, REFRACTORY NUCLEAR MATERIALS	64PRR-116
ACTS AND COMPENSATION OF POLAROGRAPHIC CELL RESISTANCE IN	HIGH LEVEL ALPHA RADIATION LABORATORY	64B-18-01
SPOSAL OF RADIOACTIVE WASTES IN NATURAL SALT FORMATIONS (	HIGH PURITY MATERIALS	64A-12-07I
DETERMINATION OF CARBON IN ALKALI METALS BY	HIGH PURITY MATERIALS	64PRR-061
NICKEL	HIGH PURITY POTASSIUM CHLORIDE / POTASSIUM OXID/	64A-13
Y	HIGH RADIATION LEVEL ANALYTICAL FACILITY (HRLAF	64B-18-06
F SMALL CRYSTALS	HIGH RADIATION LEVEL ANALYTICAL LABORATORY	64PRR-018
COPY USING LONG ABSORPTION PATH LENGTHS AND A DEMOUNTABLE	HIGH SENSITIVITY COULOMETRIC TITRATOR (ENGINEER	64A-01-05
/ EUROPIUM / GADOLINIUM / GALLIUM / GERMANIUM / HAFFNIUM /	HIGH SENSITIVITY COULOMETRIC TITRATOR, ORNL MODE	64PRR-081
METHOD	HIGH SPECIFIC RESISTANCE SOLUTIONS /ORGANIC EXTR	64PRR-001
/AL REDOX REACTION IN AQUEOUS HYDROFLUORIC ACID WITH THE	HIGH TEMPERATURE CHEMICAL DOSIMETERS)	64A-06-02
RODE FOR USE IN OBTAINING FUNDAMENTAL / EVALUATION OF THE	HIGH TEMPERATURE OXIDATION	64A-06-06
RODE BY OTHERS	HIGH TEMPERATURE SPECTROPHOTOMETRIC CELL ASSEMBL	64A-02-01A
EXTENSION OF THE USE OF THE	HOLDER FOR USE IN OBTAINING ABSORPTION SPECTRA O	64A-02-01E
GENERAL	HOLLOW CATHODE LAMP ATOMIC ABSORPTION SPECTROS	64PRR-005
HIGH RADIATION LEVEL ANALYTICAL FACILITY (	HOLMIUM / INDIUM / IODINE / IRIIDIUM / IRON / LA/	64PRR-154
/CF / ARSENIC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-115M	HOMOGENEOUS REACTOR FUEL, COULOMETRIC TITRATION	64PRR-264
/((HYDRATED VANADIUM(III) SULFATE / LITHIUM FLUO BORATE /	HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELEC/	64A-05-05C
/TE / LITHIUM FLUC BORATE / HYDRATED NICKEL FLUO BORATE /	HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECT	64A-05-05A
RATE / HYDRATED NICKEL FLUO BOR/ INORGANIC PREPARATIONS (	HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECT	64A-05-05D
DI ETHYL TRI DECYL AMINE 6 AMINC 3,9 DI ETHYL TRI DECANE	HOT ANALYSES LABORATORY	64B-18-03
NIORIUM, SPECTROMETRIC	HRLAF)	64B-18-06
POLAROGRAPHY IN	HSA / CERIUM-141, CERIUM-144 / CESIUM-134 / CHR/	64PRR-230
/HE DIVALENT LEAD TO LEAD METAL REDOX REACTION IN AQUEOUS	HYDRATED NICKEL FLUC BORATE / HYDRATED VANADIUM/	64A-13
II) INDICATOR METHOD THORIUM, AMPEROMETRIC DI SODIUM DI	HYDRATED VANADIUM(III) FLUO BORATE / POTASSIUM /	64A-13
I) METHOD ALUMINUM AND THORIUM, VOLUMETRIC DI SODIUM DI	HYDRATED VANADIUM(III) SULFATE / LITHIUM FLUO BO	64A-13
/ RAPID DETERMINATION OF LOW CONCENTRATIONS OF OXYGEN AND	HYDRO CHLORIDE) /THIOATE / FLUIDIZED COKE / 3,9	64A-05-04
CUUM EXTRACTION	HYDRO QUINONE METHOD	64PRR-125
/HY AS APPLIED TO NUCLEAR TECHNOLOGY II. ANALYSIS OF THE	HYDROFLUORIC ACID AND OTHER GLASS CORRODING MEDI	64A-05-05
IN CONCENTRATED LITHIUM CHLORIDE SOLUTIONS (FREE ACID /	HYDROFLUORIC ACID WITH THE HORIZONTAL ORIFICE T	64A-05-05C
THIUM CHLORIDE SOLUTIONS - DETERMINATION OF FREE ACID AND	HYDROGEN ETHYLENE DI AMINE TETRA ACETATE - IRON(	64PRR-131
L 2 (ALPHA METHYL BENZYL) PHENCL / TETRA BUTYL AMMONIUM	HYDROGEN ETHYLENE DI AMINE TETRA ACETATE (EDTA	64PRR-127
BRCRN (BCRATE) POTENTIOMETRIC MANNITOL - SODIUM	HYDROGEN IN ALKALI METALS BY A MODIFIED AMALGAM/	64PRR-288
PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, VOLUMETRIC SODIUM	HYDROGEN IN ALKALI METALS BY AMALGAMATION AND VA	64A-06-07
RADIOLYSIS OF CHLORIDE SOLUTIONS (SCAVENGING OF	HYDROLYSIS PRODUCTS OF URANIUM CARBIDES AND THO/	64PRR-035
/ VANADIUM(III) FLUO BORATE / POTASSIUM SULFIDE / LITHIUM	HYDROLYZABLE CATION / BORIC ACID / WEAK BASES)	65A-06-01
UM-137	HYDROLYZABLE METAL REACTIONS IN CONCENTRATED LI	64PRR-291
INTERNATIONAL ATOMIC ENERGY AGENCY (	HYDROXIDE / LITHIUM CHLORIDE SALT BRIDGE) /BUTY	64A-06-08
THE NEW	HYDROXIDE TITRATION METHOD	64PRR-220
XCITATION	HYDROXIDE TITRATION METHOD /RIC ACID, AND ORTHO	64PRR-265
TIVE METHODS FOR THE DETERMINATION OF DISSOLVED GASES AND	HYDROXYL FREE RADICAL WITH METHANOL)	64A-03-05
M OXIDE CARRIER DISTILL/ SPECTROCHEMICAL DETERMINATION OF	HYPO BROMITE / ANHYDROUS ALUMINUM CHLORIDE / TH/	64A-13
NG DI/ SPECTROCHEMICAL DETERMINATION OF VOLATILE FLUORIDE	IAEA) INTERCOMPARISON OF DETERMINATIONS OF CESI	64A-12-02D
EDOX AND ACID - BASE POTENTIOMETRIC TITRATIONS (PLATINUM	IMAGE OF ANALYTICAL CHEMISTRY IN SCIENCE	64PRR-332
PUTER INPUT INFORMATION FOR ANNUAL REVISION TO CUMULATIVE	IMPURITIES IN LITHIUM FLUORIDE POWDER BY SPARK E	64A-08-02B
CUMULATIVE	IMPURITIES IN REACTOR COOLANT WATER /EY OF SENSI	64PRR-100
953-1963)	IMPURITIES IN URANIUM COMPOUNDS USING THE GALLIUM	64PRR-083
GLASSY CARBON	IMPURITIES IN URANIUM COMPOUNDS USING THE ROTATI	64PRR-082
DETERMINATION OF CHLORIDE WITH A PYROLYTIC GRAPHITE	IN-BURET REFERENCE ELECTRODE) /RODE FOR MICRO R	64A-06-12
YLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / PYROLYTIC GRAPHITE	INDEXES FOR THE ORNL MASTER ANALYTICAL MANUAL /M	64PRR-146
ASE POTENTIOME/ PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND	INDEXES TO THE ORNL MASTER ANALYTICAL MANUAL	64C-20-01
SY CARBON)	INDEXES TO THE ORNL MASTER ANALYTICAL MANUAL (I	64PRR-096
SOLID	INDICATOR ELECTRODE	64A-06-03A
	INDICATOR ELECTRODE	64A-06-11
	INDICATOR ELECTRODE) / / LITHIUM FLUORIDE - BER	64A-02-02
	INDICATOR ELECTRODE FOR MICRO REDOX AND ACID - B	64A-06-12
	INDICATOR ELECTRODES (PYROLYTIC GRAPHITE / GLAS	64A-06-03

UM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE - IRON(II)	INDICATOR METHOD THORIUM, AMPEROMETRIC DI SODI	64PRR-131
SULFUR (SULFIDE AND NONSULFIDE)	INDIRECT POLAROGRAPHIC METHOD	64PRR-126
// GADOLINIUM / GALLIUM / GERMANIUM / HAFNIUM / HOLMIUM /	INDIUM / IODINE / IRIIDIUM / IRON / LANTHANUM /	64PRR-154
OF HAIR AND ITS SURFACE CONTAMINATION	INDIVIDUAL IDENTIFICATION BY ACTIVATION ANALYSIS	64PRR-268
DEXES FOR THE ORNL MASTER / PREPARATION OF COMPUTER INPUT	INFORMATION FOR ANNUAL REVISION TO CUMULATIVE IN	64PRR-146
YL BORAZINE	INFRARED ABSORPTION SPECTRA OF N,N,N// TRI METH	64PRR-079
	INFRARED SPECTROSCOPY	64A-10
SULFATE / LITHIUM FLUO BCRATE / HYDRATED NICKEL FLUO BOR/	INORGANIC PREPARATIONS (HYDRATED VANADIUM(III)	64A-13
IVE INDEXES FOR THE ORNL MASTER / PREPARATION OF COMPUTER	INPUT INFORMATION FOR ANNUAL REVISION TO CUMULAT	64PRR-146
TS (ELECTRON SPIN RESONANCE)	INSTRUMENTAL APPROACHES TO ANALYSIS OF FUSED SAL	64A-02-03
CAL MANUAL	INSTRUMENTAL METHODS FOR THE ORNL MASTER ANALYTI	64PRR-226
	INSTRUMENTATION	64A-01
	INSTRUMENTATION	64A-06-03G
	INSTRUMENTATION	64A-11-03
/ ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY - ANALYTICAL	INSTRUMENTATION - MOLTEN SALT SYSTEMS, RADIOACT/	64PRR-038
REVIEW OF - ELECTRONIC CIRCUITS AND	INSTRUMENTATION SYSTEMS	64PRR-027
INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)	INTERCOMPARISON OF DETERMINATIONS OF CESIUM-137	64A-12-02D
SECOND-ORDER	INTERFERENCE IN ACTIVATION ANALYSIS	64PRR-056
RCOMPARISON OF DETERMINATIONS OF CESIUM-137	INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA) INTE	64A-12-02D
	INTERNATIONAL DIRECTORY OF RADIOISOTOPES	64PRR-042
REVIEW OF -	IODIDE SCINTILLATION CRYSTALS / ERMINATION OF EUR	64PRR-019
OPIUM(II) AND TOTAL EUROPIUM - EUROPIUM ACTIVATED LITHIUM	IODINE EVALUATION OF IODINE-125	64PRR-076
MEASUREMENT TECHNIQUES FOR CLINICAL APPLICATIONS OF RADIO	IODINE / IRIIDIUM / IRON / LANTHANUM / LEAD / LI/	64PRR-154
/IUM / GALLIUM / GERMANIUM / HAFNIUM / HOLMIUM / INDIUM /	IODINE ACTIVITY IN AQUEOUS SOLUTIONS	64PRR-263
	IODINE ADSORBED ON CHARCOAL, NEUTRON ACTIVATION	64PRR-149
ANALYSIS (ISOTOPIC CARRIER) METHOD	IODINE-125 IN CLINICAL APPLICATIONS	64A-12-02E
	IODINE-125 IN CLINICAL APPLICATIONS	64PRR-024
ABSOLUTE DETERMINATION OF	IODINE-125 MEASUREMENT TECHNIQUES FOR CLINICAL A	64PRR-076
ABSOLUTE DETERMINATION OF	IODINE-125 MEASUREMENT TECHNIQUES FOR CLINICAL A	64PRR-277
APPLICATIONS OF RADIO IODINE	IODINE-131 / IRIIDIUM-194 / IRON-55, IRON-59 / M/	64PRR-230
APPLICATIONS	ION COMPLEXES	64PRR-077
/OMIUM-51 / COBALT-58 / COPPER-64 / GOLD-198 / GOLD-199 /	ION EXCHANGE SEPARATION OF BORON FROM OTHER ELEM	64PRR-221
EQUILIBRIUM DISTRIBUTION OF METAL -	IONIZATION CHAMBER	64PRR-129
ENTS	FLAME	64A-06-04
NCENTRATIONS OF ORGANIC CONTAMINANTS IN AIR	AUTO	64PRR-017
	IONS - SELECTIVE EXTRACTION OF MERCURY(II), SIL/	64A-12-03A
/KYL PHOSPHORO THICIC TRI AMIDES AS EXTRACTANTS FOR METAL	IONS ABOUT NICKEL(II) IONS IN THE MOLTEN LITHIUM	64PRR-070
FLUORIDE - SODIUM FLUORIDE - P/ COORDINATION OF FLUORIDE	IONS IN THE MOLTEN LITHIUM FLUORIDE - SODIUM FLU	64PRR-070
ORIDE - P/ COORDINATION OF FLUORIDE IONS ABOUT NICKEL(II)	IRIDIUM / IRON / LANTHANUM / LEAD / LITHIUM / L/	64PRR-154
/LIUM / GERMANIUM / HAFNIUM / HOLMIUM / INDIUM / IODINE /	IRIDIUM-194 / IRON-55, IRON-59 / MERCURY-203 /	64PRR-230
/BALT-58 / COPPER-64 / GOLD-198 / GOLD-199 / IODINE-131 /	IRON / LANTHANUM / LEAD / LITHIUM / LUTETIUM /	64PRR-154
/MANIUM / HAFNIUM / HOLMIUM / INDIUM / IODINE / IRIIDIUM /	IRON IN MOLTEN FLUORIDE	64PRR-046
RAPID SCAN VOLTAMMETRY - CHRONOPOTENTIOMETRIC STUDIES OF	IRON IN MOLTEN FLUORIDES	64PRR-295
VOLTAMMETRY AND CHRONOPOTENTIOMETRY OF	IRON-55	64PRR-059
IN AUTOMOTIVE ENGINES BY LIQUID SCINTILLATION COUNTING OF	IRON-55, IRON-59 / MERCURY-203 / MOLYBDENUM-99 /	64PRR-230
/ER-64 / GOLD-198 / GOLD-199 / IODINE-131 / IRIIDIUM-194 /	IRON-59 / MERCURY-203 / MOLYBDENUM-99 / NEODYMI/	64PRR-230
/OLD-198 / GOLD-199 / IODINE-131 / IRIIDIUM-194 / IRON-55,	IRON(II) INDICATOR METHOD THORIUM, AMPEROMETRI	64PRR-131
C DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE -	IRON(III) IN SODIUM FLUORIDE - LITHIUM FLUORIDE	64PRR-104
- POTASSIUM FLUORIDE - URANIUM/ DETERMINATION OF TRACES OF	IRRADIATED LIQUIDS	64A-06-09
TITRIMETRY OF ACIDS IN	IRRADIATED, HIGH FIRED, REFRACTORY NUCLEAR MATER	64PRR-116
IALS	DISSOLUTION OF	64A-12-02A
	EPITHERMAL NEUTRON	64A-12-08C
	TITANIUM	64A-14-01A
	METHYL	64PRR-078
	SYNTHESIS OF METHYL	64PRR-134
/OACTIVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI	ISO CYANIDE	64PRR-139
/OACTIVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI	ISO OCTYL AMINE (OR TRI CAPRYL AMINE) EXTRACT/	64PRR-278
BROMINE-82M - A NEW BROMINE	ISO OCTYL AMINE EXTRACTION - PROPORTIONAL ALPHA/	64A-12-01D
UTRON ACTIVATION CROSS SECTION)	ISOMER	64A-12-03F
SOMERS IN DIFFERENT CHEMICAL MEDIA	ISOMER OF BROMINE - BROMINE-82M (HALF LIFE / NE	64PRR-031
OF TELLURIUM-127, TELLURIUM-129, AN/ CHEMICAL EFFECTS OF	ISOMERIC TRANSITIONS - SEPARATION OF TELLURIUM I	64PRR-032
UM ISOMERS IN DIFFERENT CHEMICAL MEDIA/ CHEMICAL EFFECTS OF	ISOMERIC TRANSITIONS - SEPARATION OF THE ISOMERS	64A-12-03F
EFFECTS OF ISOMERIC TRANSITIONS - SEPARATION OF TELLURIUM	ISOMERIC TRANSITIONS - THE SEPARATION OF TELLURI	64PRR-032
CTS OF ISOMERIC TRANSITIONS - THE SEPARATION OF TELLURIUM	ISOMERS IN DIFFERENT CHEMICAL MEDIA	64PRR-032
/ICAL EFFECTS OF ISOMERIC TRANSITIONS - SEPARATION OF THE	ISOMERS IN DIFFERENT CHEMICAL MEDIA /EMICAL EFTE	64PRR-031
INTILLATOR FOR NEUTRON DETECTION USING LITHIUM-6 ENRICHED	ISOMERS OF TELLURIUM-127, TELLURIUM-129, AND TE/	64PRR-098
INTILLATOR FOR NEUTRON DETECTION USING LITHIUM-6 ENRICHED	ISOTOPE	64PRR-309
	ISOTOPE	64PRR-310
	APPLICATION OF	64PRR-315
	ISOTOPES TO ANALYTICAL CHEMISTRY	64PRR-151
NICKEL, NEUTRON ACTIVATION ANALYSIS (FAST NEUTRON -	ISOTOPIC AND ACCELERATOR NEUTRON SOURCES	64PRR-149
ODINE ADSORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSIS (	ISOTOPIC CARRIER) METHOD	64A-09-02
	ISOTOPIC CARRIER) METHOD	64PRR-033
HORO THIOATE IN AN/ SELECTIVE DETERMINATION OF MERCURY BY	ISOTOPIC COMPOSITION OF ATMOSPHERIC NEON	64PRR-154
/ BARIUM / BORON / BROMINE / CADMIUM / CALCIUM / CERIUM/	ISOTOPIC EXCHANGE WITH MERCURIC DI N BUTYL PHOSP	64PRR-102
	ISOTOPIC MASS SPECTROMETRY / ALUMINUM / ANTIMONY	64PRR-153
	ISOTOPIC MASS SPECTROMETRY OF THE ELEMENTS	64PRR-323
GENERAL OPERATING CONDITIONS FOR	ISOTOPIC MASS SPECTROMETRY OF THE ELEMENTS	64PRR-316
GEOLOGICAL AGE DETERMINATION BY	ISOTOPIC MEASUREMENTS	64A-12-07J
THE USE OF	ISOTOPIC NEUTRON SOURCES FOR CHEMICAL ANALYSIS	64PRR-105
NEUTRON ABSORPTION ANALYSIS WITH	ISOTOPIC SOURCES	64PRR-088
/ARCH AND DEVELOPMENT GROUP MONTHLY SUMMARY - DEC., 1963 /	JAN., 1964 / FEB., 1964 / MAR., 1964 / APR., 1964 //	64PRR-086
ORT, ANALYTICAL CHEMISTRY DIVISION	JAN.-DEC., 1963 - STATISTICAL QUALITY CONTROL REP	64PRR-085
STATISTICAL QUALITY CONTROL REPORT,	JAN.-JUNE, 1964	64PRR-087
AL QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIVISION,	JAN.-MAR., 1964	64PRR-105
AL QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIVISION,	JAN.-SEPT., 1963	64PRR-074
EB., 1964 / MAR., 1964 / APR., 1964 / MAY, 1964 / JUNE, 1964 /	JULY, 1964 / AUG., 1964 / SEPT.-OCT., 1964 / 1964 / F	64PRR-073
REPORT OF FOREIGN TRAVEL	JULY-1-30, 1963	64A-05-05B
TRIP REPORT,	JULY-16-AUG. 15, 1963	64PRR-105
AVE POTENTIAL VALUES	JUNCTION POTENTIALS IN THE MEASUREMENT OF HALF-W	64A-14-02
/N., 1964 / FEB., 1964 / MAR., 1964 / APR., 1964 / MAY, 1964 /	JUNE, 1964 / JULY, 1964 / AUG., 1964 / SEPT.-OCT., /	64A-01-04
DETERMINATION OF ALDEHYDES AND	KETONES	64PRR-152
CALCULATION OF DIFFUSION COEFFICIENT FROM THE	KOUTECKY EQUATION (COMPUTER PROGRAM DIFFUSE)	64A-12-03G
CULAR SIEVE ABSORPTION METHOD	KRYPTON AND XENON FROM CONTAMINATING GASES, MOLE	
	SEPARATION OF	
	YIELDS OF	

GASES IN SOLIDS - RELEASE MEASUREMENT AND COLLECTION FOR	MASS SPECTROMETRIC ANALYSIS	64B-16
	MASS SPECTROMETRIC ANALYSIS	TOTAL 64PRR-266
	MASS SPECTROMETRY	64A-09
	TRU MASS SPECTROMETRY	64A-09-01
/ BORON / BROMINE / CADMIUM / CALCIUM / CERIUM / ISOTOPIC	MASS SPECTROMETRY / ALUMINUM / ANTIMONY / BARIUM	64PRR-154
ISOTOPIC	MASS SPECTROMETRY OF THE ELEMENTS	64PRR-102
GENERAL OPERATING CONDITIONS FOR ISOTOPIC	MASS SPECTROMETRY OF THE ELEMENTS	64PRR-153
	ORNL MASTER ANALYTICAL MANUAL	64C-20
CUMULATIVE INDEXES TO THE	ORNL MASTER ANALYTICAL MANUAL	64C-20-01
MAINTENANCE OF THE	ORNL MASTER ANALYTICAL MANUAL	64C-20-02
	ORNL MASTER ANALYTICAL MANUAL	64C
TYPING AND PRINTING METHODS FOR THE	ORNL MASTER ANALYTICAL MANUAL	64PRR-225
WRITING INSTRUMENTAL METHODS FOR THE	ORNL MASTER ANALYTICAL MANUAL	64PRR-226
	INDEXES TO THE ORNL MASTER ANALYTICAL MANUAL (1953-1963)	64PRR-096
ON FOR ANNUAL REVISION TO CUMULATIVE INDEXES FOR THE	ORNL MASTER ANALYTICAL MANUAL /MPUTER INPUT INFORMATI	64PRR-146
THODS	ORNL MASTER ANALYTICAL MANUAL AND NUMBERING OF THE ME	64PRR-224
	ORNL MASTER ANALYTICAL MANUAL, SUPPLEMENT 6	64PRR-093
/.,1963 / JAN.,1964 / FEB.,1964 / MAR.,1964 / APR.,1964 /	MAY,1964 / JUNE,1964 / JULY,1964 / AUG.,1964 / /	64PRR-105
CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL ACID	MEDIA	64PRR-053
CHRONOPOTENTIOMETRY OF PLUTONIUM IN MINERAL ACID	MEDIA	64PRR-300
LAROGRAPHY IN HYDROFLUORIC ACID AND OTHER GLASS CORRODING	MEDIA	64A-05-05
S - SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL	MEDIA	64A-12-03F
THE SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL	MEDIA /EMICAL EFFECTS OF ISOMERIC TRANSITIONS -	64PRR-032
/CTIVE DETERMINATION OF MERCURY BY ISOTOPIC EXCHANGE WITH	MERCURIC DI N BUTYL PHOSPHORO THIOATE IN AN EXT	64PRR-033
/ON / LANTHANUM / LEAD / LITHIUM / LUTETIUM / MAGNESIUM /	MERCURY / MOLYBDENUM / NEODYMIUM / NEPTUNIUM / /	64PRR-154
BUTYL PHOSPHORO THIOATE IN AN/ SELECTIVE DETERMINATION OF	MERCURY BY ISOTOPIC EXCHANGE WITH MERCURIC DI N	64PRR-033
VARYING POTENTIAL (POLAROGRAPHY / ELECTROLYSIS / HANGING	MERCURY DROP ELECTRODE) /AMMETRY WITH LINEARLY	64A-01-06
VERTICAL ORIFICE RAPID TEFLON DROPPING	MERCURY ELECTRODE	64A-05-05E
HE VERTICAL ORIFICE TEFLON CAPILLARY OF A TEFLON DROPPING	MERCURY ELECTRODE	64PRR-095
OF FLUORIC ACID WITH THE HORIZONTAL ORIFICE TEFLON DROPPING	MERCURY ELECTRODE /EODX REACTION IN AQUEOUS HYDR	64A-05-05C
SION OF THE USE OF THE HORIZONTAL ORIFICE TEFLON DROPPING	MERCURY ELECTRODE BY OTHERS	64A-05-05D
AL / EVALUATION OF THE HORIZONTAL ORIFICE TEFLON DROPPING	MERCURY ELECTRODE FOR USE IN OBTAINING FUNDAMENT	64A-05-05A
	MERCURY-197M2, MERCURY-197, PRODUCT ANALYSIS GUIDE	64PRR-141
DE	MERCURY-197M2, MERCURY-197, PRODUCT ANALYSIS GUI	64PRR-141
/GOLD-199 / IODINE-131 / IRIIDIUM-194 / IRON-55, IRON-59 /	MERCURY-203 / MOLYBDENUM-99 / NEODYMIUM-147 - P/	64PRR-230
/XYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE /	MERCURY(II) DI N BUTYL PHOSPHORO DI THIOATE / F/	64A-05-04
/ OR DECCMPCSION OF VARIOUS MATERIALS (HAFNIUM OXIDE /	MERCURY(III) SULFIDE / URANIUM(IV) OXIDE / N TRI/	64A-05-04
S AS EXTRACTANTS FOR METAL IONS - SELECTIVE EXTRACTION OF	MERCURY(III), SILVER(II), AND COPPER(II) /TRI AMIDE	64A-12-03A
E SOLUTIONS - DETERMINATION OF FREE ACID AND HYDROLYZABLE	METAL REACTIONS IN CONCENTRATED LITHIUM CHLORID	64PRR-291
STUDIES OF THE ABSORPTION SPECTRA OF MOLTEN ALKALI	METAL - ALKALI METAL HALIDE SYSTEMS	64A-02-01D
EQUILIBRIUM DISTRIBUTION OF	METAL - FLUORIDE COMPLEXES	64PRR-029
EQUILIBRIUM DISTRIBUTION OF	METAL - ION COMPLEXES	64PRR-077
SPECTROMETRIC STUDY OF MOLTEN LITHIUM	METAL - LITHIUM CHLORIDE SOLUTIONS	64PRR-069
/TIAL AND DERIVATIVE POLAROGRAPHY TO THE DETERMINATION OF	METAL COMPLEXES IN ORGANIC EXTRACTS AND COMPENS/	64PRR-001
TANTS FOR METALS	METAL DI N BUTYL PHOSPHORO DI THIOATES AS EXTRAC	64A-12-03B
OF THE ABSORPTION SPECTRA OF MOLTEN ALKALI METAL - ALKALI	METAL HALIDE SYSTEMS	64A-02-01D
/EXA ALKYL PHOSPHORO THICIC TRI AMIDES AS EXTRACTANTS FOR	METAL IONS - SELECTIVE EXTRACTION OF MERCURY(III)	64A-12-03A
D WITH THE HOR/ PLAROGRAPHY OF THE DIVALENT LEAD TO LEAD	METAL REDOX REACTION IN AQUEOUS HYDROFLUORIC ACI	64A-05-05C
POTENTIOMETRIC MEASUREMENT	METAL 1,10 PHENANTHROLINE COMPLEX EQUILIBRIA BY	64PRR-023
	METALLIC OXIDES, LECO CONDUCTOMETRIC METHOD	64PRR-122
CARBON IN METALS AND	METALLURGY	64PRR-041
REVIEW OF - RADIOACTIVE TRACERS IN PHYSICAL	METALS	64A-12-03B
METAL DI N BUTYL PHOSPHORO DI THIOATES AS EXTRACTANTS FOR	METALS /HE REACTION OF MOLTEN LITHIUM FLUORIDE -	64PRR-321
SODIUM FLUORIDE - POTASSIUM FLUORIDE WITH SEVERAL ACTIVE	METALS AND ALKALINE EARTH ELEMENTS)	64A-08-01C
FLAME PHOTOMETRY (SEPARATION OF BARIUM FROM ALKALI	METALS AND METALLIC OXIDES, LECO CONDUCTOMETRIC	64PRR-122
METHOD	METALS BY A MODIFICATION OF THE AMALGAMATION MET	64A-06-05
HOD	METALS BY A MODIFIED AMALGAMATION TECHNIQUE /ATI	64PRR-288
ON OF LOW CCNCENTRATIONS OF OXYGEN AND HYDROGEN IN ALKALI	METALS BY AMALGAMATION AND VACUUM EXTRACTION	64A-06-07
DETERMINATION OF HYDROGEN IN ALKALI	METALS BY HIGH TEMPERATURE OXIDATION	64A-06-06
DETERMINATION OF CARBON IN ALKALI	METALS FROM URANIUM BY CELLULOSE COLUMN CHROMATO	64A-12-03E
GRAPHY	METALS IN MOLTEN FLUORIDE SALTS	64A-02-02B
DECOMPOSITION POTENTIALS OF PURE	METHANE /CTION WITH TRI N OCTYL PHOSPHINE OXIDE	64PRR-080
AND ITS DIRECT COLORIMETRIC DETERMINATION WITH DI BENZOYL	METHANOL)	64A-03-05
RIDE SOLUTIONS (SCAVENGING OF HYDROXYL FREE RADICAL WITH	METHYL ADENINE, AND METHYLATION OF 6 DI METHYL A	64PRR-036
MINO PURINE	METHYL AMINO PURINE	64PRR-036
HE STRUCTURE OF 3 METHYL ADENINE, AND METHYLATION OF 6 DI	METHYL AMMONIUM THIO CYANATE /LENT ACTINIDE ELEM	64PRR-050
ENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL	METHYL AMMONIUM THIO CYANATE /OM LANTHANIDE ELEM	64A-12-03C
ENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL	METHYL BENZYL) PHENOL DETERMINATION OF CESIUM	64PRR-062
AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 (ALPHA	METHYL BENZYL) PHENOL / TETRA BUTYL AMMONIUM HY	64A-06-08
NONAQUEOUS TITRIMETRY OF PHENOLS (4 SEC BUTYL 2 (ALPHA	METHYL BORAZINE	64A-14-01B
N,N,N,N// TRI	METHYL BORAZINE	64PRR-079
SYNTHESIS AND INFRARED ABSORPTION SPECTRA OF N,N,N,N// TRI	METHYL BORAZINE / BIS (OXYGEN, OXYGEN DI BUTYL/	64A-05-04
/ OXIDE / MERCURY(II) SULFIDE / URANIUM(IV) OXIDE / N TRI	METHYL BORAZINE AS A LIQUID SCINTILLATOR SOLVENT	64A-12-04B
FOR THERMAL NEUTRON DETECTION	METHYL GLYOXIME	64A-03-01
BALT-60 GAMMA RADIATION CN THE REACTION OF NICKEL WITH DI	METHYL ISO CYANIDE	64A-14-01A
	METHYL ISO CYANIDE	64PRR-078
SYNTHESIS OF	METHYL NAPHTHALENE	64A-12-04A
LIQUID SCINTILLATORS THAT CONTAIN I	METHYL NAPHTHALENE	64A-14-03
PURIFICATION OF ALPHA	METHYL NAPHTHALENE	64PRR-030
LIQUID SCINTILLATORS USING I	METHYLATION OF 6 DI METHYL AMINO PURINE	64PRR-036
THE STRUCTURE OF 3 METHYL ADENINE, AND	MICRO REDOX AND ACID - BASE POTENTIOMETRIC TITR/	64A-06-12
/ GRAPHITE CUP AS BOTH VESSEL AND INDICATOR ELECTRODE FOR	MICRO REDOX AND ACID - BASE POTENTIOMETRIC TITRA	64PRR-066
/ PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND ELECTRODE FOR	MICROSCOPE FACILITY FOR STUDYING RADIOACTIVE MAT	64A-11-01A
ERIALS	MICROSCOPICAL STUDY OF THE STRUCTURE OF SPHERICA	64PRR-317
L THORIA SOL-GEL BEADS	A	64A-11
	OPTICAL AND ELECTRON	64PRR-318
	ANALYTICAL ELECTRON	64A-11-04
ISTANCE TO OTHER LABORATORY CIVISIO/	ELECTRON AND ELECTRON DIFFRACTION RESEARCH ASS	64A-11-01
	ELECTRON	64PRR-053
CHRONOPOTENTIOMETRY OF PLUTONIUM IN	MINERAL ACID MEDIA	64PRR-300
CHRONOPOTENTIOMETRY OF PLUTONIUM IN	MINERAL ACID MEDIA	64A-12-08E
OR	MISCELLANEOUS USES OF THE 14-MEV NEUTRON GENERAT	64PRR-330
	MODERN METHODS IN LIQUID SCINTILLATOR TECHNOLOGY	

SEPARATION OF KRYPTON AND XENON FROM CONTAMINATING GASES,	MOLECULAR SIEVE ABSORPTION METHOD	64PRR-152
STUDIES OF THE ABSORPTION SPECTRA OF	MOLTEN ALKALI METAL - ALKALI METAL HALIDE SYSTEM	64A-02-01D
CAN VOLTAMMETRY - CHRONOPOTENTIOMETRIC STUDIES OF IRON IN	MOLTEN FLUORIDE	64PRR-046
VOLTAMMETRIC MEASUREMENTS IN	MOLTEN FLUORIDE SALT SYSTEMS	64PRR-297
- SODIUM FLUORIDE - POTASSIUM FLUORIDE / / VOLTAMMETRY OF	MOLTEN FLUORIDE SALT SYSTEMS (LITHIUM FLUORIDE	64A-02-02
CONTAINERS FOR	MOLTEN FLUORIDE SALTS	64A-02-01B
DECOMPOSITION POTENTIALS OF PURE METALS IN	MOLTEN FLUORIDE SALTS	64A-02-02B
DIRECT SPECTROPHOTOMETRIC STUDIES OF RECOX REACTIONS IN	MOLTEN FLUORIDE SALTS	64A-02-02E
ELECTRODE / NICKEL/ REFERENCE ELECTRODES COMPATIBLE WITH	MOLTEN FLUORIDE SALTS (PLATINUM QUASI REFERENCE	64PRR-065
RECOVERY OF PROTACTINIUM AND URANIUM FROM	MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS OXID	64PRR-101
RECOVERY OF URANIUM AND PROTACTINIUM FROM	MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS OXID	64PRR-047
CURRENT - VOLTAGE CURVES FOR ZIRCONIUM AND URANIUM IN	MOLTEN FLUORIDES	64PRR-295
VOLTAMMETRY AND CHRONOPOTENTIOMETRY OF IRON IN	MOLTEN FLUORIDES	64PRR-296
POLAROGRAPHY IN	MOLTEN FLUORIDES	64PRR-070
COORDINATION OF FLUORIDE IONS ABOUT NICKEL(II) IONS IN THE	MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POT/	64A-02-02C
SSIUM FLUORIDE	VOLTAMMETRY OF NICKEL(II) IN	64PRR-045
SSIUM FLUORIDE	VOLTAMMETRY OF NICKEL IN	64PRR-321
SSIUM/ SPECTROPHOTOMETRIC OBSERVATIONS OF THE REACTION OF	MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POT/	64PRR-069
S	SPECTROMETRIC STUDY OF	64A-04-01
	MOLTEN SALT REACTOR EXPERIMENT	64PRR-333
SEPARATION OF PROTACTINIUM FROM	MOLTEN SALT REACTOR FUEL COMPOSITION	64A-02
ANALYTICAL STUDIES OF	MOLTEN SALT SYSTEMS	64A-02-01
ABSORPTION SPECTROPHOTOMETRIC STUDIES RELATED TO	MOLTEN SALT SYSTEMS	64PRR-038
TRY IN NUCLEAR TECHNOLOGY - ANALYTICAL INSTRUMENTATION -	MOLTEN SALT SYSTEMS, RADIOACTIVITY STANDARDS, N/	64A-06-15
ANALYSIS OF ARC FUSED EUROPIUM	MOLYBDATE	64PRR-154
/ANUM / LEAD / LITHIUM / LUTETIUM / MAGNESIUM / MERCURY /	MOLYBDENUM / NEODYMIUM / NEPTUNIUM / NICKEL / O/	64A-12-01C
DECAY OF	MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-020
DECAY OF	MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-273
DECAY OF	MOLYBDENUM-99 - TECHNETIUM-99M	64PRR-230
/INE-131 / IRIIDIUM-194 / IRON-55, IRON-59 / MERCURY-203 /	MOLYBDENUM-99 / NEODYMIUM-147 - PROMETHIUM-147 /	64PRR-105
964 / ANALYTICAL CHEMISTRY RESEARCH AND DEVELOPMENT GROUP	MONTHLY SUMMARY - DEC., 1963 / JAN., 1964 / FEB.,	64A-02-02D
VOLTAMMETRY OF THE	MSR COOLANT SALT AND MSR FUEL SALT	64A-02-02D
VOLTAMMETRY OF THE MSR COOLANT SALT AND	MSR FUEL SALT	64PRR-117
ZIRCONIUM IN	MSRE FUEL, AMPEROMETRIC CUPFERRON TITRATION METH	64PRR-118
CHROMIUM IN	MSRE FUEL, AMPEROMETRIC FERROUS SULFATE TITRATIO	64PRR-120
URANIUM IN	MSRE FUEL, POLAROGRAPHIC METHOD	64PRR-119
FLUORIDE IN	MSRE FUEL, PYROLYSIS METHOD	64A-08-01A
HEIGHT / COMPUTER CODE FOR X-RAY FLUORESCENCE ANALYSIS OF	MULTICOMPONENT ALLOYS / ENT OF ABSORPTION-EDGE	64PRR-271
HE ANALYSIS OF SPECTROMETRIC ABSORPTION DATA FROM DYNAMIC	MULTICOMPONENT SYSTEMS / REACTION RATE DATA BY T	64A-01-07
SPECTROPHOTOMETER	SAFETY CIRCUIT FOR THE	64A-14-01B
	N,N,N// TRI METHYL BORAZINE	64PRR-079
SYNTHESIS AND INFRARED ABSORPTION SPECTRA OF	N,N,N// TRI METHYL BORAZINE	64A-12-04B
LATOR SOLVENT FOR THERMAL NEUTRON DETECTION	N,N,N// TRI METHYL BORAZINE AS A LIQUID SCINTIL	64PRR-287
MINATION OF LOW CONCENTRATIONS OF OXYGEN IN POTASSIUM AND	NAK BY A MODIFIED AMALGAMATION TECHNIQUE / DETER	64A-12-04A
LIQUID SCINTILLATORS THAT CONTAIN I METHYL	NAPHTHALENE	64A-14-03
PURIFICATION OF ALPHA METHYL	NAPHTHALENE	64PRR-030
LIQUID SCINTILLATORS USING I METHYL	NAPHTHALENE	64A-06-02
CAL DOSIMETERS)	DISPOSAL OF RADIOACTIVE WASTES IN	64A-12-031
PLUTONIUM-244)	SEARCH FOR	64PRR-329
	HOW A SEWING	64PRR-154
/ LITHIUM / LUTETIUM / MAGNESIUM / MERCURY /	MOLYBDENUM /	64PRR-230
/M-194 / IRON-55, IRON-59 / MERCURY-203 /	MOLYBDENUM-99 /	64A-09-02
ISOTOPIC COMPOSITION OF ATMOSPHERIC	NEODYMIUM-147 - PROMETHIUM-147 / OSMIUM-191 / P/	64PRR-154
/UTETIUM / MAGNESIUM / MERCURY / MOLDYADENUM / NEODYMIUM /	NEPTUNIUM / NICKEL / OSMIUM / PALLADIUM / PLAT/	64PRR-151
NICKEL, NEUTRON ACTIVATION ANALYSIS (FAST	NEUTRON - ISOTOPIC CARRIER) METHOD	64A-12-07J
S	NEUTRON ABSORPTION ANALYSIS WITH ISCTOPIC SOURCE	64PRR-218
PARTICLE SIZE DISTRIBUTION IN THORIUM OXIDE,	NEUTRON ACTIVATION - SEDIMENTATION METHOD	64PRR-016
DETERMINATION OF TRACE ELEMENTS IN DRUGS BY	NEUTRON ACTIVATION ANALYSIS	64PRR-314
EXPLANATION AND DEMONSTRATION OF	NEUTRON ACTIVATION ANALYSIS	64PRR-151
TOPIC CARRIER) METHOD	NICKEL, NEUTRON ACTIVATION ANALYSIS (FAST NEUTRON - ISO	64PRR-149
METHOD	IODINE ADSORBED ON CHARCOAL, NEUTRON ACTIVATION ANALYSIS (ISOTOPIC CARRIER)	64A-12-07G
DE / SELENIUM)	APPLIED NEUTRON ACTIVATION ANALYSIS (OXYGEN-18 / FLUORI	64A-12-01D
NEW ISOMER OF BROMINE - BROMINE-82M (HALF LIFE /	NEUTRON ACTIVATION CROSS SECTION)	64A-12-01G
STUDIES OF	NEUTRON DEFICIENT HAFNIUM RADIONUCLIDES	64PRR-06D
A NEW SCINTILLATOR FOR THERMAL	NEUTRON DETECTION	64PRR-099
A UNIQUE SCINTILLATOR FOR	NEUTRON DETECTION	64PRR-311
A UNIQUE SCINTILLATOR FOR	NEUTRON DETECTION	64A-12-04B
HYL BORAZINE AS A LIQUID SCINTILLATOR SOLVENT FOR THERMAL	NEUTRON DETECTION USING LITHIUM-6 ENRICHED ISOTO	64PRR-098
PE	NEUTRON DETECTION USING LITHIUM-6 ENRICHED ISOTO	64PRR-309
PE	A UNIQUE LIQUID SCINTILLATOR FOR	64PRR-002
	REACTOR	64A-12-08
	14-MEV NEUTRON GENERATOR	64A-12-08E
MISCELLANEOUS USES OF THE 14-MEV	NEUTRON GENERATOR	64A-12-08A
S INFLUENCE ON CROSS SECTION/ OUTPUT SPECTRUM FROM 14-MEV	NEUTRON GENERATORS - ITS RAPID ESTIMATION AND IT	64PRR-306
NCE IN ACTIVATION ANALYSIS	OUTPUT SPECTRA OF 14-MEV	64A-12-02A
UM-136	EPITHERMAL	64A-12-08B
	CATALOG OF 14-MEV	64PRR-011
	NEUTRON REACTIONS	64PRR-315
	NONREACTOR	64PRR-316
	ISOTOPIC AND ACCELERATOR	64A-12-08D
	THE USE OF ISOTOPIC	64PRR-313
DETERMINATION OF OXYGEN WITH 14-MEV	NEUTRONS	64A-06-16
REACTIONS OBSERVED WITH 14-MEV	NEUTRONS	64A-02-02E
COULOMETRIC DETERMINATION OF	NICKEL	64PRR-154
TEN FLUORIDE SALTS (PLATINUM QUASI REFERENCE ELECTRODE)	NICKEL - NICKEL(II) OXIDE REFERENCE ELECTRODE)	64A-13
/GNESIUM / MERCURY / MOLDYBDENUM / NEODYMIUM / NEPTUNIUM /	NICKEL / OSMIUM / PALLADIUM / PLATINUM / POTASS/	64A-02-01A
/D VANADIUM(III) SULFATE / LITHIUM FLUO BORATE / HYDRATED	NICKEL FLUO BORATE / HYDRATED VANADIUM(III) FLUO/	64PRR-264
ASSEMBLY	NICKEL HIGH TEMPERATURE SPECTROPHOTOMETRIC CELL	64PRR-045
TITRATION METHOD	URANIUM, COPPER, AND	64A-02-01F
IDE - POTASSIUM FLUORIDE	VOLTAMMETRY OF	64A-03-01
ABSORPTION SPECTRUM OF URANIUM(VI) FLUORIDE GAS (	NICKEL SPECTROPHOTOMETRIC ABSORPTION CELL)	64PRR-151
EFFECT OF COBALT-60 GAMMA RADIATION ON THE REACTION OF	NICKEL WITH DI METHYL GLYOXIME	
ON - ISOTOPIC CARRIER) METHOD	NICKEL, NEUTRON ACTIVATION ANALYSIS (FAST NEUTR	

LUORIDE - POTASSIUM FLUORIDE	VOLTAMMETRY OF	NICKEL(II) IN MOLTEN LITHIUM FLUORIDE - SODIUM F	64A-02-02C
SODIUM FLUORIDE - P/ COORDINATION OF FLUORIDE IONS ABOUT		NICKEL(II) IONS IN THE MOLTEN LITHIUM FLUORIDE -	64PRR-070
IDE SALTS (PLATINUM QUASI REFERENCE ELECTRODE / NICKEL -		NICKEL(II) OXIDE REFERENCE ELECTRODE) / EN FLUOR	64A-02-02E
		NIOTIUM, SPECTROMETRIC HYDRO QUINONE METHOD	64PRR-125
	PROTACTINIUM STABILITY IN THORIUM	NITRATE - NITRIC ACID SOLUTIONS	64PRR-072
SULFATE METHOD		NITRATE (NITROGEN) VOLUMETRIC FERROUS AMMONIUM	64PRR-121
	ACTIVATION ANALYSIS OF URANYL	NITRATE SOLUTIONS	64A-12-07H
RADIOLYTIC AND PHOTOLYTIC REDUCTION OF AQUEOUS SILVER		NITRATE SOLUTIONS	64PRR-044
PROTACTINIUM STABILITY IN THORIUM NITRATE -		NITRIC ACID SOLUTIONS	64PRR-072
CARBON IN AQUEOUS AND		NITRIC ACID SOLUTIONS	64PRR-267
AS CHROMATOGRAPHIC DETERMINATION OF CARBON IN AQUEOUS AND		NITRIC ACID SOLUTIONS	64A-05-03
ETHOD		COMBUSTION G	64PRR-121
/ GAS CHRCMATOGRAPH FOR THE ANALYSIS OF CORROSIVE GASES (		(NITROGEN) VOLUMETRIC FERROUS AMMONIUM SULFATE M	64A-05-01
/THE ANALYSIS OF CCRROSIVE GASES (NITROGEN DI OXIDE / DI		(NITROGEN DI OXIDE / DI NITROGEN TRI OXIDE / CHLO	64A-05-01
(NITROGEN DI OXIDE / DI NITROGEN TRI OXIDE / CHLORINE /		(NITROGEN TRI OXIDE / CHLORINE / NITROSYL CHLORIDE /	64A-05-01
/AROGRAPHY / THIRD DERIVATIVE DC POLAROGRAPHY / SIGNAL TO		(NITROSYL CHLORIDE) / ANALYSIS OF CORROSIVE GASES	64A-05-01
AND DECAY		NOISE RATIO (S/N) IN DC POLAROGRAPHY / RESOLU/	64A-01-01
PHY / RESOLUTION OF POLAROGRAPHIC WAVES / POLAROGRAPHY IN		NOMOGRAPHS FOR CALCULATING INDUCED RADIOACTIVITY	64PRR-055
(ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL AMMONIUM H/		NONAQUEOUS SOLVENTS AND SOLVENT EXTRACTS) / OGRA	64A-01-01
THORIUM-228 BY GAMMA SPECTROMETRY		NONAQUEOUS TITRIMETRY OF PHENOLS (4 SEC BUTYL 2	64A-06-08
FORNIUM-252		NONDESTRUCTIVE DETERMINATION OF URANIUM-232 AND	64PRR-304
ORNIUM-252 - APPLICATION OF PROMPT GAMMA-RAYS FRO/ DIRECT		NONDESTRUCTIVE METHOD FOR DETERMINATION OF CALI	64PRR-025
		NONDESTRUCTIVE METHOD FOR DETERMINATION OF CALIF	64PRR-051
		NONREACTOR NEUTRON SOURCES	64PRR-011
	SULFUR (SULFIDE AND	NONSULFIDE) INDIRECT POLAROGRAPHIC METHOD	64PRR-126
S BY GAS CHROMATCGRAPHY (SOLVENT EXTRACTANTS / PARAFFINS		NORMAL OCTANE THROUGH NORMAL PENTA DECANE) / ENT	64A-05-02
Y (SOLVENT EXTRACTANTS / PARAFFINS NORMAL OCTANE THROUGH		NORMAL PENTA DECANE) / ENTS BY GAS CHROMATOGRAPH	64A-05-02
ANNUAL PROGRESS REPORT FOR PERIOD ENDING		NOV.15,1963, ANALYTICAL CHEMISTRY DIVISION	64PRR-092
APPLICATION OF		NUCLEAR ANALYSIS TO FORENSIC SCIENCE	64PRR-274
/ENTATION - MOLTEN SALT SYSTEMS, RADIOACTIVITY STANDARDS,		NUCLEAR ANALYSIS, SPECTROSCOPY, GAS CHROMATOGRA/	64PRR-038
TROLLED POTENTIAL COULOMETRY - NEW ANALYTICAL TOOL IN THE		NUCLEAR AND RADIOCHEMICAL ANALYSES	64A-12
MASS NUMBERS RANGING FROM 184 THROUGH 192/ PROPERTIES OF		NUCLEAR ENERGY PROGRAM	64PRR-331
MASS NUCLEI (MASS NUMBERS RANGING FROM 1/ PROPERTIES OF		NUCLEAR LEVELS IN A NUMBER OF EVEN MASS NUCLEI (	64PRR-034
DISSCLUTION OF IRRADIATED, HIGH FIRED, REFRACTORY		NUCLEAR LEVELS IN A NUMBER OF EVEN-A NUCLEI EVEN	64A-12-01F
BASIC		NUCLEAR MATERIALS	64PRR-116
		NUCLEAR PROPERTIES AND ACTIVATION ANALYSIS	64PRR-009
		NUCLEAR PROPERTIES OF RADIONUCLIDES	64A-12-01
		NUCLEAR SAFETY PROGRAM	64A-11-02
		NUCLEAR TECHNOLOGY	64PRR-037
IS PRODUCTS OF URANIUM / GAS CHROMATOGRAPHY AS APPLIED TO		NUCLEAR TECHNOLOGY II. ANALYSIS OF THE HYDROLYS	64PRR-035
UME OF THE SEVENTH CONFERENCE ON ANALYTICAL CHEMISTRY IN		NUCLEAR TECHNOLOGY - ANALYTICAL INSTRUMENTATION/	64PRR-038
/OF NUCLEAR LEVELS IN A NUMBER OF EVEN-A NUCLEI EVEN MASS		NUCLEI (MASS NUMBERS RANGING FROM 184 THROUGH /	64A-12-01F
92/ PROPERTIES OF NUCLEAR LEVELS IN A NUMBER OF EVEN MASS		NUCLEI (MASS NUMBERS RANGING FROM 184 THROUGH /	64PRR-034
ROM 1/ PROPERTIES OF NUCLEAR LEVELS IN A NUMBER OF EVEN-A		NUCLEI EVEN MASS NUCLEI (MASS NUMBERS RANGING F	64A-12-01F
AMINO ACIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RIBO		NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LABELED	64A-07
PRECISION OF ACTIVATION ANALYSIS OF SHORT-LIVED		NUCLIDES	64PRR-275
ORGANIZATION OF THE ORNL MASTER ANALYTICAL MANUAL AND		NUMBERING OF THE METHODS	64PRR-224
VELS IN A NUMBER OF EVEN-A NUCLEI EVEN MASS NUCLEI (MASS		NUMBERS RANGING FROM 184 THROUGH 192) / CLEAR LE	64A-12-01F
OF NUCLEAR LEVELS IN A NUMBER OF EVEN MASS NUCLEI (MASS		NUMBERS RANGING FROM 184 THROUGH 192) / OPERITIES	64PRR-034
VARIATION OF CESIUM IN THE		OCEAN	64PRR-028
S CHROMATOGRAPHY (SOLVENT EXTRACTANTS / PARAFFINS NORMAL		OCTANE THROUGH NORMAL PENTA DECANE) / ENTS BY GA	64A-05-02
/IVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO		OCTYL AMINE (OR TRI CAPRYL AMINE) EXTRACTION /	64PRR-134
/IVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO		OCTYL AMINE EXTRACTION - PROPORTIONAL ALPHA COU/	64PRR-139
C/ SEPARATION OF URANIUM BY SOLVENT EXTRACTION WITH TRI N		OCTYL PHOSPHINE OXIDE AND ITS DIRECT COLORIMETRI	64PRR-080
TWO CARBON THROUGH FIVE CARBON PARAFFINS AND		OLEFINS, GAS CHROMATOGRAPHIC METHOD	64PRR-123
FOUR CARBON THROUGH EIGHT CARBON PARAFFINS AND		OLEFINS, GAS CHROMATOGRAPHIC METHOD	64PRR-124
TRY OF THE ELEMENTS		OPERATING CONDITIONS FOR ISOTOPIC MASS SPECTROME	64PRR-153
		OPTICAL AND ELECTRON MICROSCOPY	64A-11
		OPTICAL INSTRUMENTATION	64A-11-03
ARCH ASSISTANCE TO OTHER LABORATORY DIVISIO/ ELECTRON AND		OPTICAL MICROSCOPY AND ELECTRON DIFFRACTION RESE	64A-11-04
CHOOSING		OPTIMUM COUNTING METHODS AND RADIOTRACERS	64PRR-054
/ GNOME)		ORE SELECTION FOR PROJECT COACH (TRANSPLUTONIUM	64A-12-03H
TION DETERMINATION OF PARTS PER BILLION CONCENTRATIONS OF		ORGANIC CONTAMINANTS IN AIR	64A-06-04
/ POLAROGRAPHY TO THE DETERMINATION OF METAL COMPLEXES IN		FLAME IONIZA	64PRR-001
		ORGANIC EXTRACTS AND COMPENSATION OF POLAROGRA/	64A-14
		ORGANIC PREPARATIONS	64PRR-224
L AND NUMBERING OF THE METHODS		ORGANIZATION OF THE ORNL MASTER ANALYTICAL MANUA	64A-05-05E
	VERTICAL	ORIFICE RAPID TEFLON DROPPING MERCURY ELECTRODE	64PRR-095
RCURY ELECTRODE	FABRICATION OF THE VERTICAL	ORIFICE TEFLON CAPILLARY OF A TEFLON DROPPING ME	64A-05-05C
REACTION IN AQUEOUS HYDROFLUORIC ACID WITH THE HORIZONTAL		ORIFICE TEFLON DROPPING MERCURY ELECTRODE / EDOX	64A-05-05D
ERS	EXTENSION OF THE USE OF THE HORIZONTAL	ORIFICE TEFLON DROPPING MERCURY ELECTRODE BY OTH	64A-05-05A
E IN OBTAINING FUNDAMENTAL / EVALUATION OF THE HORIZONTAL		ORIFICE TEFLON DROPPING MERCURY ELECTRODE FOR US	64PRR-301
	CURRENT WORK AT	ORNL	64PRR-303
	RECENT RADIOCHEMICAL WORK AT	ORNL	64PRR-305
SOME EXPERIENCES IN ENVIRONMENTAL ANALYSES AT		ORNL	64PRR-318
ANALYTICAL ELECTRON MICROSCOPY - PAST AND PRESENT AT		ORNL	64PRR-272
	COMMENTARY ON	ORNL DOUBLE MAGNET MASS SPECTROMETER	64PRR-018
DESIGN AND CONSTRUCTION OF		ORNL HIGH RADIATION LEVEL ANALYTICAL LABORATORY	64C-20
		ORNL MASTER ANALYTICAL MANUAL	64C-20-01
CUMULATIVE INDEXES TO THE		ORNL MASTER ANALYTICAL MANUAL	64C-20-02
MAINTENANCE OF THE		ORNL MASTER ANALYTICAL MANUAL	64C
	TYPING AND PRINTING METHODS FOR THE	ORNL MASTER ANALYTICAL MANUAL	64PRR-225
WRITING INSTRUMENTAL METHODS FOR THE		ORNL MASTER ANALYTICAL MANUAL	64PRR-226
INDEXES TO THE		ORNL MASTER ANALYTICAL MANUAL (1953-1963)	64PRR-096
RMATION FOR ANNUAL REVISION TO CUMULATIVE INDEXES FOR THE		ORNL MASTER ANALYTICAL MANUAL /MPUTER INPUT INFO	64PRR-146
HE METHODS	ORGANIZATION OF THE	ORNL MASTER ANALYTICAL MANUAL AND NUMBERING OF T	64PRR-224
		ORNL MASTER ANALYTICAL MANUAL, SUPPLEMENT 6	64PRR-093
TEST PROCEDURE FOR HIGH SENSITIVITY COULOMETRIC TITRATOR,		ORNL MODEL Q-2564	64PRR-081
ITRATOR (ENGINEERING DRAWINGS / TEST SPECIFICATIONS / T/		CHECK OUT AND	64A-01-05
SAFETY CIRCUIT FOR THE MULTIPLIER PHOTOTUBE OF THE		ORNL MODEL Q-2564 HIGH SENSITIVITY COULOMETRIC T	64A-01-07
/ONO BUTYL PHOSPHORIC ACID, DI BUTYL PHOSPHORIC ACID, AND		ORNL MODEL VII FLAME SPECTROPHOTOMETER	64PRR-265
/ MERCURY / MOLYBDENUM / NEODYMIUM / NEPTUNIUM / NICKEL		ORTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, V/	64PRR-154
/Y-203 / MOLYBDENUM-99 / NEODYMIUM-147 - PROMETHIUM-147 /		OSMIUM / PALLADIUM / PLATINUM / POTASSIUM / PRA/	64PRR-230
		OSMIUM-191 / PALLADIUM-109 / POTASSIUM-42 / PRA/	

E HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECTRODE BY	OTHERS	EXTENSION OF THE USE OF TH	64A-05-05D
PID ESTIMATION AND INFLUENCE IN ACTIVATION ANALYSIS	OUTPUT SPECTRA OF 14-MEV NEUTRON GENERATORS - RA		64PRR-306
ITS RAPID ESTIMATION AND ITS INFLUENCE ON CROSS SECTION/	OUTPUT SPECTRUM FROM 14-MEV NEUTRON GENERATORS -		64A-12-08A
ERMINATION OF CARBON IN ALKALI METALS BY HIGH TEMPERATURE	OXIDATION	DET	64A-06-06
NSURANIUM (TRU) PROCESS SOLUTIONS, AMMONIUM PER SULFATE	OXIDATION - PROPORTIONAL ALPHA COUNTING METHOD /		64PRR-136
D FOR THE EVALUATION OF ATMOSPHERIC POLLUTION - SULFUR DI	OXIDE	RADIO RELEASE METHO	64A-12-06A
S FOR THE EVALUATION OF ATMOSPHERIC POLLUTION - SULFUR DI	OXIDE	RADIO RELEASE METHOD	64PRR-312
OF CORROSIVE GASES (NITROGEN DI OXIDE / DI NITROGEN TRI	OXIDE / CHLORINE / NITROSYL CHLORIDE) / ANALYSIS		64A-05-01
OGRAPH FOR THE ANALYSIS OF CORROSIVE GASES (NITROGEN DI	OXIDE / DI NITROGEN TRI OXIDE / CHLORINE / NITR		64A-05-01
UM PHOSPHIDE / HIGH PURITY POTASSIUM CHLORIDE / POTASSIUM	OXIDE / LITHIUM ANTIMONIDE) / HLORIDE / DYSPROSI		64A-13
/SOLUTION OR DECOMPOSITION OF VARIOUS MATERIALS (HAFNIUM	OXIDE / MERCURY(II) SULFIDE / URANIUM(IV) OXIDE/		64A-05-04
/IALS (HAFNIUM OXIDE / MERCURY(II) SULFIDE / URANIUM(IV)	OXIDE / N TRI METHYL BORAZINE / BIS (OXYGEN, O/		64A-05-04
F URANIUM(VI) IN PHOSPHORIC ACID SOLUTIONS OF URANIUM(IV)	OXIDE /60 GAMMA RADIATION ON THE DETERMINATION O		64A-03-02
/URANIUM BY SOLVENT EXTRACTION WITH TRI N OCTYL PHOSPHINE	OXIDE AND ITS DIRECT COLORIMETRIC DETERMINATION/		64PRR-080
TION OF IMPURITIES IN URANIUM COMPOUNDS USING THE GALLIUM	OXIDE CARRIER DISTILLATION TECHNIQUE / DETERMINA		64PRR-083
LECTRODE	OXIDE FILM FORMATION ON THE PYROLYTIC GRAPHITE E		64A-06-03B
PLATINUM QUASI REFERENCE ELECTRODE / NICKEL - NICKEL(II)	OXIDE REFERENCE ELECTRODE) / EN FLUORIDE SALTS (		64A-02-02E
PARTICLE SIZE DISTRIBUTION IN THORIUM	OXIDE, NEUTRON ACTIVATION - SEDIMENTATION METHOD		64PRR-218
URANIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS	OXIDES	RECOVERY OF PROTACTINIUM AND	64PRR-065
ACTINIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRECIPITATION AS	OXIDES	RECOVERY OF URANIUM AND PROT	64PRR-101
CARBON IN METALS AND METALLIC	OXIDES, LECO CONDUCTOMETRIC METHOD		64PRR-122
ED AMAL/ THE RAPID DETERMINATION OF LOW CONCENTRATIONS OF	OXYGEN AND HYDROGEN IN ALKALI METALS BY A MODIFI		64PRR-288
/RANIUM(IV) OXIDE / N TRI METHYL BORAZINE / BIS (OXYGEN,	OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE/		64A-05-04
AMALGAMATION METHOD	OXYGEN IN ALKALI METALS BY A MODIFICATION OF THE		64A-06-05
MATION / THE RAPID DETERMINATION OF LOW CONCENTRATIONS OF	OXYGEN IN POTASSIUM AND NAK BY A MODIFIED AMALGA		64PRR-287
CETERMINATION OF	OXYGEN WITH 14-MEV NEUTRONS		64A-12-08D
/FIDE / URANIUM(IV) OXIDE / N TRI METHYL BORAZINE / BIS (	OXYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI/		64A-05-04
APPLIED NEUTRON ACTIVATION ANALYSIS (	OXYGEN-18 / FLUORIDE / SELENIUM)		64A-12-07G
// MOLYBDENUM / NEODYMIUM / NICKEL / OSMIUM /	PALLADIUM / PLATINUM / POTASSIUM / PRASEODYMIUM/		64PRR-154
DENUM-99 / NEODYMIUM-147 - PROMETHIUM-147 / OSMIUM-191	PALLADIUM-109 / POTASSIUM-42 / PRASEODYMIUM-142/		64PRR-230
ANALYSIS OF BOND	PAPER		64A-12-07C
D TWO CARBON THROUGH FIVE CARBON	PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHIC METHO		64PRR-123
D FOUR CARBON THROUGH EIGHT CARBON	PARAFFINS AND OLEFINS, GAS CHROMATOGRAPHIC METHO		64PRR-124
/C DILUENTS BY GAS CHROMATOGRAPHY (SOLVENT EXTRACTANTS /	PARAFFINS NORMAL OCTANE THROUGH NORMAL PENTA DE/		64A-05-02
TRON ACTIVATION - SEDIMENTATION METHOD	PARTICLE SIZE DISTRIBUTION IN THORIUM OXIDE, NEU		64PRR-218
ANALYTICAL ELECTRON MICROSCOPY -	PAST AND PRESENT AT ORNL		64PRR-318
MP ATOMIC ABSORPTION SPECTROSCOPY USING LONG ABSORPTION	PATH LENGTHS AND A DEMCUNTABLE HOLLOW CATHODE LA		64PRR-005
180 DEGREE COMPTON SCATTERED ANNIHILATION GAMMA-RAY SUM	PEAK OBSERVED IN GAMMA-RAY SPECTROMETRY		64PRR-040
VENT EXTRACTANTS / PARAFFINS NORMAL OCTANE THROUGH NORMAL	PENTA DECANE) /ENTS BY GAS CHROMATOGRAPHY (SOL		64A-05-02
TS IN AIR	PER BILLION CONCENTRATIONS OF ORGANIC CONTAMINAN		64A-06-04
/CIUM IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, AMMONIUM	PER SULFATE OXIDATION - PROPORTIONAL ALPHA COUN/		64PRR-136
RIC MEASUREMENT	PHENANTHROLINE COMPLEX EQUILIBRIA BY POTENTIOMET		64PRR-023
TER EXTRACTION WITH 4 SEC BUTYL 2 (ALPHA METHYL BENZYL)	PHENOL DETERMINATION OF CESIUM AND RUBIDIUM AF		64PRR-062
/METRY OF PHENOLS (4 SEC BUTYL 2 (ALPHA METHYL BENZYL)	PHENOL / TETRA BUTYL AMMONIUM HYDROXIDE / LITHI/		64A-06-08
PHENOL / TETRA BUTYL AMMONIUM H/ NONAQUEOUS TITRIMETRY OF	PHENOLS (4 SEC BUTYL 2 (ALPHA METHYL BENZYL)		64A-06-08
RETENTION DATA FOR POLY	PHENYL COMPOUNDS		64PRR-013
TRATION OF URANIUM(IV) AND URANIUM(VI) IN SODIUM TRI POLY	PHOSPHATE MEDIUM /OLLED POTENTIAL COULOMETRIC TI		64PRR-071
/ PHOSPHORIC ACID, AND ORTHO PHOSPHORIC ACID IN TRI BUTYL	PHOSPHATE, VOLUMETRIC SODIUM HYDROXIDE TITRATIO/		64PRR-265
/ONIUM TETRA CHLORIDE / URANIUM TRI CHLORIDE / DYSPROSIUM	PHOSPHIDE / HIGH PURITY POTASSIUM CHLORIDE / PO/		64A-13
/RATION OF URANIUM BY SOLVENT EXTRACTION WITH TRI N OCTYL	PHOSPHINE OXIDE AND ITS DIRECT COLORIMETRIC DET		64PRR-080
9 AND STRONTIUM-90 IN AQUEOUS SOLUTIONS, DI 2 ETHYL HEXYL	PHOSPHORIC ACID - AMSCO EXTRACTION METHOD /IUM-8/		64PRR-142
/TYL PHOSPHORIC ACID, DI BUTYL PHOSPHORIC ACID, AND ORTHO	PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, VOLUMET/		64PRR-265
60 GAMMA RADIATION ON THE DETERMINATION OF URANIUM(VI) IN	PHOSPHORIC ACID SOLUTIONS OF URANIUM(IV) OXIDE /		64A-03-02
I BUTYL PHOSPHATE, / MONO BUTYL PHOSPHORIC ACID, DI BUTYL	PHOSPHORIC ACID, AND ORTHO PHOSPHORIC ACID IN TR		64PRR-265
RTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, / MONO BUTYL	PHOSPHORIC ACID, DI BUTYL PHOSPHORIC ACID, AND O		64PRR-265
/DI THIO PHOSPHORYL) DI SULFIDE / MERCURY(II) DI N BUTYL	PHOSPHORO DI THIOATE / FLUIDIZED COKE / 3,9 DI /		64A-05-04
METAL DI N BUTYL	PHOSPHORO DI THIOATES AS EXTRACTANTS FOR METALS		64A-12-03B
OF MERCURY BY ISCTOPIC EXCHANGE WITH MERCURIC DI N BUTYL	PHOSPHORO THIOATE IN AN EXTRACTION SYSTEM /ATION		64PRR-033
ETAL IONS - SELECTIVE EXTRACTION/ TRI ALKYL AND HEXA ALKYL	PHOSPHORO THIOIC TRI AMIDES AS EXTRACTANTS FOR M		64A-12-03A
ADIOISOTOPES TO THE DETERMINATION OF SODIUM, LITHIUM, AND	PHOSPHORUS	APPLICATION OF R	64A-12-06B
/ METHYL BCRAZINE / BIS (OXYGEN, OXYGEN DI BUTYL DI THIO	PHOSPHORYL) DI SULFIDE / MERCURY(II) DI N BUTY/		64A-05-04
A VERSATILE ELECTRONIC COMPUTER FOR	PHOTOELECTRIC SPECTROCHEMICAL ANALYSIS		64PRR-067
OLUTIONS	PHOTOLYTIC REDUCTION OF AQUEOUS SILVER NITRATE S		64PRR-044
CHEMICAL ISOLATION AND FLAME	PHOTOMETRIC DETERMINATION OF BARIUM		64PRR-281
THE COLLECTION AND FLAME	PHOTOMETRIC DETERMINATION OF CESIUM		64PRR-026
TALS AND ALKALINE EARTH ELEMENTS)	PHOTOMETRY (SEPARATION OF BARIUM FROM ALKALI ME		64A-08-01C
TOMETER	PHOTOTUBE OF THE ORNL MODEL VII FLAME SPECTROPHO		64A-01-07
PPPLICATION OF ACTIVATION ANALYSIS TO FORENSIC SCIENCE I.	PHYSICAL EVIDENCE	A	64PRR-014
REVIEW OF - RADIOACTIVE TRACERS IN	PHYSICAL METALLURGY		64PRR-041
ALPHA,ALPHA/ DI	PIPERIDYL		64A-14-01E
THE	PLACE OF ATOMIC ABSORPTION IN TISSUE ANALYSIS		64PRR-280
ED POTENTIAL COULOMETRY	PLACEMENT OF THE REFERENCE ELECTRODE IN CONTROLL		64A-01-08
/ / NEODYMIUM / NEPTUNIUM / NICKEL / OSMIUM / PALLADIUM /	PLATINUM / POTASSIUM / PRASEODYMIUM / RHENIUM //		64PRR-154
R MICRO REDOX AND ACID - BASE POTENTIOMETRIC TITRATIONS (	PLATINUM IN-BURET REFERENCE ELECTRODE) /RODE FO		64A-06-12
/RENCE ELECTRODES COMPATIBLE WITH MOLTEN FLUORIDE SALTS (	PLATINUM QUASI REFERENCE ELECTRODE / NICKEL - N/		64A-02-02E
CHRONOPOTENTIOMETRY OF	PLUTONIUM		64A-05-06
TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION/	PLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (		64PRR-137
TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (TT/	PLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (		64PRR-138
CHRONOPOTENTIOMETRY OF	PLUTONIUM IN MINERAL ACID MEDIA		64PRR-053
CHRONOPOTENTIOMETRY OF	PLUTONIUM IN MINERAL ACID MEDIA		64PRR-300
TOTAL	PLUTONIUM, THENOYL TRI FLUORO ACETONE EXTRACTION		64PRR-219
ARCH FOR NATURAL TRANSURANIC RADIOACTIVITY (CURIUM-247)	PLUTONIUM-244)	SE	64A-12-031
CONTROLLED POTENTIAL DC	POLAROGRAPH VOLTAMMETER - DESIGN AND EVALUATION		64A-01-03
/NTS IN DC POLAROGRAPHY (POTENTIOSTATIC COMPENSATION FOR	POLAROGRAPHIC CELL RESISTANCE / TIME DERIVATIVE/		64A-01-01
/ METAL COMPLEXES IN ORGANIC EXTRACTS AND COMPENSATION OF	POLAROGRAPHIC CELL RESISTANCE IN HIGH SPECIFIC /		64PRR-001
OPPING MERCURY ELECTRODE FOR USE IN OBTAINING FUNDAMENTAL	POLAROGRAPHIC DATA /HORIZONTAL ORIFICE TEFLON DR		64A-05-05A
DERIVATIVE DC POLAROGRAPHY AS A TECHNIQUE IN QUANTITATIVE	POLAROGRAPHIC MEASUREMENTS	SECOND	64PRR-270
URANIUM IN MSRE FUEL,	POLAROGRAPHIC METHOD		64PRR-120
SULFUR (SULFIDE AND NONSULFIDE) INDIRECT	POLAROGRAPHIC METHOD		64PRR-126
/O NOISE RATIO (S/N) IN DC POLAROGRAPHY / RESOLUTION OF	POLAROGRAPHIC WAVES / POLAROGRAPHY IN NONAQUEOU/		64A-01-01
CONTROLLED POTENTIAL DC	POLAROGRAPHY		64PRR-283
RECENT DEVELOPMENTS IN DC	POLAROGRAPHY		64PRR-285

HOW A SEWING NEEDLE AND TEFLON ARE ADVANCING	POLAROGRAPHY	64PRR-329
LICATION OF DERIVATIVE TECHNIQUES TO STATIONARY ELECTRODE	POLAROGRAPHY	THE APP 64PRR-299
OLAROGRAPHIC CELL RESISTANCE // RECENT DEVELOPMENTS IN DC	POLAROGRAPHY (POTENTIOSTATIC COMPENSATION FOR P	64A-01-01
/ ELECTRODE VOLTAMMETRY WITH LINEARLY VARYING POTENTIAL (	POLAROGRAPHY / ELECTROLYSIS / HANGING MERCURY D/	64A-01-06
/N FOR POLAROGRAPHIC CELL RESISTANCE / TIME CERIVATIVE DC	POLAROGRAPHY / FIRST DERIVATIVE DC POLAROGRAPHY/	64A-01-01
/VE DC POLAROGRAPHY / SIGNAL TO NOISE RATIO (S/N) IN DC	POLAROGRAPHY / RESOLUTION OF POLAROGRAPHIC WAVE/	64A-01-01
/ / TIME DERIVATIVE DC PCLAROGRAPHY / FIRST DERIVATIVE DC	POLAROGRAPHY / SECOND DERIVATIVE DC POLAROGRAPH/	64A-01-01
/ SECOND DERIVATIVE DC PCLAROGRAPHY / THIRD DERIVATIVE DC	POLAROGRAPHY / SIGNAL TO NOISE RATIO (S/N) IN/	64A-01-01
/ FIRST DERIVATIVE DC POLAROGRAPHY / SECOND DERIVATIVE DC	POLAROGRAPHY / THIRD DERIVATIVE DC POLAROGRAPHY/	64A-01-01
/REFERENCE ELECTRODE - APPLICATIONS IN CONTROLLED POTENTIAL	POLAROGRAPHY AND VOLTAMMETRY AND IN CHRONOPOTEN/	64PRR-286
ROGRAPHIC MEASUREMENTS	POLAROGRAPHY AS A TECHNIQUE IN QUANTITATIVE POLA	64PRR-270
S CORRODING MEDIA	POLAROGRAPHY IN HYDROFLUORIC ACID AND OTHER GLAS	64A-05-05
	POLAROGRAPHY IN MOLTEN FLUORIDES	64PRR-296
/IN DC PCLAROGRAPHY / RESOLUTION OF POLAROGRAPHIC WAVES /	POLAROGRAPHY IN NONAQUEOUS SOLVENTS AND SOLVENT/	64A-01-01
REDOX REACTION IN AQUEOUS HYDROFLUORIC ACID WITH THE HOR/	POLAROGRAPHY OF THE DIVALENT LEAD TO LEAD METAL	64A-05-05C
EXES / APPLICATION OF CONTROLLED POTENTIAL AND DERIVATIVE	POLAROGRAPHY TO THE DETERMINATION OF METAL COMPL	64PRR-001
/REFERENCE ELECTRODE APPLICATIONS IN CONTROLLED POTENTIAL	POLAROGRAPHY, CONTROLLED POTENTIAL VOLTAMMETRY,/	64A-01-02
RADIO RELEASE METHODS FOR THE EVALUATION OF ATMOSPHERIC	POLLUTION	64PRR-308
RADIO RELEASE METHOD FOR THE EVALUATION OF ATMOSPHERIC	POLLUTION - SULFUR DI OXIDE	64A-12-06A
RADIO RELEASE METHODS FOR THE EVALUATION OF ATMOSPHERIC	POLLUTION - SULFUR DI OXIDE	64PRR-312
	USE AND CARE OF	64PRR-227
	RETENTION DATA FOR	64PRR-013
IC TITRATION OF URANIUM(IV) AND URANIUM(VI) IN SODIUM TRI	POLY PHOSPHATE MEDIUM /OLLED POTENTIAL COULOMETR	64PRR-071
/M / NEPTUNIUM / NICKEL / OSMIUM / PALLADIUM / PLATINUM /	POTASSIUM / PRASEODYMIUM / RHENIUM / RUBIDIUM //	64PRR-154
/E RAPID DETERMINATION OF LOW CONCENTRATIONS OF OXYGEN IN	POTASSIUM AND NAK BY A MODIFIED AMALGAMATION TE/	64PRR-287
/RANIUM TRI CHLORIDE / DYSPROSIUM PHOSPHIDE / HIGH PURITY	POTASSIUM CHLORIDE / POTASSIUM OXIDE / LITHIUM /	64A-13
OF NICKEL IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE -	POTASSIUM FLUORIDE	64PRR-045
NICKEL(II) IN MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE -	POTASSIUM FLUORIDE	VOLTAMMETRY OF 64A-02-02C
/CES OF IRON(III) IN SODIUM FLUORIDE - LITHIUM FLUORIDE -	POTASSIUM FLUORIDE - URANIUM(IV) FLUORIDE WITH /	64PRR-104
/RIDE SALT SYSTEMS (LITHIUM FLUORIDE - SODIUM FLUORIDE -	POTASSIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLI/	64A-02-02
) IONS, IN THE MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE -	POTASSIUM FLUORIDE EUTECTIC /ONS ABOUT NICKEL(II)	64PRR-070
E REACTION OF MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE -	POTASSIUM FLUORIDE WITH SEVERAL ACTIVE METALS /H	64PRR-321
/ DYSPROSIUM PHOSPHIDE / HIGH PURITY POTASSIUM CHLORIDE /	POTASSIUM OXIDE / LITHIUM ANTIMONIDE) /HLORIDE	64A-13
/ICKEL FLUO BORATE / HYDRATED VANADIUM(III) FLUO BORATE /	POTASSIUM SULFIDE / LITHIUM HYPO BROMITE / ANYH/	64A-13
/MIUM-147 - PROMETHIUM-147 / OSMIUM-191 / PALLADIUM-109 /	POTASSIUM-42 / PRASEODYMIUM-142 / PRASEODYMIUM-/	64PRR-230
/O STATIONARY ELECTRODE VOLTAMMETRY WITH LINEARLY VARYING	POTENTIAL I POLAROGRAPHY / ELECTROLYSIS / HANGI/	64A-01-06
ERMINATION OF METAL COMPLEXES / APPLICATION OF CONTROLLED	POTENTIAL AND DERIVATIVE POLAROGRAPHY TO THE DET	64PRR-001
NO URANIUM(VI) IN SODIUM TRI POLY PHOSPHATE M/	POTENTIAL COULOMETRIC TITRATION OF URANIUM(IV) A	64PRR-071
NCE OF PLACEMENT OF THE REFERENCE ELECTRODE IN CONTROLLED	POTENTIAL COULOMETRY	SIGNIFICA 64A-01-08
E NUCLEAR ENERGY PROGRAM	POTENTIAL COULOMETRY - NEW ANALYTICAL TCOL IN TH	64PRR-331
D EVALUATION	POTENTIAL DC POLAROGRAPH VOLTAMMETER - DESIGN AN	64A-01-03
	POTENTIAL DC POLAROGRAPHY	64PRR-283
/E QUASI REFERENCE ELECTRODE - APPLICATIONS IN CONTROLLED	POTENTIAL POLAROGRAPHY AND VOLTAMMETRY AND IN C/	64PRR-286
/A SIMPLE REFERENCE ELECTRODE APPLICATIONS IN CONTROLLED	POTENTIAL POLAROGRAPHY, CONTROLLED POTENTIAL VO/	64A-01-02
CE OF JUNCTION PCTENTIALS IN THE MEASUREMENT OF HALF-WAVE	POTENTIAL VALUES	SIGNIFICAN 64A-05-05B
ICATIONS IN CONTROLLED PCTENTIAL POLAROGRAPHY, CONTROLLED	POTENTIAL VOLTAMMETRY, AND CHRONOPOTENTIOMETRY /	64A-01-02
TIAL VALUES	POTENTIALS IN THE MEASUREMENT OF HALF-WAVE POTEN	64A-05-05B
TS	POTENTIALS OF PURE METALS IN MOLTEN FLUORIDE SAL	64A-02-02B
TION METHOD	POTENTIOMETRIC MANNITOL - SODIUM HYDROXIDE TITRA	64PRR-220
STUDY OF METAL I, 10 PHENANTHROLINE COMPLEX EQUILIBRIA BY	POTENTIOMETRIC MEASUREMENT	64PRR-023
/ AND INDICATOR ELECTRODE FOR MICRO REDOX AND ACID - BASE	POTENTIOMETRIC TITRATIONS (PLATINUM IN-BURET R/	64A-06-12
BOTH VESSEL AND ELECTRODE FOR MICRO REDOX AND ACID - BASE	POTENTIOMETRIC TITRATIONS /YTIC GRAPHITE CUP AS	64PRR-066
	POTENTIOMETRY	64A-06-03C
LL RESISTANCE // RECENT DEVELOPMENTS IN DC POLAROGRAPHY (	POTENTIOSTATIC COMPENSATION FOR POLAROGRAPHIC CE	64A-01-01
ETERMINATION OF CERTAIN IMPURITIES IN LITHIUM FLUORIDE	POWDER BY SPARK EXCITATION	64A-08-02B
/M / NICKEL / OSMIUM / PALLADIUM / PLATINUM / POTASSIUM /	PRASEODYMIUM / RHENIUM / RUBIDIUM / RUTHENIUM //	64PRR-154
/ETHIUM-147 / OSMIUM-191 / PALLADIUM-109 / POTASSIUM-42 /	PRASEODYMIUM-142 / PRASEODYMIUM-143 / PROMETHI/	64PRR-230
/-191 / PALLADIUM-109 / POTASSIUM-42 / PRASEODYMIUM-142 /	PRASEODYMIUM-143 / PROMETHIUM-147 / RUBIDIUM-86/	64PRR-230
/ANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE	PRECIPITATION - PROPORTIONAL ALPHA COUNTING MET/	64PRR-133
/ANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE	PRECIPITATION - PROPORTIONAL ALPHA COUNTING MET/	64PRR-137
PROTACTINIUM AND URANIUM FROM MOLTEN FLUORIDE SYSTEMS BY	PRECIPITATION - PROPORTIONAL ALPHA COUNTING MET/	64PRR-140
URANIUM AND PROTACTINIUM FROM MOLTEN FLUORIDE SYSTEMS BY	PRECIPITATION AS OXIDES	RECOVERY OF 64PRR-065
REFERENCE TO COULMETRY	PRECIPITATION AS OXIDES	RECOVERY OF 64PRR-101
	PRECISE DETERMINATION OF URANIUM, WITH SPECIAL R	64PRR-290
NUCLIDES	PRECISION IN ACTIVATION ANALYSIS	64A-12-07A
	PRECISION OF ACTIVATION ANALYSIS OF SHORT-LIVED	64PRR-275
	PRECISION OF MEASUREMENTS	64A-12-02C
EFFECT OF GAMMA SPECTROMETER LIVE TIME ON	PREPARATIONS	64A-14
ORGANIC	PREPARATIONS (HYDRATED VANADIUM(III) SULFATE /	64A-13
LITHIUM FLUO BORATE / HYDRATED NICKEL FLUO BOR/ INORGANIC	PRINTING METHODS FOR THE ORNL MASTER ANALYTICAL	64PRR-225
MANUAL	PRODUCT ANALYSIS GUIDE	64PRR-141
	PRODUCT ANALYSIS GUIDE	64PRR-143
	PRODUCT ANALYSIS GUIDE	64PRR-144
	PRODUCT ANALYSIS GUIDE	64PRR-145
IC-77 / BARIUM-131 / BROMINE-82 / CADMIUM-115M HSA / CER/	PRODUCT ANALYSIS GUIDE - ANTIMONY-125 CF / ARSEN	64PRR-230
	PROGRAMS	64A-14-04
ANALYTICAL CHEMISTRY DIVISION	PROGRESS REPORT FOR PERIOD ENDING NOV.15,1963, A	64PRR-092
	PROJECT COACH (TRANSPLUTONIUM / GNOME)	64A-12-03H
	PROJECTS	64A-04
/ IRON-59 / MERCURY-203 / MOLYBDENUM-99 / NEODYMIUM-147 -	PROMETHIUM-147 / OSMIUM-191 / PALLADIUM-109 / P/	64PRR-230
/9 / POTASSIUM-42 / PRASEODYMIUM-142 / PRASEODYMIUM-143 /	PROMETHIUM-147 / RUBIDIUM-86 / RUTHENIUM-103, R/	64PRR-230
HOD FOR DETERMINATION OF CALIFORNIUM-252 - APPLICATION OF	PROMPT GAMMA-RAYS FROM SPONTANEOUS FISSION / MET	64PRR-051
OLUTIONS, THENOYL TRI FLUORO ACETONE (TTA) EXTRACTION -	PROPORTIONAL ALPHA COUNTING METHOD /) PROCESS S	64PRR-138
TRU) PROCESS SOLUTIONS, AMMONIUM PER SULFATE OXIDATION -	PROPORTIONAL ALPHA COUNTING METHOD /NSURANIUM (	64PRR-136
TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE EXTRACTION -	PROPORTIONAL ALPHA COUNTING METHOD /S SOLUTIONS,	64PRR-139
TRI ISO OCTYL AMINE (OR TRI CAPRYL AMINE) EXTRACTION -	PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TR	64PRR-134
U) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION -	PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TR	64PRR-133
U) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION -	PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TR	64PRR-137
U) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPITATION -	PROPORTIONAL ALPHA COUNTING METHOD /URANIUM (TR	64PRR-140
STEMS BY PRECIPITATION AS OXIDES	PROTACTINIUM AND URANIUM FROM MOLTEN FLUORIDE SY	64PRR-065
CIPITATION AS OXIDES	PROTACTINIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRE	64PRR-101

SECTION IC ACID SOLUTIONS	SEPARATION OF DECOMPOSITION POTENTIALS OF	PROTACTINIUM FROM MOLTEN SALT REACTOR FUEL COMPO PROTACTINIUM STABILITY IN THORIUM NITRATE - NITR PURE METALS IN MOLTEN FLUORIDE SALTS PURIFICATION OF ALPHA METHYL NAPHTHALENE PURINE THE STRUCTURE PYRITIC MATERIALS PYRITIC MATERIALS PURITY POTASSIUM CHLORIDE / POTASSIUM OXIDE / L/ PYRIDINE EXTRACTION - GAMMA COUNTING METHOD PYROLYSIS METHOD PYROLYTIC GRAPHITE / GLASSY CARBON) PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND ELECTR PYROLYTIC GRAPHITE CUP AS BOTH VESSEL AND INDICA PYROLYTIC GRAPHITE ELECTRODE PYROLYTIC GRAPHITE ELECTRODE /METRY OF CERIUM(IV PYROLYTIC GRAPHITE ELECTRODES PYROLYTIC GRAPHITE INDICATOR ELECTRODE PYROLYTIC GRAPHITE INDICATOR ELECTRODE) / / LIT Q.R.E.) A SIMPLE REFERENCE ELECTRODE APPLICATI Q-2564 CHECK OUT AND TEST PROCED Q-2564 HIGH SENSITIVITY COULOMETRIC TITRATOR (E QUALITATIVE AND QUANTITATIVE ANALYSIS OF ALIPHAT QUALITY CONTROL QUALITY CONTROL MEASUREMENTS COMPUTER PR QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIV QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIV QUALITY CONTROL REPORT, ANALYTICAL CHEMISTRY DIV QUALITY CONTROL REPORT, JAN.-JUNE, 1964 QUANTITATIVE ANALYSIS OF ALIPHATIC DILUENTS BY G QUANTITATIVE POLAROGRAPHIC MEASUREMENTS QUASI REFERENCE ELECTRODE - APPLICATIONS IN CONT QUASI REFERENCE ELECTRODE (Q.R.E.) A SIMPLE RE QUASI REFERENCE ELECTRODE / NICKEL - NICKEL(II)/ QUENCHING TECHNIQUE QUINONE METHOD RADIATION DETECTORS AND COUNTING STATISTICS RADIATION LABORATORY RADIATION LEVEL ANALYTICAL FACILITY (HRLAF) RADIATION LEVEL ANALYTICAL LABORATORY RADIATION ON ANALYTICAL METHODS RADIATION ON ARSENAZO-III SOLUTIONS RADIATION ON THE DETERMINATION OF URANIUM(VI) IN RADIATION ON THE REACTION OF NICKEL WITH DI METH RADIATION ON 2 THENOYL TRI FLUORO ACETONE (TTA RADICAL WITH METHANOL) RADIO RADIO IODINE EVALUATION OF IODIN RADIO RELEASE METHOD FOR THE EVALUATION OF ATMOS RADIO RELEASE METHODS FOR THE EVALUATION OF ATMO RADIO RELEASE METHODS FOR THE EVALUATION OF ATMO RADIOACTIVE MATERIALS RADIOACTIVE MATERIALS RADIOACTIVE SAMPLES RADIOACTIVE SOLUTIONS / MEASUREMENT OF ABSORPTI/ RADIOACTIVE TRACERS IN PHYSICAL METALLURGY RADIOACTIVE WASTE DISPOSAL SLURRIES RADIOACTIVE WASTES IN NATURAL SALT FORMATIONS ( ) RADIOACTIVITY RADIOACTIVITY (CURIUM-247 / PLUTONIUM-244) RADIOACTIVITY AND DECAY RADIOACTIVITY IN AQUEOUS SOLUTIONS, PYRIDINE EXT RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SO RADIOACTIVITY STANDARDS RADIOACTIVITY STANDARDS, NUCLEAR ANALYSIS, SPEC/ RADIOCHEMICAL ANALYSES RADIOCHEMICAL SEPARATIONS RADIOCHEMICAL STUDIES RADIOCHEMICAL WORK AT CRNL RADIOCHEMISTRY AND ACTIVATION ANALYSIS /OF ARTIF RADIOISOTOPES - RADIOISOTOPES RADIOISOTOPES RADIOISOTOPES RADIOISOTOPES - RADIOCHEMISTRY LABORATORY RADIOISOTOPES IN ALKALINE EARTH ANALYSIS RADIOISOTOPES IN ALKALINE EARTH ANALYSIS RADIOISOTOPES IN CHEMICAL ANALYSIS RADIOISOTOPES TO ANALYTICAL CHEMISTRY RADIOISOTOPES TO THE DETERMINATION OF SODIUM, LI RADIOLYSIS OF CHLORIDE SOLUTIONS (SCAVENGING OF RADIOLYTIC AND PHOTOLYTIC REDUCTION OF AQUEOUS S RADIONUCLIDES RADIONUCLIDES RADIOIOTIN WITH 2 THENOYL TRI FLUORO ACETONE RADIOIOTRACERS RADIUM-226 / THORIUM / COAL / FALLOUT / LEAD-210 LOW LEVEL ANALYSES (	64PRR-333 64PRR-072 64A-02-02B 64A-14-03 64PRR-036 64A-12-071 64PRR-061 64A-13 64PRR-150 64PRR-119 64A-06-03 64PRR-066 64A-06-12 64A-06-03B 64PRR-048 64A-06-11 64A-02-02 64A-01-02 64PRR-081 64A-01-05 64A-05-02 64B-15 64A-12-05B 64PRR-085 64PRR-087 64PRR-088 64PRR-086 64A-05-02 64PRR-270 64PRR-286 64A-01-02 64A-02-02E 64PRR-058 64PRR-125 64PRR-004 64B-18-01 64B-18-06 64PRR-018 64A-03 64A-03-03 64A-03-02 64A-03-01 64A-03-04 64A-03-05 64PRR-076 64A-12-06A 64PRR-308 64PRR-312 64A-11-01 64A-11-01A 64A-08-02A 64A-08-01A 64PRR-041 64A-06-10 64A-06-02 64A-12-02 64A-12-031 64PRR-055 64PRR-150 64PRR-132 64PRR-133 64PRR-134 64PRR-137 64PRR-138 64PRR-139 64PRR-140 64PRR-039 64PRR-038 64A-12 64PRR-010 64A-12-03 64PRR-303 64PRR-294 64B-18-05 64PRR-042 64PRR-052 64PRR-298 64B-18-05 64PRR-097 64PRR-302 64PRR-307 64A-12-06 64A-12-06B 64A-03-05 64PRR-044 64A-12-01 64A-12-01G 64PRR-064 64PRR-054 64A-12-03J
OF 3 METHYL ADENINE, AND METHYLATION OF 6 DI METHYL AMINO ACTIVATION ANALYSIS OF HIGH ACTIVATION ANALYSIS OF HIGH /IDE / URANIUM TRI CHLORIDE / DYSPROSIUM PHOSPHIDE / HIGH RUTHENIUM RADIOACTIVITY IN AQUEOUS SOLUTIONS, FLUORIDE IN MSRE FUEL, SOLID INDICATOR ELECTRODES ( ) ODE FOR MICRO REDOX AND ACID - BASE POTENTIOMETRIC TITRA/ TOR ELECTRODE FOR MICRO REDOX AND ACID - BASE POTENTIOE/ OXIDE FILM FORMATION ON THE , MANGANESE(VII), CHROMIUM(VI), AND VANADIUM(V) WITH THE METRIC TITRATION OF URANIUM(IV) WITH CERIUM(IV) UTILIZING DETERMINATION OF CHLORIDE WITH A HIUM FLUORIDE - BERYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE / ONS IN CONTROLLED POTENT/ THE QUASI REFERENCE ELECTRODE ( ) URE FOR HIGH SENSITIVITY COULOMETRIC TITRATOR, ORNL MODEL NGINEERING DRAWINGS / TEST SPECIFICATIONS / T/ ORNL MODEL IC DILUENTS BY GAS CHROMATOGRAPHY (SOLVENT EXTRACTANTS / OGRAM FOR ACCUMULATING STANDARD GAMMA-RAY SPECTRA AND FOR ISION, JAN.-MAR., 1964 ISION, JAN.-SEPT., 1963 ISION JAN.-DEC., 1963 - AS CHROMATOGRAPHY (SOLVENT EXTRACTANTS / QUALITATIVE AND SECOND DERIVATIVE DC POLAROGRAPHY AS A TECHNIQUE IN ROLLED POTENTIAL POLAROGRAPHY AND VOLTAMMETRY A/ A SIMPLE REFERENCE ELECTRODE APPLICATIONS IN CONTROLLED POTENT/ THE /CTRODES COMPATIBLE WITH MOLTEN FLUORIDE SALTS (PLATINUM QUID SCINTILLATION COUNTING OF CARBON-14 USING A BALANCED NIOBIUM, SPECTROMETRIC HYDRO HIGH LEVEL ALPHA HIGH DESIGN AND CONSTRUCTION OF ORNL HIGH EFFECTS OF EFFECT OF COBALT-60 GAMMA EFFECT OF COBALT-60 GAMMA EFFECT OF COBALT-60 GAMMA EFFECT OF COBALT-60 GAMMA LYSIS OF CHLORIDE SOLUTIONS (SCAVENGING OF HYDROXYL FREE E-125 MEASUREMENT TECHNIQUES FOR CLINICAL APPLICATIONS OF PHERIC POLLUTION - SULFUR DI OXIDE SPHERIC POLLUTION SPHERIC POLLUTION - SULFUR DI OXIDE ELECTRON MICROSCOPY OF ELECTRON MICROSCOPE FACILITY FOR STUDYING DISPOSABLE SPECTROGRAPHIC EXCITATION CHAMBER FOR /RAY ANALYSIS (ABSORPTION-EDGE ANALYSIS OF SOLIDS AND OF REVIEW OF - DETERMINATION OF SOLIDS IN DISPOSAL OF MEASUREMENT OF SEARCH FOR NATURAL TRANSURANIC NMOGRAPHS FOR CALCULATING INDUCED REACTION - GAMMA COUNTING METHOD RUTHENIUM LUTIONS, DIRECT MEASUREMENT METHOD GROSS ALPHA LUTIONS, LANTHANUM FLUORIDE PRECIPITATION - / GROSS ALPHA GROSS ALPHA LUTIONS, TRI ISO OCTYL AMINE (OR TRI CAPRYL/ GROSS ALPHA GROSS ALPHA LUTIONS, LANTHANUM FLUORIDE PRECIPITATION/ PLUTONIUM ALPHA ALPHA LUTIONS, THENOYL TRI FLUORO ACETONE (TT/ PLUTONIUM ALPHA ALPHA LUTIONS, TRI ISO OCTYL AMINE EXTRAC/ TRANSPLUTONIUM ALPHA ALPHA LUTIONS, LANTHANUM FLUORIDE PRECIPIT/ TRANSPLUTONIUM ALPHA ALPHA REPORT FOR ANALYTICAL CHEMISTS - AVAILABILITY AND USE OF /LOGY - ANALYTICAL INSTRUMENTATION - MOLTEN SALT SYSTEMS, NUCLEAR AND RECENT ACTS AND ERRORS ENCOUNTERED IN GAMMA-RAY SPECTROMETRY FOR RADIOISOTOPES - REVIEW OF - INTERNATIONAL DIRECTORY OF SHIELDED FACILITY FOR USE IN THE ANALYSIS OF SHIELDED FACILITY FOR USE IN THE ANALYSIS OF THIUM, AND PHOSPHORUS HYDROXYL FREE RADICAL WITH METHANOL) ILVER NITRATE SOLUTIONS NUCLEAR PROPERTIES OF STUDIES OF NEUTRON DEFICIENT HAFNIUM SELECTIVE LIQUID-LIQUID EXTRACTION OF CHOOSING OPTIMUM COUNTING METHODS AND LOW LEVEL ANALYSES (	64PRR-333 64PRR-072 64A-02-02B 64A-14-03 64PRR-036 64A-12-071 64PRR-061 64A-13 64PRR-150 64PRR-119 64A-06-03 64PRR-066 64A-06-12 64A-06-03B 64PRR-048 64A-06-11 64A-02-02 64A-01-02 64PRR-081 64A-01-05 64A-05-02 64B-15 64A-12-05B 64PRR-085 64PRR-087 64PRR-088 64PRR-086 64A-05-02 64PRR-270 64PRR-286 64A-01-02 64A-02-02E 64PRR-058 64PRR-125 64PRR-004 64B-18-01 64B-18-06 64PRR-018 64A-03 64A-03-03 64A-03-02 64A-03-01 64A-03-04 64A-03-05 64PRR-076 64A-12-06A 64PRR-308 64PRR-312 64A-11-01 64A-11-01A 64A-08-02A 64A-08-01A 64PRR-041 64A-06-10 64A-06-02 64A-12-02 64A-12-031 64PRR-055 64PRR-150 64PRR-132 64PRR-133 64PRR-134 64PRR-137 64PRR-138 64PRR-139 64PRR-140 64PRR-039 64PRR-038 64A-12 64PRR-010 64A-12-03 64PRR-303 64PRR-294 64B-18-05 64PRR-042 64PRR-052 64PRR-298 64B-18-05 64PRR-097 64PRR-302 64PRR-307 64A-12-06 64A-12-06B 64A-03-05 64PRR-044 64A-12-01 64A-12-01G 64PRR-064 64PRR-054 64A-12-03J		

A NUMBER OF EVEN-A NUCLEI EVEN MASS NUCLEI (MASS NUMBERS	RANGING FROM 184 THROUGH 192) /CLEAR LEVELS IN	64A-12-01F
EAR LEVELS IN A NUMBER OF EVEN MASS NUCLEI (MASS NUMBERS	RANGING FROM 184 THROUGH 192) /OPERTIES OF NUCL	64PRR-034
GEN IN POTASSIUM AND NAK BY A MODIFIED AMALGAMATION / THE	RAPID DETERMINATION OF LOW CONCENTRATIONS OF OXY	64PRR-287
GEN AND HYDROGEN IN ALKALI METALS BY A MODIFIED AMAL/ THE	RAPID DETERMINATION OF LOW CONCENTRATIONS OF OXY	64PRR-288
LYSIS OUTPUT SPECTRA OF 14-MEV NEUTRON GENERATORS -	RAPID ESTIMATION AND INFLUENCE IN ACTIVATION ANA	64PRR-306
ION/ OUTPUT SPECTRUM FROM 14-MEV NEUTRON GENERATORS - ITS	RAPID ESTIMATION AND ITS INFLUENCE ON CROSS SECT	64A-12-08A
UDIES OF IRON IN MOLTEN FLUORIDE	RAPID SCAN VOLTAMMETRY - CHRONOPOTENTIOMETRIC ST	64PRR-046
	RAPID SEPARATION AND DETERMINATION OF TECHNETIUM	64A-12-03D
	RAPID TEFLON DROPPING MERCURY ELECTRODE	64A-05-05E
VERTICAL ORIFICE	RARE EARTH ELEMENT ALPHA EMITTERS (EUROPIUM)	64A-12-01E
STUDIES OF	RARE GASES	64PRR-017
AUTO IONIZING PROCESSES IN THE	RATE DATA BY THE ANALYSIS OF SPECTROMETRIC ABSOR	64PRR-271
PIION / A GENERALIZED COMPUTER PROGRAM TO OBTAIN REACTION	RATES IN AUTOMOTIVE ENGINES BY LIQUID SCINTILLAT	64PRR-059
ION COUNTING OF IRON-55	REACTION IN AQUEOUS HYDROFLUORIC ACID WITH THE H	64A-05-05C
OR/ POLAROGRAPHY OF THE DIVALENT LEAD TO LEAD METAL REDOX	REACTION OF MOLTEN LITHIUM FLUORIDE - SODIUM FLU	64PRR-321
ORIDE - POTASSIUM/ SPECTROPHOTOMETRIC OBSERVATIONS OF THE	REACTION OF NICKEL WITH DI METHYL GLYOXIME	64A-03-01
EFFECT OF COBALT-60 GAMMA RADIATION ON THE	REACTION RATE DATA BY THE ANALYSIS OF SPECTROMET	64PRR-271
RIC ABSORPTION / A GENERALIZED COMPUTER PROGRAM TO OBTAIN	REACTIONS	64A-12-08B
CATALOG OF 14-MEV NEUTRON	REACTIONS IN CONCENTRATED LITHIUM CHLORIDE SOLUT	64PRR-291
IONS - DETERMINATION OF FREE ACID AND HYDROLYZABLE METAL	REACTIONS IN CONCENTRATED LITHIUM CHLORIDE SOLUT	65A-06-01
IONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID / WE/	REACTIONS IN MOLTEN FLUORIDE SALTS	64PRR-319
DIRECT SPECTROPHOTOMETRIC STUDIES OF REDOX	REACTIONS OBSERVED WITH 14-MEV NEUTRONS	64PRR-313
	REACTOR	64A-04-02
OR THE DETERMINATION OF DISSOLVED GASES AND IMPURITIES IN	REACTOR COOLANT WATER /EY OF SENSITIVE METHODS F	64PRR-100
	REACTOR ENGINEERING SERVICE LABORATORY	64B-19
	REACTOR EXPERIMENT	64A-04-01
MOLTEN SALT	REACTOR FUEL COMPOSITION	64PRR-333
SEPARATION OF PROTACTINIUM FROM MOLTEN SALT	REACTOR FUEL, COULOMETRIC TITRATION METHOD	64PRR-264
URANIUM, COPPER, AND NICKEL IN HOMOGENEOUS	REACTOR FUELS	64A-05
CHEMICAL ANALYSIS OF ADVANCED	REACTOR NEUTRON FLUX - CHARACTERISTICS AND USES	64PRR-002
	REACTOR PROJECTS	64A-04
ANALYTICAL CHEMISTRY FOR	REAGENTS	64PRR-229
	REDETERMINATION OF THE HALF-LIFE OF URANIUM-232	64A-12-01I
	REDETERMINATION OF THE HALF-LIFE OF URANIUM-232	64PRR-043
LYTIC GRAPHITE CUP AS BOTH VESSEL AND ELECTRODE FOR MICRO	REDOX AND ACID - BASE POTENTIOMETRIC TITRATIONS	64PRR-066
/ITE CUP AS BOTH VESSEL AND INDICATOR ELECTRODE FOR MICRO	REDOX AND ACID - BASE POTENTIOMETRIC TITRATIONS/	64A-06-12
THE HOR/ POLAROGRAPHY OF THE DIVALENT LEAD TO LEAD METAL	REDOX REACTION IN AQUEOUS HYDROFLUORIC ACID WITH	64A-05-05C
DIRECT SPECTROPHOTOMETRIC STUDIES OF	REDOX REACTIONS IN MOLTEN FLUORIDE SALTS	64PRR-319
RADIOLYTIC AND PHOTOLYTIC	REDUCTION OF AQUEOUS SILVER NITRATE SOLUTIONS	64PRR-044
DISSOLUTION OF IRRADIATED, HIGH FIRED,	REFRACTORY NUCLEAR MATERIALS	64PRR-116
TROMETRIC ANALYSIS	RELEASE MEASUREMENT AND COLLECTION FOR MASS SPEC	64PRR-266
POLLUTION - SULFUR DI OXIDE	RADIO RELEASE METHOD FOR THE EVALUATION OF ATMOSPHERIC	64A-12-06A
C POLLUTION	RADIO RELEASE METHODS FOR THE EVALUATION OF ATMOSPHERI	64PRR-308
C POLLUTION - SULFUR DI CXIDE	RADIO RELEASE METHODS FOR THE EVALUATION OF ATMOSPHERI	64PRR-312
	RESINS	64A-11-05
ULTRASTRUCTURE STUDIES OF EXCHANGE	RESISTANCE / TIME DERIVATIVE DC POLAROGRAPHY / /	64A-01-01
/PHY (POTENTIOSTATIC COMPENSATION FOR POLAROGRAPHIC CELL	RESISTANCE IN HIGH SPECIFIC RESISTANCE SOLUTION/	64PRR-001
/ ORGANIC EXTRACTS AND COMPENSATION OF POLAROGRAPHIC CELL	RESISTANCE SOLUTIONS /ORGANIC EXTRACTS AND COMPE	64PRR-001
NSATION OF PCLAROGRAPHIC CELL RESISTANCE IN HIGH SPECIFIC	RESOLUTION OF GAMMA-RAY SPECTRA	64A-12-05A
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-090
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-276
	ELECTRONIC RESOLUTION OF GAMMA-RAY SPECTRA	64PRR-293
/PHY / SIGNAL TO NOISE RATIO (S/N) IN DC POLAROGRAPHY /	RESOLUTION OF POLAROGRAPHIC WAVES / POLAROGRAPH/	64A-01-01
TAL APPROACHES TO ANALYSIS OF FUSED SALTS (ELECTRON SPIN	RESONANCE)	64A-02-03
HEMISTRY IN NUCLEAR TECHNOLOGY - ANALYTICAL INSTRUMENT/ A	RESUME OF THE SEVENTH CONFERENCE ON ANALYTICAL C	64PRR-038
	RETENTION DATA FOR POLY PHENYL COMPOUNDS	64PRR-013
IGN SYSTEMS	REVIEW OF - ELECTRONIC CIRCUITS AND INSTRUMENTAT	64PRR-027
OPES	REVIEW OF - INTERNATIONAL DIRECTORY OF RADIOISOT	64PRR-042
LLURGY	REVIEW OF - RADIOACTIVE TRACERS IN PHYSICAL META	64PRR-041
ER / PREPARATION CF COMPUTER INPUT INFORMATION FOR ANNUAL	REVISION TO CUMULATIVE INDEXES FOR THE CRNL MAST	64PRR-146
/MIUM / PALLADIUM / PLATINUM / PCTASSIUM / PRASEODYMIUM /	RHENIUM / RUBIDIUM / RUTHENIUM / SAMARIUM / SEL/	64PRR-154
BELED AMINO ACIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRICAL	RIBO NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LA	64A-07
LATILE FLUCRIDE IMPURITIES IN URANIUM COMPOUNDS USING THE	ROTATING DISK SPARK TECHNIQUE /TERMINATION OF VO	64PRR-082
/LADIUM / PLATINUM / POTASSIUM / PRASEODYMIUM / RHENIUM /	RUBIDIUM / RUTHENIUM / SAMARIUM / SELENIUM / SI/	64PRR-154
LPHA METHYL BENZYL) PHENOL DETERMINATION OF CESIUM AND	RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL 2 I A	64PRR-062
// PRASEODYMIUM-142 / PRASEODYMIUM-143 / PROMETHIUM-147 /	RUBIDIUM-86 / RUTHENIUM-103, RUTHENIUM-106 / S/	64PRR-230
/ATINUM / PCTASSIUM / PRASEODYMIUM / RHENIUM / RUBIDIUM /	RUTHENIUM / SAMARIUM / SELENIUM / SILICON / SIL/	64PRR-154
	RUTHENIUM / SELENIUM)	64A-08-01B
RIDINE EXTRACTION - GAMMA COUNTING METHOD	RUTHENIUM RADIOACTIVITY IN AQUEOUS SOLUTIONS, PY	64PRR-150
/-142 / PRASEODYMIUM-143 / PROMETHIUM-147 / RUBIDIUM-86 /	RUTHENIUM-103, RUTHENIUM-106 / SAMARIUM-153 / S/	64PRR-230
/MIUM-143 / PROMETHIUM-147 / RUBIDIUM-86 / RUTHENIUM-103,	RUTHENIUM-106 / SAMARIUM-153 / SCANDIUM-56 / SE/	64PRR-230
/IRD DERIVATIVE DC POLAROGRAPHY / SIGNAL TO NOISE RATIO (	S/N) IN DC POLAROGRAPHY / RESOLUTION OF POLARO/	64A-01-01
	SAFETY	64PRR-222
HE ORNL MDEL VII FLAME SPECTROPHOTOMETER	SAFETY CIRCUIT FOR THE MULTIPLIER PHOTOTUBE OF T	64A-01-07
	SAFETY PROGRAM	64A-11-02
	SALT	64A-02-02D
VOLTAMMETRY OF THE MSR COOLANT SALT AND MSR FUEL	SALT AND MSR FUEL SALT	64A-02-02D
VOLTAMMETRY OF THE MSR COOLANT	SALT BRIDGE) /BUTYL 2 (ALPHA METHYL BENZYL) P	64A-06-08
HENOL / TETRA BUTYL AMMONIUM HYDROXIDE / LITHIUM CHLORIDE	SALT FORMATIONS (HIGH TEMPERATURE CHEMICAL DOSI	64A-06-02
METERS) DISPOSAL OF RADIOACTIVE WASTES IN NATURAL	SALT REACTOR EXPERIMENT	64A-04-01
	SALT REACTOR FUEL COMPOSITION	64PRR-333
SEPARATION OF PROTACTINIUM FROM MOLTEN	SALT SYSTEMS	64A-02
ANALYTICAL STUDIES OF MOLTEN	SALT SYSTEMS	64A-02-01
ABSORPTION SPECTROPHOTOMETRIC STUDIES RELATED TO MOLTEN	SALT SYSTEMS	64PRR-297
VOLTAMMETRIC MEASUREMENTS IN MOLTEN FLUORIDE	SALT SYSTEMS (LITHIUM FLUORIDE - SODIUM FLUORID	64A-02-02
E - POTASSIUM FLUCRIDE / / VOLTAMMETRY OF MOLTEN FLUORIDE	SALT SYSTEMS, RADIOACTIVITY STANDARDS, NUCLEAR /	64PRR-038
/NUCLEAR TECHNOLOGY - ANALYTICAL INSTRUMENTATION - MOLTEN	SALT SYSTEMS, RADIOACTIVITY STANDARDS, NUCLEAR /	64A-02-01B
CONTAINERS FOR MOLTEN FLUORIDE	SALTS	A
MPEROMETRIC TITRATION OF CHROMIUM IN MIXTURES OF FLUORIDE	SALTS	64PRR-012
ECOMPOSITION POTENTIALS CF PURE METALS IN MOLTEN FLUORIDE	SALTS	D
PHOTOMETRIC STUDIES OF REDOX REACTIONS IN MOLTEN FLUORIDE	SALTS	64A-02-02B
	DIRECT SPECTRO	64PRR-319
INSTRUMENTAL APPROACHES TO ANALYSIS OF FUSED	SALTS (ELECTRON SPIN RESONANCE)	64A-02-03

KEL/ REFERENCE ELECTRODES COMPATIBLE WITH MOLTEN FLUORIDE	SALTS (PLATINUM QUASI REFERENCE ELECTRODE / NIC	64A-02-02E
/ASSIUM / PRASEODYMIUM / RHENIUM / RUBIDIUM / RUTHENIUM /	SAMARIUM / SELENIUM / SILICON / SILVER / SODIUM/	64PRR-154
COLORIMETRIC DETERMINATION OF	SAMARIUM WITH ARSENATO-III	64A-06-14
/THIUM-147 / RUBIDIUM-86 / RUTHENIUM-103, RUTHENIUM-106 /	SAMARIUM-153 / SCANDIUM-56 / SELENIUM-75 / SILV/	64PRR-230
OF IRON IN MOLTEN FLUORIDE	RAPID SCAN VOLTAMMETRY - CHRONOPOTENTIOMETRIC STUDIES	64PRR-046
/IDIUM-86 / RUTHENIUM-103, RUTHENIUM-106 / SAMARIUM-153 /	SCANDIUM-56 / SELENIUM-75 / SILVER-110M / SILVE/	64PRR-230
ED IN GAMMA-RAY SPECTROMETRY	SCATTERED ANNIHILATION GAMMA-RAY SUM PEAK OBSERV	64PRR-040
L)	RADIOLYSIS OF CHLORIDE SOLUTIONS (SCAVENGING OF HYDROXYL FREE RADICAL WITH METHANO	64A-03-05
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC	SCIENCE	64A-12-07B
APPLICATION OF NUCLEAR ANALYSIS TO FORENSIC	SCIENCE	64PRR-274
THE NEW IMAGE OF ANALYTICAL CHEMISTRY IN	SCIENCE	64PRR-332
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC	SCIENCE I. PHYSICAL EVIDENCE	64PRR-014
APPLICATION OF ACTIVATION ANALYSIS TO FORENSIC	SCIENCE II. DRUGS	64PRR-015
	GAMMA SCINTILLATION COUNTER	64PRR-147
NCEDED QUENCHING TECHNIQUE	LIQUID SCINTILLATION COUNTING OF CARBON-14 USING A BALA	64PRR-058
WEAR RATES IN AUTOMOTIVE ENGINES BY	LIQUID SCINTILLATION COUNTING OF IRON-55	64PRR-059
1) AND TOTAL EUROPIUM - EUROPIUM ACTIVATED LITHIUM IODIDE	SCINTILLATION COUNTING TECHNIQUES	64PRR-003
ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID	SCINTILLATION CRYSTALS / TERMINATION OF EUROPIUM(I	64PRR-019
ABSOLUTE COUNTING OF BETA EMITTERS BY THE LIQUID	SCINTILLATION METHOD	64A-12-04C
	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION	64PRR-289
	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION	64PRR-099
-6 ENRICHED ISOTOPE	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION USING LITHIUM	64PRR-311
-6 ENRICHED ISOTOPE	A UNIQUE LIQUID SCINTILLATOR FOR NEUTRON DETECTION USING LITHIUM	64PRR-098
	A NEW SCINTILLATOR FOR THERMAL NEUTRON DETECTION	64PRR-309
ON	N,N,N// TRI METHYL BORAZINE AS A LIQUID SCINTILLATOR SOLVENT FOR THERMAL NEUTRON DETECTI	64PRR-060
	MODERN METHODS IN LIQUID SCINTILLATOR TECHNOLOGY	64A-12-04B
	LIQUID SCINTILLATORS	64PRR-330
	LIQUID SCINTILLATORS THAT CONTAIN 1 METHYL NAPHTHALENE	64A-12-04
	LIQUID SCINTILLATORS USING 1 METHYL NAPHTHALENE	64A-12-04A
URIUM-247 / PLUTONIUM-244)	SEARCH FOR NATURAL TRANSURANIC RADIOACTIVITY (C	64PRR-030
ERMINATION OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4	SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL DET	64A-12-031
RA BUTYL AMMONIUM H/ NONAQUEOUS TITRIMETRY OF PHENOLS (4	SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / TET	64PRR-062
	SECOND-ORDER INTERFERENCE IN ACTIVATION ANALYSIS	64A-06-08
SIZE DISTRIBUTION IN THORIUM OXIDE, NEUTRON ACTIVATION -	SEDIMENTATION METHOD	64PRR-056
NOME)	ORE SELECTION FOR PROJECT COACH (TRANSPLUTONIUM / G	64PRR-218
XCHANGE WITH MERCURIC DI N BUTYL PHOSPHORIC TRIOATE IN AN/	SELECTIVE DETERMINATION OF MERCURY BY ISOTOPIC E	64A-12-033H
/SPHORO THICIC TRI AMIDES AS EXTRACTANTS FOR METAL IONS -	SELECTIVE EXTRACTION OF MERCURY(II), SILVER(I),/	64PRR-033
ITH 2 THENOYL TRI FLUORO ACETONE	SELECTIVE LIQUID-LIQUID EXTRACTION OF RADIOTIN W	64A-12-03A
/F TRIVALENT ACTINIDE ELEMENTS FROM LANTHANIDE ELEMENTS -	SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAP/	64PRR-064
/ROACH TO THE SEPARATION OF TRIVALENT ACTINIDE ELEMENTS -	SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRI CAP/	64A-12-03C
	ATOMIC ABSORPTION (RUTHENIUM /	64PRR-050
LIED NEUTRON ACTIVATION ANALYSIS (OXYGEN-18 / FLUORIDE /	SELENIUM)	64A-08-018
/ASEODYMIUM / RHENIUM / RUBIDIUM / RUTHENIUM / SAMARIUM /	SELENIUM / SILICON / SILVER / SODIUM / STRONTIUM/	APP 64A-12-07G
/HENIUM-103, RUTHENIUM-106 / SAMARIUM-153 / SCANDIUM-56 /	SELENIUM-75 / SILVER-110M / SILVER-111 / SODIUM/	64PRR-154
LVED GASES AND IMPURITIES IN REAC/ A LITERATURE SURVEY OF	SENSITIVE METHODS FOR THE DETERMINATION OF DISSO	64PRR-230
	RAPID SEPARATION AND DETERMINATION OF TECHNETIUM	64PRR-100
LINE EARTH ELEMENTS)	SODIUM SEPARATION FROM BIOLOGICAL MATERIAL	64A-12-03D
NG GASES, MOLECULAR SIEVE ABSORPTION METHOD	SEPARATION OF BARIUM FROM ALKALI METALS AND ALKA	64PRR-063
TOR FUEL COMPOSITION	ION EXCHANGE SEPARATION OF BORON FROM OTHER ELEMENTS	64A-08-01C
	SEPARATION OF KRYPTON AND XENON FROM CONTAMINATI	64PRR-221
	SEPARATION OF PROTACTIONIUM FROM MOLTEN SALT REAC	64PRR-152
	SEPARATION OF SODIUM (SODIUM-24)	64PRR-333
	SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHE	64A-12-06C
MICAL MEDIA	CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS -	64A-12-03F
MICAL MED/ CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS - THE	SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHE	64PRR-032
URIUM-129, AN/ CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS -	SEPARATION OF THE ISOMERS OF TELLURIUM-127, TELL	64PRR-031
LOSE COLUMN CHROMATOGRAPHY	SEPARATION OF TRACE METALS FROM URANIUM BY CELLU	64A-12-03E
CTIVE LIQUID-LIQUID EXTRACTION WITH/ A NEW APPROACH TO THE	SEPARATION OF TRIVALENT ACTINIDE ELEMENTS - SELE	64PRR-050
ANTHANIDE ELEMENTS - SELECTIVE LIQ/ A NEW APPROACH TO THE	SEPARATION OF TRIVALENT ACTINIDE ELEMENTS FROM L	64A-12-03C
TRI N OCTYL PHOSPHINE OXIDE AND ITS DIRECT COLORIMETRIC/	SEPARATION OF URANIUM BY SOLVENT EXTRACTION WITH	64PRR-080
RADIOCHEMICAL	SEPARATIONS	64PRR-010
PR., 1964 / MAY, 1964 / JUNE, 1964 / JULY, 1964 / AUG., 1964 /	SEPT.-OCT., 1964 / 1964 / FEB., 1964 / MAR., 1964 / A	64PRR-105
TRIP REPORT TO GENERAL ATOMIC,	SEPT. 28, 1964	64PRR-103
THE ROLE OF	SERENDIPITY IN RESEARCH	64PRR-322
	SERVICE ANALYSES	64B
REACTOR ENGINEERING	SERVICE LABORATORY	64B-19
CLEAR TECHNOLOGY - ANALYTICAL INSTRUMENT/ A RESUME OF THE	SEVENTH CONFERENCE ON ANALYTICAL CHEMISTRY IN NU	64PRR-038
PHY	SEWING NEEDLE AND TEFLON ARE ADVANCING POLAROGRA	64PRR-329
IOISOTOPES	SHIELDED FACILITY FOR USE IN THE ANALYSIS OF RAD	64PRR-052
IOISOTOPES	SHIELDED FACILITY FOR USE IN THE ANALYSIS OF RAD	64PRR-298
	SHORT-LIVED NUCLIDES	64PRR-275
PRECISION OF ACTIVATION ANALYSIS OF	SIEVE ABSORPTION METHOD	64PRR-152
OF KRYPTON AND XENON FROM CONTAMINATING GASES, MOLECULAR	SIGNAL TO NOISE RATIO (S/N) IN DC POLAROGRAPH/	64A-01-01
/IVE DC POLAROGRAPHY / THIRD DERIVATIVE DC POLAROGRAPHY /	SILICON / SILVER / SODIUM / STRONTIUM / SULFUR /	64PRR-154
// RHENIUM / RUBIDIUM / RUTHENIUM / SAMARIUM / SELENIUM /	SILICON DIODE DETECTOR METHOD	64PRR-135
A SPECTROMETRY OF TRANSURANIUM (TRU) PROCESS SOLUTIONS,	SILVER / SODIUM / STRONTIUM / SULFUR / TANTALUM/	64PRR-154
// RUBIDIUM / RUTHENIUM / SAMARIUM / SELENIUM / SILICON /	SILVER NITRATE SOLUTIONS	64PRR-044
RADIOLYTIC AND PHOTOLYTIC REDUCTION OF AQUEOUS	SILVER-110M / SILVER-111 / SODIUM-24 / TIN-113 /	64PRR-230
UTHENIUM-106 / SAMARIUM-153 / SCANDIUM-56 / SELENIUM-75 /	SILVER-111 / SODIUM-24 / TIN-113 /UTHENIUM-106 /	64PRR-230
SAMARIUM-153 / SCANDIUM-56 / SELENIUM-75 / SILVER-110M /	SILVER(I), AND COPPER(I) / TRI AMIDES AS EXTRACTA	64A-12-03A
NTS FOR METAL IONS - SELECTIVE EXTRACTION OF MERCURY(II),	SLURRIES	64A-06-10
DETERMINATION OF SOLIDS IN RADIOACTIVE WASTE DISPOSAL	SEPARATION OF SODIUM (SODIUM-24)	64A-12-06C
	SODIUM / STRONTIUM / SULFUR / TANTALUM / TECHNE/	64PRR-154
/M / RUTHENIUM / SAMARIUM / SELENIUM / SILICON / SILVER /	SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETA	64PRR-127
TE (EDTA) METHOD	SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETA	64PRR-131
TE - IRON(III) INDICATOR METHOD	SODIUM FLUORIDE - LITHIUM FLUORIDE - POTASSIUM F	64PRR-104
FLUORIDE - URANIUM/ DETERMINATION OF TRACES OF IRON(III) IN	SODIUM FLUORIDE - POTASSIUM FLUORIDE	64A-02-02C
VOLTAMMETRY OF NICKEL(II) IN MOLTEN LITHIUM FLUORIDE -	SODIUM FLUORIDE - POTASSIUM FLUORIDE	64PRR-045
VOLTAMMETRY OF NICKEL IN MOLTEN LITHIUM FLUORIDE -	SODIUM FLUORIDE - POTASSIUM FLUORIDE / LITHIUM /	64A-02-02
/TRY OF MOLTEN FLUORIDE SALT SYSTEMS (LITHIUM FLUORIDE -	SODIUM FLUORIDE - POTASSIUM FLUORIDE EUTECTIC /O	64PRR-070
NS ABOUT NICKEL(II) IONS IN THE MOLTEN LITHIUM FLUORIDE -	SODIUM FLUORIDE - POTASSIUM FLUORIDE WITH SEVER/	64PRR-321
/OBSERVATIONS OF THE REACTION OF MOLTEN LITHIUM FLUORIDE -		

BORON (BORATE) POTENTIOMETRIC MANNITOL -	SODIUM HYDROXIDE TITRATION METHOD	64PRR-220
ORTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE, VOLUMETRIC	SODIUM HYDROXIDE TITRATION METHOD /RIC ACID, AND	64PRR-265
L COULOMETRIC TITRATION OF URANIUM(IV) AND URANIUM(VI) IN	SODIUM SEPARATION FROM BIOLOGICAL MATERIAL	64PRR-063
APPLICATION OF RADICISOTOPES TO THE DETERMINATION OF	SODIUM TRI POLY PHOSPHATE MEDIUM /COLLED POTENTIA	64PRR-071
SEPARATION OF SODIUM (	SODIUM, LITHIUM, AND PHOSPHORUS	64A-12-06B
/ SCANDIUM-56 / SELENIUM-75 / SILVER-110M / SILVER-111 /	SODIUM-24)	64A-12-06C
MICROSCOPICAL STUDY OF THE STRUCTURE OF SPHERICAL THORIA	SODIUM-24 / TIN-113 /UTHENIUM-106 / SAMARIUM-153	64PRR-230
/ GLASSY CARBON)	SOL-GEL BEADS	64PRR-317
MASS SPECTROMETRIC ANALYSIS	SOLID INDICATOR ELECTRODES (PYROLYTIC GRAPHITE	64A-06-03
T OF ABSORP/ X-RAY ANALYSIS (ABSORPTION-EDGE ANALYSIS OF	SOLIDS - RELEASE MEASUREMENT AND COLLECTION FOR	64PRR-266
DETERMINATION OF	SOLIDS AND OF RADIOACTIVE SOLUTIONS / MEASUREMENT	64A-08-01A
/E ANALYSIS OF ALIPHATIC DILUENTS BY GAS CHROMATOGRAPHY (	SOLIDS IN RADIOACTIVE WASTE DISPOSAL SLURRIES	64A-06-10
IDE AND ITS DIRECT COLORIMETRIC/ SEPARATION OF URANIUM BY	SOLVENT EXTRACTANTS / PARAFFINS NORMAL OCTANE T/	64A-05-02
ROGRAPHIC WAVES / POLAROGRAPHY IN NONAQUEOUS SOLVENTS AND	SOLVENT EXTRACTION WITH TRI N OCTYL PHOSPHINE OX	64PRR-080
N,N,N// TRI METHYL BORAZINE AS A LIQUID SCINTILLATOR	SOLVENT EXTRACTS) /OGRAPHY / RESOLUTION OF POLA	64A-01-01
UTION OF POLAROGRAPHIC WAVES / POLAROGRAPHY IN NONAQUEOUS	SOLVENT FOR THERMAL NEUTRON DETECTION	64A-12-04B
NEUTRON ABSORPTION ANALYSIS WITH ISOTOPIC	SOLVENTS AND SOLVENT EXTRACTS) /OGRAPHY / RESOL	64A-01-01
NONREACTOR NEUTRON	SOURCES	64A-12-07J
ISOTOPIC AND ACCELERATOR NEUTRON	SOURCES	64PRR-011
THE USE OF ISOTOPIC NEUTRON	SOURCES FOR CHEMICAL ANALYSIS	64PRR-315
ATION OF CERTAIN IMPURITIES IN LITHIUM FLUORIDE POWDER BY	SPARK EXCITATION	64PRR-316
E IMPURITIES IN URANIUM COMPOUNDS USING THE ROTATING DISK	SPARK TECHNIQUE /TERMINATION OF VOLATILE FLUORID	64A-08-02B
AND COMPENSATION OF POLAROGRAPHIC CELL RESISTANCE IN HIGH	SPECIFIC RESISTANCE SOLUTIONS /ORGANIC EXTRACTS	64PRR-082
TIVITY COULOMETRIC TITRATOR (ENGINEERING DRAWINGS / TEST	SPECIFICATIONS / TROUBLE-SHOOTING GUIDE) /SENSI	64PRR-001
ELECTRONIC RESOLUTION OF GAMMA-RAY	SPECTRA	64A-01-05
ELECTRONIC RESOLUTION OF GAMMA-RAY	SPECTRA	64A-12-05A
ELECTRONIC RESOLUTION OF GAMMA-RAY	SPECTRA	64PRR-090
ELECTRONIC RESOLUTION OF GAMMA-RAY	SPECTRA	64PRR-276
COMPUTER PROGRAM FOR ACCUMULATING STANDARD GAMMA-RAY	SPECTRA AND FOR QUALITY CONTROL MEASUREMENTS	64PRR-293
LIDE SYSTEMS	STUDIES OF THE ABSORPTION	64A-12-05B
SYNTHESIS AND INFRARED ABSORPTION	SPECTRA OF MOLTEN ALKALI METAL - ALKALI METAL HA	64A-02-01D
HOLDER FOR USE IN OBTAINING ABSORPTION	SPECTRA OF N,N,N// TRI METHYL BORAZINE	64PRR-079
RYLLIUM FLUORIDE - ZIRCONIUM FLUORIDE AND IN / ABSORPTION	SPECTRA OF SMALL CRYSTALS	64A-02-01E
IMATION AND INFLUENCE IN ACTIVATION ANALYSIS	SPECTRA OF URANIUM(III) IN LITHIUM FLUORIDE - BE	64A-02-01C
OUTPUT	SPECTRA OF 14-MEV NEUTRON GENERATORS - RAPID EST	64PRR-306
X-RAY AND	SPECTROCHEMICAL ANALYSES	64A-08
X-RAY AND	SPECTROCHEMICAL ANALYSES	64A-08-01
X-RAY AND	SPECTROCHEMICAL ANALYSES	64A-08-02
A VERSATILE ELECTRONIC COMPUTER FOR PHOTOELECTRIC	SPECTROCHEMICAL ANALYSIS	64PRR-067
URANIUM COMPOUNDS USING THE GALLIUM OXIDE CARRIER DISTILL/	SPECTROCHEMICAL ANALYSIS LABORATORY	64B-17
DE IMPURITIES IN URANIUM COMPOUNDS USING THE ROTATING DI/	SPECTROCHEMICAL DETERMINATION OF IMPURITIES IN U	64PRR-083
E SAMPLES	SPECTROCHEMICAL DETERMINATION OF VOLATILE FLUORID	64PRR-082
COMMENTARY ON ORNL DOUBLE MAGNET MASS	SPECTROGRAPHIC EXCITATION CHAMBER FOR RADIOACTIV	64A-08-02A
NTS	SPECTROMETER	64PRR-272
/ PROGRAM TO OBTAIN REACTION RATE DATA BY THE ANALYSIS OF	SPECTROMETER LIVE TIME ON PRECISION OF MEASUREME	64A-12-02C
MASS	SPECTROMETRIC ABSORPTION DATA FROM DYNAMIC MULT/	64PRR-271
S IN SOLIDS - RELEASE MEASUREMENT AND COLLECTION FOR MASS	SPECTROMETRIC ANALYSIS	64B-16
NIOBIUM,	SPECTROMETRIC ANALYSIS	64PRR-266
THIUM CHLORIDE SOLUTIONS	SPECTROMETRIC HYDRO QUINONE METHOD	64PRR-125
MASS	SPECTROMETRIC STUDY OF MOLTEN LITHIUM METAL - LI	64PRR-069
TRU MASS	SPECTROMETRY	64A-09
DETERMINATION OF URANIUM-232 BY GAMMA	SPECTROMETRY	64A-09-01
IVE DETERMINATION OF URANIUM-232 AND THORIUM-228 BY GAMMA	SPECTROMETRY	64A-12-02F
RED ANNIHILATION GAMMA-RAY SUM PEAK OBSERVED IN GAMMA-RAY	SPECTROMETRY	64PRR-304
RON / BROMINE / CADMIUM / CALCIUM / CERIUM/ ISOTOPIC MASS	SPECTROMETRY 180 DEGREE COMPTON SCATTE	64PRR-040
/L STUDY OF ARTIFACTS AND ERRORS ENCOUNTERED IN GAMMA-RAY	SPECTROMETRY / ALUMINUM / ANTIMONY / BARIUM / BO	64PRR-154
ISOTOPIC MASS	SPECTROMETRY FOR RADIOCHEMISTRY AND ACTIVATION /	64PRR-294
GENERAL OPERATING CONDITIONS FOR ISOTOPIC MASS	SPECTROMETRY OF THE ELEMENTS	64PRR-102
UTIONS, SILICON DIODE DETECTOR METHOD	SPECTROMETRY OF THE ELEMENTS	64PRR-153
FOR THE MULTIPLIER PHOTOTUBE OF THE ORNL MODEL VII FLAME	SPECTROMETRY OF TRANSURANIUM (TRU) PROCESS SOL	64PRR-135
ABSORPTION SPECTRUM OF URANIUM(VI) FLUORIDE GAS (NICKEL	SPECTROPHOTOMETER	64A-01-07
NICKEL HIGH TEMPERATURE	SPECTROPHOTOMETRIC ABSORPTION CELL)	64A-02-01F
LIQUIDS	SPECTROPHOTOMETRIC CELL ASSEMBLY	64A-02-01A
OF MOLTEN LITHIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM/	SPECTROPHOTOMETRIC CELL FOR USE WITH CORROSIVE L	64PRR-068
MOLTEN FLUORIDE SALTS	SPECTROPHOTOMETRIC OBSERVATIONS OF THE REACTION	64PRR-321
T SYSTEMS	SPECTROPHOTOMETRIC STUDIES OF REDOX REACTIONS IN	64PRR-319
ABSORPTION	SPECTROPHOTOMETRIC STUDIES RELATED TO MOLTEN SAL	64A-02-01
INFRARED	SPECTROSCOPY	64A-10
AND A DEMOUNTABLE HOLLOW CATHODE LAMP	SPECTROSCOPY USING LONG ABSORPTION PATH LENGTHS	64PRR-005
E DETECTORS	SPECTROSCOPY WITH LITHIUM DRIFTED GERMANIUM DIOD	64A-12-02B
/SALT SYSTEMS, RADIOACTIVITY STANDARDS, NUCLEAR ANALYSIS,	SPECTROSCOPY, GAS CHROMATOGRAPHY, AUTOMATION, E/	64PRR-038
PID ESTIMATION AND ITS INFLUENCE ON CROSS SECTION/ OUTPUT	SPECTRUM FROM 14-MEV NEUTRON GENERATORS - ITS RA	64A-12-08A
ECTROPHOTOMETRIC ABSORPTION CELL)	SPECTRUM OF URANIUM(VI) FLUORIDE GAS (NICKEL SP	64A-02-01F
A MICROSCOPICAL STUDY OF THE STRUCTURE OF	SPHERICAL THORIA SOL-GEL BEADS	64PRR-317
F CALIFORNIUM-252 - APPLICATION OF PROMPT GAMMA-RAYS FROM	SPIN RESONANCE)	64A-02-03
IONS	SPONTANEOUS FISSION / METHOD FOR DETERMINATION O	64PRR-051
OL MEASUREMENTS	STABILITY IN THORIUM NITRATE - NITRIC ACID SOLUT	64PRR-072
ALYTICAL CHEMISTS - AVAILABILITY AND USE OF RADIOACTIVITY	STANDARD GAMMA-RAY SPECTRA AND FOR QUALITY CONTR	64A-12-05B
/CAL INSTRUMENTATION - MOLTEN SALT SYSTEMS, RADIOACTIVITY	STANDARDS	64PRR-039
THE APPLICATION OF DERIVATIVE TECHNIQUES TO	STANDARDS, NUCLEAR ANALYSIS, SPECTROSCOPY, GAS /	64PRR-038
ARYIN/ THEORY AND APPLICATION OF THE DERIVATIVE METHOD TO	STATIONARY ELECTRODE POLAROGRAPHY	64PRR-299
HEMISTRY DIVISION, JAN.-MAR.,1964	STATIONARY ELECTRODE VOLTAMMETRY WITH LINEARLY V	64A-01-06
HEMISTRY DIVISION, JAN.-SEPT.,1963	STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL C	64PRR-085
HEMISTRY DIVISION	STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL C	64PRR-087
64	STATISTICAL QUALITY CONTROL REPORT, ANALYTICAL C	64PRR-088
	STATISTICAL QUALITY CONTROL REPORT, JAN.-JUNE,19	64PRR-086
	STATISTICS	64PRR-004
RADIATION DETECTORS AND COUNTING	STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TE/	64PRR-154
/NIUM / SAMARIUM / SELENIUM / SILICON / SILVER / SODIUM /	STRONTIUM-89 AND STRONTIUM-90 IN AQUEOUS SOLUTIO	64PRR-142
NS, DI 2 ETHYL HEXYL PHOSPHORIC ACID - AMSCO EXTRACTION /	STRONTIUM-90 IN AQUEOUS SOLUTIONS, DI 2 ETHYL HE	64PRR-142
XYL PHOSPHORIC ACID - AMSCO EXTRACTION / STRONTIUM-89 AND	STRUCTURE OF SPHERICAL THORIA SOL-GEL BEADS	64PRR-317
A MICROSCOPICAL STUDY OF THE		

F 6 DI METHYL AMINE PURINE THE STRUCTURE OF 3 METHYL ADENINE, AND METHYLATION O 64PRR-036
 FLUO BOR/ INORGANIC PREPARATIONS (HYDRATED VANADIUM(III) SULFATE / LITHIUM FLUO BORATE / HYDRATED NICKEL 64A-13
 NITRATE (NITROGEN) VOLUMETRIC FERROUS AMMONIUM SULFATE METHOD 64PRR-121
 / IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, AMMONIUM PER SULFATE OXIDATION - PROPORTIONAL ALPHA COUNTING/ 64PRR-136
 CHROMIUM IN MSRE FUEL, AMPEROMETRIC FERROUS SULFATE TITRATION METHOD 64PRR-118
 / BORATE / HYDRATED VANADIUM(III) FLUO BORATE / POTASSIUM SULFIDE / LITHIUM HYPO BROMITE / ANHYDROUS ALUM/ 64A-13
 / / BIS (OXYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERCURY(II) DI N BUTYL PHOSPHORO DI T/ 64A-05-04
 / ION OF VARIOUS MATERIALS (HAFNIUM OXIDE / MERCURY(II) SULFIDE / URANIUM(IV) OXIDE / N TRI METHYL BORA/ 64A-05-04
 METHOD SULFUR I SULFIDE AND NONSULFIDE) INDIRECT POLAROGRAPHIC 64PRR-126
 OGRAPHIC METHOD SULFUR (SULFIDE AND NONSULFIDE) INDIRECT POLAR 64PRR-126
 / IUM / SELENIUM / SILICON / SILVER / SODIUM / STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TE/ 64PRR-154
 EASE METHOD FOR THE EVALUATION OF ATMOSPHERIC POLLUTION - SULFUR DI OXIDE RADIO REL 64A-12-06A
 ASE METHODS FOR THE EVALUATION OF ATMOSPHERIC POLLUTION - TANTALUM / SULFUR DI OXIDE RADIO RELE 64PRR-312
 180 DEGREE COMPTON SCATTERED ANNIHILATION GAMMA-RAY SUM PEAK OBSERVED IN GAMMA-RAY SPECTROMETRY 64PRR-040
 /LYTICAL CHEMISTRY RESEARCH AND DEVELOPMENT GROUP MONTHLY SUMMARY - DEC., 1963 / JAN., 1964 / FEB., 1964 / M/ 64PRR-105
 UAL IDENTIFICATION BY ACTIVATION ANALYSIS OF HAIR AND ITS SURFACE CONTAMINATION INDIVID 64PRR-268
 N OF DISSOLVED GASES AND IMPURITIES IN REAC/ A LITERATURE SURVEY OF SENSITIVE METHODS FOR THE DETERMINATIO 64PRR-100
 CARBON-14 LABELED AMINO ACIDS) ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RIBO NUCLEIC ACIDS / TAKATSY LOOP / 64A-07
 /N// TRI METHYL BORAZINE SYNTHESIS AND INFRARED ABSORPTION SPECTRA OF N,N 64PRR-079
 ANALYTICAL BIOCHEMISTRY (SYMMETRICAL RIBO NUCLEIC ACIDS / TAKATSY LOOP / CARBON-14 LABELED AMINO ACIDS) A 64A-07
 /ENIUM / SILICON / SILVER / SODIUM / STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / T/ 64PRR-154
 RAPID SEPARATION AND DETERMINATION OF TECHNETIUM 64A-12-03D
 /ICON / SILVER / SODIUM / STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / T/ 64PRR-154
 COULOMETRIC DETERMINATION OF TECHNETIUM-99 64A-06-13
 DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M 64A-12-01C
 DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M 64PRR-020
 DECAY OF MOLYBDENUM-99 - TECHNETIUM-99M 64PRR-273
 ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY 64PRR-037
 MODERN METHODS IN LIQUID SCINTILLATOR TECHNOLOGY 64PRR-330
 CTS OF URANIUM / GAS CHROMATOGRAPHY AS APPLIED TO NUCLEAR TECHNOLOGY II. ANALYSIS OF THE HYDROLYSIS PRODU 64PRR-035
 /THE SEVENTH CONFERENCE ON ANALYTICAL CHEMISTRY IN NUCLEAR TECHNOLOGY - ANALYTICAL INSTRUMENTATION - MOLTE/ 64PRR-038
 HOW A SEWING NEEDLE AND TEFLON ARE ADVANCING POLAROGRAPHY 64PRR-329
 ECTRODE FABRICATION OF THE VERTICAL ORIFICE TEFLON CAPILLARY OF A TEFLON DROPPING MERCURY EL 64PRR-095
 VERTICAL CRIFICE RAPID TEFLON DROPPING MERCURY ELECTRODE 64A-05-05E
 FABRICATION OF THE VERTICAL CRIFICE TEFLON CAPILLARY OF A TEFLON DROPPING MERCURY ELECTRODE 64PRR-095
 IN AQUEOUS HYDROFLUORIC ACID WITH THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECTRODE / EDOX REACTION 64A-05-05C
 EXTENSION OF THE USE OF THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECTRODE BY OTHERS 64A-05-05D
 AINING FUNDAMENTAL / EVALUATION OF THE HORIZONTAL ORIFICE TEFLON DROPPING MERCURY ELECTRODE FOR USE IN OBT 64A-05-05A
 / / SODIUM / STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THUL/ 64PRR-154
 / CHEMICAL EFFECTS OF ISOMERIC TRANSITIONS - SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL MEDIA 64A-12-03F
 / MICAL EFFECTS OF ISOMERIC TRANSITIONS - THE SEPARATION OF TELLURIUM ISOMERS IN DIFFERENT CHEMICAL MEDIA /E 64PRR-032
 / ATION OF THE ISOMERS OF TELLURIUM-127, TELLURIUM-129, AND TELLURIUM-121 /S OF ISOMERIC TRANSITIONS - SEPAR 64PRR-031
 / TS OF ISOMERIC TRANSITIONS - SEPARATION OF THE ISOMERS OF TELLURIUM-127, TELLURIUM-129, AND TELLURIUM-121 /S OF ISOMERIC 64PRR-031
 / TRANSITIONS - SEPARATION OF THE ISOMERS OF TELLURIUM-127, TELLURIUM-129, AND TELLURIUM-121 /S OF ISOMERIC 64PRR-031
 / L OF RADIOACTIVE WASTES IN NATURAL SALT FORMATIONS (HIGH TEMPERATURE CHEMICAL DOSIMETERS) DISPOSA 64A-06-02
 / DETERMINATION OF CARRON IN ALKALI METALS BY HIGH TEMPERATURE OXIDATION 64A-06-06
 NICKEL HIGH TEMPERATURE SPECTROPHOTOMETRIC CELL ASSEMBLY 64A-02-01A
 /STRONTIUM / SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM // 64PRR-154
 IUM, AMPEROMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE - IRON(III) INDICATOR METHOD THOR 64PRR-131
 ORIUM, VOLUMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI AMINE TETRA ACETATE (EDTA) METHOD ALUMINUM AND TH 64PRR-127
 /PHENOLS (4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL AMMONIUM HYDROXIDE / LITHIUM CHLORID/ 64A-06-08
 /S ALUMINUM CHLORIDE / THORIUM TETRA CHLORIDE / ZIRCONIUM TETRA CHLORIDE / URANIUM TRI CHLORIDE / DYSPROS/ 64A-13
 / IUM HYPO BROMITE / ANHYDROUS ALUMINUM CHLORIDE / THORIUM TETRA CHLORIDE / ZIRCONIUM TETRA CHLORIDE / URA/ 64A-13
 // SULFUR / TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM // 64PRR-154
 LIQUID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO ACETONE 64PRR-021
 LIQUID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL TRI FLUORO ACETONE 64PRR-022
 SELECTIVE LIQUID-LIQUID EXTRACTION OF RADIOTIN WITH 2 THENOYL TRI FLUORO ACETONE 64PRR-064
 /RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (TTA) EXTRACTION -/ 64PRR-138
 EFFECT OF COBALT-60 GAMMA RADIATION ON 2 THENOYL TRI FLUORO ACETONE (TTA) SOLUTIONS 64A-03-04
 TOTAL PLUTONIUM, THENOYL TRI FLUORO ACETONE EXTRACTION METHOD 64PRR-219
 TO STATIONARY ELECTRODE VOLTAMMETRY WITH LINEARLY VARYING/ THEORY AND APPLICATION OF THE DERIVATIVE METHOD 64A-01-06
 A NEW SCINTILLATOR FOR THERMAL NEUTRON DETECTION 64PRR-06D
 TRI METHYL BORAZINE AS A LIQUID SCINTILLATOR SOLVENT FOR THERMAL NEUTRON DETECTION N,N//N// 64A-12-04B
 FLUORIDE - POTASSIUM FLUORIDE - URANIUM(IV) FLUORIDE WITH THIO CYANATE /III) IN SODIUM FLUORIDE - LITHIUM 64PRR-104
 LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /LENT ACTINIDE ELEMENTS - SELECTIVE 64PRR-050
 LIQUID-LIQUID EXTRACTION WITH TRI CAPRYL METHYL AMMONIUM THIO CYANATE /OM LANTHANIDE ELEMENTS - SELECTIVE 64A-12-03C
 /N TRI METHYL BORAZINE / BIS (OXYGEN, OXYGEN DI BUTYL DI THIO PHOSPHORYL) DI SULFIDE / MERCURY(III) DI N/ 64A-05-04
 /HORYL) DI SULFIDE / MERCURY(III) DI N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL TRI DEC/ 64A-05-04
 Y BY ISOTOPIC EXCHANGE WITH MERCURIC DI N BUTYL PHOSPHORO THIOATE IN AN EXTRACTION SYSTEM /ATION OF MERCUR 64PRR-033
 METAL DI N BUTYL PHOSPHORO DI THIOATES AS EXTRACTANTS FOR METALS 64A-12-03B
 - SELECTIVE EXTRACTION/ TRI ALKYL AND HEXA ALKYL PHOSPHORO THIOIC TRI AMIDES AS EXTRACTANTS FOR METAL IONS 64A-12-03A
 /VE DC POLAROGRAPHY / SECOND DERIVATIVE DC POLAROGRAPHY / THIRD DERIVATIVE DC POLAROGRAPHY / SIGNAL TO NO/ 64A-01-01
 A MICROSCOPICAL STUDY OF THE STRUCTURE OF SPHERICAL THORIA SOL-GEL BEADS 64PRR-317
 LOW LEVEL ANALYSES (RADIUM-226 / THORIUM / COAL / FALLOUT / LEAD-210) 64A-12-03J
 /TANTALUM / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM / TUNGSTEN // 64PRR-154
 ALYSIS OF THE HYDROLYSIS PRODUCTS OF URANIUM CARBIDES / TO NUCLEAR TECHNOLOGY II. AN 64PRR-035
 PROACTINIUM STABILITY IN THORIUM NITRATE - NITRIC ACID SOLUTIONS 64PRR-072
 N METHOD PARTICLE SIZE DISTRIBUTION IN THORIUM OXIDE, NEUTRON ACTIVATION - SEDIMENTATIO 64PRR-218
 /E / LITHIUM HYPO BROMITE / ANHYDROUS ALUMINUM CHLORIDE / THORIUM TETRA CHLORIDE / ZIRCONIUM TETRA CHLORID/ 64A-13
 / LENE DI AMINE TETRA ACETATE - IRON(III) INDICATOR METHOD THORIUM, AMPEROMETRIC DI SODIUM DI HYDROGEN ETHY 64PRR-131
 / NE DI AMINE TETRA ACETATE (EDTA) METHOD ALUMINUM AND THORIUM, VOLUMETRIC DI SODIUM DI HYDROGEN ETHYLE 64PRR-127
 / NONDESTRUCTIVE DETERMINATION OF URANIUM-232 AND THORIUM-228 BY GAMMA SPECTROMETRY 64PRR-304
 / TECHNETIUM / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM / TUNGSTEN / URANIUM // 64PRR-154
 /OSTATIC COMPENSATION FOR POLAROGRAPHIC CELL RESISTANCE / THULIUM-170, PRODUCT ANALYSIS GUIDE 64PRR-144
 / EFFECT OF GAMMA SPECTROMETER LIVE TIME DERIVATIVE DC POLAROGRAPHY / FIRST DERIVAT/ 64A-01-01
 /M / TELLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIME ON PRECISION OF MEASUREMENTS 64A-12-02C
 / 56 / SELENIUM-75 / SILVER-110M / SILVER-111 / SODIUM-24 / TIN / TITANIUM / TUNGSTEN / URANIUM / VANADIUM / 64PRR-154
 THE PLACE OF ATOMIC ABSORPTION IN TIN-113 /UTHENIUM-106 / SAMARIUM-153 / SCANDIUM- 64PRR-230
 /LLURIUM / TERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM / TUNGSTEN / URANIUM / VANADIUM / YTTE/ 64PRR-280
 TITANIUM / TUNGSTEN / URANIUM / VANADIUM / YTTE/ 64PRR-154

ZIRCONIUM IN MSRE FUEL, AMPEROMETRIC CUPFERRON
CHROMIUM IN MSRE FUEL, AMPEROMETRIC FERROUS SULFATE
IRON (BORATE) POTENTIOMETRIC MANNITOL - SODIUM HYDROXIDE
PPER, AND NICKEL IN HOMOGENEOUS REACTOR FUEL, COULOMETRIC
ACID IN TRI BUTYL PHOSPHATE, VOLUMETRIC SODIUM HYDROXIDE
LTS
UM TRI POLY PHOSPHATE M/ CONTROLLED POTENTIAL COULOMETRIC
NG PYRCLYTIC GRAPHITE ELECTRODES
ELECTRODE FOR MICRO REDOX AND ACID - BASE POTENTIOMETRIC
ELECTRODE FOR MICRO REDOX AND ACID - BASE POTENTIOMETRIC
TIONS / T/ ORNL MODEL Q-2564 HIGH SENSITIVITY COULOMETRIC
K OUT AND TEST PROCEDURE FOR HIGH SENSITIVITY COULOMETRIC

THYL BENZYL) PHENOL / TETRA BUTYL AMMONIUM H/ NONAQUEOUS
CONTROLLED POTENTIAL COULOMETRY - NEW ANALYTICAL
DE SCINTILLATION CRYST/ DETERMINATION OF EUROPIUM(III) AND
COLLECTION FOR MASS SPECTROMETRIC ANALYSIS
ACTION METHOD

ALYSIS
ABSORPTION OF
DETERMINATION OF
DETERMINATION OF
SEPARATION OF
REVIEW OF - RADIOACTIVE
FLUORIDE - POTASSIUM FLUORIDE - URANIUM/ DETERMINATION OF
DIFFERENT CHEMICAL MEDIA CHEMICAL EFFECTS OF ISOMERIC
RIUM-127, TELLURIUM-129, AN/ CHEMICAL EFFECTS OF ISOMERIC
S IN DIFFERENT CHEMICAL MED/ CHEMICAL EFFECTS OF ISOMERIC
GAMMA
CRE SELECTION FOR PROJECT COACH (

UM (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE EXTRAC/
UM (TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PRECIPI/
UM-244)
PER SULFATE OXIDATION - PROPORTIONAL ALPHA/ AMERICIUM IN
EASUREMENT METHOD GROSS ALPHA RADIOACTIVITY IN
M FLUORIDE PRECIPITATION - / GROSS ALPHA RADIOACTIVITY IN
M FLUORIDE PRECIPITATION/ PLUTONIUM ALPHA RADIOACTIVITY IN
M FLUORIDE PRECIPI/ TRANSPLUTONIUM ALPHA RADIOACTIVITY IN
DIODE DETECTOR METHOD ALPHA SPECTROMETRY OF
TRI FLUORO ACETONE (TT/ PLUTONIUM ALPHA RADIOACTIVITY IN
OCTYL AMINE (OR TRI CAPRYL/ GROSS ALPHA RADIOACTIVITY IN
OCTYL AMINE EXTRAC/ TRANSPLUTONIUM ALPHA RADIOACTIVITY IN

REPORT OF FOREIGN
REPORT ON FOREIGN
REPORT OF FOREIGN
REPORT OF FOREIGN
REPORT ON FOREIGN
PRESENT BYWAYS AND FUTURE
IDES AS EXTRACTANTS FOR METAL IONS - SELECTIVE EXTRACTIO/
TIVE EXTRACTIO/ TRI ALKYL AND HEXA ALKYL PHOSPHORO THIOIC
/ DI BUTYL PHOSPHORIC ACID, AND ORTHO PHOSPHORIC ACID IN
/NIUM (TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE (OR
TINIDE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH
HANIDE ELEMENTS - SELECTIVE LIQUID-LIQUID EXTRACTION WITH
/RIUM TETRA CHLORIDE / ZIRCONIUM TETRA CHLORIDE / URANIUM
6 AMINO 3,9 DI ETHYL
COKE / 3,9 DI ETHYL TRI DECYL AMINE 6 AMINO 3,9 DI ETHYL
/TYL PHOSPHORO DI THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL
LIQUID-LIQUID EXTRACTION OF CESIUM WITH 2 THENOYL
LIQUID-LIQUID EXTRACTION OF CESIUM WITH THENOYL
CTIVE LIQUID-LIQUID EXTRACTION OF RADIOTIN WITH 2 THENOYL
/IVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS, THENOYL
EFFECT OF COBALT-60 GAMMA RADIATION ON 2 THENOYL
TOTAL PLUTONIUM, THENOYL
/RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS,
/RADIOACTIVITY IN TRANSURANIUM (TRU) PROCESS SOLUTIONS,
N,N/,N//
SYNTHESIS AND INFRARED ABSORPTION SPECTRA OF N,N/,N//
/NIUM OXIDE / MERCURY(III) SULFIDE / URANIUM(IV) OXIDE / N
VENT FOR THERMAL NEUTRON DETECTION N,N/,N//
IMETRIC/ SEPARATION OF URANIUM BY SOLVENT EXTRACTION WITH
YSIS OF CORROSIVE GASES (NITROGEN DI OXIDE / DI NITROGEN
METRIC TITRATION OF URANIUM(IV) AND URANIUM(VI) IN SODIUM

LIQUID EXTRACTION WIT/ A NEW APPROACH TO THE SEPARATION OF
ENTS - SELECTIVE LIQ/ A NEW APPROACH TO THE SEPARATION OF
C TITRATOR (ENGINEERING DRAWINGS / TEST SPECIFICATIONS /
IDATION - PROPORTIONAL ALPHA/ AMERICIUM IN TRANSURANIUM (TRU)
OD GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
IPITATION - / GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
IPITATIO/ PLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
IPI/ TRANSPLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
METHOD ALPHA SPECTROMETRY OF TRANSURANIUM (TRU)
ONE (TT/ PLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
R TRI CAPRYL/ GROSS ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)
RAC/ TRANSPLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANIUM (TRU)

/ (TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACETONE (TRU)
BALT-60 GAMMA RADIATION ON 2 THENOYL TRI FLUORO ACETONE (TRU)

TITANIUM IRRADIATIONS AT THE 14-MEV GENERATOR
TITRATION METHOD
TITRATION METHOD
TITRATION METHOD
TITRATION METHOD
URANIUM, CO
TITRATION METHOD /RIC ACID, AND ORTHO PHOSPHORIC
TITRATION OF CHROMIUM IN MIXTURES OF FLUORIDE SA
TITRATION OF URANIUM(IV) AND URANIUM(VI) IN SODI
TITRATION OF URANIUM(IV) WITH CERIUM(IV) UTILIZI
TITRATIONS (PLATINUM IN-BURET REFERENCE ELECTR/

TITRATIONS /YTIC GRAPHITE CUP AS BOTH VESSEL AND
TITRATOR (ENGINEERING DRAWINGS / TEST SPECIFICA
TITRATOR, ORNL MODEL Q-2564 CHEC
TITRIMETRY OF ACIDS IN IRRADIATED LIQUIDS
TITRIMETRY OF PHENOLS (4 SEC BUTYL 2 (ALPHA ME
TOOL IN THE NUCLEAR ENERGY PROGRAM
TOTAL EUROPIUM - EUROPIUM ACTIVATED LITHIUM IODI
TOTAL GASES IN SOLIDS - RELEASE MEASUREMENT AND
TOTAL PLUTONIUM, THENOYL TRI FLUORO ACETONE EXTR
TRACE ELEMENTS BY HAIR
TRACE ELEMENTS IN DRUGS BY NEUTRON ACTIVATION AN
TRACE ELEMENTS IN WOOL
TRACE METALS FROM URANIUM BY CELLULOSE COLUMN CH
TRACERS IN PHYSICAL METALLURGY
TRACES OF IRON(III) IN SODIUM FLUORIDE - LITHIUM
TRANSITIONS - SEPARATION OF TELLURIUM ISOMERS IN
TRANSITIONS - SEPARATION OF THE ISOMERS OF TELLU
TRANSITIONS - THE SEPARATION OF TELLURIUM ISOMER
TRANSITIONS IN THE DECAY OF KRYPTON-79
TRANSPLUTONIUM (G NOME)
TRANSPLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANI
TRANSPLUTONIUM ALPHA RADIOACTIVITY IN TRANSURANI
TRANSURANIC RADIOACTIVITY (CURIUM-247 / PLUTONI
TRANSURANIUM (TRU) PROCESS SOLUTIONS, AMMONIUM
TRANSURANIUM (TRU) PROCESS SOLUTIONS, DIRECT M
TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANU
TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANU
TRANSURANIUM (TRU) PROCESS SOLUTIONS, LANTHANU
TRANSURANIUM (TRU) PROCESS SOLUTIONS, SILICON
TRANSURANIUM (TRU) PROCESS SOLUTIONS, THENOYL
TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO
TRANSURANIUM (TRU) PROCESS SOLUTIONS, TRI ISO
TRANSURANIUM ELEMENT PROCESSING

TRAVEL
TRAVEL
TRAVEL
TRAVEL JULY-1-30,1963
TRAVEL MAR.21-APR.11,1964
TRENDS IN ACTIVATION ANALYSIS
TRI ALKYL AND HEXA ALKYL PHOSPHORO THIOIC TRI AM
TRI AMIDES AS EXTRACTANTS FOR METAL IONS - SELEC
TRI BUTYL PHOSPHATE, VCLUMETRIC SODIUM HYDROXID/
TRI CAPRYL AMINE) EXTRACTION - PROPORTIONAL AL/
TRI CAPRYL METHYL AMMONIUM THIO CYANATE /LENT AC
TRI CAPRYL METHYL AMMONIUM THIO CYANATE /OM LANT
TRI CHLORIDE / DYSPROSIUM PHOSPHIDE / HIGH PURI/
TRI DECANE
TRI DECANE HYDRO CHLORIDE) /THIOATE / FLUIDIZED
TRI DECYL AMINE 6 AMINO 3,9 DI ETHYL TRI DECANE/
TRI FLUORO ACETONE
TRI FLUORO ACETONE
TRI FLUORO ACETONE
TRI FLUORO ACETONE (TTA) EXTRACTION - PROPORT/
TRI FLUORO ACETONE (TTA) SOLUTIONS
TRI FLUORO ACETONE EXTRACTION METHOD
TRI ISO OCTYL AMINE (OR TRI CAPRYL AMINE) EXT/
TRI ISO OCTYL AMINE EXTRACTION - PROPORTIONAL A/
TRI METHYL BORAZINE
TRI METHYL BORAZINE
TRI METHYL BORAZINE / BIS (OXYGEN, OXYGEN DI B/
TRI METHYL BORAZINE AS A LIQUID SCINTILLATOR SOL
TRI N OCTYL PHOSPHINE OXIDE AND ITS DIRECT COLOR
TRI OXIDE / CHLORINE / NITROSYL CHLORIDE) /ANAL
TRI POLY PHOSPHATE MEDIUM /OLLED POTENTIAL COULO
TRIP REPORT TO GENERAL ATOMIC, SEPT.28,1964
TRIP REPORT, JULY-16-AUG.15,1963
TRIVALENT ACTINIDE ELEMENTS - SELECTIVE LIQUID-L
TRIVALENT ACTINIDE ELEMENTS FROM LANTHANIDE ELEM
TROUBLE-SHOOTING GUIDE) /SENSITIVITY COULOMETRI
TRU) PROCESS SOLUTIONS, AMMONIUM PER SULFATE OX
TRU) PROCESS SOLUTIONS, DIRECT MEASUREMENT METH
TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PREC
TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PREC
TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PREC
TRU) PROCESS SOLUTIONS, LANTHANUM FLUORIDE PREC
TRU) PROCESS SOLUTIONS, SILICON DIODE DETECTOR
TRU) PROCESS SOLUTIONS, THENOYL TRI FLUORO ACET
TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE (O
TRU) PROCESS SOLUTIONS, TRI ISO OCTYL AMINE EXT
TRU MASS SPECTROMETRY
TTA) EXTRACTION - PROPORTIONAL ALPHA CCUNTING /
EFFECT OF CO

64A-12-08C
64PRR-117
64PRR-118
BO 64PRR-220
64PRR-264
64PRR-265
64PRR-012
64PRR-071
64PRR-048
64A-06-12
64PRR-066
64A-01-05
64PRR-081
64A-06-09
64A-06-08
64PRR-331
64PRR-019
64PRR-266
64PRR-219
64A-12-07E
64PRR-016
64PRR-269
64A-12-03E
64PRR-041
64PRR-104
64A-12-03F
64PRR-031
64PRR-032
64A-12-01B
64A-12-03H
64PRR-139
64PRR-140
64A-12-03I
64PRR-136
64PRR-132
64PRR-133
64PRR-137
64PRR-140
64PRR-135
64PRR-138
64PRR-134
64PRR-139
64A-04-03
64PRR-091
64PRR-094
64PRR-115
64PRR-074
64PRR-084
64PRR-007
64A-12-03A
64A-12-03A
64PRR-265
64PRR-134
64PRR-050
64A-12-03C
64A-13
64A-14-01C
64A-05-04
64A-05-04
64PRR-021
64PRR-022
64PRR-064
64PRR-138
64A-03-04
64PRR-219
64PRR-134
64PRR-139
64A-14-01B
64PRR-079
64A-05-04
64A-12-04B
64PRR-080
64A-05-01
64PRR-071
64PRR-103
64PRR-073
64PRR-050
64A-12-03C
64A-01-05
64PRR-136
64PRR-132
64PRR-133
64PRR-137
64PRR-140
64PRR-135
64PRR-138
64PRR-134
64PRR-139
64A-09-01
64PRR-138
64A-03-04

ERBIUM / THALLIUM / THORIUM / THULIUM / TIN / TITANIUM / ANALYTICAL MANUAL	TUNGSTEN / URANIUM / VANADIUM / YTTERBIUM / ZINC / TYPING AND PRINTING METHODS FOR THE ORNL MASTER	64PRR-154 64PRR-225
USING LITHIUM-6 ENRICHED ISOTOPE	ULTRASTRUCTURE STUDIES OF EXCHANGE RESINS	64A-11-05
LITHIUM-6 ENRICHED ISOTOPE	A UNIQUE LIQUID SCINTILLATOR FOR NEUTRON DETECTION	64PRR-309
YIELDS OF KRYPTON AND XENON FROM FISSION OF GALLIUM / THORIUM / THULIUM / TIN / TITANIUM / TUNGSTEN /	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION	64PRR-099
STEMS BY PRECIPITATION AS OXIDES	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION	64PRR-311
RECOVERY OF	A UNIQUE SCINTILLATOR FOR NEUTRON DETECTION USING	64PRR-098
SEPARATION OF TRACE METALS FROM	URANIUM	64A-12-03G
MOSPHINE OXIDE AND ITS DIRECT COLORIMETRIC/ SEPARATION OF	URANIUM / VANADIUM / YTTERBIUM / ZINC / ZIRCONIUM /	64PRR-154
AR TECHNOLOGY 11. ANALYSIS OF THE HYDROLYSIS PRODUCTS OF	URANIUM AND PROTACTINIUM FROM MOLTEN FLUORIDE SY	64PRR-101
R DISTILL/ SPECTROCHEMICAL DETERMINATION OF IMPURITIES IN	URANIUM BY CELLULOSE COLUMN CHROMATOGRAPHY	64A-12-03E
CHEMICAL DETERMINATION OF VOLATILE FLUORIDE IMPURITIES IN	URANIUM BY SOLVENT EXTRACTION WITH TRI N OCTYL P	64PRR-080
ATION AS OXIDES	URANIUM CARBIDES AND THORIUM CARBIDES / TO NUCLE	64PRR-035
RECOVERY OF PROTACTINIUM AND	URANIUM COMPOUNDS USING THE GALLIUM OXIDE CARRIE	64PRR-083
CURRENT - VOLTAGE CURVES FOR ZIRCONIUM AND	URANIUM COMPOUNDS USING THE ROTATING DISK SPARK/	64PRR-082
DE / THORIUM TETRA CHLORIDE / ZIRCONIUM TETRA CHLORIDE /	URANIUM FROM MOLTEN FLUORIDE SYSTEMS BY PRECIPIT	64PRR-065
OR FUEL, COULOMETRIC TITRATION METHOD	URANIUM IN MOLTEN FLUORIDES	64PRR-047
THE ACCURATE AND PRECISE DETERMINATION OF	URANIUM IN MSRE FUEL, POLAROGRAPHIC METHOD	64PRR-120
REDETERMINATION OF THE HALF-LIFE OF	URANIUM TRI CHLORIDE / DYSPROSIUM PHOSPHIDE / H/	64A-13
A REDETERMINATION OF THE HALF-LIFE OF	URANIUM, COPPER, AND NICKEL IN HOMOGENEOUS REACT	64PRR-264
Y	URANIUM, WITH SPECIAL REFERENCE TO COULOMETRY	64PRR-290
NONDESTRUCTIVE DETERMINATION OF	URANIUM-232	64A-12-01I
DETERMINATION OF	URANIUM-232	64PRR-043
ORIDE - ZIRCONIUM FLUORIDE AND IN / ABSORPTION SPECTRA OF	URANIUM-232 AND THORIUM-228 BY GAMMA SPECTROMETR	64PRR-304
MOSPHATE M/ CONTROLLED POTENTIAL COULOMETRIC TITRATION OF	URANIUM-232 BY GAMMA SPECTROMETRY	64A-12-02F
SODIUM FLUORIDE - LITHIUM FLUORIDE - POTASSIUM FLUORIDE -	URANIUM(III) IN LITHIUM FLUORIDE - BERYLLIUM FLU	64A-02-01C
ARIOUS MATERIALS (HAFNIUM OXIDE / MERCURY(II) SULFIDE /	URANIUM(IV) AND URANIUM(VI) IN SODIUM TRI POLY P	64PRR-071
ERMINATION OF URANIUM(VI) IN PHOSPHORIC ACID SOLUTIONS OF	URANIUM(IV) FLUORIDE WITH THIO CYANATE / I/JI) P	64PRR-104
GRAPHITE ELECTRODES	URANIUM(IV) OXIDE / N TRI METHYL BORAZINE / BIS/	64A-05-04
TRIC ABSORPTION CELL)	URANIUM(IV) OXIDE /60 GAMMA RADIATION CN THE DET	64A-03-02
ECT OF COBALT-60 GAMMA RADIATION ON THE DETERMINATION OF	URANIUM(IV) WITH CERTIUM(IV) UTILIZING PYROLYTIC	64PRR-048
ROLLED POTENTIAL COULOMETRIC TITRATION OF URANIUM(IV) AND	URANIUM(VI) FLUORIDE GAS (NICKEL SPECTROPHOTOME	64A-02-01F
ACTIVATION ANALYSIS OF	URANIUM(VI) IN PHOSPHORIC ACID SOLUTIONS OF URA/	64A-03-02
MINATION OF HYDROGEN IN ALKALI METALS BY AMALGAMATION AND	URANIUM(VI) IN SODIUM TRI POLY PHOSPHATE MEDIUM	64PRR-071
TION POTENTIALS IN THE MEASUREMENT OF HALF-WAVE POTENTIAL	URANYL NITRATE SOLUTIONS	64A-12-07H
THORIUM / THULIUM / TIN / TITANIUM / TUNGSTEN / URANIUM /	VACUUM EXTRACTION	64A-06-07
IUM FLUO BCRATE / HYDRATED NICKEL FLUO BORATE / HYDRATED	VALUES	64A-05-05B
DRATED NICKEL FLUO BOR/ INORGANIC PREPARATIONS (HYDRATED	SIGNIFICANCE OF JUNC	64PRR-154
AMMETRY OF CERIUM(IV), MANGANESE(IV), CHROMIUM(IV), AND	VANADIUM / YTTERBIUM / ZINC / ZIRCONIUM / LIUM /	64A-13
SPECTROCHEMICAL ANALYSIS	VANADIUM(III) FLUO BORATE / POTASSIUM SULFIDE /	64A-13
MAGNESIUM, VOLUMETRIC	VANADIUM(III) SULFATE / LITHIUM FLUO BORATE / HY	64PRR-049
ELECTRODE	VANADIUM(IV) WITH THE PYROLYTIC GRAPHITE ELECTRO/	64PRR-067
OPPING MERCURY ELECTRODE	A VERSATILE ELECTRONIC COMPUTER FOR PHOTOELECTRIC	64PRR-223
BASE POTENTIOMETRIC TITRA/ PYROLYTIC GRAPHITE CUP AS BOTH	VERSENE METHOD	64A-05-05E
ND ACID - BASE POTENTIOME/ PYROLYTIC GRAPHITE CUP AS BOTH	VERTICAL ORIFICE RAPID TEFLON DROPPING MERCURY E	64PRR-095
S USING THE ROTATING DI/ SPECTROCHEMICAL DETERMINATION OF	VERTICAL ORIFICE TEFLON CAPILLARY OF A TEFLON DR	64PRR-066
EN FLUORIDES	VESSEL AND ELECTRODE FOR MICRO REDOX AND ACID -	64A-06-12
T SYSTEMS	VESSEL AND INDICATOR ELECTRODE FOR MICRO REDOX A	64PRR-082
ON IN MOLTEN FLUORIDE	VOLATILE FLUORIDE IMPURITIES IN URANIUM COMPOUND	64PRR-047
MOLTEN FLUORIDES	VOLTAGE CURVES FOR ZIRCONIUM AND URANIUM IN MOLT	64A-01-03
E - APPLICATIONS IN CONTROLLED POTENTIAL POLAROGRAPHY AND	VOLTAMMETER - DESIGN AND EVALUATION	64PRR-297
IUM(VI), AND VANADIUM(IV) WITH THE PYROLYTIC GRAPHITE ELE/	VOLTAMMERIC MEASUREMENTS IN MOLTEN FLUORIDE SAL	64A-06-03D
THIUM FLUORIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE / /	VOLTAMMETRY	64PRR-046
- SODIUM FLUORIDE - POTASSIUM FLUORIDE	VOLTAMMETRY - CHRONOPOTENTIOMETRIC STUDIES OF IR	64PRR-295
RIDE - SODIUM FLUORIDE - POTASSIUM FLUORIDE	VOLTAMMETRY AND CHRONOPOTENTIOMETRY OF IRON IN M	64PRR-286
SALT	VOLTAMMETRY OF CERIUM(IV), MANGANESE(VII), CHROM	64A-02-02
ICATION OF THE DERIVATIVE METHOD TO STATIONARY ELECTRODE	VOLTAMMETRY OF MOLTEN FLUORIDE SALT SYSTEMS (LI	64PRR-045
N CONTROLLED POTENTIAL POLAROGRAPHY, CONTROLLED POTENTIAL	VOLTAMMETRY OF NICKEL IN MOLTEN LITHIUM FLUORIDE	64A-02-02C
NE TETRA ACETATE (EDTA) METHOD	VOLTAMMETRY OF NICKEL(III) IN MOLTEN LITHIUM FLUO	64A-02-02D
C ACID, AND ORTHO PHOSPHORIC ACID IN TRI BUTYL PHOSPHATE,	VOLTAMMETRY OF THE MSR COOLANT SALT AND MSR FUEL	64A-01-06
DETERMINATION OF SOLIDS IN RADIOACTIVE	VOLTAMMETRY WITH LINEARLY VARYING POTENTIAL (P/	64A-01-02
TURE CHEMICAL DOSIMETERS)	VOLTAMMETRY, AND CHRONOPOTENTIOMETRY /ICATIONS I	64PRR-127
TION OF DISSOLVED GASES AND IMPURITIES IN REACTOR COOLANT	VOLUMETRIC DI SODIUM DI HYDROGEN ETHYLENE DI AMI	64PRR-121
(I S/N) IN DC POLAROGRAPHY / RESOLUTION OF POLAROGRAPHIC	VOLUMETRIC FERROUS AMMONIUM SULFATE METHOD	64PRR-265
SOLUTIONS (FREE ACID / HYDROLYZABLE CATION / BORIC ACID /	VOLUMETRIC SODIUM HYDROXIDE TITRATION METHOD /RI	64PRR-223
ILLATION COUNTING OF IRON-55	VOLUMETRIC VERSENE METHOD	64A-06-10
CORROSIVE LIQUIDS	WASTE DISPOSAL SLURRIES	64A-06-02
DETERMINATION OF TRACE ELEMENTS IN	WASTES IN NATURAL SALT FORMATIONS (HIGH TEMPERA	64PRR-100
CURRENT	WATER /EY OF SENSITIVE METHODS FOR THE DETERMINA	64A-01-01
RECENT RADIOCHEMICAL	WAVES / POLAROGRAPHY IN NONAQUEOUS SOLVENTS AND/	65A-06-01
ANALYTICAL MANUAL	WEAK BASES) /IN CONCENTRATED LITHIUM CHLORIDE S	64PRR-059
IDS AND OF RADIOACTIVE SOLUTIONS / MEASUREMENT OF ABSORP/	WEAR RATES IN AUTOMOTIVE ENGINES BY LIQUID SCINT	64PRR-068
MEASUREMENT OF ABSORPTION-EDGE HEIGHT / COMPUTER CODE FOR	WINDOWLESS SPECTROPHOTOMETRIC CELL FOR USE WITH	64PRR-269
ABSORPTION METHOD	WOOL	64A-12-07D
YIELDS OF KRYPTON AND	WOOL ANALYSIS	64PRR-301
XENON FROM FISSION OF URANIUM	WORK AT ORNL	64PRR-303
A STUDY OF FISSION	WRITING INSTRUMENTAL METHODS FOR THE ORNL MASTER	64PRR-226
IUM	X-RAY ANALYSIS (ABSORPTION-EDGE ANALYSIS OF SOL	64A-08-01A
HULIUM / TIN / TITANIUM / TUNGSTEN / URANIUM / VANADIUM /	X-RAY AND SPECTROCHEMICAL ANALYSES	64A-08
/ TITANIUM / TUNGSTEN / URANIUM / VANADIUM / YTTERBIUM /	X-RAY AND SPECTROCHEMICAL ANALYSES	64A-08-01
NIUM / TUNGSTEN / URANIUM / VANADIUM / YTTERBIUM / ZINC /	X-RAY AND SPECTROCHEMICAL ANALYSES	64A-08-02
ZIRCONIUM / LIUM / THORIUM / THULIUM / TIN / TITA	X-RAY FLUORESCENCE ANALYSIS OF MULTICOMPONENT A/	64A-08-01A
CURRENT - VOLTAGE CURVES FOR	XENON FROM CONTAMINATING GASES, MOLECULAR SIEVE	64PRR-152
	XENON FROM FISSION OF URANIUM	64A-12-03G
	YIELDS OF AMERICIUM-241	64PRR-057
	YIELDS OF KRYPTON AND XENON FROM FISSION OF URAN	64A-12-03G
	YTTERBIUM / ZINC / ZIRCONIUM / LIUM / THORIUM / T	64PRR-154
	ZINC / ZIRCONIUM / LIUM / THORIUM / THULIUM / TIN	64PRR-154
	ZIRCONIUM / LIUM / THORIUM / THULIUM / TIN / TITA	64PRR-154
	ZIRCONIUM AND URANIUM IN MOLTEN FLUORIDES	64PRR-047

LLIUM FLUORIDE / LITHIUM FLUORIDE - BERYLLIUM FLUORIDE -	ZIRCONIUM FLUORIDE / PYROLYTIC GRAPHITE INDICAT/	64A-02-02
/ URANIUM(III) IN LITHIUM FLUORIDE - BERYLLIUM FLUORIDE -	ZIRCONIUM FLUORIDE AND IN LITHIUM FLUORIDE - BE/	64A-02-01C
ITRATION METHOD	ZIRCONIUM IN MSRE FUEL, AMPEROMETRIC CUPFERRON T	64PRR-117
// ANHYDROUS ALUMINUM CHLORIDE / THORIUM TETRA CHLORIDE /	ZIRCONIUM TETRA CHLORIDE / URANIUM TRI CHLORIDE/	64A-13
LIQUID SCINTILLATORS THAT CONTAIN	1 METHYL NAPHTHALENE	64A-12-04A
LIQUID SCINTILLATORS USING	1 METHYL NAPHTHALENE	64PRR-030
IOMETRIC MEASUREMENT	1,10 PHENANTHROLINE COMPLEX EQUILIBRIA BY POTENT	64PRR-023
TITANIUM IRRADIATIONS AT THE	14-MEV GENERATOR	64A-12-08C
MISCELLANEOUS USES OF THE	14-MEV NEUTRON GENERATOR	64A-12-08
AND ITS INFLUENCE ON CROSS SECTION/ OUTPUT SPECTRUM FROM	14-MEV NEUTRON GENERATORS - ITS RAPID ESTIMATION	64A-12-08E
INFLUENCE IN ACTIVATION ANALYSIS	OUTPUT SPECTRA OF 14-MEV NEUTRON GENERATORS - RAPID ESTIMATION AND	64PRR-306
	CATALOG OF 14-MEV NEUTRON REACTIONS	64A-12-088
	DETERMINATION OF OXYGEN WITH 14-MEV NEUTRONS	64A-12-080
	REACTIONS OBSERVED WITH 14-MEV NEUTRONS	64PRR-313
RAY SUM PEAK OBSERVED IN GAMMA-RAY SPECTROMETRY	180 DEGREE COMPTON SCATTERED ANNIHILATION GAMMA-	64PRR-040
VEN-A NUCLEI EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM	184 THROUGH 192) /CLEAR LEVELS IN A NUMBER OF E	64A-12-01F
A NUMBER OF EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM	184 THROUGH 192) /OPERTIES OF NUCLEAR LEVELS IN	64PRR-034
EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM 184 THROUGH	192) /CLEAR LEVELS IN A NUMBER OF EVEN-A NUCLEI	64A-12-01F
EVEN MASS NUCLEI (MASS NUMBERS RANGING FROM 184 THROUGH	192) /OPERTIES OF NUCLEAR LEVELS IN A NUMBER OF	64PRR-034
INDEXES TO THE ORNL MASTER ANALYTICAL MANUAL (1953-1963)		64PRR-096
OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH 4 SEC BUTYL	2 (ALPHA METHYL BENZYL) PHENOL DETERMINATION	64PRR-062
MMONIUM H/ NONAQUEOUS TITRIMETRY OF PHENOLS (4 SEC BUTYL	2 (ALPHA METHYL BENZYL) PHENOL / TETRA BUTYL A	64A-06-08
/ STRONTIUM-89 AND STRONTIUM-90 IN AQUEOUS SOLUTIONS, DI	2 ETHYL HEXYL PHOSPHORIC ACID - AMSCO EXTRACTION	64PRR-142
LIQUID-LIQUID EXTRACTION OF CESIUM WITH	2 THENOYL TRI FLUORO ACETONE	64PRR-021
SELECTIVE LIQUID-LIQUID EXTRACTION OF RADIOTIN WITH	2 THENOYL TRI FLUORO ACETONE	64PRR-064
EFFECT OF COBALT-60 GAMMA RADIATION ON	2 THENOYL TRI FLUORO ACETONE (TTA) SOLUTIONS	64A-03-04
AMINO PURINE	THE STRUCTURE OF 3 METHYL ADENINE, AND METHYLATION OF 6 DI METHYL	64PRR-036
	6 AMINO 3,9 DI ETHYL TRI DECAE	64A-14-01C
E / FLUIDIZED COKE / 3,9 DI ETHYL TRI DECYL AMINE 6 AMINO	3,9 DI ETHYL TRI DECAE HYDRO CHLORIDE) /THIOAT	64A-05-04
/Y(II) DI N BUTYL PHOSPHORO DI THIOATE / FLUIDIZED COKE /	3,9 DI ETHYL TRI DECYL AMINE 6 AMINO 3,9 DI ETH/	64A-05-04
ETERMINATION OF CESIUM AND RUBIDIUM AFTER EXTRACTION WITH	4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL D	64PRR-062
ETRA BUTYL AMMONIUM H/ NONAQUEOUS TITRIMETRY OF PHENOLS (	4 SEC BUTYL 2 (ALPHA METHYL BENZYL) PHENOL / T	64A-06-08
ORNL MASTER ANALYTICAL MANUAL, SUPPLEMENT 6		64PRR-093
	6 AMINO 3,9 DI ETHYL TRI DECAE	64A-14-01C
/ THIOATE / FLUIDIZED COKE / 3,9 DI ETHYL TRI DECYL AMINE	6 AMINO 3,9 DI ETHYL TRI DECAE HYDRO CHLORIDE /	64A-05-04
THE STRUCTURE OF 3 METHYL ADENINE, AND METHYLATION OF	6 DI METHYL AMINO PURINE	64PRR-036

Author Index

A

APPLE, R. F.	64A-04-01
APPLE, R. F.	64PRR-012
APPLE, R. F.	64PRR-116
APPLE, R. F.	64PRR-117
APPLE, R. F.	64PRR-118
APPLE, R. F.	64PRR-119
APPLE, R. F.	64PRR-120
 ATTRILL, J. E.	 64PRR-013

B

*BARTON, C. J.	64PRR-072
 BATE, L. C.	 64A-12-03E
BATE, L. C.	64A-12-07D
BATE, L. C.	64A-12-07E
BATE, L. C.	64A-12-07F
BATE, L. C.	64PRR-014
BATE, L. C.	64PRR-015
BATE, L. C.	64PRR-016
BATE, L. C.	64PRR-218
BATE, L. C.	64PRR-268
BATE, L. C.	64PRR-269
BATE, L. C.	64PRR-274
 BELEW, W. L.	 64A-01-01
BELEW, W. L.	64A-01-02
BELEW, W. L.	64A-01-03
BELEW, W. L.	64A-01-04
BELEW, W. L.	64PRR-001
BELEW, W. L.	64PRR-270
BELEW, W. L.	64PRR-285
BELEW, W. L.	64PRR-286
 BIGGERS, R. E.	 64PRR-271
 BOTTS, J. L.	 64PRR-035

BOYD, C. M.	64A-04-02
 BRADY, L. J.	 64B-18-04
BRADY, L. J.	64PRR-121
 BURNS, J. F.	 64PRR-017
BURNS, J. F.	64PRR-073
 BURROS, C. L.	 64A-12-03J
BURROS, C. L.	64PRR-305

C

CAMERON, A. E.	64A-08-02
CAMERON, A. E.	64A-09
CAMERON, A. E.	64A-09-01
CAMERON, A. E.	64A-09-02
CAMERON, A. E.	64B-16
CAMERON, A. E.	64B-17
CAMERON, A. E.	64B-19
CAMERON, A. E.	64PRR-074
CAMERON, A. E.	64PRR-272
CAMERON, A. E.	64PRR-323 - 328
 CANADA, D. C.	 64PRR-219
 CARTER, J. A.	 64A-08-02A
CARTER, J. A.	64A-08-02B
CARTER, J. A.	64B-17
CARTER, J. A.	64PRR-075
CARTER, J. A.	64PRR-082
CARTER, J. A.	64PRR-083
 *CHILTON, J. M.	 64PRR-043
 *CLARK, R. P.	 64PRR-095
 COMBS, Z.	 64B-17
 CONNELLY, M. V.	 64PRR-220

CONNELLY, M. V.	64PRR-221	=DUNN, J. W.,	64PRR-059
COOPER, J. H.	64B-18-01	DYER, F. F.	64A-12-05B
CORBIN, L. T.	64A-04	DYER, F. F.	64A-12-07A
CORBIN, L. T.	64B-18	DYER, F. F.	64A-12-07B
CORBIN, L. T.	64PRR-018	DYER, F. F.	64A-12-07C
CORBIN, L. T.	64PRR-052	DYER, F. F.	64PRR-002
CORBIN, L. T.	64PRR-222	DYER, F. F.	64PRR-056
CORBIN, L. T.	64PRR-298	DYER, F. F.	64PRR-274
		DYER, F. F.	64PRR-275
COSTANZO, D. A.	64A-04-03		
COSTANZO, D. A.	64PRR-019	EBLEN, B. G.	64B-15
COSTANZO, D. A.	64PRR-271		
COSTANZO, D. A.	64PRR-291	EBY, R. E.	64A-09-01
=CROWTHER, P.	64A-12-01C	ELDRIDGE, J. S.	64A-12-01A
=CROWTHER, P.	64A-12-02D	ELDRIDGE, J. S.	64A-12-01B
=CROWTHER, P.	64A-12-02E	ELDRIDGE, J. S.	64A-12-01C
=CROWTHER, P.	64PRR-020	ELDRIDGE, J. S.	64A-12-02A
=CROWTHER, P.	64PRR-021	ELDRIDGE, J. S.	64A-12-02B
=CROWTHER, P.	64PRR-022	ELDRIDGE, J. S.	64A-12-02D
=CROWTHER, P.	64PRR-024	ELDRIDGE, J. S.	64A-12-02E
=CROWTHER, P.	64PRR-076	ELDRIDGE, J. S.	64A-12-05A
=CROWTHER, P.	64PRR-273	ELDRIDGE, J. S.	64PRR-003
=CROWTHER, P.	64PRR-277	ELDRIDGE, J. S.	64PRR-020
=CROWTHER, P.	64PRR-294	ELDRIDGE, J. S.	64PRR-024
		ELDRIDGE, J. S.	64PRR-025
*CUNEO, D. R.	64PRR-065	ELDRIDGE, J. S.	64PRR-037
*CUNEO, D. R.	64PRR-072	ELDRIDGE, J. S.	64PRR-038
*CUNEO, D. R.	64PRR-101	ELDRIDGE, J. S.	64PRR-051
*CUNEO, D. R.	64PRR-333	ELDRIDGE, J. S.	64PRR-076
		ELDRIDGE, J. S.	64PRR-273
		ELDRIDGE, J. S.	64PRR-276
		ELDRIDGE, J. S.	64PRR-277
		ELDRIDGE, J. S.	64PRR-294
DALE, J. M.	64A-02-02	EMERY, J. F.	64A-12-01D
DALE, J. M.	64A-04-01	EMERY, J. F.	64A-12-01J
DALE, J. M.	64PRR-023	EMERY, J. F.	64A-12-07A
DALE, J. M.	64PRR-296	EMERY, J. F.	64A-12-07B
DALE, J. M.	64PRR-297	EMERY, J. F.	64A-12-07C
		EMERY, J. F.	64A-12-07G
DAVIS, H. G.	64PRR-266	EMERY, J. F.	64PRR-014
		EMERY, J. F.	64PRR-274
DUNLAP, L. B.	64PRR-071	EMERY, J. F.	64PRR-275
		EMERY, J. F.	64PRR-278
DUNN, H. W.	64A-08-01A		

D

E

F

FARRAR, L. G.	64B-18-06
FARRAR, L. G.	64PRR-264
FELDMAN, C.	64A-08-01
FELDMAN, C.	64A-08-01B
FELDMAN, C.	64A-08-01C
FELDMAN, C.	64PRR-005
FELDMAN, C.	64PRR-026
FELDMAN, C.	64PRR-028
FELDMAN, C.	64PRR-037
FELDMAN, C.	64PRR-038
FELDMAN, C.	64PRR-279
FELDMAN, C.	64PRR-280
FELDMAN, C.	64PRR-281
FERGUSON, N. M.	64PRR-281
FISHER, D. J.	64A-01
FISHER, D. J.	64A-01-01
FISHER, D. J.	64A-01-02
FISHER, D. J.	64A-01-03
FISHER, D. J.	64A-04-01
FISHER, D. J.	64PRR-027
FISHER, D. J.	64PRR-037
FISHER, D. J.	64PRR-038
FISHER, D. J.	64PRR-270
FISHER, D. J.	64PRR-282
FISHER, D. J.	64PRR-283
FISHER, D. J.	64PRR-284
FISHER, D. J.	64PRR-285
FISHER, D. J.	64PRR-286
=FOLSOM, T. R.	64PRR-028

G

=GAITANIS, M. J.	64A-04-01
=GARDNER, R. P.	64PRR-059
*GILBERT, R. A.	64PRR-043
GOEKING, C. F.	64PRR-057
GOLDBERG, G.	64A-06-05
GOLDBERG, G.	64A-06-06

GOLDBERG, G.	64A-06-07
GOLDBERG, G.	64PRR-287
GOLDBERG, G.	64PRR-288
GOLDSTEIN, G.	64A-12-03D
GOLDSTEIN, G.	64A-12-04A
GOLDSTEIN, G.	64A-12-04C
GOLDSTEIN, G.	64PRR-029
GOLDSTEIN, G.	64PRR-030
GOLDSTEIN, G.	64PRR-077
GOLDSTEIN, G.	64PRR-289

*GRIMES, W. R.	64PRR-065
*GRIMES, W. R.	64PRR-101

H

HAGA, F. E.	64A-04-01
HAGA, F. E.	64A-04-03
HAHN, R. L.	64A-12-03F
HAHN, R. L.	64A-12-03G
HAHN, R. L.	64A-12-07K
HAHN, R. L.	64PRR-004
HAHN, R. L.	64PRR-031
HAHN, R. L.	64PRR-032
HANDLEY, T. H.	64A-12-01E
HANDLEY, T. H.	64A-12-01F
HANDLEY, T. H.	64A-12-01G
HANDLEY, T. H.	64A-12-03A
HANDLEY, T. H.	64A-12-03B
HANDLEY, T. H.	64PRR-033
HANDLEY, T. H.	64PRR-034
HANDLEY, T. H.	64PRR-310

*HARMATZ, B.	64A-12-01F
*HARMATZ, B.	64PRR-034

HARMON, T. G.	64A-11

HEACKER, F. K.	64A-04-01
=HEALY, W. B.	64A-12-07D
=HEALY, W. B.	64A-12-07F
=HEALY, W. B.	64PRR-269

HILL, F. M.	64PRR-122

HILL, F. M.	64PRR-127
HOLSOPPLE, H. L.	64A-12-04B
HOLSOPPLE, H. L.	64A-14
HOLSOPPLE, H. L.	64PRR-078
HOLSOPPLE, H. L.	64PRR-079
HORTON, A. D.	64A-05-01
HORTON, A. D.	64A-05-02
HORTON, A. D.	64A-06-04
HORTON, A. D.	64PRR-035
HORTON, A. D.	64PRR-123
HORTON, A. D.	64PRR-124
HORTON, C. A.	64A-02-03
HORTON, C. A.	64A-07
HORTON, C. A.	64PRR-036
HORTON, C. A.	64PRR-080

J

JONES, H. C.	64A-01-03
JONES, H. C.	64A-01-05
JONES, H. C.	64PRR-081
*JONES, R. J.	64PRR-082
*JONES, R. J.	64PRR-083

K

*KATZ, S.	64PRR-082
*KATZ, S.	64PRR-083

KELLEY, M. T.	64A-01
KELLEY, M. T.	64A-01-01
KELLEY, M. T.	64A-01-02
KELLEY, M. T.	64A-01-03
KELLEY, M. T.	64A-08-01
KELLEY, M. T.	64A-11
KELLEY, M. T.	64A-13
KELLEY, M. T.	64C-20
KELLEY, M. T.	64PRR-018
KELLEY, M. T.	64PRR-037
KELLEY, M. T.	64PRR-038
KELLEY, M. T.	64PRR-084
KELLEY, M. T.	64PRR-085

KELLEY, M. T.	64PRR-086
KELLEY, M. T.	64PRR-087
KELLEY, M. T.	64PRR-088
KELLEY, M. T.	64PRR-270
KELLEY, M. T.	64PRR-285
KELLEY, M. T.	64PRR-286
KELLEY, M. T.	64PRR-290

*KELLY, M. J.	64PRR-065
*KELLY, M. J.	64PRR-072
*KELLY, M. J.	64PRR-101
*KELLY, M. J.	64PRR-333

*KLEIN, A. S.	64PRR-096

KOCHANNY, G. L.	64A-03-02
KOCHANNY, G. L.	64A-03-03
KOCHANNY, G. L.	64A-03-04

KOIRTYOHANN, S. R.	64PRR-005

KUBOTA, H.	64A-03-05
KUBOTA, H.	64A-05-04
KUBOTA, H.	65A-06-01
KUBOTA, H.	64A-06-02
KUBOTA, H.	64A-06-09
KUBOTA, H.	64A-06-10
KUBOTA, H.	64PRR-125
KUBOTA, H.	64PRR-265
KUBOTA, H.	64PRR-291

L

LAING, W. R.	64B-18-02
LAING, W. R.	64PRR-266

LAMB, C. E.	64B-18-03
LAMB, C. E.	64PRR-018

LAVALLE, D. E.	64A-13

LAYTON, F. L.	64PRR-122
LAYTON, F. L.	64PRR-126

=LEDDICOTTE, G. W.	64PRR-014
=LEDDICOTTE, G. W.	64PRR-016
=LEDDICOTTE, G. W.	64PRR-218

=LEDDICOTTE, G. W.	64PRR-222	=MAMANTOV, G.	64PRR-046
*LEUZE, R. E.	64PRR-043	=MAMANTOV, G.	64PRR-047
*LITMAN, A. P.	64PRR-103	=MAMANTOV, G.	64PRR-295
		=MAMANTOV, G.	64PRR-296
		=MAMANTOV, G.	64PRR-297
LUND, J. R.	64A-05-04	MANNING, D. L.	64A-02-02
LUND, J. R.	64A-06-08	MANNING, D. L.	64PRR-037
LUND, J. R.	64A-06-09	MANNING, D. L.	64PRR-038
LUND, J. R.	64A-06-10	MANNING, D. L.	64PRR-045
LUND, J. R.	64A-06-11	MANNING, D. L.	64PRR-046
		MANNING, D. L.	64PRR-047
LYNN, E. C.	64PRR-127	MANNING, D. L.	64PRR-091
LYNN, E. C.	64PRR-223	MANNING, D. L.	64PRR-131
		MANNING, D. L.	64PRR-295
LYON, W. S.	64A-12	MANNING, D. L.	64PRR-296
LYON, W. S.	64A-12-011	MANNING, D. L.	64PRR-297
LYON, W. S.	64A-12-04A		
LYON, W. S.	64PRR-006	MEYER, A. S.	64A-04-01
LYON, W. S.	64PRR-007	MEYER, A. S.	64A-04-02
LYON, W. S.	64PRR-014	MEYER, A. S.	64A-05
LYON, W. S.	64PRR-030	MEYER, A. S.	64A-05-01
LYON, W. S.	64PRR-037	MEYER, A. S.	64A-06-04
LYON, W. S.	64PRR-038		
LYON, W. S.	64PRR-039	MEYER, H. C.	64A-04-03
LYON, W. S.	64PRR-040		
LYON, W. S.	64PRR-041	MILLER, F. J.	64A-06-03
LYON, W. S.	64PRR-042	MILLER, F. J.	64A-06-11
LYON, W. S.	64PRR-043	MILLER, F. J.	64PRR-048
LYON, W. S.	64PRR-089	MILLER, F. J.	64PRR-049
LYON, W. S.	64PRR-090		
LYON, W. S.	64PRR-128	MOORE, F. L.	64A-04-03
LYON, W. S.	64PRR-129	MOORE, F. L.	64A-12-03C
LYON, W. S.	64PRR-130	MOORE, F. L.	64PRR-021
LYON, W. S.	64PRR-292	MOORE, F. L.	64PRR-022
LYON, W. S.	64PRR-293	MOORE, F. L.	64PRR-025
LYON, W. S.	64PRR-294	MOORE, F. L.	64PRR-050
LYON, W. S.	64PRR-312	MOORE, F. L.	64PRR-051
LYON, W. S.	64PRR-316	MOORE, F. L.	64PRR-064
		MOORE, F. L.	64PRR-132
		MOORE, F. L.	64PRR-133
		MOORE, F. L.	64PRR-134
		MOORE, F. L.	64PRR-135
		MOORE, F. L.	64PRR-136
		MOORE, F. L.	64PRR-137
		MOORE, F. L.	64PRR-138
		MOORE, F. L.	64PRR-139
MADDOX, W. L.	64A-04-01		
MADDOX, W. L.	64A-04-03		
*MAHLMAN, H. A.	64PRR-044		

M

MOORE, F. L. 64PRR-140

MORTON, J. E. 64PRR-052
MORTON, J. E. 64PRR-141
MORTON, J. E. 64PRR-142
MORTON, J. E. 64PRR-145
MORTON, J. E. 64PRR-298

MUELLER, T. R. 64A-01-06
MUELLER, T. R. 64A-01-08
MUELLER, T. R. 64A-04-03
MUELLER, T. R. 64PRR-299

MULLINS, W. T. 64A-04-03

=MUZZARELLI, R. A. A. 64A-12-03E

N

=NORRIS, J. A. 64PRR-067

P

=PAL, B. C. 64PRR-036

=PAPPAS, W. S. 64PRR-075

PARKER, H. A. 64PRR-052
PARKER, H. A. 64PRR-143
PARKER, H. A. 64PRR-144
PARKER, H. A. 64PRR-145
PARKER, H. A. 64PRR-298

=PERONE, S. P. 64A-01-06

=PERONE, S. P. 64PRR-299

=PETERS, D. G. 64A-05-06

=PETERS, D. G. 64PRR-053

=PETERS, D. G. 64PRR-300

=PRO, M. J. 64PRR-014

=PRO, M. J. 64PRR-015

Q

QUINCY, R. B. 64A-13

R

RAAEN, H. P. 64A-05-05
RAAEN, H. P. 64C-20
RAAEN, H. P. 64PRR-092
RAAEN, H. P. 64PRR-093
RAAEN, H. P. 64PRR-094
RAAEN, H. P. 64PRR-095
RAAEN, H. P. 64PRR-096
RAAEN, H. P. 64PRR-146
RAAEN, H. P. 64PRR-224
RAAEN, H. P. 64PRR-225
RAAEN, H. P. 64PRR-226
RAAEN, H. P. 64PRR-227
RAAEN, H. P. 64PRR-329

RAINEY, W. T., JR. 64PRR-013

RAINS, T. C. 64A-08-01C
RAINS, T. C. 64PRR-026
RAINS, T. C. 64PRR-028
RAINS, T. C. 64PRR-281

REYNOLDS, S. A. 64A-12-01H
REYNOLDS, S. A. 64A-12-02C
REYNOLDS, S. A. 64A-12-02F
REYNOLDS, S. A. 64A-12-03H
REYNOLDS, S. A. 64A-12-03I
REYNOLDS, S. A. 64A-12-03J
REYNOLDS, S. A. 64PRR-054
REYNOLDS, S. A. 64PRR-097
REYNOLDS, S. A. 64PRR-147
REYNOLDS, S. A. 64PRR-148
REYNOLDS, S. A. 64PRR-222
REYNOLDS, S. A. 64PRR-228
REYNOLDS, S. A. 64PRR-229
REYNOLDS, S. A. 64PRR-301
REYNOLDS, S. A. 64PRR-302
REYNOLDS, S. A. 64PRR-303
REYNOLDS, S. A. 64PRR-304
REYNOLDS, S. A. 64PRR-305

RICCI, E. 64A-12-07K
RICCI, E. 64A-12-08A
RICCI, E. 64A-12-08C
RICCI, E. 64PRR-008

RICCI, E.	64PRR-055	SCROGGIE, L. E.	64PRR-100
RICCI, E.	64PRR-056		
RICCI, E.	64PRR-306	*SHAFFER, J. H.	64PRR-065
		*SHAFFER, J. H.	64PRR-101
RICKARD, R. R.	64PRR-057	*SHAFFER, J. H.	64PRR-333
RICKARD, R. R.	64PRR-149		
RICKARD, R. R.	64PRR-150	SHULTS, W. D.	64A-05-06
RICKARD, R. R.	64PRR-151	SHULTS, W. D.	64PRR-053
RICKARD, R. R.	64PRR-263	SHULTS, W. D.	64PRR-300
ROSS, H. H.	64A-12-04B	SITES, J. R.	64B-16
ROSS, H. H.	64A-12-06A	SITES, J. R.	64PRR-102
ROSS, H. H.	64PRR-009	SITES, J. R.	64PRR-153
ROSS, H. H.	64PRR-010	SITES, J. R.	64PRR-154 - 217
ROSS, H. H.	64PRR-058		
ROSS, H. H.	64PRR-059	*SMITH, G. P.	64PRR-070
ROSS, H. H.	64PRR-060		
ROSS, H. H.	64PRR-098	SPITZER, E. J.	64PRR-102
ROSS, H. H.	64PRR-099	SPITZER, E. J.	64PRR-153
ROSS, H. H.	64PRR-307	SPITZER, E. J.	64PRR-154 - 217
ROSS, H. H.	64PRR-308		
ROSS, H. H.	64PRR-309	=SPRONK, N.	64PRR-063
ROSS, H. H.	64PRR-310		
ROSS, H. H.	64PRR-311	STELZNER, R. W.	64A-01-03
ROSS, H. H.	64PRR-312	STELZNER, R. W.	64A-01-04
ROSS, H. H.	64PRR-330	STELZNER, R. W.	64A-01-07
		STELZNER, R. W.	64A-04-01
ROSS, W. J.	64A-12-06B	STELZNER, R. W.	64A-04-03
ROSS, W. J.	64A-12-06C	STELZNER, R. W.	64PRR-037
ROSS, W. J.	64A-12-07H	STELZNER, R. W.	64PRR-038
ROSS, W. J.	64A-12-07I		
ROSS, W. J.	64A-12-07J	=STOKELY, J. R.	64PRR-064
ROSS, W. J.	64A-12-08B		
ROSS, W. J.	64PRR-061	STRAIN, J. E.	64A-12-07J
ROSS, W. J.	64PRR-062	STRAIN, J. E.	64A-12-08B
ROSS, W. J.	64PRR-310	STRAIN, J. E.	64A-12-08D
ROSS, W. J.	64PRR-313	STRAIN, J. E.	64A-12-08E
		STRAIN, J. E.	64PRR-011
RUBIN, I. B.	64A-05-03	STRAIN, J. E.	64PRR-065
RUBIN, I. B.	64A-07	STRAIN, J. E.	64PRR-072
RUBIN, I. B.	64PRR-152	STRAIN, J. E.	64PRR-101
RUBIN, I. B.	64PRR-267	STRAIN, J. E.	64PRR-103
		STRAIN, J. E.	64PRR-313
		STRAIN, J. E.	64PRR-314
		STRAIN, J. E.	64PRR-315
		STRAIN, J. E.	64PRR-316
		STRAIN, J. E.	64PRR-333
SCROGGIE, L. E.	64A-10		
SCROGGIE, L. E.	64PRR-079		

SUSANO, C. D.	64PRR-037	WHITE, J. C.	64PRR-104
SUSANO, C. D.	64PRR-038	WHITE, J. C.	64PRR-105 - 114
		WHITE, J. C.	64PRR-332
T			
TALBOTT, C. K.	64B-15	WILLMARTH, T. E.	64A-11
TALBOTT, C. K.	64B-19	WILLMARTH, T. E.	64PRR-044
		WILLMARTH, T. E.	64PRR-317
		WILLMARTH, T. E.	64PRR-318
THOMASON, P. F.	64A-04-03		
THOMASON, P. F.	64A-05	WILSON, G. R.	64B-15
THOMASON, P. F.	64A-05-04		
THOMASON, P. F.	64A-06	*WINSBRO, W. R.	64PRR-018
THOMASON, P. F.	64A-06-12		
THOMASON, P. F.	64A-14	WRIGHT, H. W.	64A-11
THOMASON, P. F.	64PRR-037		
THOMASON, P. F.	64PRR-038	=WRIGHT, R. R.	64PRR-075
THOMASON, P. F.	64PRR-066		
THOMASON, P. F.	64PRR-222	WYATT, E. I.	64B-18-05
THOMASON, P. F.	64PRR-331	WYATT, E. I.	64PRR-052
		WYATT, E. I.	64PRR-057
TRAVAGLINI, A. L.	64A-04-03	WYATT, E. I.	64PRR-230 - 262
TRAVAGLINI, A. L.	64A-06-13	WYATT, E. I.	64PRR-263
TRAVAGLINI, A. L.	64A-06-14	WYATT, E. I.	64PRR-298
TRAVAGLINI, A. L.	64A-06-15		
TRAVAGLINI, A. L.	64A-06-16		
		Y	
=TUCKERMAN, M. M.	64PRR-016	*YEATTS, L. B., JR.	64PRR-013
W			
WALTON, J. R.	64A-09-02	=YERICK, R. E.	64PRR-060
		=YERICK, R. E.	64PRR-099
*WATSON, G. M.	64PRR-065	=YERICK, R. E.	64PRR-311
*WATSON, G. M.	64PRR-101		
		YOUNG, J. P.	64A-02-01
=WEBER, C. W.	64PRR-075	YOUNG, J. P.	64PRR-068
		YOUNG, J. P.	64PRR-069
		YOUNG, J. P.	64PRR-070
		YOUNG, J. P.	64PRR-115
=WEEKLEY, R. E.	64PRR-067	YOUNG, J. P.	64PRR-319 - 320
		YOUNG, J. P.	64PRR-321
		YOUNG, J. P.	64PRR-322
WHITE, J. C.	64A-02		
WHITE, J. C.	64A-03	Z	
WHITE, J. C.	64A-04	ZITTEL, H. E.	64A-03-01
WHITE, J. C.	64A-05	ZITTEL, H. E.	64A-06-03
WHITE, J. C.	64A-06	ZITTEL, H. E.	64A-06-11
WHITE, J. C.	64A-07	ZITTEL, H. E.	64PRR-012
WHITE, J. C.	64A-12	ZITTEL, H. E.	64PRR-048
WHITE, J. C.	64A-14	ZITTEL, H. E.	64PRR-049
WHITE, J. C.	64PRR-062	ZITTEL, H. E.	64PRR-071
WHITE, J. C.	64PRR-080		

ANALYTICAL CHEMISTRY DIVISION

NOVEMBER 16, 1964

M. T. KELLEY,¹ DIRECTOR
D. M. WILSON, SECRETARY
C. D. SUSANO, ASSOCIATE DIRECTOR
B. E. YOUNG, SECRETARY

STAFF
L. G. FARRAR,¹ RADIATION AND SAFETY OFFICER
J. S. ELDRIDGE,¹ COORDINATOR FOR RADIOCHEMICAL ANALYSES IN AN EMERGENCY
H. P. RAAEN,¹ REPORTS EDITOR
P. A. DERIEUX, CLERK-TYPIST
A. L. HARROD, PROCUREMENT

¹DUAL CAPACITY
²ON LEAVE OF ABSENCE
³NONCITIZEN GUEST
⁴ORINS FELLOW
⁵NDEA FELLOW (NATIONAL DEFENSE EDUCATION ACT)

INTERNAL DISTRIBUTION

1. Biology Library	83. M. T. Kelley
2-4. Central Research Library	84. W. R. Laing
5. Reactor Division Library	85. C. E. Lamb
6. Laboratory Shift Supervisor	86. J. A. Lane
7-8. ORNL - Y-12 Technical Library	87. C. E. Larson
Document Reference Section	88. D. E. LaValle
9-43. Laboratory Records Department	89. T. A. Lincoln
44. Laboratory Records, ORNL R.C.	90. S. C. Lind
45. S. E. Beall	91. R. S. Livingston
46. D. S. Billington	92. R. N. Lyon
47. E. G. Bohlmann	93. W. S. Lyon
48-57. G. E. Boyd	94. H. G. MacPherson
58. R. B. Briggs	95. H. V. Malmstadt (consultant)
59. O. W. Briscoe	96. H. F. McDuffie
60. F. R. Bruce	97. A. S. Meyer
61. A. E. Cameron	98. K. Z. Morgan
62. S. F. Carson	99. G. H. Morrison (consultant)
63. J. A. Carter	100. M. L. Moss (consultant)
64. J. H. Cooper	101. M. L. Nelson
65. L. T. Corbin	102-103. R. B. Parker
66. J. A. Cox	104. H. P. Raaen
67. F. L. Culler	105. A. F. Rupp
68. J. E. Cunningham	106. J. M. Schreyer (Y-12)
69. R. E. Eby	107. H. E. Seagren
70. L. G. Farrar	108. J. R. Sites
71. C. Feldman	109. M. J. Skinner
72. D. E. Ferguson	110. A. H. Snell
73. D. J. Fisher	111. E. G. Struxness
74. J. H. Frye, Jr.	112. C. D. Susano
75. N. H. Furman (consultant)	113. E. H. Taylor
76. J. L. Gabbard	114. P. F. Thomason
77. J. H. Gillette	115. G. M. Watson
78. W. R. Grimes	116. A. M. Weinberg
79. A. Hollaender	117-122. J. C. White
80. A. S. Householder	123. G. C. Williams
81. R. W. Johnson	124. T. E. Willmarth
82. W. H. Jordan	125. E. I. Wyatt

EXTERNAL DISTRIBUTION

126. Sterling Forest Laboratory, Union Carbide Corporation, New York
127. R. W. McNamee, Union Carbide Corporation, New York
128. R. C. Shank, Idaho Falls
129. O. Bizzell, Office of Isotope Development, AEC, Washington, D.C.
130. R. J. Brouns, General Electric Company, Richland
131. duPont Company, Wilmington
132. Bettis Plant, Westinghouse Atomic Power Laboratory

- 133. National Lead Company of Ohio, Raw Materials Development Laboratory, Cincinnati
- 134. J. A. Dean, University of Tennessee
- 135. G. Mamantov, University of Tennessee
- 136. L. B. Rogers, Purdue University
- 137. Research Center Library, Union Carbide Corporation, P.O. Box 324, Tuxedo, New York
- 138. Research and Development Division, AEC, ORO
- 139-736. Given distribution as shown in TID-4500 (37th ed.) under Chemistry category (75 copies - CFSTI)

Reports previously issued in this series are as follows:

ORNL-686	Period Ending March 31, 1950
ORNL-788	Period Ending June 30, 1950
ORNL-867	Period Ending October 10, 1950
ORNL-955	Period Ending January 10, 1951
ORNL-1088	Period Ending March 26, 1951
ORNL-1113	Period Ending June 26, 1951
ORNL-1129	Period Ending September 10, 1951
ORNL-1233	Period Ending December 26, 1951
ORNL-1276	Period Ending March 26, 1952
ORNL-1361	Period Ending June 26, 1952
ORNL-1423	Period Ending September 26, 1952
ORNL-1474	Period Ending January 10, 1953
ORNL-1547	Period Ending April 20, 1953
ORNL-1639	Period Ending October 20, 1953
ORNL-1717	Period Ending April 20, 1954
ORNL-1788	Period Ending October 20, 1954
ORNL-1880	Period Ending April 20, 1955
ORNL-1973	Period Ending October 20, 1955
ORNL-2070	Period Ending April 20, 1956
ORNL-2218	Period Ending December 31, 1956
ORNL-2453	Period Ending December 31, 1957
ORNL-2662	Period Ending December 31, 1958
ORNL-2866	Period Ending December 31, 1959
ORNL-3060	Period Ending December 31, 1960
ORNL-3243	Period Ending December 31, 1961
ORNL-3397	Period Ending December 31, 1962
ORNL-3537	Period Ending November 15, 1963