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Summaries of FY 1980 Research in the Nuclear Sciences

June 1980

U.S. Department of Energy

Directorate of Energy Research

Division of Nuclear Sciences

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Summaries of FY 1980 Research in the Nuclear Sciences

450 7771
June 1980

U.S. Department of Energy
Directorate of Energy Research
Division of Nuclear Sciences
Washington, DC 20545

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Dear Colleague:

For fiscal year 1978 the DOE Division of Nuclear Sciences issued a descriptive booklet entitled "Summaries of FY 1978 Research in the Nuclear Sciences." These summaries constitute the basic document by which the Nuclear Sciences Program of DOE's Office of Basic Energy Sciences can be made known in some technical detail to interested people. It is addressed to those in government and the scientific community who may wish to learn of the nature of the research being conducted under the support of this program.

For the FY 1980 edition we request that you and/or your colleagues provide for us by May 1, 1980, an up-to-date one-page summary of the Nuclear Sciences activities under your cognizance. Please retain the same format as the enclosed example but delete the AK-OW-OX-OY-Z budget and reporting classification, the fiscal year designation, and the funding level. To minimize the retyping burden and publishing delays, please provide finished copy ready for reproduction. The summaries should be complete and self-contained providing information on project scope and objectives and avoiding undue speculation about future plans. Please address your replies to S. L. Whetstone or J. L. Burnett.

We very much appreciate your assistance in this matter.

Sincerely,

A handwritten signature in black ink that reads "James S. Kane". The signature is fluid and cursive, with a long horizontal stroke at the end.

James S. Kane
Associate Director
for Basic Energy Sciences
Office of Energy Research

Enclosure

INTRODUCTION

It is hoped that this report will prove useful as a convenient compilation and index of the projects funded in fiscal year 1980 by the DOE Division of Nuclear Sciences/Office of Basic Energy Sciences.

Attached to each summary is information regarding the category in the Federal Budget to which the project belongs, as well as the amount of operating expense funds provided in FY80. (\$1 K = \$1,000) The budget codes can be interpreted as follows:

- 01: Low Energy Nuclear Research
- 02: Nuclear Data Measurements
- 03: Nuclear Data Compilation and Evaluation
- 04: Heavy Element Chemistry
- 02-01: Electromagnetic Isotope Separation
- 02-02: Special Isotope Preparation

Projects funded under the first three budget categories: -01, -02, and -03 are currently managed by S. L. Whetstone, Division of Nuclear Physics; -04, -02-01, and -02-02, by J. L. Burnett of the Division of Chemical Sciences. Detailed information about a given project may best be obtained by communicating directly with the investigators listed.

It should be noted that an appreciable program of research in nuclear science (including medium-energy, heavy-ion, and nuclear theory research) is also supported by the Department of Energy in the Division of Nuclear Physics/Office of High Energy and Nuclear Physics.

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LABORATORIES

Ames Laboratory
Iowa State University

-01 \$190 K

John C. Hill, F. K. Wohn

I. Decay of Fission Products. The major thrust in our program is the study of the decay of neutron-rich nuclides produced by fission at the High Flux Beam Reactor at Brookhaven. The fission products are mass separated using the TRISTAN separator system. The elements Zn through Sr and Ag through Ba are available through use of an in-beam target ion-source combination. Measurements of γ rays, conversion electrons, and β rays are used to study nuclides with half-lives as short as a few 100 milliseconds. The above measurements establish the structure of nuclei far to the neutron-rich side of stability. At present emphasis is being placed on the study of the regions near the doubly-magic nuclei ^{132}Sn and ^{78}Ni . The results of these studies are also of interest for the design of fission reactors and modeling of loss-of-coolant accidents, since the heat distribution in the reactor core depends on the fission products available and the energies of the γ and β radiation emitted.

II. Heavy Ion Coulomb Dissociation. A search is underway for Coulomb dissociation produced by the interaction of relativistic heavy ions produced at the Bevalac accelerator at Berkeley with selected targets. The (X, Xn) reaction where X is a relativistic projectile of energy $2\text{C}\alpha/\text{A}$ ranging from p to ^{40}Ar is used to indicate the presence of Coulomb-dissociation. In this process the target nucleus is excited by photon exchange when the two nuclei are too far apart for the nuclear interaction to be significant. It is expected that if Coulomb dissociation does occur the nucleus will be excited into the giant dipole or some higher multipole resonance. The process will enable us to study the excitation of giant resonances at relativistic energies by purely electromagnetic interactions.

III. Decay of Neutron-Rich Nuclides with $A < 70$. It is quite difficult to produce and study very neutron-rich nuclides outside the fission region. We make use of the unique flux of high-energy neutrons produced at the main beam stop at LAMPF. The nuclides of interest which are produced by spallation are separated by rapid gas-phase radiochemistry. Two new nuclides, ^{39}S ($T_{1/2}=11.5\text{s}$) and ^{46}Ar ($T_{1/2}=8.9\text{s}$) have been isolated and their decay schemes determined. Aside from the interest of these studies for nuclear structure considerations, the characteristics of these neutron-rich nuclides must be determined in order to model the r and s processes in stars in which the heavy elements are produced.

Nuclear Research FY 1980

C. N. Davids, A. J. Elwyn, G. T. Garvey, W. F. Henning, R. E. Holland, R. J. Holt, H. E. Jackson, Jr., V. E. Krohn, W. Kutschera, R. D. McKeown, F. P. Mooring, L. Meyer-Schutzmeister, J. E. Monahan, G. R. Ringo, J. P. Schiffer, R. K. Smither, J. L. Yntema.

I. Neutron Electric Dipole Moment. The existence of a nonvanishing neutron EDM would challenge the fundamental symmetries under space inversion and time reversal. Its magnitude would test gauge theories of the weak interaction. This experiment will measure the EDM by observing the effect of an electric field on the precession of bottled ultracold neutrons. The anticipated sensitivity in the current phase of the experiment is 1×10^{-25} e-cm.

II. Photonuclear Research. Includes non-E1 giant resonance phenomena, basic reaction mechanisms in light nuclei, fundamental properties of the deuteron, and photon scattering experiments to study couplings between collective excitations in medium and heavy nuclei. The major effort in FY 1980 is dedicated to accurate neutron-polarization measurements in deuteron photo-disintegration.

III. Weak Interaction Research. The nucleus is used as a laboratory to study fundamental symmetries of the weak interaction. Experiments includes tests of the conserved vector current hypothesis and the existence of second-class currents. The main present effort is a search for parity violation in the reaction ${}^6\text{Li}(\alpha, \gamma){}^{10}\text{B}$, using a polarized ${}^6\text{Li}$ target.

IV. Charged-Particle Reactions and Radioactivity. Includes reactions of ${}^6\text{Li}$ and ${}^7\text{Li}$ of interest for "exotic" fusion power cycles, ${}^4\text{He}({}^3\text{He}, \gamma)$ reactions related to the solar neutrino problem, isotopes of interest to nucleosynthesis, gamma-ray studies of mirror nuclei in the $f_{7/2}$ shell, and other nuclear structure experiments. A new helium jet recoil transfer system is being developed for fast radioactivity experiments.

V. Accelerator Mass Spectrometry and Archaeological Dating. The FN tandem is used with a magnetic spectrograph to measure isotope concentrations in the range 10^{-8} to 10^{-14} . This technique has been used to measure radioactive half lives in the range 10^2 to 10^6 years, cross sections for producing isotopes of astrophysical interest by proton bombardment, and for highly efficient measurements of ${}^{14}\text{C}$ concentrations for archaeology. Feasibility studies for using the picosecond pulsing of the superconducting linac for mass spectrometry by time-of-flight are under way.

VI. Laser Fluorescence Spectroscopy. A facility is being developed with a cooled He jet for measuring isotope shifts and hyperfine interactions by Doppler-free laser fluorescence spectroscopy, using beams from the superconducting linac.

VII. Accelerator Operations. We operate a Tandem-Linac facility (a modified FN Tandem with a picosecond-pulsed superconducting linac energy booster), and a high-current single-ended 4 MV Dynamitron accelerator. About one fourth of the beam time of these accelerators is used by groups including university-based researchers.

LABORATORIES

Argonne National Laboratory
Chemistry Division

-01 \$565 K

Nuclear Research

B. B. Back, R. R. Betts, J. E. Gindler, L. E. Glendenin, B. D. Wilkins,
K. L. Wolf, A. M. Friedman, I. Ahmad, R. R. Chasman

Nuclear research supported activities in the ANL Chemistry Division include studies in nuclear fission and the nuclear structure of actinide nuclei. The nuclear fission research program is directed toward achieving a fundamental understanding of the nature of the fission process. The dependence of various aspects of the process (e.g., fissionability, fragment mass and angular distributions, kinetic energy release) on the structure, excitation energy, and angular momentum of the fission system provide fundamental information on the location of nuclear shells and on the rigidity of nuclei against centrifugal stress. Fusion and transfer reactions with both light and heavy-ion projectiles at the ANL tandem-superconducting linac, as well as the accelerators at LBL, ORNL and Michigan State University, provide a controlled and separate variation of excitation energy and angular momentum over a broad range for these studies. The current primary emphasis of the nuclear structure research program is on a search for parity doublets in the light actinides which are predicted to exist as a result of strong octupole correlations. If observed, such doublets may provide a unique tool for the study of parity-violating interactions.

LABORATORIES

Argonne National Laboratory
Chemistry Division

-02 \$120 K

Nuclear Data Measurements

L. E. Glendenin, J. E. Gindler, D. Henderson

The purpose of this nuclear measurements program is to augment the fission yield data base by determining fission product yields (mass distributions) for monoenergetic-neutron-induced fission of the fissile and fertile nuclides of importance in the ^{238}U - ^{239}Pu and ^{232}Th - ^{233}U fast-reactor breeding cycles. Knowledge of fast-neutron fission product yields is important to many aspects of reactor technology including design and operation of reactors, dosimetry, fuel reprocessing and management of radioactive waste. The fission yields are determined by radiochemical and γ -ray spectrometric measurements of the fission products in targets irradiated with monoenergetic neutrons in the energy range of 0.1 to 8 MeV provided by the ANL fast neutron generator facility. The systematics of the experimental fission yield data can then be used to calculate mass-yield distributions for fissionable nuclides irradiated with fast neutrons of a given spectral shape characteristic of a particular set of fast reactor conditions. Fission yield systematics from this program also add to our fundamental knowledge of the nuclear fission process by furnishing basic information on the dynamics of the descent from saddle to scission point, in particular on the unresolved question of how much of the potential energy release appears as nuclear dissipation energy associated with viscous heating.

LABORATORIES

Argonne National Laboratory
Chemistry Division

-04 \$960 K

Heavy Elements Chemistry Research

W. T. Carnall, J. V. Beitz, J. P. Hessler, L. Morss, J. C. Sullivan,
F. Wagner, Jr., D. W. Wester

Heavy element research at Argonne encompasses programs in both the chemistry and physics of the actinide and lanthanide elements. Efforts in solution, solid state, and photochemistry interact closely with more physically oriented program segments where mechanistic studies of energy transfer and excited state relaxation are emphasized.

While the thrust of the research is fundamental in nature, there is a clear potential in each program element for important contributions to more applied areas of the energy development mission of DOE. An understanding of the electronic structure of the actinides in their different valence states is basic to the interpretative needs of the program. A broad effort in atomic and crystal spectroscopy that has both a strong experimental and theoretical orientation is making steady progress in developing the required energy level analysis.

Existing unique facilities for pulse radiolysis make it possible to probe the course of oxidation-reduction reactions of actinides in solution over the whole range of possible valence states. Electrochemical and laser-excitation techniques are adding new dimensions to these studies, particularly in bicarbonate buffered solutions which model the aquatic environment. Volatile compounds and complexes containing the lanthanides and actinides represent potential optical gain media whose excited state relaxation characteristics are being characterized. Volatile actinide species are also the focus of the developing photochemistry effort. Programs in solid state chemistry probe the nature of actinide-oxygen interactions and their role in determining the structure and stability of complex oxyanion phases. These and other areas of the research are conducted jointly with personnel in cooperating divisions where photoelectron, Mössbauer, and extended x-ray fine structure spectroscopy facilities provide the opportunity to gain unique and complementary insights into structural relationships.

LABORATORIES.

Brookhaven National Laboratory
Department of Physics

-01 \$2027 K

Neutron-Nuclear Research

R. E. Chrien, W. R. Kane, R. F. Casten, M. L. Stelts, H. I. Liou,
D. D. Warner, R. Gill, M. Shmid, and G. Gowdy

The Brookhaven High Flux Beam Reactor, HFBR, provides a number of unique and powerful beams for neutron cross section studies, nuclear structure measurements, and fission product activity experiments. These studies are of interest to pure and applied physics.

Neutron Cross Sections. Neutron-induced reactions can be investigated at the HFBR from the thermal neutron region to energies of a few kiloelectron volts. Cross sections are measured directly by time-of-flight or diffraction techniques, or by activation through transmission filters. Because neutrons accompany the production of energy in fusion or fission processes, detailed knowledge of these neutron cross sections is of importance in energy applications.

Nuclear Structure Studies. Experience with the capture of slow neutrons shows that they are capable of populating a wide variety of final states of differing nuclear configurations by the emission of electromagnetic radiation. Neutron capture thus offers a powerful tool in nuclear structure studies. Primary and secondary gamma-ray transitions following capture provide information for assigning the quantum numbers and energies of levels in the residual nucleus. Neutron beams at thermal, resonance, and kiloelectron volts energies provide complementary information by populating states of different spin-parity range. Extensive tests of nuclear models which depend on detailed information of these levels, are being carried out.

Fission Product Studies. Neutron-induced fission leads to radioactive nuclei, or fission products, which contain an excess of neutrons as compared to stable nuclei of the same mass. The decay of these nuclei is studied by using an on-line mass separator, TRISTAN. The various radiations encountered, gamma-rays, beta-rays, and neutrons, provide stringent tests of nuclear structure models and mass formulas. They also provide useful information on the behavior of fission products. This information is needed to understand the use and disposal of nuclear fuels and for the dynamic behavior of reactors.

LABORATORIES

Brookhaven National Laboratory
Department of Physics

-01 \$174 K

Light Ions and General Nuclear Science

E. K. Warburton

D. E. Alburger

The Tandem Van de Graaff facility furnishes high energy beams of light ions ($A \leq 4$) of high quality which makes it possible to conduct a research program in nuclear physics interrelating with that of the heavy ion program. The emphasis is often focused on obtaining information on properties of individual nuclear levels. Frequently, these studies are directed toward specific problems of fundamental nucleon interactions and weak interaction physics. Decay properties of short-lived off-stability nuclides produced by light ion bombardments are studied in parallel with the heavy-ion produced species. Studies of specific residual nuclei produced by both light- and heavy-ion induced reactions permit exploration of the same system under vastly different conditions of energy and angular momentum. The 3.5-MV Van de Graaff, a useful adjunct to the Tandem nuclear physics program, is used occasionally for investigation of weak interactions via β -decay and has been useful in the testing of equipment and targets.

LABORATORIES

Brookhaven National Laboratory
Department of Chemistry

-01 \$121 K

Nuclear Spectroscopy

Y. Y. Chu, J. B. Cumming, P. E. Haustein, S. Katcoff

Investigations of the decay of radioactive nuclei, particularly those which are located far from the line of beta stability are carried out to provide the detailed spectroscopic information essential for understanding nuclear structure. Various models are being tested and new data are being provided for nuclear mass surface delineation, beta-delayed neutron emission systematics, and fission product and heavy element structure.

Studies are currently centered in three mass regions, each of which is accessible at one of the Laboratory's facilities: (1) At the unique Medium Energy Intense Neutron facility (MEIN, based on the AGS Linac) new neutron-rich isotopes of uranium, neptunium, radium, and other heavy elements are being studied. A large proportion of the nuclear data in this important region can be obtained only by radiochemical methods. (2) Neutron-deficient nuclei in the mass range from 80 to 100 which lie along the $N = Z$ line are being studied through the use of a helium-jet system at the BNL Van de Graaff laboratory and the LBL 88-inch cyclotron. This region is characterized by rapid changes as one moves from strongly deformed nuclei with $N = Z = 40$ to quasispherical ones in the vicinity of doubly magic ^{100}Sn . These are reflected in both perturbations on the nuclidic mass surface and in a variety of spectroscopic features, e.g., the trend away from complicated multi-nucleon configurations to simple shell model-like ones. (3) At the TRISTAN-II on-line isotope facility (HFBR) contributions are being made to a broad program for study of the highly neutron-rich fission products. The initial experimental program will emphasize systematic conversion electron measurements of fission product nuclides as a means of elucidating spins and parities of nuclear levels.

The determination of half-lives in the region between 10 and 1000 years is another part of this program and a specially fabricated differential proportional counter permits relatively rapid estimates of half-lives in this poorly known region.

Brookhaven National Laboratory
Department of Nuclear Energy

-03 \$1138 K

NATIONAL NUCLEAR DATA CENTER

S. Pearlstein, C. Dunford, M. Bhat

The National Nuclear Data Center (NNDC) is responsible for the performance of four related data compilation, evaluation and information service functions: (1) the bibliographic indexing of the literature on neutron and charged particle physics investigations, (2) the compilation of experimental data resulting from those investigations; (3) the coordination of neutron, charged particle, nuclear structure and radioactive decay data evaluation; and (4) the centralized dissemination of stored information on the bibliography, experimental data and evaluated data for neutron, charged particle and nuclear structure physics.

Data from neutron and charged particle measurements performed in the U.S. and Canada are collected by scanning all the pertinent journal and report literature; attending professional meetings; visiting the important data-producing laboratories; and by corresponding by telephone and letter when necessary. Information is also collected from other U.S. centers and foreign scientists through cooperative arrangements with the international data centers maintained by the International Atomic Energy Agency (IAEA) in Vienna, Nuclear Energy Agency (NEA) near Saclay, and the USSR in Obninsk. The NNDC is responsible for solving all technical problems relating to the content and format of bibliographic and experimental data exchanged with other centers and for the computerization of data libraries.

The NNDC assists applied and basic research scientists by coordinating inter-laboratory groups of experts in the distillation of experimental data to provide recommended values for nuclear data. There are two major efforts coordinated by the NNDC: (1) The Cross Section Evaluation Working Group, consisting of representatives from over 20 U.S. laboratories, meeting biannually to develop an internationally recognized data base for nuclear energy applications; and (2) the U.S. Nuclear Data Network, consisting of low energy nuclear physics information centers, meeting biannually to develop an internationally recognized data base for nuclear energy research. These coordinated efforts unite and integrate data compilation and evaluation efforts to achieve maximum utilization of manpower.

A file of requests for measurements is maintained at the NNDC to support the Department of Energy (DOE) Nuclear Data Committee (DOE/NDC) reviews of such material. The NNDC publishes the U.S. Compilation of Requests for Nuclear Data and also transmits contributions to the Worldwide Request List (WRENDA), the compilation of worldwide requests.

LABORATORIES

Idaho National Engineering Laboratory
EG&G Idaho, Inc.

-03 \$115 K
-02 \$ 95 K
-01 \$ 40 K

Nuclear Data Measurement and Evaluation

R. L. Heath, C. W. Reich

I. Nuclear-Data Evaluation for the Nuclear Data Sheets. As one of the groups participating in the International Nuclear Structure and Decay Data Evaluation Network, this program is responsible for the ten mass chains in the region $153 < A < 162$. To achieve a four-year cycle time on all mass-chain evaluations, for publication in the Nuclear Data Sheets, this requires completion of two to three A chains per year.

II. Radioactive-Nuclide Decay Studies. This phase of the program involves measurement of radioactive-nuclide decay properties of interest to basic low-energy nuclear-structure physics and relevant to various activities in Nuclear Sciences. Current emphasis is on the investigation of selected nuclides in the mass region $A \leq 230$, to provide information on the level properties of nuclei which lie near the beginning of the actinide region of strongly deformed nuclei. This work is related to the IAEA Coordinated Research Program on the Measurement of Transactinium Isotope Nuclear Decay Data. It involves the measurement of highly precise decay data for a number of actinide isotopes important for fast-reactor fuel-cycle and materials safeguards applications. The INEL contribution to this Program is the measurement of precise gamma-ray intensities.

III. Neutron-Capture Gamma-Ray Spectroscopy. This activity involves the study of the primary and secondary gamma-ray transitions emitted following neutron capture as a means of investigating the low-energy level structure of selected nuclides. Studies involve the use of the 2- and 24-keV "filtered" neutron beams from the HFBR at BNL to provide "resonance-averaged" primary capture gamma-ray spectra.

IV. Delayed-Neutron Spectroscopy. A program to measure the spectrum of delayed neutrons emitted from individual fission-product nuclides has been initiated. Fission-product isotopes are produced "on-line" using the TRISTAN isotope-separator facility located at BNL. Proton-recoil counter techniques will be employed to measure the neutron spectra in the energy region between a few keV and a few hundred keV. Data presently available in this energy region are deficient.

LABORATORIES

Lawrence Berkeley Laboratory
Nuclear Science Division

-01 \$213 K

Nuclear Reactions

J. Cerny, H. E. Conzett

This light ion research program has utilized 40-100 MeV ^3He beams and the on-line mass analysis system RAMA at the 88-inch Cyclotron to discover three beta-delayed proton emitters: ^{20}Mg , ^{24}Si , and ^{36}Ca . RAMA employs a helium jet to transport activity via skimmers to a hollow cathode ion source. Activity is extracted, mass separated and deposited on thin foils or on a magnetic tape system in the analyzer focal plane. Discovery of these nuclides, which is only made possible by providing a low background environment via mass selection, completes three isospin quintets whose members are all bound to isospin-allowed particle decay modes and provides a significant new test of the isobaric multiplet mass equation for quintets. Many unknown, proton-rich light nuclides (e.g. ^{22}Al , ^{35}Ca) with highly unique properties remain to be discovered and can be produced best by the high energy p and ^3He beams available at the 88-inch Cyclotron. Other light ion studies involving exotic reactions, such as ($^4\text{He}, ^2\text{He}$) investigations, have led to the identification of two-neutron, high spin states in nuclei throughout the 1p and 2s1d shells.

Spin-dependent interactions in nuclear reactions and scattering at incident proton and deuteron beam energies from 15 to 60 MeV are also studied. This important energy region is largely unexplored since it is inaccessible to the polarized beams from tandem accelerators. Current projects include: 1) Measurements of the various polarization observables in pd scattering for comparison with exact three-nucleon calculations. 2) An accurate model-independent determination of an important deuteron D-state parameter from measurements of the cross section and tensor analyzing power in dp scattering. 3) Experiments which display uniquely the operation of a basic symmetry property of the nuclear interaction. Two of the fundamentally important experiments of this nature being pursued are: i) a determination of the weak-interaction parity violating part of the nucleon-nucleon force from a measurement of the longitudinal analyzing power in pp scattering at 50 MeV, and ii) a test of the principle of time-reversal invariance in nuclear reactions from measurements of the analyzing-power and the polarization in a reaction and its inverse, respectively.

LABORATORIES

Lawrence Berkeley Laboratory
Nuclear Science Division

-01 \$55 K

Fission and Heavy Ion Studies

L. G. Moretto

Our fission program is a subset of our broader field of research, namely heavy ion reactions. Several aspects of the fission process are being considered. a) Direct fission vs. ordinary compound nucleus fission. There is evidence that a fission-like component present in many heavy ion reactions may not arise from compound nucleus formation. If this is the case, neutron decay competition should be absent. The angular momentum distribution associated with the fragments as determined by measuring the dependence of the gamma-ray multiplicity vs. mass asymmetry should reveal whether there are neutron emission and other competing channels or whether there is indication of direct fission. b) Sequential fission decay after deep inelastic processes is used to determine the degree of alignment of the fragment spin. A complete theory for the in- and out-of-plane angular distributions has been developed including the essential dependence of the fission decay width upon angular momentum. c) It is commonly stated that an increase in angular momentum increases the fission probability. We have found that for large fissionability parameters this is not the case. At large angular momenta an enhancement of alpha decay is to be expected as compared to both fission and neutron emission.

LABORATORIES

Lawrence Berkeley Laboratory
Nuclear Science Division

-01 \$600 K

88-Inch Cyclotron Operation

B. G. Harvey

The 88-Inch Cyclotron is a variable energy isochronous cyclotron with spiral ridge focussing. Maximum energies for the accelerated particles are 60 MeV for protons, 65 MeV for deuterons, 130 MeV for alpha particles and 145 MeV for ^3He . Intensities of the light ions are limited by the deflector to about 3000 watts of power output; polarized beams are limited by source intensities. Ion sources for the cyclotron include filament arc sources for light ions and an axially injected polarized proton and deuteron source. The axial injection line has the capability of injecting other charged ions prepared in an external source. The project operates, maintains, and improves the cyclotron and beam transport facilities up to the experimental areas, maintains the building and shop facilities, and coordinates machine use by local and outside experimenters. The cyclotron operates 20 eight-hour shifts per week for in-beam experiments in nuclear chemistry and physics, isotope production and beam development.

There are some ongoing experimental programs at the 88-Inch Cyclotron which do not qualify as basic nuclear research. They collectively use $\lesssim 6\%$ of the total available beam time and are encouraged because they all represent good science with application, in many cases, to urgent national problems. Many of these projects also make good use of the unique capabilities of the Cyclotron. Curie quantities of the positron emitters ^{11}C and ^{13}N are produced for tagging amino acids such as valine or dihydroxyphenylalanine for evaluation of pancreas, myocardial and brain metabolism. Bombardments of d/l leucine with polarized protons are being made in a search for the origin of the left-handedness of the amino acids, basic constituents of living organisms. Biomedical work at the cellular level includes radioprotection, LET studies and exposures at relatively low nuclear fragmentation. Large scale production of ^{18}F is being developed, and recoil ^{18}F atoms are being used to label glycine in compounds for possible use in nuclear medicine. Random bit errors induced by cosmic rays in computer chips used in satellites are being studied with heavy ion beams, which are also used to calibrate detection instruments for the satellite work. In other studies, the amounts of low Z elements in atmospheric aerosols are being determined by charged-particle induced reactions, and meteorite formation is being investigated with in situ determinations of the micro-distributions of Bi and Pb in unequilibrated ordinary chondrites.

Lawrence Berkeley Laboratory
Nuclear Science Division

-01 \$337 K

Nuclear Instrumentation and Advanced Detector Systems

F. S. Goulding, C. R. Gruhn

I. Instrumentation for Nuclear Science. Three main functions are performed: (i) maintaining all general purpose electronic instruments including data acquisition and processing systems used by the Nuclear Science Division, (ii) developing special purpose instruments and hardware associated with general divisional systems, and (iii) carrying out hardware research and development aimed toward long term needs.

II. Detector Research and Development. A liquid Xe ionization chamber has been designed as a prototype for a liquid Xe detector ball to be used as a 4π γ -ray detector. The goal is to achieve a resolution of 30 keV FWHM on 1 MeV γ -rays but substantially better results are theoretically possible. Such a detector would exhibit an energy resolution intermediate between that of germanium and that of scintillation detectors.

III. Advanced Detector Systems. This project is aimed toward improvements in semi-conductor detectors for use in a broad range of nuclear experiments of interest to many laboratories in the United States. The effort is split between some work designed to elucidate radiation-damage effects and mechanisms in high-purity germanium detectors and considerable work on detector technology. Recent radiation damage work has included studies of both neutron damage and of damage induced by high-energy charged particles in high-purity germanium detectors. As might be expected, the character of the damage, such as its annealing behavior as a function of temperature, is quite different in the two cases and is still under investigation. High purity germanium detector development is concentrated on the problems of producing reliable thin n^+ contacts (made by phosphorous or arsenic ion-implantation) and on provision of good surface protection to make the detectors relatively insensitive to ambient contaminants. The development of hydrogenated-amorphous germanium sputtered coatings has successfully solved the protection problem. Very large-area (5 and 7 cm diameter) lithium-drifted silicon detectors have been developed for use in detector telescopes for long-range particle spectroscopy and ion-identification. Some of these detectors have extremely uniform thickness ($<10\mu\text{m}$ variation in 5 mm total thickness) and thin dead layers ($<10\mu\text{m}$), while others are position-sensitive devices.

LABORATORIES

Lawrence Berkeley Laboratory
Nuclear Science Division

-03 \$235 K

Isotopes Project

Janis M. Dairiki

The Isotopes Project compiles and evaluates nuclear structure and decay data. From 1940-1978 the project had as its main objective the production of the Table of Isotopes; the seventh edition, published in 1978 by John Wiley, is the last of the series. This comprehensive data compilation is used both in nuclear applications and in basic research; 5000 copies of the seventh edition have been sold in the first year. The project also compiles and publishes the Table of Nuclear Moments, the only such table maintained on a continuing basis. The most recent version was published as an appendix in the seventh edition of the Table of Isotopes. Extensive computer programs have been developed since 1971 to expedite the handling and storage of data and to aid in the selection, editing and convenient final presentation of the data for publication.

The size of the evaluation task has increased dramatically with the exponential growth in the volume and complexity of experimental data. In order to avoid costly duplication, the Isotopes Project now coordinates its evaluation efforts with those of other data centers through both an international data network and the U.S. Nuclear Data Network (NDN), under the management of the National Nuclear Data Center (BNL). The evaluation of 28 mass chains ($A = 167-194$) with a 4-year cycle time has been assigned to the LBL group as a principal responsibility. Evaluated mass-chain data from all network members are maintained in an internationally recognized database, the Evaluated Nuclear Structure Data File (ENSDF), and are published in Nuclear Data Sheets.

The Isotopes Project has been asked to produce, on behalf of the NDN, a Radioactivity Handbook for applied users. Data will be taken from the ENSDF file. The Handbook is scheduled to be published at four-year intervals, beginning in 1982.

LABORATORIES

Lawrence Berkeley Laboratory
Materials and Molecular Research Division

-04 \$915 K

Actinide Chemistry

Norman Edelstein

The basic purpose of this project is to study actinide materials in order to provide the basic knowledge necessary for their safe and economic utilization in present day and future technology. This program includes studies of the preparation and physical and chemical properties of a variety of new gaseous, liquid, and solid phases. Synthesized compounds will be characterized by x-ray diffraction, optical and vibrational spectroscopy, and magnetic resonance and magnetic susceptibility techniques. Equilibrium constants for complex formation will be measured. From the complementary studies, new insights into the structural and chemical principles of actinide compounds will be gained to imagine new bonding situations and to design new synthetic schemes to produce new materials.

A major aspect of the program is concerned with the design of sequestering agents for the actinide ions (in particular plutonium (IV)) which can engulf such ions. These compounds are intended to be used in the treatment of actinide poisoning as well as for possible applications in the treatment of spent nuclear reactor fuels. The preparation, structural, and physical studies of new types of organo-actinide, related organolanthanide, and new actinide inorganic complexes (such as the borohydrides) will continue to be studied. Studies on the optical spectra of free atoms and ions, and on actinide ions in crystals and in molecular compounds, will be pursued with emphasis on free ions which have the same oxidation state as found in chemical compounds.

LABORATORIES

Lawrence Livermore National Laboratory

-02 \$150 K
-01 \$150 K
-02 \$150 K

Studies of (n, charged particle) Reactions with 14-15 MeV Neutrons

R. C. Haight, S. M. Grimes, and H. H. Barschall

Materials bombarded by fusion neutrons are altered by nuclear transmutations that produce hydrogen and helium. To assess the potential performance of these materials for fusion reactor application, cross section data are required by the fusion community and the Office of Fusion Energy. Under the sponsorship of the DOE Office of Basic Energy Sciences, we measure these quantities by detecting the charged particles emitted by materials under bombardment by neutrons of 14 to 15 MeV. By also measuring the energy and angular distributions of the charged particles, we are able to test nuclear reaction theories through model calculations and to deduce KERMA factors for consideration of energy deposition by the neutrons.

R. J. Borg, M. Lindner, and D. A. Leich

Nuclear Astrophysics. It is widely believed that the β^- decay of ^{187}Re provides the most reliable nuclear chronometer for dating the age of our galaxy. However, the half-life of this isotope is not reliably known. Our program is the direct experimental measurement of the decay rate by measuring the production of ^{187}Os from chemically pure Re.

R. A. Meyer, E. A. Henry, and G. L. Struble

Study of Isotopes Important to the Reactor Decay Heat Problem. We use rapid, automated, nuclear-chemistry techniques to isolate and study short-lived fission products. This method isolates isotopes of a particular atomic number rather than mass number in contrast to on-line mass-separation techniques. With the chemical method, it is often possible to enhance a particular isotope by a sequence of timed, chemical-separation steps. We use two techniques for chemical isolation of fission products: autobatch and continuous. In the former a computer-controlled batch chemical system is integrated with our spectroscopy equipment and performs chemical separations within times as short as one second, followed by measurement and recycle within less than 30 s. The latter technique produces steady-state sources by use of gas-jet delivery of fission products, and in-flight gas-phase chemical reactions to chemically purify the desired species.

LABORATORIES

Los Alamos Scientific Laboratory
Physics Division

-02 \$175 K
-01 \$125 K
-02 \$120 K
-02 \$120 K

H. Britt, R. Brown, D. Drake, J. Gilmore, N. Jarmie, G. Ohlsen, G. Russell,
J. Wilhelmy

I. Low-Energy Fusion Cross Sections. Measurements are being made of cross sections for reactions among the hydrogen isotopes ^2H and ^3H in the bombarding energy range 10-120 keV. The measurements involve a large improvement in the precision of both absolute cross section and energy determinations over previous experiments. These reactions are of fundamental importance to the understanding, design, and development of future controlled-fusion, energy-production systems. It is expected that improved cross section information will have significant impact on development in many applied fusion programs.

II. Nuclear Fission. This program has aimed primarily at using various experimental techniques to infer the properties of the nuclear potential energy surface which controls the fission process in actinide elements. Results have confirmed the influence of deformed nuclear shells on the fundamental character of fission and indicates that the underlying potential energy surface is much more complex than previously supposed. Measurements of mass and kinetic energy distributions for very heavy actinides indicate dramatic changes in scission properties for fissioning in the heavy actinide region (Cf-Fm). These changes from predominantly asymmetric to predominantly symmetric mass distributions appear to indicate the importance of nuclear shells for shapes near scission.

III. Neutron Capture Reactions. This research program investigates the neutron capture reaction both below and above the giant dipole resonance. Measurements include the asymmetry of γ -rays for neutrons between 20 and 30 MeV to obtain evidence for the isovector quadrupole resonance. On the low energy side of the giant dipole resonance, capture cross sections and angular distributions of γ -rays are being studied for both closed-shell and deformed nuclei to test the current theoretical models of the capture mechanism.

IV. Fertile-to-Fissile Conversion Program. Basic neutronics data, initiated by 800 MeV proton spallation reactions, are important to spallation neutron source development and electronuclear fuel production. The LASL Fertile-to-Fissile Conversion (FERFICON) program is a cooperative effort with the Chalk River Nuclear Laboratory. The LASL experiments provide an extension to 800 MeV of similar measurements (but more exhaustive in numbers) being conducted using the TRIUMF-Cyclotron in Vancouver, B.C. The Canadian measurements are being done at proton energies of 350 and 480 MeV. The LASL FERFICON program consists of two parts: a) determination of total neutron yields from targets, and b) measurements of fertile-to-fissile conversion efficiencies. The experiments are relevant to the above applications and provide data to validate computer codes.

Los Alamos Scientific Laboratory
Theoretical Division

-03 \$260 K

Physics of Production and Transmutation of Nuclei

P. G. Young, G. M. Hale, E. D. Arthur, D. C. Dodder, D. G. Madland

I. R-Matrix Theory

Development and application of R-matrix techniques are carried out to describe nuclear reactions among light elements. Emphasis is placed on interpretation and improvement of nuclear data that are used as cross section standards or that are important to fusion reactor studies, and to providing theoretical support to light element experimental programs. Mass systems presently under study include $A = 2, 4, 5, 6, 7$, and 11 . Methods of implementing charge independence in R-matrix analyses and other basic developments are being investigated.

II. Reaction Theory Studies

Development of compound nucleus, statistical, preequilibrium, and direct reaction theory models, and studies of parameter systematics are carried out for improved evaluation and extrapolation of nuclear data. Emphasis is placed on improvement of level-density representations, direct reaction channels, gamma-ray probabilities, and fission channels in model codes used for nuclear data evaluations. Parameter optimization studies are performed with emphasis on nuclei pertinent to national energy programs. Global neutron optical-model parameters are being derived on a shell-by-shell basis and, in regions of strong nuclear deformation, the optical potential is deformed by use of the coupled-channel formalism and the collective model.

III. Fission Yield Theory

Development of fission yield theory is carried out for the purpose of deriving more reliable data. The primary goal is to apply recent advances in the understanding of the fission process up to the scission point to detailed calculations of particle-emission properties and distributions of fragments beyond the scission point. Concurrently, the phenomenological fission yield relationships utilized in ENDF/B evaluated data files will be reformulated as advances are made in fundamental yield theory.

IV. Data Evaluation

Limited support is provided to incorporate certain BES-sponsored measurements and calculations into ENDF/B evaluated nuclear data files. Current evaluation projects include development of charged-particle-induced data libraries for fusion applications based on the above R-matrix analyses and incorporation of new experimental data into the ENDF/B ${}^6\text{Li}$ and ${}^7\text{Li}$ evaluations.

LABORATORIES

Los Alamos Scientific Laboratory
Critical Assemblies Laboratory

-01 \$30 K

High-Pressure ^3He Neutron Scintillation Spectrometer

Albert E. Evans

A high-pressure (2300 psig) helium-gas scintillator cell previously built at LASL will be emptied and filled with ^3He gas and evaluated as a neutron spectrometer. Some experimentation with gas mixtures (a trace of Xe or other Noble gas is required) and with the reflective inner surface of the cell will be required in order to obtain optimum results. A filling manifold will have to be built to pressurize the cell and to recover and purify the ^3He . Tests will be conducted using monoenergetic neutrons from a Van de Graaff accelerator.

This proposal is in support of the TRISTAN project at Brookhaven National Laboratory. It was requested at a Delayed-Neutron Workshop held at Los Alamos on 3-4 January, 1980, by participants planning the TRISTAN program. It is hoped that the work will lead to the development of a fast-risetime (< 5 ns), efficient fast-neutron spectrometer suitable for n- γ and n-n coincidence spectrometry at relatively low fluxes, such as in the decay of delayed-neutron-emitting fission products.

LABORATORIES

Los Alamos Scientific Laboratory
Chemistry - Materials Science Division

-04 \$83 K
-04 \$102 K

Thermodynamics of Transplutonium Elements and Early Actinides

John W. Ward

This research program is concerned with the measurement of thermodynamic properties of actinide elements and compounds by high temperature Knudsen effusion/mass spectrometric techniques. Of particular interest are those systems for which there are at present little data (or for which the data appear unreliable). The pure metals are being examined first. Definitive values have been measured for ^{241}Am and ^{243}Am , and ^{249}Cf . Preliminary results are now being evaluated for ^{249}Bk and ^{231}Pa . Metal-oxide systems will also be studied with these techniques, as well as alloys and other compounds of interest. Combination of precise vapor-pressure values with thermodynamic functions calculated on the basis of electronic and magnetic properties allows tabulation of heats, entropies, free-energies and heat capacities from 298K to the highest temperatures of measurement. The increase in the stability of the dipositive state in the heavy actinides is being studied, utilizing vaporization techniques from appropriate liquid-metal solvents.

Chemistry of Oxo Complexes

R. A. Penneman, P. G. Eller and T. L. Cremers (Post Doc)
Los Alamos Scientific Laboratory
University of California
Los Alamos, NM 87545

The basic chemistry of light actinides is being developed, especially the less studied valences and species of Pa and U. Specific projects include: Crystals of UO_2Cl , UOF_4 ; the extensive chemistry of UOF_4 and UF_5 in acetonitrile, dimethylformamide and 50 non-aqueous systems; reactions of oxy-organics with UF_6 , UF_5 ; complex formation, ionic and molecular species stabilization; structural properties; the role played by 5f electrons; properties of Pa, d-block vs f-block character; hydrolytic behavior, binding of soft ligands; non-aqueous synthetic techniques; single-crystal x-ray diffraction and nuclear magnetic resonance; synthesis and characterization of novel light actinide compounds; (1) Isolation and characterization of MO_2 ($\text{M} = \text{Pa}, \text{U}$) species. (2) Preparation and structure of the presently unknown PaF_6 species. (3) Complexes of U(V) and Pa(V). (4) Non-aqueous chemistry of UOX_4 , MX_5 , MOX_3 , and M(III) ($\text{M} = \text{Pa}, \text{U}$). (5) Crown ether chemistry of Pa. (6) Horizontal and vertical bonding comparisons.

LABORATORIES

Oak Ridge National Laboratory
Physics Division

-01 , \$245 K

Light Ion Nuclear Physics

F. E. Bertrand

The research performed under this task is designed to elucidate excitations of the nucleus. Such excitations may be the result of collective motion in which a majority of the nucleons in the nucleus move together or the result of single-particle excitations between nuclear energy levels. Our approach to the research is designed to study both of these types of nuclear excitations.

Through the use of inelastic scattering of intermediate-energy protons, deuterons, and alphas, we study the most extreme example of collective excitation, giant resonances. On the other hand, the (p,n) reaction is often selective in its excitation of nuclear states having simple particle-hole configurations. The use of α -particle-induced Coulomb excitation has allowed a direct measurement (transition rate) of the collectivity of nuclear levels.

This task is directly related to the other research programs of the Physics Division, which are designed to investigate nuclear properties through the use of heavy-ion and pion-induced reactions.

LABORATORIES

Oak Ridge National Laboratory
Physics Division

-01 \$550 K

Basic Neutron Physics Research

J. A. Harvey, D. J. Horen, C. H. Johnson, R. L. Macklin, S. Raman and
G. G. Slaughter

Neutron spectroscopy is a unique technique for studying the detailed structure of nuclei at high excitation. The purpose of this program is to measure, analyze and interpret neutron cross sections, principally of enriched isotopes, for basic nuclear physics but also to be responsive to applied cross section needs for fusion and fission reactors. The measurements are made with the ORNL electron linear accelerator. It is usually necessary to make as many types of measurements as possible to understand the nature of neutron reaction mechanisms and nuclear structure. This program covers six types of experiments.

1. High-resolution differential elastic (and inelastic) scattering measurements up to ~ 2 MeV to determine the Q -values of resonances.
2. High-resolution total cross section measurements from 0.01 eV to 80 MeV to study level densities, the fragmentation of single particle states for light or near closed-shell nuclides, the more complex multiple quasi-particle nature (intermediate structure) of medium weight nuclides and s-, p-, and d-wave neutron strength functions and statistical properties of complex nuclides.
3. High-resolution gamma-ray spectral measurements from neutron capture in individual resonances up to ~ 50 keV to obtain a better understanding of the nature of the capturing process (i.e., compound nucleus vs semi-direct processes; also the location of F2, M1, E1 strengths) and for nuclear spectroscopy of nuclides up to excitation energies of several MeV, particularly those which cannot be studied in detail by other means.
4. Capture cross section measurements up to neutron energies of ~ 3 MeV of nuclides of importance in the chronology of element formation in the galaxy, of nuclides which contribute to the better understanding of the capturing process (i.e., gamma ray strength functions), and for applied needs for reactors and neutron capture cross section standards.
5. Subthreshold and threshold fission cross section and fragment anisotropy measurements on targets such as ^{232}Th and ^{231}Pa , in cooperation with Los Alamos Scientific Laboratory and Bruyères-le-Châtel to investigate the shape of the potential energy surface and the nature of strongly deformed states trapped in a possible third minimum of the fission barrier.
6. Reaction cross section measurements such as the (n, α) reaction in the resonance energy region to learn about the nature of the processes and possible intermediate structure; also accurate (n, α) measurements on ^6Li to establish it as a standard for keV neutron fluxes.

Oak Ridge National Laboratory
Physics Division

-02 \$390 K

Actinide Neutron Cross Sections

J. W. T. Dabbs, C. H. Johnson, L. W. Weston, J. A. Harvey, M. L. Williams and S. Raman

This program's primary goal is to obtain accurate differential (i.e. as a function of neutron energy) neutron cross sections (fission, capture and total) for all actinide nuclides which occur in fission reactors, so the behavior of reactors can be predicted with a high degree of confidence under all circumstances. A secondary goal is to permit predictions of the amount of the various nuclides which will be produced under all conditions of reactor operation. This is basic to any realistic assessment of the problems involved in handling, shipping, storing, safeguarding, and (possibly) reprocessing of spent fuel.

1. This work includes differential neutron fission, capture and total cross section measurements on U, Np, Pu, Am and Cm isotopes and on other nuclides as required. The choice of measurements is on the bases of need, quality of existing data, and feasibility.
2. An important aspect, recently added to the program, is the analysis of a number of actinide samples irradiated in EBR-II for 5 years ending in 1970. The results of these analyses will serve as a cross-check on the accuracy of calculations based on the differential data. A discrepancy of a factor 2 has already been found in the first sample.
3. Sensitivity and uncertainty analyses are used for supplemental analysis of the results and to help guide the program.
4. An "Actinide Newsletter" is published annually (3 issues so far) for the purpose of improving world-wide coordination of actinide research.

LABORATORIES

Oak Ridge National Laboratory
Engineering Physics Division

-02 \$1150 K

Operations - Oak Ridge Electron Linear Accelerator
J. A. Harvey, R. W. Peelle, T. A. Lewis, H. A. Todd, R. G. Alsmiller

The task of the Oak Ridge Electron Linear Accelerator (ORELA) is to provide the best feasible pulsed neutron source for neutron cross section measurements over the entire neutron energy region of importance to fusion and fission power systems and of interest for low-energy nuclear physics studies. For a great share of the cross sections being studied, an electron linac like ORELA is the best type of accelerator. Neutron cross section measurements made by the time-of-flight method require an intense pulsed-neutron source which is provided here by a high-current, short-burst electron beam incident on a high-Z target surrounded by a moderator. The short-burst performance of ORELA remains the best available anywhere in the world, although the linacs at BCMN in Geel, Belgium and at AERE-Harwell in England have been replaced with units of comparable power. The design of ORELA with 11 flight paths radiating from an evacuated target room makes possible simultaneous use by many experimenters, a feature which greatly increases the total output and cost effectiveness of the facility. ORELA is used by experimenters of the Physics, Engineering Physics, Solid State, and Chemistry Divisions of ORNL and by other DOE-supported nuclear physicists for accurate high-resolution neutron cross section measurements in the energy range from ~ 0.01 eV to 80 MeV. The measurements are directed toward the high priority needs for neutron cross-section data for controlled fusion and fission reactor designs, to the establishment of neutron cross section standards, to provide cross sections needed for calculating the production and burn-up of actinides in power reactors, and to the understanding of neutron reaction mechanisms and nuclear structure. Energy-dependent neutron cross sections and related measurements of almost every variety are made with this facility, including total, capture, fission, elastic and inelastic scattering, (n,p) and (n,α) reaction cross sections, $\bar{\nu}(E)$, and the gamma-ray spectra from capture and inelastic scattering.

In detail the task is accomplished by a program of aggressive operation and maintenance of the existing linear accelerator and a companion development effort to improve the performance, reliability and versatility of the machine for the needed experiments. The most far-reaching current efforts involve improvement in electron gun design and operational use of a prebuncher to narrow the overall charge pulse injected into the accelerator waveguide.

LABORATORIES

Oak Ridge National Laboratory
Engineering Physics Division

-02 \$455 K

Nuclear Data for Fusion and Fission Reactors

C. Y. Fu, D. C. Larson, R. R. Spencer

The work undertaken under this program provides some of the basic nuclear data most required for the design of nuclear power producing systems. The work is divided into two subtasks:

A. Nuclear Data for Fusion Energy. The Oak Ridge Electron Linear Accelerator, ORELA, is used to obtain neutron interaction cross sections, including gamma-ray production, for nuclides of interest over the complete energy range of interest to prospective fusion energy devices. Work concentrates on nuclides, partial cross sections and energy regions unique to fusion energy applications and unlikely to be obtained in other ongoing programs. Experimental work at present concentrates on neutron and gamma-ray emission spectra and on transmission measurements. The results of the measurements are incorporated into the U. S. national reference evaluated data file system, ENDF/B, so that they become directly usable in fusion energy system applications. Evaluation for the fusion system materials C, F, Sc, Fe, Cu, and Pb are performed under this subtask for the ENDF/B system. In order to provide the correct method of interpolating and extrapolating the experimental data for the evaluations, theoretical model codes are developed and used.

B. Nuclear Data for Fission Systems. The average number of neutrons emitted in the neutron-induced fission of the fissile isotopes is the most important parameter required in the design of fission reactors, affecting the safety, performance and economy of the reactor systems. Measurements of $\bar{\nu}$ vs neutron energy for the fissile isotopes are carried out by comparison with a ^{252}Cf spontaneous fission neutron source (ratio measurement), thus any uncertainty or error in the value of $\bar{\nu}_p$ for ^{252}Cf directly affects power reactor design. A measurement of this important standard to the desired uncertainty of $\sim 1/4\%$ is being completed utilizing ORELA as the neutron source for the calibration of a neutron-detecting Gd-poisoned scintillator tank. These calibrations for certain neutron angle and energy ranges are combined with neutron transport calculations of tank efficiency. The successor experiments are expected to emphasize the measurement of cross sections important to improved fuel efficiency in light water reactors. The work involves development and calibration of counting devices, measurement, data analysis, and supportive neutron and gamma-ray transport calculations.

LABORATORIES

Oak Ridge National Laboratory
Engineering Physics Division

-02 \$50 K

Electronuclear Fuel Production Physics Studies

R. G. Alsmiller, Jr., T. A. Gabriel

The purpose of this program is to develop the medium-energy nuclear cross section data and the charged and neutral particle transport methods that are necessary for carrying out feasibility and engineering design studies for electronuclear fuel production (EFP). Because of the large amount of particle production data that is needed to carry out the design calculations, much reliance must be placed on nuclear models. Uncertainties in EFP design calculations at present are due in part to the approximate manner in which medium-energy fission is treated in the available intranuclear-cascade-evaporation models of medium-energy nuclear reactions. In this task efforts will be made to improve this aspect of the model. Careful comparisons will be made between experimental and calculated nuclear data to ensure the validity of the results obtained with the models used. Also, comparisons between results obtained with the transport methods developed as part of the program and suitable experimental data will be made to ensure the validity of the methods for design calculations.

Oak Ridge National Laboratory
Health & Safety Research Division

-02 \$75 K

One-Atom Detection Solar Neutrino Measurements

S. D. Kramer, G. S. Hurst, W. R. Garrett

The discrepancy between recent experimental results and theoretical calculations for the solar neutrino flux casts considerable doubt on the correctness of current theories of either stellar evolution or weak interactions. The best way to resolve this problem would be to perform additional detection experiments, using a variety of target atoms that sample neutrinos in several different energy regimes.

John Bahcall [Phys. Rev. Lett. 23, 251 (1969) and Rev. Mod. Phys. 50, 881 (1978)] has pointed out the importance of the reaction ${}^7\text{Li}(\nu, e){}^7\text{Be}$ as a neutrino detector. Unfortunately, until now there has been no way to detect extremely small amounts of the reaction product, ${}^7\text{Be}$. However, time- and spacial-coincidence techniques based on the use of resonance ionization spectroscopy in conjunction with position-sensitive proportional counters, both of which have been under extensive study at Oak Ridge National Laboratory, appear to offer a means of detecting the electron capture decay of ${}^7\text{Be}$ at the very low count rates characteristic of neutrino detection experiments. This or other techniques based on resonance ionization spectroscopy could also prove useful in additional solar neutrino detection reactions such as ${}^{71}\text{Ga}(\nu, e^{-}){}^{71}\text{Ge}$ and ${}^{81}\text{Br}(\nu, e^{-}){}^{81}\text{Kr}$.

LABORATORIES

Oak Ridge National Laboratory
Physics Division

-03 \$575 K

Nuclear Data Project

M. J. Martin

The Nuclear Data Project (NDP) is an evaluation center which, as part of the U.S. Nuclear Data Network, is responsible for collecting and evaluating nuclear structure information for 70 mass chains in the mass region $A \geq 195$.

The work involves reading and critical analysis of all literature on nuclei in the above mass region. For each research paper, the evaluators extract the data, compare them with data from other sources, and prepare critical reviews with recommended values for a wide range of nuclear structure properties. Systematic trends in these properties are investigated both as a guide in the evaluation procedure and as a means of gaining new insight into nuclear structure phenomena.

Data evaluated by the NDP are made available to both the research and the applied communities directly and through Network publication of the Nuclear Data Sheets. The NDP maintains responsibility for the scientific editorship of this monthly journal.

Chemistry of Transuranium Elements and Compounds

R. L. Hahn, R. G. Haire, J. Halperin,
L. Maya, G. D. O'Kelley, G. M. Begun

Studies of the chemical and physical properties of the 5f-actinide elements, and of the homologous 4f-lanthanides, comprise the major effort of the research program in the Transuranium Research Laboratory. Because fundamental information about the heavier actinides, from curium through einsteinium, is still relatively scarce, we determine oxidation states, redox potentials, electronic configurations, absorption spectra, crystal structures, ionic and atomic radii, thermodynamic properties, and the chemical effects of radioactive decay of these elements and their compounds. Recent results include determinations of the enthalpies of vaporization and of solution of ^{243}Am and ^{249}Cf metals; observation of a change in crystal structure of ^{243}Am metal at high pressures, > 150 kbar; measurements of the magnetic susceptibilities of ^{248}Cm , ^{249}Bk and ^{249}Cf metals and of $^{253}\text{Es}_2\text{O}_3$; and details of the chemical effects that result from radioactive decay of the tri- and di-halides in the chain, $^{253}\text{Es} \xrightarrow{\alpha} ^{249}\text{Bk} \xrightarrow{\beta} ^{249}\text{Cf}$.

Although much information is available for the lighter actinides, especially from uranium through americium, because of their importance in nuclear reactor technology, little data exist for them under the conditions that are expected in the natural environment and in nuclear waste repositories. We are studying these elements in solution, to identify species at very low concentrations, and to elucidate effects of pH, Eh and complexation phenomena. In research relevant to waste disposition, we have investigated the adsorption/migration of Am, Np, U, and Pu in geologic media (clays and minerals), and the effectiveness of rare earth orthophosphates (synthetic monazites) as alternate containment forms for actinide elements.

LABORATORIES

Oak Ridge National Laboratory
Chemical Technology Division

-02-01 \$1300 K

ELECTROMAGNETIC ISOTOPE SEPARATION

E. Newman, W. A. Bell, H. R. Gwinn,
J. G. Tracy

The objective of this program is to use the calutrons to separate and provide multigram quantities of highly enriched separated stable and selected radioactive isotopes, including the actinides, to the research, commercial, and nuclear medical communities. An important aspect of the program is the research and development activities in ion source technology, beam dynamics, ion retention, and chemical recovery procedures. All isotopically enriched samples are distributed through a regular sales program or are circulated to the research community on a loan basis from the Research Materials Collection administered under the direction of DOE. In the operation of this national resource, the program is responsible for the production, distribution, quality control, and reprocessing of the material in the Research Materials Collection.

LABORATORIES

Oak Ridge National Laboratory
Operations Division

-02-02 \$2190 K

High Flux Isotope Reactor
J. A. Cox

The main purpose of the High Flux Isotope Reactor (HFIR) is to make research quantities of ^{252}Cf and other transuranium isotopes. These materials are produced in the flux trap in the center of the HFIR fuel element where a thermal-neutron flux of 3×10^{15} neutrons/cm²·s is available to irradiate the ^{244}Cm target material. Additional irradiation facilities are also provided in the beryllium reflector to increase the production rate of the heavy isotopes.

As a secondary purpose, the HFIR has facilities for performing diverse irradiations, tests, and experiments which can benefit from the exceptionally high neutron flux available. In the fuel element flux trap a hydraulic-rabbit tube provides access to the maximum thermal-neutron flux in the reactor for short-term irradiations and other positions are ideal for fast-neutron irradiation-damage studies. The beryllium reflector contains numerous experiment facilities with thermal-neutron fluxes up to 1×10^{15} neutrons/cm²·s. These facilities can accommodate either static experimental capsules or complex fuel-testing engineering loops. Four beam tubes are utilized for neutron-diffraction experiments and the installation of a small-angle neutron scattering facility was sponsored by the National Science Foundation for use by researchers from universities, industry, and other national laboratories.

The HFIR is operated to maximize the on-stream time commensurate with the requirements of the diverse irradiation programs being conducted. This policy usually results in an on-stream time in excess of 90% as is illustrated by the 91.4% attained in CY-1979 which was slightly lower than the record 94.4% attained in CY-1977.

LABORATORIES

Oak Ridge National Laboratory
Chemical Technology Division

-02-02 \$4468 K

TRANSURANIUM ELEMENT PROCESSING

L. J. King, F. R. Chattin, M. H. Lloyd,
J. E. Bigelow, E. D. Collins

The Transuranium Processing Plant (TRU) is the production, storage, and distribution center for the DOE heavy element research program. Since it began operations in 1966, TRU has been the only source in the United States of significant quantities of berkelium, californium, einsteinium, and fermium. TRU is a remotely-operated, hot-cell, chemical processing facility of advanced design. It functions integrally with the researchers in preparing suitable research-grade isotopes, rather than merely as a supplier. About 25 HFIR targets per year are being fabricated, irradiated, and processed to produce about 500 mg of ^{252}Cf , 50 mg of ^{249}Bk , 2.5 mg of ^{253}Es , 300 μg of isotopically pure ^{253}Es , and 1.5 pg of ^{257}Fm . Reprocessing of stored ^{252}Cf produces about 100 mg of ^{248}Cm annually. Approximately 50 shipments to researchers are made per year. These include shipments of normal production materials plus special forms and specially-prepared isotopes that were requested by researchers. The transuranium materials continue to be used nationally and internationally to study the basic chemistry and physics of the transuranium elements.

LABORATORIES

Oak Ridge National Laboratory
Operation Division

-02-02 \$27 K

Distribution of Special Isotopes for Research

C. L. Ottinger

Isotopes from the Research Materials Collection are distributed to DOE contractors and others performing research in which the DOE has programmatic interest. In some cases, special processing, handling, packaging, shipping, analysis, or other arrangements are required before shipment can be made. This task consists of providing such special services as needed.

Pacific Northwest Laboratory
Physical Sciences Department

-02 \$230 K

Fission Yield and Delayed Neutron Studies with an On-Line Mass Spectrometer

P. L. Reeder and R. A. Warner

This program provides basic nuclear data on fission yields and decay characteristics of short-lived fission products (particularly delayed neutron precursors). These basic data have applications to decay heat calculations, determination of fission-product inventory, calculations of delayed neutron abundances and burnup measurements. Delayed neutron data are particularly important in reactor dynamics calculations. In addition, fission yield data are needed for comparisons with predictions of theoretical models of nuclear fission. Decay characteristics of short-lived fission products provide much information for nuclear structure theories.

Data are obtained on individual fission products produced and separated with the SOLAR on-line mass spectrometer facility. The surface ionization source used with the SOLAR facility provides ion beams of a single chemical element in contrast to ion sources currently in use at other on-line facilities. Fission yields are measured by counting individual atoms with an electron multiplier detector. Decay characteristics of short-lived fission products are measured with various beta, gamma and neutron counters and spectrometers. Some of the delayed neutron studies will be carried out at the new TRISTAN on-line isotope separator facility at Brookhaven National Laboratory.

We are currently using the short bursts of neutrons from TRIGA reactor pulses to measure the ratio of the fission yields of isomers of isotopes of Br, Rb, In, I and Cs from the thermal neutron fission of ^{235}U . These data are to be included in the ENDF/B evaluated nuclear data file for general use in fission yield calculations. Isomer yield data are important for developing theoretical understanding of how angular momentum is distributed in the fission process.

Development efforts are underway to construct a new type of neutron spectrometer with better resolution and much greater efficiency than existing ^3He ionization chambers. The neutron spectrometer will use gas scintillation proportional counter techniques. It will be used for measurements of energy spectra of delayed neutrons from mass separated precursors and for neutron-gamma coincidence studies.

UNIVERSITIES

Clark University
Department of Chemistry

-01 \$75 K

Atomic Mass Measurements and Nuclear Spectroscopy
at TRISTAN

D. S. Brenner

Our research program is concerned with measuring atomic masses of short-lived, neutron-rich fission products using the TRISTAN on-line mass separator located at the High Flux Beam Reactor (HFBR), Brookhaven National Laboratory. The determination of accurate masses for neutron-rich nuclei is useful in refining mass equations which, in turn, are important for calculations related to astrophysical processes and to control and safety of nuclear reactors.

During the past year our efforts have been to (1) aid Brookhaven personnel in the installation and testing of TRISTAN at the HFBR, (2) procure, install, and make available research equipment for members of the Users' Group at the facility, and (3) develop computer software for analysis of experimental data.

In the coming year we expect to begin a program of measurements of β -ray end-point energies and nuclear decay schemes following successful demonstration of the capabilities of the TRISTAN facility.

UNIVERSITIES

University of Colorado
Nuclear Physics Laboratory

-01 \$685 K

J. J. Kraushaar, P. D. Kunz, D. A. Lind, R. J. Peterson, R. A. Ristinen,
E. S. Rost, W. R. Smythe, C. D. Zafiratos, C. S. Zaidins

I. Direct Reaction Studies. Light ion beams from the AVF cyclotron are used to induce a wide variety of reactions, with a particular emphasis on those with outgoing neutrons. Theoretical descriptions of these reactions are developed and tested. Well understood reactions allow quantitative studies of the structure of complex nuclei. Examples include the role of the pairing interaction seen by two-nucleon transfer, shell-model states seen in single and three nucleon transfer and isospin effects studied by charge exchange.

II. Compound Reaction Studies. Collective nuclear structure is studied by the gamma and neutron decay of compound nuclei, including coincidence studies between several gamma ray or neutron detectors. Time-of-flight data are used to specify the neutron energies. Coincident gamma spectra are used to determine the level schemes of complex nuclei, with the aid of direct reaction analyses. Thermonuclear reaction rates of interest to astrophysical nucleosynthesis are measured over a wide range of energies.

III. Intermediate Energy Physics. Experimental and theoretical studies are directed towards an understanding of the mechanisms of direct reactions induced by pi mesons and energetic protons. Experiments are performed at LAMPF, TRIUMF, and the Indiana University Cyclotron Facility. As these probes are better understood they are utilized to examine previously inaccessible features of nuclear structure.

UNIVERSITIES

Colorado School of Mines
Physics Department

-02 \$50 K (24 mos.)

The Measurement of Total Cross Sections for Nuclear Reactions Induced by Low Energy Charged Particles

F. Edward Cecil

Scope of Work

Measurement of the total cross sections at very low energies (between about 50 and 150 keV) of a broad class of deuteron- or triton-induced one- or two-nuclear transfer reactions on light ($6 \leq A \leq 19$) targets.

The measurements will be confined to exothermic reactions with which there is an associated gamma ray (either prompt or delayed). Thick samples will be bombarded by monoenergetic beams of deuterons or tritons. Recent improved understanding of the stopping power of low energy light ions (Zeigler and Anderson, 1977) will permit the determination of the reaction cross sections from the thick target yields. The chief novelty of the measurements is their extension to unusually low energies and their consequent interest to both astrophysics and fusion energy. The deuteron measurements would be carried out on a small Cockcroft-Walton accelerator on campus, the triton measurements at the new low-energy facility at LASL.

UNIVERSITIES

Cornell University

Nuclear Science and Engineering Program

-01 \$80 K

Experimental Studies of Nuclides Far from Stability with the TRISTAN II Fission Product Separator at Brookhaven National Laboratory

D. D. Clark, G. S. Goldhaber

Studies will be made of the energy spectra of delayed neutron emitters and of the yrast bands of certain neutron-rich even-even nuclei.

The delayed neutron measurements will concentrate on the energy spectra in the 1- to 25-keV range and will employ time-of-flight techniques.

The yrast bands populated by the beta decay of high-spin isomers of odd nuclides will be studied via beta-gamma and gamma-gamma coincidences, and gamma-gamma angular correlations.

UNIVERSITIES

Denison University
Department of Physics and Astronomy -02 \$22 K

Determination of Neutron Cross Sections and Resonance Parameters

R. R. Winters

This is a collaborative effort with ORNL staff at the Oak Ridge Linear Accelerator (ORELA). The principal investigator has just completed a sabbatical at ORNL.

Data analysis on campus is facilitated by a graphics terminal connection to a computer at ORNL.

Recent work has involved studies of neutron cross sections of the osmium isotopes in the energy region of high current interest to cosmology because of their relevance to the theory of nucleosynthesis and to determination of the age of the universe.

The ratio of the inelastic to elastic neutron scattering cross sections for ^{238}U has been measured at 82 keV, and a significantly higher value found than that obtained from earlier measurements.

Other recently published work includes measurements of the neutron capture cross sections for the palladium isotopes of particular interest as inherent poisons in fission reactors.

UNIVERSITIES

Duke University	-01 \$680 K
Triangle Universities Nuclear Laboratory	-02 \$220 K

E.G. Bilpuch, Director, N.R. Roberson, R.L. Walter, H.R. Weller

I. High Resolution Resonance Studies.* A variety of ultra high resolution resonance experiments are being carried out on both the 3 MV accelerator and the FN tandem accelerator. Although there is still appreciable interest in global statistical properties (strength functions, average level densities), our major emphasis is on detailed or local statistical properties. These include short and long range correlations in level spacings, and unique measurements of interference effects for reduced width amplitudes. These latter results have provided the first verification of several theoretical predictions, as well as establishing new, as yet unexplained results.

II. Radiative Capture Reactions.* The main emphasis of these studies has been to search for effects of the giant quadrupole resonances in the radiative capture reaction for a variety of nuclei. Most of the E2 effects we have observed are consistent with only direct radiation which gives a "background" which makes the observation of E2 resonances difficult. Using our high intensity polarized neutron beam, we have shown that the neutron capture reaction appears to be a more favorable tool for studying E2 resonances since the direct strength is quite small. We are also using the polarized neutron beams to pursue our interest in few nucleon systems (eg $^3\text{He}(\vec{n}, \gamma)^4\text{He}$). These experiments are important since the few body problem is susceptible to "exact" calculations. We are continuing our use of proton beams from the Cyclo-Graaff (18-31 MeV) to study capture leading to highly excited bound and unbound final states. Our aim is to understand the reaction mechanism, to search for resonances built on these excited states, and to investigate the utility of "high energy" capture for studying highly excited states in the residual nuclei.

III. Neutron Polarization Studies. Models of neutron induced or neutron producing reactions contain terms for the nucleon-nucleus spin-orbit and isospin interactions. In the neutron polarization research we are now able to set new limits on the strength of the spin-dependent parts of both the central and isospin potentials. Much of the research utilizes the one newly developed pulsed-polarized charged particle beams either to induce (p,n) reactions or to produce secondary beams of pulsed-polarized neutrons for neutron scattering studies in the region between 8 to 14 MeV, an energy range that heretofore has been moderately unexplored. The spin-orbit interaction is being studied for the entire range of nuclei in the periodic table in order to complement comparable work for proton scattering.

IV. Neutron Cross-Section Studies.* Measurements of the interaction of neutron beams with a wide range of elements has been a major program at our laboratory for several years. One emphasis has been on the elastic scattering of neutron beams to permit development of more accurate nuclear models and also to provide accurate data for the design of fusion-energy sources. The second emphasis is to obtain information on the emission spectrum of secondary neutrons that are emitted when high-energy neutrons impinge on various isotopes that may comprise containment vessels or blankets for fusion-energy devices. The data is combined with theoretical models to generate better descriptions for inelastic neutron interactions. The energy of the incident neutrons in both of the above studies is 8 to 14 MeV, a region where neutron data of this type has been scarce.

*These projects are done in collaboration with faculty members from North Carolina State University.

UNIVERSITIES

Florida State University
Department of Chemistry

-04 \$70 K

Research in Nuclear Chemistry

Gregory R. Choppin

The primary purpose of this program is the study of the species formed by the actinide (5f) elements in aqueous solution. Parallel studies are conducted on the chemically similar lanthanide (4f) elements to gain further understanding of actinide properties by use of techniques not available for actinide studies. Potentiometry, calorimetry, visible spectroscopy, nuclear magnetic resonance spectrometry and solvent extraction are the techniques used to characterize the thermodynamic and kinetic stability of complexes formed by these 4f and 5f cations with a variety of organic and inorganic ligands. One project includes characterization of inner vs. outer sphere nature of complexes of the halate and the haloacetate complexes of tri- tetra- and hexavalent actinides. The effects of enthalpy and entropy on complexation by dicarboxylate, polyphosphate (ATP), ascorbic acid and bicarbonate ligands are being investigated. These ligands were chosen to gain insight in actinide behavior in natural and biological systems. The binding of actinides by humic and fulvic acids is a continuing major effect. Humic and fulvic acids are major components of soil and serve as transport media for metal ions in fresh water systems.

UNIVERSITIES

Georgia Institute of Technology
School of Physics

-01 \$20 K

J. L. Wood

Nuclear Structure from Radioactive Decay. This program is aimed at making detailed and systematic studies of low-energy nuclear structure. The experimental part of the program involves gamma-ray and conversion-electron spectroscopy of mass-separated radioactive sources. These radioactive sources are produced and studied at the UNISOR facility at Oak Ridge using reactions induced by heavy-ion beams from the Oak Ridge Isochronous Cyclotron. Particular emphasis is placed on the investigation of isotopes lying far from the beta stable region: The UNISOR on-line isotope separator facility is uniquely suited for the study of low-energy low-spin states of nuclei far from beta stability in the neutron-deficient regions. These experimental measurements are combined with an extensive program in nuclear systematics to organize and interpret the level scheme data obtained. In addition, comparison with current models is made; particularly, models of particle - core coupling, model descriptions of fermion and boson degrees of freedom and their interaction, and models of excited 0^+ states in even nuclei.

UNIVERSITIES

University of Iowa
Department of Physics

-01 \$47 K

E. Norbeck

I. Elastic Scattering ${}^6\text{Li} + {}^6\text{Li}$ and ${}^7\text{Li} + {}^7\text{Li}$ Using 2.0 to 5.5 MeV Beams. High precision measurements are made and compared with a commonly used theoretical model for nuclear scattering, the double-folding model with "realistic" nucleon-nucleon interactions. These studies provide a severe test for the model. At high energies, only the outer edge of the internuclear potential affects the scattering, but at low energies, where the wavelength is long, the model is required to predict the entire range of the potential. For high energy ${}^6\text{Li}$ scattering, the folding model fails, presumably because of the breakup ${}^6\text{Li} \rightarrow \alpha + d$. Preliminary results indicate that the model provides an excellent description of the scattering for energies below the threshold for breakup.

II. ${}^6\text{Li} + {}^6\text{Li} \rightarrow 3{}^4\text{He}$. This multibody process is studied experimentally and the data compared with predictions of a finite-range distorted-wave Born approximation. At low energies the most critical part of the calculation is the potential that governs the approach of the ${}^6\text{Li}$ nuclei. A variety of potentials can successfully predict elastic scattering, but preliminary results indicate that only the folded potential can also correctly predict the angular correlations of the ${}^4\text{He}$.

UNIVERSITIES

Iowa State University
Physics Department

-01 --(\$124 K/24 mos.)

Nuclear Size and Shape Research

D. A. Lewis

A movable laser spectroscopy system is being developed to be used at accelerator and reactor facilities for hyperfine determinations with short-lived nuclei. Experiments are planned for the ATLAS facility at Argonne National Lab and for the TRISTAN isotope separator at Brookhaven National Lab.

UNIVERSITIES

University of Kentucky

Department of Physics and Astronomy

-01 \$60 K

Total (p,n) and (α ,n) Cross Sections for Nucleosynthesis and Nuclear Applications

Fletcher Gabbard, Robert L. Hershberger

Scope of Work

Experimental measurements of selected total (p,n) and (α ,n) reaction cross sections using the University of Kentucky Van de Graaff accelerator, followed by comparisons with model calculations made for astrophysical purposes and with the results obtained from global optical potentials.

For the period of the next two years, we propose to continue systematic measurements, using thin targets of (p,n) and (α ,) reaction cross-sections and reaction rates. We propose to measure total (p,n) and (α ,n) cross sections for enriched targets of ^{51}V , ^{54}Cr , ^{61}Ni , ^{64}Ni , ^{65}Cu , ^{67}Zn , ^{68}Zn , and ^{75}As . The greatest source of error in this type of measurement is the determination of target thickness. In our work we are generally able to check measurements with target thickness determinations made by Rutherford scattering of protons and alpha particles in a high precision scattering chamber. The proposed measurements will be made with an absolute accuracy of $\lesssim 5\%$.

UNIVERSITIES

University of Kentucky
Department of Chemistry

-01 \$30 K

Nuclear Structure Studies of Transitional Nuclei

S. W. Yates

A systematic investigation of the nuclear level structures of the stable even-mass transitional nuclei by $(n,n'\gamma)$ reaction spectroscopy has been initiated. Questions regarding the nuclear shapes and the applicability of various nuclear models for these nuclei are being addressed. The phenomenon of collective enhancements of inelastic neutron scattering cross sections and the role of nuclear deformation effects are under examination. Comparisons between population systematics of the $(n,n'\gamma)$ reaction and other reactions are made.

Studies of the stable platinum nuclei represent the first part of a comprehensive survey of this mass region. From γ -ray angular distribution and excitation function measurements, the properties of the low-lying states in ^{194}Pt have been characterized. Essentially all known levels having $I \leq 6$ below 2 MeV are observed, and spin assignments and new level placements have been made. The negative-parity states have been interpreted in terms of the semidecoupled model. The positive-parity states have been compared with asymmetric rotor, pairing-plus-quadrupole, γ -unstable, interacting-boson-approximation, and boson-expansion model calculations. Preliminary results from a similar inelastic neutron scattering study of ^{198}Pt have produced much new information on this little studied nuclide. Each of these $(n,n'\gamma)$ studies has been complemented by neutron time-of-flight measurements.

Fast Neutron Scattering Cross Section Research

L.E. Beghian, G.H.R. Kegel, G.P. Couchell, J.J. Egan, A. Mittler, D.J. Pullen, W.A. Schier, E. Sheldon

I. Inelastic Cross Sections for ^{232}Th and ^{238}U from $(n,n'\gamma)$ Measurements.

Inelastic cross sections in ^{232}Th and ^{238}U have been obtained for states in the excitation energy range 0.7 - 2.0 MeV. The level cross sections have been inferred from 125° gamma-ray production measurements which employed a Ge(Li) spectrometer in conjunction with time-of-flight techniques and Compton suppression via a NaI(Tl) annulus. Inelastic scattering from states in the region of excitation near 1 MeV and above is an important process which contributes to the shape of the low energy spectrum in fast reactors. The high level density in this region of excitation makes direct observation by (n,n') very difficult. The excellent energy resolution attainable in gamma-ray spectroscopy makes this technique very attractive.

II. Cross Sections for ^{232}Th and ^{238}U from (n,n') Measurements. Work is in progress on (n,n') measurements for states in ^{232}Th and ^{238}U above the ground state rotational band. Using disk scatterers and the time-of-flight technique we have been able to achieve an overall energy resolution of 15 keV optimized for the detection of neutrons of 250-300 keV in energy. This allows us to study the inelastic cross sections by direct neutron measurements as a complement to our $(n,n'\gamma)$ work.

III. E O Transitions in ^{232}Th and ^{238}U . In obtaining cross sections from gamma-ray data care must be taken in accounting for electric monopole transitions. We have estimated EO strengths in these nuclei by comparing cross sections obtained in $(n,n'\gamma)$ measurements with (n,n') level cross sections determined by the neutron-time-of-flight method. Computer-assisted stripping of the neutron time-of-flight spectra is required to obtain individual level cross sections for most cases of interest. As a rule this method is sensitive to EO branching ratios of 20% or larger.

IV. Ring Geometry Measurements of Inelastically Scattered Neutrons for $E_n < 200$ keV. Neutrons scattered from the ground state and inelastically scattered from the 45-keV state in ^{238}U have been measured in ring geometry for incident energies, $E_n < 200$ keV. The time-of-flight measurement in this "open geometry" method yields good time resolution at 50 cm flight paths.

V. Computer Simulated Time-of-Flight Spectra. We have written the computer code IMBUI to simulate neutron time-of-flight spectra for different experimental conditions. This code includes the effects of neutron target cross sections and kinematics, flight path dispersion caused by the scatterer geometry, energy dispersion introduced through the scatterer kinematics by the finite range of scattering angles, and neutron attenuation.

VI. Theoretical Calculations of Inelastic Cross Sections in ^{232}Th . The cross section data for ^{232}Th at incident energies from 0.8 - 2.1 MeV populating a variety of excited levels have been compared with the predictions of the compound-nucleus (CN) model using appropriate optical potential parameters. With increasing projectile energy, the CN model progressively falls short of matching the data, due to the onset of direct interaction (DI) contributions and fluctuation interference effects. To allow for the DI contributions, their magnitudes have been evaluated using coupled-equations and direct-interaction programs.

UNIVERSITIES

University of Maryland

Department of Chemistry

-01 \$88 K

Radioactive Decay Studies at TRISTAN II

W. B. Walters

The purpose of these studies is to determine the positions, decay branches, decay multipolarities, spins and parities of the excited levels in nuclides populated in the decay of selected fission product nuclides isolated by the on-line isotope separator TRISTAN II at the High Flux Beam Reactor at Brookhaven National Laboratory. Gamma ray singles and coincidence spectra will be measured using a multidetector coincidence and angular correlation system that is under development. Nuclides of interest span the region in which the nuclear shape is transforming from the closed shell at $N=82$ to deformed structures for $N>90$, or lie near the double magic ^{132}Sn nucleus.

UNIVERSITIES

Massachusetts Institute of Technology
Laboratory for Nuclear Science/Spectroscopy Laboratory -01 \$73 K⁹⁷

M.S. Feld, P.G. Pappas, D.E. Murnick, M. Deutch

Laser-Induced Nuclear Orientation. Laser-induced nuclear orientation and its applications is being explored in this project. The basic idea is to use intense monochromatic laser radiation to optically pump isomeric atoms, i.e., atoms whose nuclei are in isomeric states. The nuclear orientation thus induced manifests itself in the angular distribution of the subsequent nuclear emission and decay. By employing the techniques of laser saturation spectroscopy extremely narrow resonances ($\sim 10^{-7}$ to 10^{-8} eV), comparable in resolution to Mossbauer effect resonances, should be attainable. Observation of the effect leads to determination of excited state nuclear moments and isomer shift.

Laser-induced nuclear orientation has been observed via gamma ray anisotropies in two separate systems; one, ^{22}Na , in a cell and the second, $^{24\text{m}}\text{Na}$, produced on-line using a Van de Graaf accelerator. Preliminary results of the $^{24\text{m}}\text{Na}$ experiments have shown that the g factor is negative in $^{24\text{m}}\text{Na}$ and that the $^{24}\text{Na} - ^{24\text{m}}\text{Na}$ isomer shift is less than 240 MHz.

Efforts are under way to produce dense targets and beams with a high degree of polarization for use in nuclear physics. Experiments are on going in two atomic systems - lithium and sodium.

UNIVERSITIES

The University of Michigan
Department of Nuclear Engineering

-02 \$128 K

G. T. Baldwin, D. J. Grady, G. F. Knoll, M. Mahdavi,
and D. McKeon

I. Absolute Fission Cross Section. We are completing a series of measurements on U-233 and Np-237 using our photoneutron source facilities. These measurements will yield absolute fission cross sections at discrete energies ranging from 23 to 964 keV. Techniques are similar to those we have employed in previous absolute cross section measurements on U-235 and Pu-239. Neutron source strengths are measured in the University of Michigan manganese bath relative to the secondary national neutron standard NBS-2.

II. Capture Cross Section Measurement Using Photoneutron Sources. Two independent experiments are currently in progress that are aimed at the determination of absolute capture cross sections. The first involves capture in In-115, and will employ $4\pi\beta\text{-}\gamma$ detection of the induced activity in a series of target foils. This capture cross section is of primary interest as a standard in the keV neutron energy range.

We are also involved in a measurement of the Th-232 capture cross section at 23 keV. This cross section is of considerable technological interest, and will also be measured using activation techniques.

III. Facility Development for Measurement at 14 MeV. The installation of a 14 MeV neutron generator is nearing completion in a new laboratory that formerly housed the University of Michigan cyclotron. Our plan is to use these facilities for the measurement of absolute cross sections using both proton recoil monitors and associated particle counting for flux determination. We will begin with a series of fission cross section measurements on U-235, Pu-239, U-233, Np-237, and U-238. Targets used for these measurements will be the same fissile foils used for previous photoneutron experiments.

UNIVERSITIES

University of Michigan
Department of Physics

-01 \$55 K

Precision Positron Polarimetry--A New Technique in Weak Interaction Studies

Arthur Rich, David E. Newman

This is the first experiment to use the high precision comparison of positron polarization from different nuclei to test weak interaction beta decay theories. The basis of this technique is the use of a new type of positron polarimeter which, in conjunction with a beta spectrometer, will allow us to measure the difference in polarization of positrons from two sources to precisions two orders of magnitude better than is currently possible.

We are using this technique in an initial experiment to compare the polarization of positrons from ^{22}Na and ^{68}Ga . Previous studies of ^{22}Na decay have produced a number of mutually inconsistent experimental measurements which imply a polarization difference of up to 10^{-2} for these nuclei. We expect to achieve an accuracy of $2 - 3 \times 10^{-3}$ and thus we should be able to discriminate clearly among these predictions.

A further and probably more significant result of this work should be the successful demonstration of our polarization comparison technique as it applies to a number of tests of fundamental weak interaction theories. By selecting the nuclei to be studied, and with some modification of the apparatus, we eventually expect to search for Fierz interference and second class currents, measure weak magnetism, and contribute to the study of time reversal using this technique.

UNIVERSITIES

Middle Tennessee State University
Department of Chemistry and Physics -01 \$35 K

Nuclear Structure Studies via Neutron Interactions

R. F. Carlton

This is a collaborative effort with ORNL staff at the Oak Ridge Linear Accelerator (ORELA). An analysis is underway of neutron transmission measurements made at the ORELA to systematically investigate neutron cross sections for stable isotopes relevant to tests of nuclear models. A graphics terminal will be established on campus to permit use of computer facilities at ORNL.

Initial studies will involve $^{122}, ^{124}\text{Sn}$ and $^{186}, ^{182}, ^{188}\text{Os}$.

UNIVERSITIES

University of New Mexico
Department of Chemistry

-04 \$93 K (24 mos.)

The Development of Surface Immobilized Ligands for Actinide Separations

Robert T. Paine

The project is directed toward the development of improved syntheses and purification schemes for dialkyl-N,N-dialkylcarbonylmethylene phosphonate and dialkyl-N,N-dialkylcarbonyl phosphonate ligands which are currently employed in advanced actinide waste reprocessing schemes or show promise for such applications. The coordination chemistry of these ligands is being explored with transition metal, lanthanide, and actinide ions typically present in HLLW solutions. The characterization and structure elucidation of the isolated complexes by infrared, visible-UV, ESR and multinuclear NMR spectroscopies and single crystal X-ray diffraction analyses are leading to a more thorough understanding of the metal ion extraction processes. The results of this program and the presence of several practical problems in the process chemistry have led to investigations which produced routes to the chemical bonding of phosphonate ligands on silica. The program now is specifically involved in the following projects: perfecting extractive purification schemes for free phosphonates; expanding the synthetic routes for the immobilization of phosphonates on silica and other inorganic supports; characterizing the ligand bonding mode on silica using various spectroscopic techniques; examining the coordination chemistry of the bonded ligands; determining the structures of actinide ion-phosphonate complexes and determining the potential of the silica/ligand materials as single phase extraction column packing substances.

UNIVERSITIES

The University of New Mexico
Nuclear Engineering Department

-02 \$61 K

J. C. Robertson, D. Sloan

I. Absolute Fission Cross Sections in the 14 MeV Region. Measurements are being made of the absolute fission cross sections of U-235, Pu-239, U-233 and Np-237, in the 14 MeV energy region. In addition the angular distribution of the fission fragments is being measured as a separate project. These measurements are required because the presently available data are inadequate and not sufficiently accurate.

II. A 14 MeV Recoil Proton Monitor. A 14 MeV proton recoil monitor has been designed and constructed to measure the absolute neutron flux in the 14 MeV fission cross section measurements. Extensive calculations of the efficiency of this monitor have been made and compared with the calculations of other authors. It is clear that a major source of uncertainty in the efficiency is the lack of precise knowledge of the angular distribution of the n-p elastic scattering cross section. The efficiency can alter by up to 3% depending on the form of the angular distribution which is used.

III. K-Correction in $4\pi\beta\text{-}\gamma$ Coincidence Counting. The magnitude of the K-correction in determining the absolute activity of foil sources by $4\pi\beta\text{-}\gamma$ coincidence counting is being investigated as a function of Z, thickness and β end point energy. The magnitude of this correction, which allows for complex decay schemes and the counts produced in the β -counter by gamma radiation, has not been well established. This limits the accuracy which can be achieved in foil source standardization.

UNIVERSITIES

Brooklyn College of CUNY
Dynamitron Laboratory

-01 \$72 K

High Resolution Photofission Measurements in ^{238}U and ^{232}Th .

H. Lancman.

Previous photofission measurements have been carried out with a gamma ray energy resolution of ~ 100 keV, mainly using bremsstrahlung. This resolution makes it impossible to study details of structure in the energy dependence of photofission cross sections near threshold. Our measurements employ photons from known (p, γ) resonances in a number of nuclei. This technique takes advantage of the Doppler shift of the energy of the photon emitted by the recoiling nucleus at a given proton resonance. Typical energy spreads vary between 20 and 40 keV and an energy resolution of 200 eV is easily attainable. The yield is typically 10^3 photons per μA of proton beam on target, which makes it necessary to use high beam currents. The measurements are being carried out on our 3.75 MeV Dynamitron which has a maximum proton beam current of 2 mA. Polycarbonate films are used as fission track detectors.

Our aim is to determine the photofission cross sections of ^{238}U and ^{232}Th in the 5 - 13 MeV range of excitation energy. The number of suitable (p, γ) resonances is adequate for covering this range with an average energy step of 100 keV. Regions of particular interest, especially those near threshold can be covered almost continuously. The very high gamma ray energy resolution makes it possible to search for structure in the cross section resulting from class II states in the second well of the fission barrier. The results are being compared with model calculations in order to determine the barrier parameters of the two nuclei.

UNIVERSITIES

University of Albany, New York

-02 \$29 K

Neutron Physics Research

J. B. Garb, V. K. Tikku (University of Albany)

J. A. Harvey, R. L. Macklin (ORNL)

Neutron Total Cross Section in the Resonance Region

These studies performed with ORELA, provide information on the parameters (E_0 , Γ_n , J^π etc...) of a large number of resonances in many nuclei. From this information, one can investigate the average quantities such as nuclear level densities and strength functions, which are related respectively to nuclear structure and neutron interaction mechanisms, below 1 MeV. One can investigate the parameters of the optical model and characteristics of intermediate states. The distribution of level spacings and neutron reduced widths are also useful in the understanding of neutron-nuclear interaction processes.

Neutron Capture Cross Sections

These studies are complementary to the total cross section studies and have a greater sensitivity for the detection of weak levels which are usually populated by p- or d-wave neutron capture. Hence these studies provide additional information about the average properties of the higher angular momentum states. In addition these studies also provide values of radiative widths, which are useful in the calculation of resonance absorption integral for reactor application. Moreover the energy averaged values of neutron capture cross sections in the 30-100 keV region, in some nuclei also provide useful data for the study of nucleosynthesis of elements in astronomical applications.

UNIVERSITIES

University of North Carolina at Chapel Hill -01 \$178 K

Studies of Nuclear Processes at Triangle Universities Nuclear Laboratory (TUNL)

T. B. Clegg, E. J. Ludwig, E. Merzbacher, W. J. Thompson

I. Polarization Effects in Nuclear Reactions. Beams of polarized protons and deuterons from the TUNL Lamb-shift polarized ion source are used for studies of nuclear reaction mechanisms and nuclear spectroscopy. Nuclear reactions induced by polarized deuterons have been used to investigate the mechanism by which one or more nucleons are picked up from various nuclei. The patterns exhibited by the vector and tensor analyzing powers are frequently indicative of the spin and parity of the residual levels and the angular momentum involved in populating these levels.

II. Spin-Dependent Potentials in Nuclear Scattering. Experimental and theoretical research in this area includes the following: the energy dependence of nucleon spin-orbit potentials, the relation of d,t,³He and heavy-ion spin-dependent potentials to nucleon potentials, spin-spin effective interactions in nucleon-nucleus scattering, and the effects of nuclear structure on scattering potentials.

III. High Resolution Studies of Resonances. Beams of polarized and unpolarized protons are used to excite isospin-forbidden resonances in nuclei. The TUNL high-energy-resolution system is employed since these resonances are usually narrower than the normal accelerator beam resolution. These studies are designed to attempt to establish the origin of the apparent isospin mixing. The reduced widths of these resonances are determined for a range of self-conjugate target nuclei.

IV. A New Facility for Scattering Spin-Polarized Neutrons. Spin-polarized beams of protons and deuterons have been heavily utilized tools for TUNL research programs since 1970. Often these beams have been tools to study scattering and reaction processes in which outgoing neutrons have been detected. These measurements have been severely hampered by an inability to determine accurately the outgoing neutron energy. Within the past year we have been able to pulse these polarized beams with high efficiency so the outgoing neutron energies can be accurately measured by determining their flight time from target to detector. This new facility is being exploited heavily, using the $D(\vec{d}, \vec{n})^3\text{He}$ reaction to produce polarized neutrons, to measure cross sections for elastic scattering of polarized neutrons from a wide range of nuclei. The data obtained have previously been unavailable with sufficient accuracy to test theoretical methods of the spin-dependence of the neutron-nucleus interaction.

V. Atomic Effects on Nuclear Reactions. These investigations aim to explore the interface between atomic and nuclear physics by observing energy changes in nuclear systems induced by the electrons immediately surrounding the nucleus. Phenomena such as very narrow resonances in scattering from light nuclei, as observed using polarized beams and the TUNL high-energy-resolution system, are being studied.

North Carolina State University	-01	\$65 K
Triangle Universities Nuclear Laboratory	-02	\$70 K

C. R. Gould, G. E. Mitchell, L. W. Seagondollar, D. R. Tilley

I. High Resolution Resonance Studies. * A variety of ultra high resolution resonance experiments are being carried out on both the 3 MV accelerator and the FN tandem accelerator. Although there is still appreciable interest in global statistical properties (strength functions, average level densities), our major emphasis is on detailed or local statistical properties. These include short and long range correlations in level spacings, and unique measurements of interference effects for reduced width amplitudes. These latter results have provided the first verification of several theoretical predictions, as well as establishing new, as yet unexplained results.

II. Radiative Capture Reactions. * The main emphasis of these studies has been to search for effects of the giant quadrupole resonances in the radiative capture reaction for a variety of nuclei. Most of the E2 effects we have observed are consistent with only direct radiation which gives a "background" which makes the observation of E2 resonances difficult. Using our high intensity polarized neutron beam, we have shown that the neutron capture reaction appears to be a more favorable tool for studying E2 resonances since the direct strength is quite small. We are also using the polarized neutron beams to pursue our interest in few nucleon systems (e.g. $^3\text{He}(n,\gamma)^4\text{He}$). These experiments are important since the few body problem is susceptible to "exact" calculations. We are continuing our use of proton beams from the Cyclo-Graaff (18-31 MeV) to study capture leading to highly excited bound and unbound final states. Our aim is to understand the reaction mechanism, to search for resonances built on these excited states, and to investigate the utility of "high energy" capture for studying highly excited states in the residual nuclei.

III. Neutron Cross-Section Studies. * Measurements of the interaction of neutron beams with a wide range of elements has been a major program at our laboratory for several years. One emphasis has been on the elastic scattering of neutron beams to permit development of more accurate nuclear models and also to provide accurate data for the design of fusion-energy sources. The second emphasis is to obtain information on the emission spectrum of secondary neutrons that are emitted when high-energy neutrons impinge on various isotopes that may comprise containment vessels or blankets for fusion-energy devices. The data is combined with theoretical models to generate better descriptions for inelastic neutron interactions. The energy of the incident neutrons in both of the above studies is 8 to 14 MeV, a region where neutron data of this type has been scarce.

* These projects are done in collaboration with faculty members from Duke University.

UNIVERSITIES

North Carolina State University
Department of Physics

-01 \$196 K (36 mos.)

A Cryogenic Polarized Target Facility

C. R. Gould, D. G. Haase

The identification of spin-spin effects in nucleon-nucleus scattering has been the object of continued study over the last decade. Measurements of spin-spin cross sections require that polarized beams and/or polarized targets be available. We propose to construct a cryogenic polarized nuclear target facility to be used in conjunction with the polarized neutron beam at the Triangle Universities Nuclear Laboratory to investigate spin-spin effects in nuclei which heretofore have not been easily polarizable. Recent developments in ultra-low temperature refrigeration and in superconducting magnet technology now make possible the construction of a facility for the brute force polarization of several nuclei, including ^{27}Al , ^{51}V , ^{93}Nb , ^{115}In and ^{209}Bi , at millikelvin temperature in high magnetic field. In the proposed experiments cross sections will be measured for neutrons in the energy range 10 to 20 MeV. Both transverse-spin and parallel-spin geometries will be used in order to study the central and tensor contributions to the spin-spin force. These experiments will be useful not only for the nuclear physics information acquired but also in demonstrating the feasibility and usefulness of brute force polarization and outlining its further applications.

UNIVERSITIES

Ohio University
Accelerator Laboratory

-02 \$16/ K

R.O. Lane

I. Structure of Light Nuclei. The special features of the Ohio University tandem accelerator are employed to probe the light nuclei via neutron elastic and inelastic scattering to yield structure information for the development of models for these nuclei. For many of the light nuclei charged particle and γ -ray reactions so common in the past have reached a limit in definitive new nuclear structure contributions, whereas the long overlooked neutron reactions when properly pursued with this unique facility are now contributing to further development of shell models and cluster models of the light nuclei. The data obtained in these studies are in most cases directly applicable to the fusion energy program by way of cross sections needed for shielding purposes as well as cross sections and nuclear model development to better predict tritium breeding and other reactions taking place in future fusion energy devices.

II. Neutron-Induced Reactions. Again the special features of this accelerator are exploited study charged particles emerging from neutron bombardment of nuclei. A truly unique spectrometer for this use has been designed and constructed at this laboratory. Virtually no measurements of these properties exist over an energy range needed both to study the nuclear reaction mechanism and to provide vital data to designers of fusion energy reactors of the future. Present-day fusion energy concepts involve reactions which produce copious quantities of neutrons which in turn can cause internal damage to structural members by the charged particles produced inside them by the high neutron flux. Theoretical studies of the data will provide an interpretation method and model development for extension to other nuclei where data do not exist.

III. Analytical Theory Development. In order to compare these measurements to the predictions of fundamental compound nuclear models it is usually necessary to analyze the data by means of an intermediate or analytical theory which interprets the data in terms directly comparable to fundamental models. New developments in this rather complex analytical theory are being made to encourage greater interaction between theory and experiment and, therefore, greater progress in our fundamental understanding of the nucleus.

UNIVERSITIES

University of Oklahoma
Department of Physics and Astronomy

-01 \$55 K (22 mos.)

Spectroscopic Studies of Transitional Nuclei

R. F. Petry

Studies of the levels in neutron-rich $^{90,92}\text{Kr}$ and $^{140,142}\text{Xe}$ populated in the beta decay of $^{90,92}\text{Br}$ and $^{140,142}\text{I}$ are underway at the TRISTAN II facility at Brookhaven National Laboratory. The objectives of the measurements is the characterization of the transition from spherical to deformed shapes in the medium-mass region. Of particular theoretical interest are now shell-model calculations of the shape transition in the $A \sim 100$ region, and the Interacting Boson Model calculations on $\text{SU}(5) \rightarrow \text{SU}(3)$ transitions.

UNIVERSITIES

University of Pennsylvania
Department of Physics

-03 \$79 K

Compilation of Information on the Energy Levels of the Light Nuclei
FY 1978 \$77,507

F. Ajzenberg-Selove

This work consists of two parts. The first is the review and evaluation of all the information available about the nuclei with $5 \leq A \leq 20$, where A is the total number of neutrons and protons in the nucleus. On the average, there are some 1500 new publications/year worldwide on these light nuclei. We evaluate these publications in the light of all other knowledge on these nuclei and prepare definitive summaries which are published once a year by the journal Nuclear Physics, generally as a complete issue of that journal. Each summary evaluates the work on two to five A-chains (families), the exact number depending on the complexity of the information. These evaluations are used throughout the world not only by basic nuclear scientists but also by scientists concerned with applications to the CTR program, nuclear medicine, etc. In 1979 we published "Energy Levels of Light Nuclei, $A = 5-10$ " in Nuclear Physics A320 1-224 (1979).

The second part of our work consists in collaborative, user-type research at P-9 at Los Alamos using 17-25 MeV tritons and the very high resolution Q3D spectrometer equipped with a helical proportional chamber. This past year we have been studying the (t,p) reactions on the Molybdenum isotopes. The studies of these two-nucleon transfer reactions are being used, inter alia, to understand the change in the structure of the Mo isotopes as one goes from the low A isotopes of that element to the high A isotopes.

While the evaluation work is more immediately relevant, our work at Los Alamos which is done with frontier-type equipment and analysis methods makes us able to better evaluate contemporary research papers.

UNIVERSITIES

Princeton University

-01 \$165 K

Nuclear Chemistry Project

R.A. Naumann, K. Krien, F. Girshick, F. Loeser

I. Charged Particle Nuclear Spectroscopy. These experiments involve the selective (p,t) and (t,p) two nucleon transfer reactions and high resolution Q3D spectrographs to study characteristics of the levels in medium and heavy nuclei. Investigations involving radioactive nuclei are included in this program. When applied to nuclei with an uneven number of protons and/or neutrons these transfer reactions preferentially populate those levels of the product nucleus having a configuration of the unpaired nucleon(s) related to that of the target nucleus. Comparisons of the spectra obtained for adjacent nuclei thus test the extent to which collective and single particle properties of nuclei are preserved on the addition of one or two nucleons.

II. In-Beam Studies of Nuclear Excited States. Nuclear reactions involving charged projectiles and subsequent neutron evaporation provide a general means for preparing excited states of nuclei in a state of polarization. However, studies of the gamma rays accompanying deexcitation of these states often fail to reveal the decay of nuclear isomeric states where low energy transitions and/or long lifetimes are involved. Since such isomeric transitions proceed predominantly by the emission of conversion electrons, an on-line magnetic electron spectrometer has been recently installed at the Princeton Cyclotron for their study. This instrument is being used to study the lifetimes, gamma ray multipolarities and moments of nuclear isomeric states by direct observation of the conversion electrons accompanying nuclear reaction.

III. Atomic Coulomb Capture of Negative Muons (in collaboration with Dr. J. D. Knight, Los Alamos). When negative particles slow in an absorber they decelerate and are captured in the positive electric field of a nucleus by energy loss to the bound atomic electrons of the absorber. After this initial binding, the negative particle passes to more deeply bound orbits by further energy loss involving electron ionization (Auger process) or radiation. A weakly interacting particle reaches the lowest bound atomic 1s state, signalling its arrival by emission of characteristic X rays. At the LAMPF meson facility employing muon beams, we measure the relative intensities of emitted muonic X rays to investigate the marked dependence of this capture process on the physical and chemical state of the atoms comprising the absorber.

UNIVERSITIES

Rensselaer Polytechnic Institute
Department of Nuclear Engineering

-02 --(\$134 K/24 mos.)

Fission Cross Section Measurements of the Even Curium Isotopes

Robert C. Block

The neutron-induced fission cross sections of $^{244,246,248}\text{Cm}$ will be measured from approximately 1 eV to 100 keV using a 75-ton lead slowing-down spectrometer. The intense neutron flux provided by the spectrometer enables the neutron-induced fission to compete with the spontaneous fission background and also permits the use of microgram quantities of highly enriched curium samples.

UNIVERSITIES

University of Tennessee
Department of Physics

-04 \$65 K

Magnetic Measurements of the Transuranium Elements and Charge State Characterization of Actinides in Monazite

Paul G. Huray

The program has both an applied and a basic research thrust through investigations of the physical properties of the transuranium elements and their compounds. Because of the natural α -decay of the elements Pu, Am, Cm, Bk, Cf, and Es the research is carried out at the Transuranium Research Laboratory of the Oak Ridge National Laboratory. Macroscopic quantities (greater than one microgram) of these elements are periodically milked from the High Flux Isotope Reactor, purified, and prepared as oxides and various crystallographic forms of the metal. With our (S.Q.U.I.D. based) micro-magnetic susceptometer we are examining the effective high temperature magnetic moments and low temperature magnetic transitions in order to determine the effective number of 5f electrons per atom and the magnitude of their overlap in the compounds and metals. With our Mössbauer apparatus we are examining the charge state of Np ions as impurities in LaPO_4 crystals. This compound (synthetic Monazite) shows strong resistance to leaching of the radioactive impurity for most transuranium elements and has therefore been proposed as a primary containment form for actinide wastes. Our charge characterization will likely aid the interpretation of the strong chemical bonding mechanism which produces this feature of the compound.

UNIVERSITIES

University of Tennessee
Department of Chemistry

-04 \$100 K

Physical-Chemical Studies of the Transuranium Elements

Joseph R. Peterson

The program provides training for pre- and postdoctoral students in chemical research with the transuranium elements through continuing investigations of the basic physical-chemical properties of these elements and the interpretation and correlation of the results obtained. New knowledge is expected to be accumulated in the role of the 5f electrons in bonding in actinide elements and compounds, the relationships of metallic structures to metallic valence and radius, the extent and magnitude of the actinide contraction, the magnetic, thermodynamic, spectroscopic, and crystallographic properties of these materials as related to general theories, the effect of self-irradiation on chemical and physical properties, the chemical consequences of radioactive decay, and in general, the range of validity of the actinide hypothesis. Specific projects include: synthesis of Cm-248, Bk-249, and Cf-249 metals for X-ray diffraction (vary temperature or pressure), magnetic susceptibility (SQUID-based microsusceptometer), and heat of solution (solution microcalorimeter) studies; spectral and X-ray diffraction studies of mixed-valence lanthanide, actinide, and mixed lanthanide-actinide halide compounds, transamericium element fluorides, and halide compounds resulting from the radioactive decay series $^{253}\text{Es} \rightarrow ^{249}\text{Bk} \rightarrow ^{249}\text{Cf}$; study of the chemical consequences of radioactive decay in the bulk phase solid state; spectroelectrochemical studies of actinides to characterize unusual oxidation states such as Am(VII), Cm (V), Bk(II), Cf(V), and Es(IV); growth of crystals of transamericium element phosphates for optical and structural characterization over time to study the effects of self-irradiation on the chemical and physical properties of these synthetic monazites.

UNIVERSITIES

Tennessee Technological University
Chemistry Department

-04 \$102 K (24 mos.)

The Investigation of the Solution Properties of the Transuranium Elements

Dale D. Ensor

The emphasis of this program is to investigate the basic properties of the transuranium elements in aqueous solution. Information gained in these investigations would be applicable to the improvement of separation techniques for the actinide elements from one another and from the chemically similar lanthanide elements. Major effort will be devoted to the evaluation of novel macrocyclic compounds as solvent extraction agents for the trivalent actinides. The size selective nature of these compounds as exhibited by their behavior with the alkali metal could allow separations based on cation size. Investigations to better define the complexation reactions of the transuranium elements by measuring the appropriate thermodynamic properties (ΔG , ΔS , ΔH) are currently underway. The measurements are concentrated on the aminopoly-carboxylate complexes which are important in certain separation schemes now used. The information obtained will be useful in better defining the role of the 5f orbitals in complexation reactions of the transuranium elements.

UNIVERSITIES

Texas A&M University
Department of Physics

Stored Ion and Laser Physics Laboratory -01 \$95 K (24 mos.)

Hyperfine Structure and Isotope Shift Measurements of Short-Lived Elements by Laser Spectroscopy

H. A. Schuessler and H. S. Lakkaraju

Novel experimental studies of nuclear moments and charge distributions for short-lived isotopes far from the valley of nuclear stability are initiated. The basic difficulty in the experiments is due to the small number of radioactive nuclei available even with modern on-line mass separators and due to the finite lifetime of these nuclei. Two sensitive methods are being developed. One uses radioactive ions stored electro-dynamically for considerable periods of time in a radio-frequency quadrupole ion trap. The other employs intracavity Doppler-free fluorescence spectroscopy. In the ion storage method, as few as a thousand ions can be investigated. The ions are stored in ultrahigh vacuum during their lifetime and practically float in free space. Laser excitation of stored radioactive ions will be used to measure the hyperfine structure splitting and eventually to cool the ions by optical side-band excitation to a temperature of less than 1°K . The high sensitivity and speed of intracavity fluorescence measurements will be utilized in the second experiment. After the present initial phase of the experiments where the unknown hyperfine structure of stable isotopes is investigated, the experiment will in the second phase be moved to the on-line mass separator at Brookhaven and should yield information on nuclear charge distributions, nuclear moments and spins in new mass regions.

UNIVERSITIES

Texas A&M University
Cyclotron Institute

-01 \$84 K

Contribution to Costs of Beam Time for Nuclear Science Research

D. H. Youngblood

The Texas A&M 88" cyclotron provides proton (≤ 55 MeV), deuteron (≤ 65 MeV), ^3He (≤ 130 MeV) and α particle (≤ 130 MeV) beams as well as a variety of heavy-ion beams for nuclear science research. Polarized proton, deuteron and ^3He beams are also available for experiments. Projects under way at the laboratory include the following. The multipole strength distribution in nuclei is being investigated with emphasis on the properties of the isoscalar giant monopole resonance. These studies are done with inelastic scattering of 130 MeV alpha particles at small angles where the monopole is enhanced. Tests of the isobaric mass multiplet equation made by measuring the masses of both proton-rich and neutron-rich nuclei are in progress. Parity violation in the hadronic weak interaction is being explored by asymmetry measurements of elastically scattered longitudinally polarized protons at 50 MeV on a hydrogen target. Studies of few nucleon systems are under way with emphasis on measuring spin correlation nucleon-nucleon parameters.

UNIVERSITIES

University of Washington
Nuclear Physics Laboratory

-01 \$755 K

E.G. Adelberger, J.S. Blair, D. Bodansky, J.G. Cramer, G.W. Farwell, I. Halpern, F.H. Schmidt, K.A. Snover, T.A. Trainor, R. Vandenbosch, W.G. Weitkamp

I. Nuclear Astrophysics. These studies are to obtain nuclear data needed for a detailed description of nucleosynthesis in astronomical environments and of the processes by which energy is generated in these environments. Such data is necessary both for the formulation of quantitative models, and for the testing of hypotheses as to the character of the physical processes involved.

II. Fundamental Symmetries. Those aspects of the fundamental interactions which can best be investigated through experiments on nuclear or atomic systems are studied; particularly those cases where the nuclear or atomic physics is exceptionally simple and well understood, so as best to illuminate the basic symmetries unencumbered by uncertainties in the many-body problem. Topics of current interest include parity mixing in light nuclei and hydrogenic atoms, β decay, and the detailed study of the breakdown of isospin symmetry. A more sensitive test of nucleon charge conservation has been performed.

III. Radiative Capture Reactions. This research program places major emphasis on the study of magnetic dipole and electric quadrupole strength. Our purpose is to deduce through detailed studies of particular nuclei the strength distribution of magnetic dipole and electric quadrupole radiation produced in radiative capture. These measurements enable the characterization of the strength distribution not only to nuclear ground states but to excited states as well. The study of strength distributions for excited states is a new development with a large potential range of applicability.

IV. Polarization Effects in Nuclear Reactions. We are carrying out a number of experiments which exploit the Lamb-shift polarized ion source as a probe of nuclear reaction mechanisms. Determination of the depolarization parameter and very accurate measurements of the analyzing power for particle emission to highly excited residual nuclei are directed toward understanding the continuous variation of reaction mechanisms from one-step excitation of single levels to absorption of a projectile with later evaporation of another. Additional analyzing-power measurements which emphasize elastic scattering and inelastic scattering to discrete levels in the residual nucleus complement the above program.

V. Accelerator Radiochronology. This newly-developed approach to radiometric dating will enable measurement of minute isotopic fractions using small amounts of source material. Present emphasis is on the development of precise techniques for the measurement of $^{10}\text{Be}/^9\text{Be}$ and $^{14}\text{C}/^{12}\text{C}$ ratios.

UNIVERSITIES

UNIVERSITY OF WASHINGTON

Department of Nuclear Engineering -02 \$30 K

Neutronics Research

G.L. Woodruff, P.J. Grant, D.L. Johnson

I. Delayed Neutron Spectroscopy. This work has concentrated on the measurement of near-equilibrium neutron energy spectra from fertile and fissile nuclei. The results are significant in the area of reactor safety, nuclear safeguards, and the level structure of nuclides far from the line of nuclear stability.

II. Alpha-n Yields. These experiments are devoted to accurate measurements of the neutron yields from (α ,n) reactions in low Z nuclides relevant to reactor applications. Particular emphasis is placed on results from higher alpha energies than used in previous experiments. The results will be important for subcritical reactivity monitoring, nuclear safeguards, and shielding requirements for both reprocessing and nuclear waste storage.

UNIVERSITIES

University of Wisconsin
Nuclear Physics Laboratory

-01 \$55 K

L.D. Knutson and P.A. Quin

I. Charge Symmetry in Neutron-Proton Scattering: Nuclear forces are said to obey the principle of charge symmetry if the interactions are invariant under the interchange of neutrons and protons. This symmetry principle apparently holds in nuclei (no firm evidence for violation of charge symmetry has been found) provided that one corrects for the effects of electromagnetic interactions. An experiment is being undertaken which will allow us to test the principle of charge symmetry in the neutron-proton system by measuring the analyzing powers for the scattering of polarized neutrons by unpolarized protons and for the scattering of unpolarized neutrons by polarized protons. If charge symmetry holds, the two analyzing powers will be equal. This experiment differs from previous tests of charge symmetry in that the interpretation of the results will be free of complications caused by electromagnetic interactions. The experiment will be carried out at the Indiana University Cyclotron Facility at a neutron energy of 200 MeV. A major part of the project involves the development and construction of various pieces of experimental apparatus including a liquid deuterium target for the production of polarized neutrons, a polarized proton target which makes use of the "spin refrigerator" method for producing polarized protons, and a pair of high-efficiency, position-sensitive neutron detectors.

UNIVERSITIES

University of Wisconsin
Nuclear Physics Laboratory

-01 \$615 K

W. Haeberli, L.D. Knutson, D. Mavis, P. Quin, H.T. Richards, S. Sen

I. Fundamental Symmetries: An experiment to test whether scattering of longitudinally polarized protons by protons exhibits mirror symmetry (i.e. parity conservation) is near completion. The results thus far indicate a non-zero longitudinal analyzing power of $(-3.2 \pm 1.1) \times 10^{-7}$. If mirror symmetry holds this quantity should be zero.

II. Radiative Capture of Polarized Particles: Our intense source of polarized protons and deuterons offers an unique opportunity to explore radiative capture of polarized neutrons. These experiments will concentrate on isospin effects in the giant dipole resonance (GDR) of light nuclei. The relatively neglected (d, γ) reactions have also become feasible and may help to understand the role of isospin mixing in the GDR, especially for self-conjugate nuclei. A large NaI spectrometer is under construction for these studies.

III. Direct Reactions with Polarized Deuterons: Measurements of the vector analyzing power are being used to obtain spectroscopic information for a number of nuclei. Tensor analyzing power measurements allow one to probe the D-state components of the deuteron and triton wave functions.

IV. Nucleon-Nucleon Experiments: Experiments to study the spin dependence of the fundamental nuclear interaction by measuring the analyzing powers for nucleon-nucleon scattering are in progress. The analyzing power is being measured for p-p scattering at 10 MeV and for n-p scattering at 25 MeV. In another experiment, the reaction $n+p \rightarrow d+\gamma$ is being studied as a potential new source of information about the nucleon-nucleon interaction.

V. Cluster States from Alpha Scattering and Reactions. Resonant scattering and reactions of alphas on light alpha particle nuclei yield precise information (J^π , E_R , Γ , Γ_R/Γ) of many highly excited cluster states.

VI. Ion Source Research and Development: Our proposal for the development of intense sources of polarized alkali beams by optical pumping with dye lasers is under investigation. Development work on the colliding beam polarized ion source and on the cesium sputter source for heavy metal ions continues.

UNIVERSITIES

Yale University

A.W. Wright Nuclear Structure Laboratory -01 \$285 K

D.A. Bromley, P.D. Parker, et al.

I. Nuclear Science with Light Ions. Having discovered pairing isomers -- a new form of nuclear excitation probing deeply buried nucleon orbitals -- in our studies of the tungsten isotopes we are scanning a much wider range of targets to establish the systematics of these isomers and thus a new aspect of nuclear shell structure; many new examples have been identified. We have completed our determination of the matrix elements for the nucleon-nucleon residual interaction in the lead region; for the first time it has been possible to study a number of the valence shells and in addition to measuring the $T = 1$ matrix elements for the first time we have demonstrated the importance of explicit core polarization phenomena. From inelastic alpha particle studies on very highly excited, high spin states in light nuclei we have extended our spectroscopic studies to very high members of rotational bands based on simple shell configurations. And continuing our work in nuclear astrophysics we have made extensive new measurements on the mass 37 system and on the radiative capture of alpha particles by helions, both critical to our understanding of solar neutrino astronomy.

II. Nuclear Physics Applied to Other Sciences. We have continued to apply our hydrogen profiling technique to many other sciences. Work on the development of a much improved bottle for storage of ultra cold neutrons continues as does work on the detailed mechanisms for hydrogen migration in metals and other solids. Using our accelerator as an ultra mass separator for ^{10}Be and ^{26}Al in geochronology studies, we have established the growth rate for ocean floor manganese nodules as 4.5 mm per million years and are now studying Pacific abyssal cores to provide a detailed measurement of cosmic radiation variability over the past few million years. We have demonstrated that currently cosmic radiations (primarily muons) are a significant cause of soft failure of large computer systems and that at the next level of circuit integration they will be the dominant cause. We have developed new theories of ion induced sputtering and made measurements to distinguish between the "thermal-spike" and "ion-explosion" variants; both these and the above hydrogen migration studies are relevant to fusion reactor inner wall problems.

UNIVERSITIES

Yale University
Electron Accelerator Laboratory

-01 \$175 K

F. W. K. Firk

Neutron Polarization Studies

A. The Double-Scattering of Fast Neutrons by Light Nuclei.

We have continued to exploit the unique source of highly polarized neutrons available at the Yale University Electron LINAC at energies between 50 keV and 5 MeV, obtained by the elastic scattering of an intense pulsed beam of photo-neutrons from selected light nuclei. Our measurements of the absolute polarization of neutrons scattered from nuclei ranging from ^4He to ^{32}S , have been included in global analyses to give new information on the nuclear structure of the compound systems. For example, our results have played a key part in the discovery of a p-wave triplet of states in the important reaction $n + ^6\text{Li}$ at an excitation energy below 10 MeV.

B. Polarization Effects in the Small-Angle Scattering of Neutrons:

Mott-Schwinger Scattering and the Polarizability of the Neutron.

We have studied $\vec{n} - ^{209}\text{Bi}$ elastic scattering as a continuous function of energy in the MeV region at angles between 3° and 20° with an absolutely calibrated source. Detailed calculations, using Hogan and Seyler's method of analysis, have been carried out and compared with our results. The sensitivity of the measurements, and of the analyses, to different values of the neutron polarizability coefficient has been investigated. As a consequence of this work, which involves a fundamental structure constant of the neutron, we have started a series of measurements of the polarization of low-energy neutrons scattered at small angles from nuclei in which the nuclear scattering amplitudes can be calculated exactly from a knowledge of the s- and p-wave resonance parameters. We fully expect to be able to set a significantly improved limit on the magnitude of the electric polarizability coefficient of the neutron as a result of our new studies.

OTHER •

National Bureau of Standards
Nuclear Radiation Division

-02 \$475 K

Differential Neutron Nuclear Data Standards

C. D. Bowman, A. D. Carlson, G. P. Lamaze, M. M. Meier, R. A. Schrack,
K. C. Duvall, O. A. Wasson, R. B. Schwartz, R. G. Johnson, I. G. Schröder

I. MeV Neutron Standards. These studies are aimed at improving the accuracy of cross section and flux monitors used as standards for neutrons in the MeV range. Redundancy in measurement methods is emphasized through parallel measurements using the NBS 100 MeV linac as a white source and the NBS positive ion accelerator for accurate measurements near 14 MeV. This work is aimed at improving the accuracy of MeV nuclear data needed in fusion reactor development, national defense, cancer therapy using neutrons, and performance evaluation of accelerator breeder concepts.

II. KeV Neutron Standards. These measurements are intended to increase the accuracy of reaction cross section standards in the keV range and bear on the improvement of breeder reactor concepts and on problems in national defense. Redundant measurement methods including filtered beams at the NBS reactor, monoenergetic neutrons at the ion accelerator, and white neutrons from the linac all are being used concurrently.

III. 1/v Neutron Standards. In the eV range of neutron interactions the near 1/v behavior of the neutron reaction cross sections of ^3He , ^6Li , and ^{10}B are useful neutron cross section standards. This effort is aimed at measuring the deviation from the 1/v cross section arising from both nuclear and atomic effects. These results should lead to improvements in commercial power reactor performance including several parts of the fuel cycle.

IV. Physics of Neutron Interactions With Matter. These studies are concentrated on the interaction between atomic and nuclear phenomena in the energy range above thermal neutron energies. While the emphasis is on fundamental physics, the work is expected to have application in improved understanding of neutron exposure to personnel, in development of special materials important to new technology, and might lead to some degree of control over nuclear reaction rates.

V. Neutron Source and Instrumentation Development. Improvements in neutron measurements are being pushed on two fronts: the development of better neutron sources and the development of new neutron detectors. Source development is aimed at a possible new source for the NBS and at the development of a small but intense neutron source which would allow the transfer of neutron measurement methods from the large accelerator and reactor of the laboratory to more general application in industry. New neutron detectors are aimed at improved accuracy in measurement of high energy neutrons and at better resolution and broader uses for position-sensitive neutron detectors.

OTHER

Rockwell International
Energy Systems Group

-02 \$70 K

Helium Production Cross Sections

Harry Farrar IV, D. W. Kneff, B. M. Oliver, M. M. Nakata

Helium Production Cross Sections for Fusion Energy Neutrons. The objective of this program is to measure experimentally the total helium generation cross sections of several separated isotopes and their associated pure elements for fusion-energy neutrons. This information is of prime importance in the development of both fusion and fast reactors because of the effects that internally-generated helium has on the mechanical and physical properties of the reactor components.

Numerous small samples are irradiated together using high-intensity neutron sources presently employed for materials testing for the U.S. magnetic fusion energy program. The helium generated in the samples is measured accurately (~1-2%) using a high-sensitivity gas mass spectrometer system. The measurements provide a direct method of determining the total helium generated by all contributing reaction channels. The helium generation cross sections are then determined from the helium measurements and the total neutron fluence received.

A significant fraction of the program effort is directed towards determining the exact spatial dependence of the neutron fluence in the irradiation assembly, since steep fluence gradients make the fluence the principal source of uncertainty in the final cross sections. This determination involves using foil activation and helium accumulation neutron dosimetry to generate a three-dimensional fluence map for the assembly. The helium accumulation neutron dosimetry uses the same helium-measuring capability of the mass spectrometer as used for the cross section determinations.

Two separate irradiations with 14.8-MeV (average energy) neutrons from a T(d,n) fusion neutron source have been completed, and helium generation cross sections for Al, Ti, Cr, Fe, Ni, ⁵⁸Ni, ⁶⁰Ni, ⁶¹Ni, ⁶²Ni, ⁶⁴Ni, Cu, ⁶³Cu, ⁶⁵Cu, and Au have been determined. Additional elements, including Be, O, F, Si, V, Cr, Mn, Zr, Nb, Mo, Sn, W, Pb, and many of their separated isotopes, have been or will be irradiated, and their cross sections will be determined. Other neutron spectra will also be used, and the cross section results will be compared with available theoretical calculations to provide important experimental tie-points to check nuclear model codes and refine model parameters.

OTHER

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-04 \$83 K

Chemistry of the Gaseous Lower Halides of Uranium

D. L. Hildenbrand

The objective of this program is to provide an accurate thermochemical characterization of the gaseous lower-valent halides and the oxyhalides of uranium. Thermochemical data are derived largely from high temperature equilibrium measurements monitored by mass spectrometry and by the torsion-effusion method. Various types of chemical beam sources are used to generate the gaseous uranium halide and oxyhalide species of interest. Reaction enthalpies, bond dissociation energies, and standard enthalpies of formation are the primary results derived from the equilibrium studies. In addition, special emphasis is placed on deriving entropy data as well, so that the estimated assignments of spectroscopic and molecular constants of the gaseous uranium compounds can be verified. The aim is to provide sufficient information so that the energetics of reactions involving uranium halides and the equilibrium properties of these systems can be accurately evaluated over wide temperature ranges. A secondary goal is the correlation of the results with the nature of the chemical bonding in these compounds.

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