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Summaries of FY 1978 Research in the Nuclear Sciences

June 1978

U.S. Department of Energy

Directorate of Energy Research

✓ Division of Nuclear Sciences

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Summaries of FY 1978 Research in the Nuclear Sciences

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Division of Nuclear Sciences

Washington, DC 20545

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INTRODUCTION

This report contains summaries of the programs funded in fiscal year 1978 by the Division of Nuclear Sciences/Office of Basic Energy Sciences. The objectives of Nuclear Sciences are as follows:

- To advance the understanding of nuclear structure, nuclear reactions, and phenomena.
- To establish a nuclear data base to assist in the design of fission and fusion reactors.
- To advance the understanding of the chemical and physical properties and behavior of the actinide elements.
- To provide research quantities of nuclear materials (isotopes and transuranium elements.)

Each summary is preceded by a heading that includes; institution, title, principal investigators, budget reporting category, BRC and operating funds provided in FY 1978. The BRC can be interpreted as follows:

Ak = Multi-Resource
AK-01 = Basic Energy Sciences
AK-01-01 = Nuclear Science
AK-01-01-01 = Low Energy Nuclear Science
AK-01-01-01-1 = Charged Particle Research
AK-01-01-01-2 = Neutron and Fission Research
AK-01-01-01-3 = Heavy Element Research
AK-01-01-02 = Isotope Preparation
AK-01-01-02-1 = Electromagnetic Isotope Separation
AK-01-01-02-2 = Special Isotope Preparation

The summaries are presented in alphabetical order by institution, first for the national laboratories and then for the universities. Indexes are appended to facilitate the location of a summary according to an investigator's name or a budget reporting category. Further information on any of the projects reported here 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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SECTION A

LABORATORIES

AMES

Nuclear Physics Measurements at On-Line Isotope Separator (TRISTAN)
AK-01-01-01-2 FY 1978 \$575,000

J. C. Hill, F. K. Wohn

The most important event in the history of the TRISTAN program since its inception in 1966 was the demonstration of the capacity to study non-gaseous fission products. The resulting facility has been renamed TRISTAN II. It was possible to obtain separated beams of Zn, Ga, Br, Rb, Ag, Cd, In, Sn, Sb, Te, I, and Cs as well as the gaseous fission products Kr and Xe. The heart of the TRISTAN II system consists of an integral target ion source combination located in the neutron beam. The ^{235}U target consists of $^{235}\text{UO}_2$ impregnated onto a graphite cloth which is placed along the inner surface of a hollow cylindrical graphite anode. The resulting fission products are thermalized in the graphite and diffuse out into the ion-source's plasma where they are ionized and then accelerated. The 1500°C temperature allows many elements to be volatilized and then separated. It is probably possible to separate the elements Ge, As, and Se with TRISTAN II, but this region has not been adequately surveyed. At the beginning of FY 1977 a decision was made to take maximum advantage of the new activities available, and all measurements on gaseous fission products using the older style stearate targets were terminated. The major effort is now concentrated on the study of the decay of even-A Ag, Cd, and In nuclei with mass numbers between $A = 118$ and 128 . Accumulation of data on the decays of ^{118}Ag , ^{120}Ag , ^{122}Ag , ^{126}Cd , ^{126}In , ^{128}In , ^{78}Zn , and ^{78}Ga has been completed, and analysis of the data is in progress. The Ames Laboratory Research Reactor (ALRR) will terminate operation at the end of December 1977 and subsequently TRISTAN will move to the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory (BNL). Most of the effort for FY 1978 will be directed towards disassembling the TRISTAN system and shipping it to BNL for reassembly on beam line H2 at the HFBR. It is estimated that TRISTAN can be reassembled by the end of FY 1978, and that the experimental program will begin in the middle of FY 1979.

ARGONNE NATIONAL LABORATORY
Physics Division

Charged Particle Research at Dynamitron and Tandem
AK-01-01-01-1 FY 1978 \$843,000

G. T. Garvey, J. P. Schiffer, C. N. Davids, A. J. Elwyn, J. R. Erskine,
W. Henning, R. E. Holland, L. Meyer-Schützmeister.

The charged-particle research at the Dynamitron consists of two major research efforts. The largest is an ongoing investigation into highly-exothermic reactions involving light nuclei. The reactions studied are selected on the basis of their intrinsic interest to nuclear physics, astrophysics, and their potential use as clean fuel for schemes employing inertially confined plasmas. All two-body final states in the reaction ${}^6\text{Li}(d, x)y$ have been measured to 10% accuracy over the interval $0.1 E_d \leq 1.0$ MeV. These results are now being analyzed in terms of an R matrix theory. The other venture is a new undertaking at Argonne wherein the effects of induced weak currents are studied in nuclear beta decay. A chamber for the precise and detailed study of the angular correlation between beta rays and subsequent decay- α particles in the $A = 8$ system has been constructed and data taking is under way. The fundamental issues addressed in this experiment are: (1) "Do second-class currents exist?", and (2) "Is the Conserved Vector Current (CVC) hypothesis correct?" Further efforts in the weak interaction program involve a measurement of the $\Delta T = 1$ parity mixing between the 5.166 and 5.112 MeV levels in ${}^{10}\text{B}$. This experiment is now in the construction phase and data taking should begin in the fall. The experiment is especially sensitive to the neutral weak interactions between hadrons.

The light-ion research at the Tandem accelerator covers a wide range of topics in nuclear spectroscopy. These range from studies of the structure of the actinide nuclei to the investigation of giant resonance phenomena. The actinide research uses simple pickup and stripping reactions to gather data on the spectra of these heaviest nuclei and further investigate their single particle structure. Giant resonance phenomena are investigated using the radiative capture of α particles. In the Ni region the E-2 capture peaks at an energy 20% above that expected for the giant E-2 resonance. Measurements looking at delayed γ rays in (α, xn) reactions have located several $d_{3/2}$ hole states in ${}^{43}\text{Ti}$. They show a 150-keV downward shift in excitation energy compared to the same levels in ${}^{43}\text{Sc}$. This is an important piece of information in trying to unravel a host of anomalous charge-dependent effects in the $A = 40$ region.

Significant progress has been made in developing high resolution high-energy γ -ray detectors. These employ a large (25 cm diameter $\times$ 25 cm long) NaI crystal and anti-coincidence shielding. At 17 MeV, energy resolution of 2.1% was achieved for two detectors.

Argonne National Laboratory
Chemistry Division

Charged-Particle Research - AK-01-01-01-1 FY 1978 \$287,000

A. M. Friedman, I. Ahmad, R. R. Chasman, M. Freedman, J. Lerner

A major portion of this research program is directed toward the study of the nuclear structure of the actinide elements by means of charged-particle reaction spectroscopy, in-beam gamma-ray spectroscopy and decay-scheme measurements. This experimental program is strongly coupled with a theoretical effort. The actinide elements constitute a particularly important series for understanding nuclear potentials and, moreover, their nuclear properties are of interest to a number of nuclear energy programs. An extensive survey of single-particle states has been completed, and the effort is now directed toward an understanding of multiparticle states and residual interactions. One member of this group is currently spending full-time on the development and implementation of a unique experiment to determine the solar-neutrino flux--a subject of considerable current interest and one which may have a major impact on our understanding of solar processes.

ARGONNE NATIONAL LABORATORY
Physics DivisionNuclear Structure Studies with Neutrons
AK-01-01-01-2 FY 1978 \$300,000

G. T. Garvey, H. E. Jackson, R. J. Holt, R. K. Smither.

The Argonne very intense, ultrahigh-resolution electron linac is the cornerstone of the photonuclear program. By using the photon induced reaction, low energy neutron energy spectra can be observed with excellent energy resolution, and the (γ, n) reaction can be utilized as a powerful tool for the spectroscopy of highly-excited individual states. In most cases, the range of excitation energies accessible to measurement can be extended beyond those available in neutron-induced reactions. Thus, threshold measurements complement (n, γ) measurements, and in many cases extend experiments to previously inaccessible classes of nuclei. A major objective of these studies is the determination of spin and parity assignments of neutron resonances. A recent major success has been the development of the ANL polarimeter for measurement of neutron polarization in (γ, n) reactions. In many cases, this latter development has made possible for the first time, unambiguous spin and parity assignments in cases of central importance to our understanding of nuclear interactions. Our results for the past two years have contributed to the resolution of major questions in nuclear structure physics, among them the question of the existence of a radiative giant M1 resonance in ^{208}Pb . The capability of the photonuclear setup has been enhanced by constructing a multidirectional beam transport system which allows angular distributions to be measured. Doubling the neutron flight path by constructing two tunnels improves the energy resolution.

Although nuclear measurements at the CP-5 reactor were terminated in July 1976, analysis of data generated in this program has continued. An extensive and very valuable body of neutron capture spectra have been gathered. We expect detailed reduction and interpretation of this data will provide useful insights into a number of questions of great current interest to our understanding of nuclear level structure. Current analysis is directed on targets in the mass region just above the closed neutron shell at $N = 82$ (Sm and Nd isotopes), the region of the so-called "transitional nuclei". The objective of this work is to compare level scheme systematics and γ -ray branching ratio systematics, in order to distinguish between the many nuclear theories which might apply.

Argonne National Laboratory
Chemistry Division

Nuclear Fission Research AK-01-01-01-2 FY 1978 \$385,000

L. E. Glendenin, J. E. Gindler, B. D. Wilkins, K. L. Wolf, B. B. Back

The program of measuring monoenergetic neutron-induced fission yields for ^{238}U at 6 neutron energies from 1.5-7.7 MeV has been completed. A similar study of ^{239}Pu from 0.1-8 MeV has begun, and future studies of ^{235}U , ^{232}Th , and ^{233}U are planned. These data will permit the computer synthesis of the fission-product mass-yield distribution to be expected from any known spectral distribution of neutrons in a reactor. Such information is essential to many aspects of reactor technology. The effect of excitation energy on fission properties also derived from this work is a subject of particular interest to theoretical interpretations of the fission process. The mono-energetic neutron fission-yield data will provide important input into evaluations of the partition of energy and the energy dependence of shell effects in fission. The nature of the fission process and the influence of excitation energy and angular momentum on fission properties are also being investigated in a number of multiparameter experiments which employ sophisticated, state-of-the-art electronic techniques and computer-based, data-acquisition systems. These experiments utilize the ANL Dynamitron, cyclotron, and Tandem Van de Graaff and take advantage of the unique facilities existing in our laboratory for the preparation of actinide targets.

Argonne National Laboratory
Chemistry Division

Heavy Element Chemistry Research AK-01-01-01-3 FY 1978 \$825,000

W. T. Carnall, H. R. Hoekstra, J. C. Sullivan, J. P. Hessler, E. J. Peterson,
R. K. Sjoblom, C. W. Williams, F. Wagner

The Heavy Element Research effort at ANL comprises several closely interacting programs in crystal and molecular spectroscopy, dynamics of reactions in solution, and inorganic solid-state chemistry. The focal point of the spectroscopy effort is the development of a fundamental understanding of energy transfer processes in the actinides and lanthanides. Absorption and fluorescence spectra of the elements in various oxidation states and phases are measured. High-resolution laser techniques and measurement of excited state lifetimes are emphasized in these studies. The data provide the basis for extensive theoretical interpretation in terms of energy level structure and mechanisms of excited-state relaxation. Fundamental mechanisms of oxidation-reduction reactions in solution are probed in a unique manner using a 20-MeV electron linac as a pulsed source of radiation. Conventional and stopped-flow spectrophotometric techniques as well as pulse radiolysis are exploited in a unique comprehensive experimental effort that provides a sound basis for interpretation of the thermodynamic and dynamic processes that characterize the chemistry of solvated actinide ions. New sensitive techniques are being developed to extend pulse radiolysis studies to extremely dilute solutions in order to probe the chemistry of actinide ions under environmental conditions. A major goal of the inorganic solid-state program is to identify and characterize stable complex phases that will be formed in the course of long-term irradiations as heavier actinides and fission products accumulate in reactor fuel elements. Chemical processes associated with long-term storage of actinide and fission product wastes in glasses or in refractory solids are also being studied.

Brookhaven National Laboratory
Chemistry Division

Nuclear Spectroscopy and Determination of Long Half Lives
AK-01-01-01-1 FY 1979 \$102,000

J. B. Cumming, G. Harbottle, P. E. Haustein, S. Katcoff

In this program new or poorly known nuclides are produced, characterized and their decay properties studied primarily to provide the data used to test and extend nuclear models. Emphasis is placed on those areas where the unique production facilities at BNL allow spectroscopic studies of nuclei far from the line of beta stability: neutron-rich species at the Medium Energy Intense Neutron Facility (MEIN) at the AGS linac and neutron deficient species at the BNL tandem Van de Graaff. Rapid and sophisticated chemical and physical procedures are developed to isolate the nuclide of interest from the much more abundant contaminating activities. 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. The spectroscopic properties measured provide a stringent test of various theories of atomic mass systematics and are pertinent to judging the validity of predictions of the existence of superheavy elements. The transmutation of materials that will be exposed to the intense neutron fields of fusion reactors will occur through the production and decay of neutron-rich nuclei. The decay properties of these nuclides thus directly affect the selection of materials to be used for the construction of fusion reactors.

Brookhaven National Laboratory
Department of Physics

Light Ions and General Nuclear Science AK-01-01-01-1 FY 1978 \$178,000

A. W. Sunyar, A. Z. Schwarzschild, D. E. Alburger, K. W. Jones

Research using light ions ($A \leq 4$) is carried out at both the Tandem Van de Graaff Facility and the small 3.5-MV Van de Graaff. This aspect of the Tandem program is related to that discussed under Heavy Ions in that the properties of nuclear matter and the dynamics of nuclear reactions are investigated by means of reactions using light-ion beams. High quality information on the properties of individual nuclear energy levels is obtained by virtue of the excellent characteristics of the Tandem beam with respect to the uniquely high energy, energy homogeneity, small size, and fine energy control. Light ions are also used to induce radio-activity for the study of problems in beta decay such as the systematics of decay rates based on half-life measurements. At lower energies similar studies are made using the 3.5-MV Van de Graaff which is a rather completely instrumented machine that can be operated with a minimum of maintenance. The small Van de Graaff has the additional capability of producing a triton beam and is one of the few accelerators in the world so equipped. Some of the work with this machine is done in direct response to questions posed by experiments carried out at the Tandem. Other research programs at the small Van de Graaff are devoted to the development of techniques for quantitative localization of biologically interesting stable tracers and x-ray studies. A small amount of time is used for the production of radioisotopes, principally magnesium-28, interesting to life sciences. The small Brookhaven Van de Graaff is in fact the only facility in the world that produces the important magnesium-28 activity on a regular basis for distribution to other institutions. Studies of the decay schemes of radioactivities produced in reactors is a continuing but small part of the general nuclear science program.

Brookhaven National Laboratory
Chemistry Division

Solar Neutrino Research AK-01-01-01-1 FY 1979 \$370,000

R. Davis, G. Friedlander, J. K. Rowley

The essential source of energy in the solar system is the sun which produces energy by a series of thermonuclear reactions occurring in its interior. It is of great scientific interest to obtain direct experimental proof of the existence of these reactions and to measure their rate by direct observations. These fusion reaction rates can be measured directly by observing the neutrino radiation from the sun. An experiment has been in progress since 1968 designed to measure part of this neutrino flux using a radiochemical method based upon the neutrino capture reaction $\nu + {}^{37}\text{Cl} \rightarrow {}^{37}\text{Ar} + e^-$. It has been found that the flux of high energy neutrinos is lower than was anticipated by theoretical calculations. Current observations with improved sensitivity indicate that the flux of solar neutrinos is at least a factor of three lower than theoretical predictions. These results have raised serious doubts about our understanding of the solar energy generating processes. Present efforts are aimed at maximizing the information output of the present experiment and searching for possible correlations between catastrophic astrophysical events (collapsing stars) and ${}^{37}\text{Ar}$ production rates with the installation of a cosmic ray muon detector around the chlorine detector. An important part of the present program is directed toward development of new radiochemical solar neutrino techniques capable of observing the low energy neutrinos produced by the basic proton-proton reaction and not detected in the present experiment. Two systems are being studied: one based on the neutrino capture reaction ${}^{71}\text{Ga}(\nu, e^-){}^{71}\text{Ge}$ and the other based on the ${}^7\text{Li}(\nu, e^-){}^7\text{Be}$ reaction. Observation of these low energy neutrinos would provide a relatively model independent verification of the p-p chain nuclear reaction as the dominant energy source in the sun.

Brookhaven National Laboratory
Nuclear Science Division

NATIONAL NUCLEAR DATA CENTER

Non-Neutron Data	AK-01-01-01-1	FY 1978	\$250,000
Neutron Data	AK-01-01-01-2	FY 1978	\$650,000

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 bi-annually 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 bi-annually 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.

Brookhaven National Laboratory
Department of Physics

Neutron Nuclear Measurements AK-01-01-01-2 FY 1978 \$1,370,000

R. E. Chrien, W. R. Kane, R. F. Casten

The Brookhaven High Flux Beam Reactor, HFBR, provides a number of unique beams for the investigation of nuclei using neutrons. The thermal region to a few tens of keV comprises the useful energy range. Neutron-induced reactions provide an important insight into nuclear structure. From the study of neutron resonances in the compound system the nature of the capture mechanism can be determined. From electromagnetic decays following neutron capture excited states of the residual nucleus from the ground state up to the excitation corresponding to the neutron separation energy can be probed. The resulting information provides stringent tests of various nuclear models. Experience with the (n,γ) reaction has shown that, in contrast to charged-particle transfer, it is capable of populating a wide variety of final states of differing nuclear configurations, subject only to the usual radiative selection rules on angular momentum and parity. Primary and secondary transitions provide useful information for spin and parity assignments by making use of the radiative selection rules, and these measurements are combined with coincidence and angular correlation measurements in gamma cascades. Neutron-induced reactions play an important role in the applications of fission and fusion reactions to energy production, since both processes are accompanied by the intense production of neutrons. Precise neutron cross-section measurements can furnish important technological data. Requests for such data, originating from reactor, biomedical, or industrial sources, are channeled through the DOE Nuclear Data Committee and published by the Brookhaven National Nuclear Data Center. Measurements of technologically important cross sections are made at the HFBR when the available beams and equipment match the required neutron energy range and precision. The major facilities available for nuclear physics research at HFBR include a neutron chopper, a neutron monochromator, a conversion electron spectrometer, neutron beam filters for thermal 2- and 24-keV beam energies, and a 3-crystal pair spectrometer for high resolution (n,γ) studies. At present an isotope separator is being installed for on-line studies of neutron-rich fission fragments.

Brookhaven National Laboratory
Nuclear Science Division

Linear Accelerator Studies for Electronuclear Fuel Production
AK-01-01-01-2 FY 1978 \$50,000

H.J.C. Kouts, P. Grand

The principal effort on an electronuclear fuel production program is at LASL. The design of the target end of the electronuclear fuel producer requires some attention to features of the accelerator, and interfacing with LASL on their progress in design. The work at BNL will cover three specific areas: (1) One of the key issues in regard to the cost, operation and reliability of the linac involves the amount of beam lost throughout the accelerator. The solution to this problem is almost entirely dependent upon the design of the injection systems and the first few MeV of the accelerator. It is proposed hereby, to undertake the study of the specific problems related to the injection system and low beta part of the linear accelerator. (2) Connected with target design considerations involving particle energy (range) and beam current, there is increasing evidence that the beam target interface is a critical element in the symbiosis of an accelerator reactor. Not only the beam on-target delivery has to be compatible with a reactor type lattice design, but that delivery has to be controlled. The requirements for tailoring the beam delivery on target will be studied. Calculations will be carried out to arrive at a beam transport and delivery system that will satisfy the reactor requirements and provide a design basis for an Electronuclear Fuel and Power Producer. (3) System studies will be carried out on a broad range of linear accelerators that might be used as inputs for the Electronuclear Fuel and Power Producer Economic Study. This study will lead to a good understanding of capital cost vs. operating costs optimization, expected reliability and mean time between failures, and will clearly indicate those areas where research and development can make major contributions to cost minimization and/or reliability.

Idaho National Engineering Laboratory
EG&G Idaho, Inc.

Nuclear Data Measurement and Evaluation AK-01-01-01-1
FY 1978 \$60,000

R. L. Heath, C. W. Reich

In the current plan for the International Nuclear Data Evaluation Network, to provide mass-chain evaluations on a timely basis, the Nuclear Physics group at INEL was assigned the responsibility for ten mass chains. These ten chains are situated in the mass region $153 \leq A \leq 162$. One objective of this program is to respond to that assignment. To provide a reasonable expectation of maintaining on a continuing basis a cycle time of approximately four years for these ten mass chains, it will be necessary to create and maintain the base data files for evaluation from the compilations produced by the Nuclear Data Project at ORNL. In addition to the evaluation effort, participation in the network will identify inadequacies in the data base for all the mass chains which have significant impact on the needs of nuclear data for various applications. An up-to-date knowledge of inadequacies in the data base is a necessary component of any systematic program of basic nuclear measurements designed to meet these needs for nuclear data in a timely manner.

A second objective of this program is the precise measurement of basic nuclear decay data of importance both to low-energy nuclear-structure physics and to applications in basic energy sciences. As one facet of this activity, this program represents a portion of the U.S. involvement in the IAEA Coordinated Research Program on the Measurement of Transactinium Isotope Nuclear Decay Data, presently involving seven nations. The principal investigator for this program is the U.S. coordinator/representative for the IAEA Program. During this fiscal year the core of a U.S. participation in this activity has been identified which is responsive in all categories of decay-data measurement identified by the IAEA.

Idaho National Engineering Laboratory
Allied Chemical

Absolute Thermal Fission Yield Measurements AK-01-01-01-2
FY 1978 \$60,000

W. J. Maeck

The primary goal is the measurement of the absolute fission yields for the thermal fission of ^{235}U and ^{239}Pu to improve the accuracy of the data and to reduce the discrepancies which currently exist in many fission yield compilations. Specifically, yields are being measured for the stable and long-lived isotopes of Kr, Rb, Sr, Zr, Mo, Ru, Xe, Cs, Ba, La, Ce, Nd, and Sm. The measurement technique is isotope dilution mass spectrometry. Six samples of each fissionable nuclide are being analyzed. Three of the samples received a relatively short neutron exposure giving a burnup of $\sim 2\%$, while the other three samples were irradiated to $\sim 50\%$ burnup. The fission product isotopic composition determined on the 2% burnup samples will require little or no correction for neutron capture; hence, a more accurate isotopic composition of each fission product element will be obtained. Analysis of the high burnup samples will provide information for the determination of the number of fissions by two completely independent techniques. One is based on the summation of all of the fission product atoms in the heavy mass peak of the fission yield curve, and the other is based on the difference in the number of target nuclide atoms before and after irradiation. All of the laboratory measurements for the six samples of ^{235}U were completed January 31, 1978, and the analysis of the ^{239}Pu samples will be completed by July 31, 1978. Of particular importance relative to the ^{235}U data is that the number of fissions determined by the two techniques described above was in excellent agreement ($\sim 0.5\%$). Based on the uncertainties associated with the measurement of the individual fission product nuclides, the propagated errors associated with the fission yields, in general, will be $\sim 1\%$. In addition to the measurement of thermal fission yields, a series of sample punchings from two experimental Advanced Test Reactor fuel plates were obtained and analyzed for Kr, Xe, Cs, and Nd. The Nd isotopic data clearly confirm the existence of a large neutron capture cross section for ^{147}Nd . The significance of this is that at high flux levels ($\geq 10^{14}$ n/cm/s) excess ^{148}Nd is produced which, when used in a burnup analysis, results in a high biased value for burnup. Based on these data, we now recommend using the sum of $^{145}\text{Nd} + ^{146}\text{Nd}$ rather than ^{148}Nd for the determination of burnup on highly enriched samples where there is only one dominant source of fission. The Kr, Xe, and Cs isotopic data are providing information for an isotope correlation data base to conduct diagnostic studies of burnup, spectrum hardness, and flux only based on relative isotopic data. The significant accomplishments of this program will be 1) improved and more accurate fission yield data for ^{235}U , 2) resolution of the apparent 8% discrepancy in the fission yields of the Xe isotopes for ^{239}Pu fission, and correction of previous yield data to accommodate the increase in the Xe yields and preserve mass balance, 3) improved methodology for the measurement of burnup relative to fully enriched high flux test irradiations, and 4) the initial establishment of a data base for isotope correlation studies relative to fully enriched reactor fuels.

Idaho National Engineering Laboratory
EG&G Idaho, Inc.

Measurement of Absolute Values of Nubar for Cf-252
AK-01-01-01-2 FY 1978 \$80,000

J. R. Smith

The objective of this task is to resolve a discrepancy that exists between manganese bath measurements of η and $\bar{\nu}$. The effort to resolve this discrepancy is divided into three stages. In the first stage, a detailed evaluation of the systematics of the manganese bath experiments was carried out. The second stage of the investigation was to perform such measurements and calculations as the first stage studies have shown to be appropriate for resolving key problems. The key experiment of this stage was a remeasurement of the ratio of the thermal absorption cross sections for hydrogen and manganese. The third stage of the investigation is a complete remeasurement of $\bar{\nu}$ for ^{252}Cf , using the manganese bath technique. It will be the goal of the present $\bar{\nu}$ measurement to resolve discrepancies in the detailed aspects of the experiment by the use of multiple techniques at INEL and by exchange of calibrations with other experimenters. The reason for this effort to resolve the $\bar{\nu} - \eta$ discrepancy is that the normalization of the data files for the fissile nuclei can thereby be established with greater accuracy and the files used with greater confidence. To assist in assuring the quality of the ENDF/B data, the principal investigator of this program will participate in the activities of this Cross Section Evaluation Working Group and contribute to its evaluative effort.

Lawrence Berkeley Laboratory
Nuclear Science Division

Nuclear Reactions AK-01-01-01-1 FY 1978 \$120,000

J. Cerny, H. E. Conzett

Cyclotron beams of light ions from protons to alpha particles, with maximum energies of 55 MeV for p,d and 130 MeV for α , and intensities of up to 100 μ amps are used for this work. Polarized beams of protons and deuterons of up to 400 na are used 15% of the time. Reaction products are detected by a variety of sophisticated solid state counters, both Li(Si) and Ge, and with a high resolution spectrometer. Much of the research activity goes toward investigation of light ion reaction mechanisms. Light ion reactions with unbound resonant final systems such as ^2He , $^4\text{He}^*$, and ^8Be requires a sophisticated solid state detector system and provides a comparison with more traditional transfer reactions. The polarized proton and deuteron beams are used to investigate outstanding questions and problems in nuclear physics in which the particle spin plays an important role. The on-line mass analysis system RAMA, has been completely assembled, has been through extensive off-line tests and has undergone its first few on-line tests. This system is designed to provide mass selection of any radionuclide with a half-life greater than 100 milliseconds and it should open up to detailed study a great number of currently inaccessible regions of nuclei. It basically consists of a helium jet transport system feeding nuclear reaction products, via skimmers, to a hollow-cathode ion source; beam extracted from this ion source is then magnetically analyzed.

Lawrence Berkeley Laboratory
Nuclear Science Division

88-Inch Cyclotron Operation AK-01-01-01-1 FY 1978 \$580,000

D. Hendrie

The 88-Inch Cyclotron is a variable energy isochronous cyclotron with spiral ridge focussing. The maximum energies of the output particles are 60 MeV for protons, 65 MeV for deuterons, 130 MeV for α particles and 145 MeV for ^3He . Intensities of the light ions are practically 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 buildings and shop facilities, and coordinates the use by local and external experimenters. The cyclotron operates 20 eight-hour shifts per week for the in-beam experiments in nuclear chemistry and physics, isotope production and beam development.

There are some on-going experimental programs at the 88-inch Cyclotron which do not qualify as basic nuclear research. They collectively use $\approx 6\%$ 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. Other radio-isotopes are produced for bio-medical imaging purposes. Several very low energy beams of ^3He , ^6Li , and ^{10}F ions have been developed to measure cross sections for reactions such as $^6\text{Li}(^6\text{Li}, \alpha n)^7\text{Be}$ and $^{19}\text{F}(\text{Li}, ^1\text{H})^{20}\text{Na}$ which are important in the CTR program. Currently under study is the cross section for the $^6\text{Li}(^9\text{He}, ^2\text{H})^7\text{Be}$ reaction which is of interest in fusion reactors operating on the $^6\text{Li}(^1\text{H}, ^3\text{He})^4\text{He}$ fuel cycle. Several other small programs are showing results with promising application in the geological, archaeological and environmental sciences including a technique for studying ground water flow-- a problem crucial to the question of nuclear waste storage. Other work, making use of fully stripped heavy ion beams, is in progress to improve understanding of energy loss processes which are expected to be important in developing heavy ion pellet fusion.

Lawrence Berkeley Laboratory
Nuclear Science Division

Nuclear Instrumentation and Advanced Detector Systems AK-01-01-01-1
FY 1978 \$225,000

F. S. Goulding

To provide general services in connection with electronic instruments used in the Nuclear Science Division. This includes operation of an equipment pool, maintaining files of drawings and records on instruments and providing operating manuals and a consulting service on all aspects of electronics and detectors to experimenters and graduate students. To carry out basic developmental and research work into instruments, detectors and the measurement techniques required to execute experiments in the Nuclear Science area. This also includes procuring, testing and selecting electronic components for use in these instruments. This work employs approximately three R&D electronics personnel and requires a significant amount of mechanical support. It results in substantial contributions to the whole field of Nuclear Science both outside and inside LBL. To develop and implement the on-line computer facilities required in the experimental areas at the 88-inch Cyclotron. This work involves two medium-sized computer systems used by a large number of experimental groups from LBL and from other research laboratories and universities. This project requires the services of 3 to 4 people including both electronic designers and computer programmers. To provide maintenance service on the shared on-line data acquisition computers for the Nuclear Science Division and to provide software support on operating systems for these computers. The purpose of the Advanced Detector Systems project is to develop the techniques, detectors and hardware required for major areas of nuclear research being performed at all laboratories in the United States. It is now focussed largely on semiconductor detectors and the associated electronics and on developing the techniques for applying these items to specific areas of research that are currently considered to be vital in nuclear research at the present time.

Lawrence Berkeley Laboratory
Nuclear Science Division

Table of Isotopes Preparation AK-01-01-01-1 FY 1978 \$190,000

C. M. Lederer

The project has compiled and evaluated data on radioactivity and nuclear structure and produced comprehensive data compilations for use in nuclear applications and basic research since 1940. The size of this task has increased with the exponential growth in the volume and complexity of the experimental data. The most recent (6th) edition of the Table of Isotopes was published in 1967 and has sold 16,000 copies to date. The 7th edition, begun in 1971, will be completed in the current fiscal year. The project has also compiled and published comprehensive Tables of Nuclear Moments since 1976; the most recent (3rd) was published in 1975. Since 1971, the project has developed new applications of computers to the compilation-evaluation-publication process, including unique systems for input/editing and for production of high-quality text and graphics directly from computer-stored data. The project belongs to the newly-formed Nuclear Data Network (NDN), consisting of the Nuclear Data Project (ORNL), the Table of Isotopes Project, and several smaller groups, under the management of the National Nuclear Data Center (BNL). The LBL group has been assigned continuing responsibility for compilation-evaluation of 39 mass chains (of a total of 250), and for the preparation of Nuclear Data Sheets from them on a 4-year cycle. In addition, the Table of Isotopes project has been asked to edit on behalf of the network a Radioactivity Handbook, to be abstracted from the data compiled by all members and published on a 4-year cycle.

Lawrence Berkeley Laboratory
Nuclear Science Division

Fission and Heavy Ion Studies AK-01-01-01-2 FY 1978 \$45,000

L. G. Moretto

Sequential fission of the heavy partner in heavy ion bombardment of massive targets is pursued. The probability of sequential fission is determined on the basis of missing binary coincidences. This probability can be studied as a function of atomic number of the fissioning nucleus, of its excitation energy and its angular momentum. Also the possibility of fission occurring in the field of the light partner can be investigated. The out-of-plane angular distribution of the fission fragments provides information on the equilibration of the rotational degrees of freedom and on the exit-channel interaction between the deep inelastic fragments. The number of γ -rays in coincidence with sequential fission provides additional information on the final angular momentum distribution. In the case in which sequential fission does not occur, the coincidence between the two deep inelastic features provides information regarding the energy thermalization and the equilibration of the neutron-to-proton ratio. The number of γ -rays measured in coincidence with the deep inelastic events provides information on the angular momentum transfer to the intrinsic rotation of the fragment and on its fractionation as a function of mass asymmetry.

Lawrence Berkeley Laboratory
Materials and Molecular Research Division

Actinide Chemistry AK-01-01-01-3 FY 1978 \$810,000

Norman M. Edelstein, Richard A. Andersen, Neil Bartlett, John G. Conway,
Kenneth N. Raymond, Glenn T. Seaborg, Robert Silva, Andrew Streitwieser,
David H. Templeton, Allan Zalkin

The basic purpose of this project is to study lanthanide and 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 identified and characterized by x-ray diffraction, optical and vibrational spectroscopy, and magnetic resonance and magnetic susceptibility techniques. Equilibrium constants for complex formation will be measured. Neutron diffraction studies will be done in cooperation with other laboratories. 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 the ion and generate neutral or negatively charged complexes. Both large absolute formation constants and a very high specificity for the actinide ions will be essential properties of these new sequestering agents. Such 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. Research to date has demonstrated the feasibility of an approach based on the chemistry of similar sequestering agents of biological origin which are used in microbial iron transport. Chelating agents incorporating hydroxamate and catecholate functional groups as the chelating moieties will continue to be investigated. The preparation, structural, and physical studies of new types of organoactinide, related organolanthanide, and new actinide inorganic complexes will continue to be studied. Studies on the optical spectra of free atoms and ions of the actinide series, and on actinide ions in crystals in collaboration with other DOE laboratories will be pursued with special emphasis on free ions which have the same oxidation state as found in chemical compounds. Collaborative experiments will continue with the laser isotope separation group at LLL to measure accurately the ionization potentials of elements of the lanthanide and actinide series.

Lawrence Livermore Laboratory
Physics Division

Studies of hydrogen and Helium Production Induced by 14 MeV Neutrons
AK-01-01-01-2 FY 1978 \$100,000

R. C. Haight, S. M. Grimes - Lawrence Livermore Laboratory

Cross sections for the production of isotopes of hydrogen and helium by 14-MeV neutrons, of interest to the development of fusion reactors are being measured. A knowledge of these cross sections is essential to the choice of materials for the first wall of a fusion reactor, since the generation of hydrogen and helium affects the mechanical properties and hence the useful lifetime of the vacuum vessel. While previous attempts to measure these cross sections were in most cases limited to reactions that resulted in a measurable radioactivity, the present method can be used for any nuclide. An essential part of this research is the LLL Rotating Target Neutron Source. Charged particles, protons, deuterons, and alpha particles, from 14-MeV neutron bombardment of selected materials are focused by a magnetic quadrupole triplet lens onto detectors which are relatively far (~ 2.5 m) from the target material and the neutron source. Data have been obtained for stainless steel and its major constituent materials (Fe, Cr, Ni), and for aluminum, titanium, vanadium, and niobium. Other structural and blanket materials will be studied in the future. This is a joint project with the University of Wisconsin.

Lawrence Livermore Laboratory
Chemistry Division

Measurement of Decay Energies of Isotopes Important to the Reactor
Decay Heat Problem AK-01-01-01-2 FY 1978 \$95,000

R. A. Meyer, S. G. Prussin, G. L. Struble

The magnitude and rate of energy release from fission products is of prime importance for analysis of loss of coolant accidents in power reactor systems. The standard under development for decay power is based upon summation calculations utilizing the measured decay characteristics of the fission products. We have used the current data file ENDF-B/IV, to identify the major contribution to the uncertainty in these calculations. For times in the range of 10 s - 100 s following reactor shutdown, the main uncertainty is due to the lack of data on the decay characteristics of some 30 fission products with half lives in the range of 1 s - 3 min. This program is directed toward the measurement of the total decay energies, the γ -ray spectra and the average γ - and β - energy releases from these isotopes. Isolation of individual nuclides are being performed with rapid radiochemical separation procedures because these techniques make available isotopes of elements not available with the purely physical separation systems currently available.

Using facilities already on-line, we are completing measurements on the neutron-rich antimony isotopes with half-lives as short as 11 s. Before the end of FY 1978 we will have completed automating batch procedures for separating bromine and tellurium and have completed gamma-ray measurements on $^{86,87}\text{Br}$ and $^{135,136}\text{Te}$.

For shorter-lived species or those for which batch procedures are inapplicable, we are developing solvent extraction and high-speed centrifugation techniques. By the end of FY'78 we plan to have taken measurements on ^{147}Ce using such techniques.

As developments occur, physical techniques will be directly coupled to chemistry systems to achieve maximum flexibility and efficiency.

Los Alamos Scientific Laboratory
Physics Division

Cross-Section Measurements of Basic Fusion Reactions
AK-01-01-01-1 FY 1978 \$95,000

N. Jarmie

The goal of this project is to provide accurate cross section data in several basic light nuclear reactions in the energy range of 10 to 100 keV. The effort will be made to measure total cross sections although information on angular distributions will be obtained. Charged particles (mostly alpha particles), neutrons, and gamma rays will be detected. The intention is to provide data accurate to $\pm 5\%$. Highlights of the method will be the use of a negative ion beam, a windowless cryogenic target, a triton beam and target, and calibration of the target density using a high-energy Van de Graaff beam. The immediate call for this data comes from designers of fusion reactor systems. The reactions

1. $T(t, \alpha)2n$ ($Q = 11.330$ MeV)
2. $D(t, n)^4\text{He}$ ($Q = 17.588$ MeV)
3. $D(d, n)^3\text{He}$ ($Q = 3.268$ MeV)

are not known consistently well.

Los Alamos Scientific Laboratory
Physics Division

Fission Studies AK-01-01-01-2 FY 1978 \$115,000

H. C. Britt, J. B. Wilhelmy

The major objective of this program has been to obtain a more complete knowledge of fission phenomena with emphasis on attempting to quantitatively understand experimental results in terms of recent fundamental advances in theoretical nuclear physics. In this context the program has emphasized the following areas: (1) Measurement of fission probabilities as a function of excitation energy in the compound system near threshold to obtain information on fission barrier parameters, (2) measurements at higher excitation energies (up to 20 MeV) to obtain information on competition between fission and neutron deexcitation and (3) development of realistic microscopic statistical models so that the experimental data can be used to yield information both on the potential energy surface associated with fission (i.e. fission barrier height) and on the fundamental symmetries of the nuclear shape in the region of the fission barrier. The nuclear symmetry properties affect the number of states available for a given process and can be deduced from high energy data on competition between fission and neutron decay. The experiments generally involve the excitation of a particular nucleus using a direct reaction and measurement of fission decays in coincidence with the outgoing direct particle (e.g. (d,pf), (t,pf), (^3He ,df)---). Additionally we have produced and have been the first to study the spontaneous fission decay properties of ^{256}Cf , ^{258}Fm and ^{259}Fm . The ^{256}Cf gave results consistent with previous systematics but the two Fm isotopes are the first known cases to show substantial deviations. Both have very short half lives, extremely high kinetic energy release and result in predominant symmetric mass division. These results have cosmological significance in that they will probably inhibit the in nature production of superheavy elements via neutron capture. In this program we have also investigated the application of two of our results and techniques to practical problems associated with the generation of nuclear power. The first is using our measured fission probabilities to simulate (n,f) cross sections for a wide variety of actinide nuclei. Many of these isotopes have practical consequences in existing and proposed nuclear reactor environments but are not available for direct laboratory measurements. The second possible practical application has involved a feasibility study to determine if simulated (n,p) and (n, α) cross sections could be obtained using direct charged particle reaction techniques. The success of this approach would enable rapid measurements for stable and non stable isotopes and would provide information needed for material damage assessment of structural materials used in high neutron fluence regions.

Los Alamos Scientific Laboratory
Physics Division

Basic Neutron Measurements Relevant to MFE Design
AK-01-01-01-2 FY 1978 \$100,000

G. A. Keyworth

The objective of our work is to provide data relevant to MFE program using our unique capability to produce clean, monoenergetic neutron beams over the critical energy range (5-14 MeV). Presently, those programs being funded to provide nuclear data for MFE applications below 14-MeV incident neutron energy either use the $^2\text{H}(\text{d},\text{n})^3\text{He}$ source reaction, which has the disadvantage of having a large and unsubtractable background from three-body breakup reactions in the deuterium gas, and "white" sources that have the inherent disadvantage of producing source neutrons in the same energy range as the secondary neutrons to be observed. Use at the LASL of the $^3\text{H}(\text{p},\text{n})^3\text{He}$ reaction and the inverse reaction gives us a unique advantage in the crucial region of interest. Only with this neutron source capability can one measure the spectra of secondary neutrons down to low energies.

We propose to measure the elastic and nonelastic cross sections and emission spectra from ^7Li . These measurements will closely parallel the previous beryllium measurements, although the $(\text{n},2\text{n})$ reaction threshold is considerably higher. We will make these measurements at a sufficient number of neutron energies and angles to characterize the energy and angular dependence of the emitted spectra. We will also pursue techniques to reduce the threshold for neutron detection by improving the dynamic range of the pulse-shape discrimination electronics used with a liquid scintillator. In addition, we will also initiate measurements on $^{10,11}\text{B}$.

Los Alamos Scientific Laboratory
Physics Division

Fertile-to-Fissile Conversion (FERFICON) Physics Experiments
AK-01-01-01-2 FY 1978 \$50,000

G. J. Russell

A cooperative program is in progress with Canadian groups at Chalk River Nuclear Laboratory and Simon Fraser University to investigate the Electronuclear Fuel Production approach to creating nuclear fuel. This international cooperative effort involves using the Los Alamos Meson Physics Facility (LAMPF) and the LASL Weapons Neutron Research (WNR) facility to extend the range of proton energies for FERFICON experiments from the 350- and 480-MeV energies used at the TRIUMF cyclotron in Vancouver, B.C., to the 800-MeV level available at LAMPF. In the LAMPF/WNR experiments, the number of leakage neutrons per proton, the fertile-to-fissile conversion ratios, and the energy deposition distributions are being measured for a few selected TRIUMF target configurations of Pb, Th, and depleted U. The Canadians have provided Th and U rods for use as targets. The results of the experiments will be compared with calculated predictions. The WNR proton beam line has been modified to accept the FERFICON experiment, and the equipment for the experiment has been installed. Measurements of leakage neutrons per proton have been started using a 9.85-cm-diam by 40.67-cm-long Pb target.

Los Alamos Scientific Laboratory
Accelerator Technology Division

Accelerator Studies for Electronuclear Fuel Production AK-01-01-01-2
FY 1978 \$300,000

E. A. Knapp, D. A. Swenson, T. J. Boyd, R. A. Jameson

An in-depth study of the parameters of a high current proton linear accelerator system designed to achieve reliable cw performance with minimal beam loss will be undertaken. Components of this study will include:

1. Preaccelerator System
2. Drift Tube Accelerator System
3. Coupled Cavity Accelerator System

At the end of Phase I, an accelerator configuration should tentatively be chosen, with frequency, length, gradient, beam properties, focusing schemes, and other parameters investigated and initial choices made. As these choices are made, they lead logically into a second phase, that of component prototype testing and evaluation.

Los Alamos Scientific Laboratory
Theoretical Division

Physics of Production and Transmutation of Nuclei AK-01-01-01-2
FY 1978 \$215,000

P. G. Young, T. R. England, G. M. Hale, E. D. Arthur, D. G. Madland,
D. Dodder

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 $A = 2, 4, 5, 7, 8$, and 11 . Methods of implementing charge independence in R-matrix analyses and other basic developments are being investigated.

Development of compound nucleus, statistical, preequilibrium, and direct reaction theory models, and studies of parameters 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 region of strong nuclear deformation, the optical potential is deformed by use of the coupled-channel formalism and collective model.

Development of fission yield theory is carried out for the purpose of deriving more reliable fission-yield 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 the properties and distributions of fragments beyond the scission point. Most of the required fission-yield data can then be extracted from the fission fragment distributions. Concurrently, the phenomenological fission yield relationships utilized in the ENDF/B evaluated data files will be reformulated as advances are made in fundamental yield theory.

Evaluation support is provided by BES-sponsored measurement programs so that new experimental data are promptly incorporated into ENDF/B evaluated nuclear data files. This list of nuclei for which LASL has primary ENDF/B responsibility includes ^1H , ^2H , ^3H , ^3He , ^4He , ^6Li , ^7Li , ^9B , ^{11}B , ^{14}N , ^{15}N , ^{16}O , ^{27}Al , Sn , ^{182}W , ^{183}W , ^{184}W , ^{186}W , and ^{233}U .

Los Alamos Scientific Laboratory
Chemistry-Nuclear Chemistry Division

Chemistry of Oxo-Complexes of the Light Actinides,
Theory and Experiment AK-01-01-01-3 FY 1978 \$85,000.

Robert A. Penneman, P. Gary Eller, and Gordon Halstead (Post Doc).

A principal objective of the proposed research is to extend our knowledge of the chemical and structural properties of early pentavalent oxo-complexes and other related compounds of the light actinides, and to carry out horizontal comparisons of chemical bonding along a series of actinide compounds. Specifically, we wish to elucidate the seemingly paradoxical d-block chemical nature of protactinium compared to the f-block nature of the heavier elements. We wish to investigate the basis of the putative instability of the "yl" oxo-cations UO_2^+ and PaO_2^+ . The significance of the study lies in the importance of a fundamental understanding of the chemistry of these elements and higher actinides related to nuclear waste problems, the behavior of these elements under the "oxo-favoring" conditions frequently encountered in waste handling schemes and in the biosphere, and the possibility of utilizing "soft" ligands for chelation and stabilization.

Los Alamos Scientific Laboratory
Chemistry-Materials Science Division

Thermodynamics of Transplutonium Elements and Early Actinides
AK-01-01-01-3 FY 1978 \$65,000

John W. Ward

This research program will pursue the measurement of thermodynamic properties of actinide elements and compounds by high temperature gaseous effusion and mass spectrometric techniques, concentrating particularly on those systems for which there are at present little data (or for which the data appear unreliable). The pure metals will be examined first; subsequent studies will include actinide oxide systems, alloys, and other compounds. The experimental data will be used in the correlations of thermodynamic and electronic properties of the study of spin-orbit splittings, apparent valence changes with temperature, and magnetic states defined by complex coupling schemes. Combination of precise vapor-pressure values with thermodynamic functions calculated on the basis of electronic properties allows tabulation of heat capacity, heat content, and entropy data from room temperature to the boiling point. The increase in the stability of the dipositive valence state in the heavy actinides will be studied, utilizing newly-developed vaporization techniques from appropriate liquid-metal solvents.

Oak Ridge National Laboratory
Physics Division

Light Ion Nuclear Physics AK-01-01-01-1 FY 1978 \$295,000

C. D. Goodman, F. Bertrand

This research deals with fundamental questions of how nuclei absorb and release energy. The program utilizes three different experimental techniques for exciting nuclei. With coulomb excitation collective modes of nuclear motion are excited through the electromagnetic interaction. With inelastic scattering of protons, deuterons and alpha particles, the different isospins and spins of these probes are exploited to help interpret the nature of giant resonances excited by these probes. With (p,n) reactions very simple rearrangements of nucleons are excited, and these simple excitations can be picked out of the complex spectra of nuclear excitations. Once these specially simple excitations are identified, the cross sections for exciting them can be used to deduce characteristics of the effective interaction between nucleons and nuclei. The (p,n) program is a collaboration between ORNL and the Indiana University Cyclotron with the additional participation of Ohio University, Kent State University, and Florida A and M University. Some of the inelastic scattering measurements were made at the cyclotrons in Grenoble, France, and in Groningen, The Netherlands. The Indiana cyclotron is also being used in this work. Vanderbilt University participated in the coulomb excitation work.

Oak Ridge National Laboratory
Physics Division

Nuclear Data Project

AK 01 01 01 1 FY 1978 \$390,000

AK 01 01 01 2 FY 1978 \$120,000

W. B. Ewbank

The Project operates as a comprehensive, integrated data evaluation center which includes features of a technical documentation center, a scientific research group for data evaluation, and a center for preparation of special publications. In addition to these self-contained activities, NDP provides technical leadership and guidance for national and international networks of nuclear structure data evaluation.

A. Technical Documentation Center (NSR)

In support of its data evaluation work, the NDP maintains a complete indexed bibliography to nuclear structure references (NSR). The bibliography is computer-based and serves as an international resource for scientific and technical research workers.

B. Scientific Data Center (ENSDF)

The evaluated nuclear structure data file (ENSDF) summarizes the experimental knowledge about each nucleus, each reaction, and each decay scheme. ENSDF is a valuable source of established data for use in calculations, in systematic studies of nuclear properties, and in preparing standard collections of accepted data.

C. Scientific Data Evaluation Group

The NDP data evaluation group consists of scientists who are skilled in understanding and interpreting experimental results from radioactivity or nuclear reactions. The principal activity of this group is to review and update the evaluated data file (ENSDF), as new experimental results appear. The scientists of the NDP evaluation group also provide a pool of experienced talent which can be focussed onto specific evaluation problems as required by other DOE programs.

D. Publications (*Nuclear Data Sheets*)

The NDP publications group uses the master files of bibliographic and numeric data to prepare camera-ready copy for its journal *Nuclear Data Sheets*. The computer programs which perform these tasks have been designed to take advantage of hardware and software maintained by the central computer facility (CSD) in support of extensive information center activities at ORNL.

E. Nuclear Data Networks

With the establishment of a national and international network of data evaluators, NDP has assumed additional responsibility to provide technical leadership for the network. NDP must direct a share of its resources toward helping other groups prepare high quality data evaluations that can be merged into ENSDF. The NDP data evaluation group has a reduced evaluation responsibility (~ 100 A-chains rather than ~ 200), which can be maintained on the four-year cycle requested by DOE with a scientific manpower commitment of 6 MY/y.

Oak Ridge National Laboratory
Physics Division

Operations - Oak Ridge Electron Linear Accelerator AK-01-01-01-2
FY 1978 \$945,000 J. A. Harvey and R. W. Peelle

The Oak Ridge Electron Linear Accelerator (ORELA) provides 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 to obtain the cross section information required for optimum design of energy systems. Neutron cross section measurements made by the time-of-flight method require an intense pulsed-neutron source which is best provided 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 linac at BCMN in Geel, Belgium has been upgraded and major improvements are being made to the linac at AERE-Harwell in England. 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, Neutron 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 40 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,alpha) reaction cross sections, $\bar{\nu}(E)$, and the gamma-ray spectra from capture and inelastic scattering.

Oak Ridge National Laboratory
Physics Division

Basic Neutron Physics Research AK-01-01-01-2 FY 1978 \$475,000
J. A. Harvey, J. L. Fowler, 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 five types of experiments: 1. High-resolution differential elastic (and inelastic) scattering measurements up to ~ 2 MeV to determine the ℓ -values of resonances. 2. High-resolution total cross section measurements from 0.01 eV to 40 MeV to study 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. The J^π and neutron widths of resonances obtained from total cross section measurement are needed to interpret most partial cross section data. 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 E2, 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. 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
Neutron Physics Division

Nuclear Data for Fusion and Fission Reactors AK-01-01-01-2
FY 1978 \$365,000

D. C. Larson, G. L. Morgan, R. R. Spencer, C. Y. Fu

The work undertaken under this program is designed to provide 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 MFE. The Oak Ridge Electron Linear Accelerator, ORELA, is used to obtain neutron interaction and gamma-ray production cross sections for some nuclides over the complete energy range of interest to MFE. Work concentrates on nuclides, partial cross sections and energy regions unique to MFE 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 in the U. S. national reference evaluated data file system, ENDF/B, so that they become directly usable in MFE transport applications. 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. $\bar{\nu}_p$ of ^{252}Cf . 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 most conveniently carried out by a simultaneous comparison (ratio measurement) with a ^{252}Cf spontaneous fission neutron source. Thus any uncertainty or error in the value of $\bar{\nu}_p$ for ^{252}Cf directly affects power reactor designs. A measurement of this important standard to the desired uncertainty of $\sim 1/4\%$ will be carried out 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 work involves development and calibration of counting devices, measurement, data analysis, and supportive neutron and gamma-ray transport calculations.

Oak Ridge National Laboratory
Chemistry Division

Nuclear Chemistry: Nuclear Reactions & Structure
AK-01-01-01-2 FY 1978 \$85,000

R. L. Hahn, J. Halperin, R. W. Stoughton

In the realm of neutron physics, we make measurements at ORELA of neutron cross sections pertinent to the optimization of fission and fusion reactor operation, permitting the realistic evaluation of nuclear parameters in planned and existing reactors. To this end, we obtain cross sections of fissile and fertile nuclides, structural materials, fission products, standards, and actinides on priority listings of needed neutron cross-sections. In addition, our neutron multiplicity counter, which is unique in the U.S.A. (similar instruments exist in the U.S.S.R. and Germany), is used to search for superheavy elements.

Oak Ridge National Laboratory
Physics Division

Actinide Neutron Cross Sections AK-01-01-01-2 FY 1979 \$345,000

J. W. T. Dabbs, S. Raman

This program is intended to provide the data base for an adequately detailed knowledge of the formation, burnup and removal of actinide nuclides ($Z \geq 90$) in all types of reactors, thermal, fast, and thermonuclear. These data are required for long range planning of actinide management. Actinide management planning is important to a number of aspects of the national nuclear energy program. The ability to predict actinide formation, burnup, removal and decay is basic to any realistic assessment of the problems involved in handling, shipping, storing, safeguarding and processing of spent fuel. Facility design for processing and waste disposal strongly depends on the net production of several of these nuclides. The data are also needed to evaluate various secondary waste processing methods.

- 1) This work includes differential neutron fission, capture and total cross section measurements of Th, U, Np, Pu, Am, and Cm isotopes and on other isotopes as the need appears to be present. The choice will be made on the bases of need, quality of existing data, and feasibility. About 18-20 such measurements appear to be strongly needed at present.
- 2) An important aspect of the program in FY 79 and 80 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. At least one discrepancy of a factor 2 has already been found in the first such "integral experiment" sample.
- 3) Measurements of capture cross sections for certain of these nuclides will be extremely difficult or impossible. The work will therefore include attempts to calculate the capture cross sections, using total cross section measurements and a sophisticated statistical model code.
- 4) Sensitivity and uncertainty analyses will be used to analyze the results and help guide the program.
- 5) An "Actinide Newsletter" is published annually for the purpose of improving world-wide coordination in actinide research.

Oak Ridge National Laboratory
Chemistry Division

Chemistry of Transuranium Elements and Compounds AK-01-01-01-3
FY 1978 \$765,000

Richard L. Hahn, Gary Beall, John H. Burns, Richard G. Haire, Bruce H. Ketelle, Manfred O. Krause, G. D. O'Kelley

The main thrust of this research program is to obtain fundamental information about oxidation states and potentials, electronic configurations, electron interactions, thermodynamic data such as heats of solution and sublimation, and crystal structures of the actinides and transactinides. We achieve this end in two distinct ways: 1) by studying weighable amounts of the HFIR-TRU produced actinide elements (up to einsteinium) at the Transuranium Research Laboratory with such measurement techniques as x-ray and electron diffraction, photoelectron and x-ray spectroscopy, spectrophotometry, and magnetic susceptibility; and 2) by using targets of the heaviest actinides such as ^{248}Cm , ^{249}Bk , ^{249}Cf and ^{254}Es with heavy ions at ORIC to produce atoms of the transfermium elements, often at the rate of a few atoms per experiment. In the latter category, techniques such as solvent extraction, ion exchange and polarography that are currently being used and developed for elements 101 to 106 will also be applicable at the new Holifield Heavy-Ion Research Facility. New research programs are developing in areas that are relevant to questions pertaining to nuclear power. A systematic study, in collaboration with other members of the ORNL Chemistry Division, is being conducted on the ion-exchange behavior of different minerals with such elements as cesium, strontium, the rare earths and the actinides. This work is germane to the nuclear waste isolation program. A second program is being initiated on the study of the solution chemistry of heavy elements, starting with measurements of complexation constants and reaction rates of the actinide and lanthanide elements with various ligands. Such basic information can be useful for the development of improved separation schemes and for predicting uptake and mobility of actinides in the environment. A third program has begun to investigate the feasibility of assaying underground fluids, such as oil, water and gas, for uranium decay products as a way of exploring for uranium. Fruitful discussions have been held with representatives of the Amoco and Socony-Mobil Oil Companies, to exchange information and to obtain the samples needed in the initial tests of the method.

Oak Ridge National Laboratory
Chemical Technology Division

Electromagnetic Isotope Separation AK-01-01-02-1 FY 1978 \$1,100,000

Eugene Newman

The purpose of this program is to provide multigram quantities of highly enriched separated stable and selected radioactive isotopes, including the actinides, to both the research and commercial communities. These isotopically enriched materials are used in determining basic nuclear properties, in determining neutronic data for design and operation of fission and fusion reactors, as mass spikes for analytical determinations, and as target material for the production of radiopharmaceuticals used in nuclear medicine. An important aspect of the program is the research and development activities in ion source technology, beam dynamics, ion retention, and chemical recovery procedures. The program is responsible for the production, distribution, quality control, and reprocessing of the material in the Research Materials Collection.

Oak Ridge National Laboratory
Operations Division, Chemical Technology Division, Solid State Division

Special Isotope Preparations AK-01-01-02-2 FY 1978 \$6,270,000

R. V. McCord, L. J. King, J. E. Ratledge, E. H. Kobisk

The prime purpose of the HFIR is to produce research quantities of ^{252}Cf and other transuranium isotopes. As a secondary purpose, the HFIR has facilities for performing miscellaneous irradiations, tests, and experiments. A hydraulic rabbit tube in the center of the flux-trap region provides probably the highest thermal-neutron flux available, 3×10^{15} neutrons/cm²·sec, for short-term irradiations. Six peripheral positions in the flux-trap region are ideal for fast-neutron irradiation-damage studies of structural materials. A pneumatic rabbit tube, for activation analyses, is also in routine operation in a reflector region where the thermal-neutron flux is 6×10^{14} neutrons/cm²·sec. Neutron-diffraction experiments are being conducted at each of the four beam tubes. The Transuranium Processing Plant (TRU) is the production, storage, and distribution center for the DOE heavy element research program. TRU is a remotely-operated, hot-cell, chemical processing facility of advanced design. It functions integrally with the researchers, 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 μg of ^{257}Fm . Reprocessing of stored ^{252}Cf produces about 100 mg of ^{248}Cm per year. Approximately 75 shipments to researchers are made per year. This program provides for the research and development associated with isotope target preparations and other forms of research materials.

Pacific Northwest Laboratory (Battelle)

Fission Yield and Delayed Neutron Studies with an On-Line Mass Spectrometer AK-01-01-01-2 FY 1978 \$175,000

P. L. Reeder

The experimental work in this program is based on use of an on-line mass spectrometer, SOLAR (Spectrometer for On-Line Analysis of Radionuclides). The SOLAR facility consists of a fissionable target contained in a surface ionization source located in a high neutron flux. Fission product ions of particular elements are accelerated from the ion source and are analyzed by a magnetic mass spectrometer. About 60 isotopes of the elements Br, Rh, Sr, In, I, Cs and Ba have been observed. The SOLAR facility has unique capability for measuring both independent and cumulative fission yields of short-lived fission product isotopes and for providing continuous sources of chemically and isotopically separated nuclides for nuclear spectroscopic studies. The following experimental measurements are planned.

1. Highest priority is being given to the remeasurement of delayed neutron emission probabilities (P_n) by both the direct ion counting and beta counting techniques in order to resolve the existing discrepancies in published values.
2. Delayed neutron energy spectra are being obtained for as many of the following nuclides as possible (dependent on counting rate limitation) - $^{87-92}\text{Br}$, $^{92-98}\text{Rb}$, $^{128-130}\text{In}$, $^{137-141}\text{I}$, and $^{141-146}\text{Cs}$ in addition to the $^{93,94,95}\text{Rb}$ and ^{143}Cs spectra already measured.
3. Measurement of gamma spectra will continue for all the nuclides listed under 2. with particular emphasis on the halogen precursors. These measurements provide data on P_n , the $\beta\gamma$ process and n,γ competition.
4. Neutron-gamma coincidence measurements will be performed on as many precursors as possible to assist in interpreting the delayed-neutron spectra.
5. Cumulative yields of 14 In isotopes will be measured for thermal neutron fission of ^{235}U . These yields will then be compared to the estimated values given in Meek and Rider's compilation.
6. Isomer yield ratios will be measured for thermal neutron induced fission of ^{235}U for the following fission products: ^{90}Rb , $^{117-123, 125, 127, 129}\text{In}$, $^{133, 134, 136}\text{I}$.

SECTION B

UNIVERSITIES

University of Colorado
Nuclear Physics Laboratory

Nuclear Physics Research at Low Energies AK-01-01-01-1 FY 1978 \$475,000

R. E. Anderson, J. J. Kraushaar, D. A. Lind, R. J. Peterson, R. A. Ristenen, W. R. Smythe, C. D. Zafiratos, C. S. Saidins

Includes the operation of the 132-Cm variable energy AVF Cyclotron (maximum energies: protons, 28 MeV; deuterons, 17.5 MeV; ^3He , 44 MeV; ^4He , 35 MeV). The facilities at the Laboratory for the study of the ($^3\text{He},n$) reaction are unique and a series of important investigations is proposed using the reaction. These include proton pairing studies in the Pb region and near the N=82 and Z=50 shell closures, as well as other nuclei that are of particular interest such as ^{90}Zr . A variety of charged particle reaction studies are proposed. The role of two-step processes in single neutron and proton transfer reactions will be emphasized this year in contrast to the (p,t) and ($^3\text{He},t$) reactions since finite range coupled channels calculations are not required. The (α,p) reaction has been shown to be an excellent tool for locating states with high spin (up to a spin of 11). The reaction not only identifies these states, but also provides spectroscopic factors and a number of studies taking advantage of these features are proposed.

Columbia University
Department of Mechanical and Nuclear Engineering

Nuclear Fission Studies and Neutron Spectroscopy AK-01-01-2
FY 1978 \$100,000

W. W. Havens, Jr., E. Melkonian

The current research program uses the Oak Ridge Electron Linear Accelerator (ORELA) at Oak Ridge as a pulsed neutron source for time-of-flight measurements. The main areas of research are:

1. Fission measurements on the isotopes ^{229}Th , ^{233}U , ^{235}U and ^{239}Pu . Event-by-event data are recorded for both the time-of-flight of the neutron inducing fission as well as energies (actually pulse heights in the solid state detector) of both fission fragments in coincidence. Improved results are to be obtained for the fission fragment mass distributions, the single fragment kinetic energies and the total kinetic energies for the various resonance levels.
2. Transmission measurements for cooled ^{229}Th samples in cooperation with ORELA staff.
3. The capture cross section measurements on ^{169}Tm and ^{197}Au which have been performed at ORELA using our Moxon-Rae detectors have been analyzed and are being prepared for publication. Good correspondence in the overlapping energy interval with earlier Nevis data was observed.

Denison University
Department of Physics

Determination of Neutron Cross Sections and Resonance Parameters
AK-01-01-01-2 FY 1978 \$14,000

R. R. Winters

Neutron total, inelastic and capture cross sections over the energy range 2-1000 keV will be made using isotopically enriched samples of ^{186}Os , ^{187}Os and ^{188}Os . The osmium cross sections are of particular significance in understanding the processes of element formation. In particular, two isotopes of osmium are produced by only the slow (s)-process of nucleosynthesis. However, the abundance of ^{187}Os is enhanced by the β decay of ^{187}Re to ^{187}Os with a half-life ~ 44 b.y., a time long compared to current estimates of the age of the universe. Using the s-process nucleosynthesis theory and the measured values of the cross sections [including that for the inelastic reaction $^{187}\text{Os}(n,n')$], an estimate of the age of the universe can be made. The neutron total and capture measurements will be made at the Oak Ridge Electron Linear Accelerator in collaboration with Dr. R. L. Macklin and Dr. J. A. Harvey. Two independent estimates of the $^{187}\text{Os}(n,n')$ cross section are planned. One approach is a scattering measurement utilizing the NBS linear accelerator and a detector system developed at the Lawrence Livermore Laboratory. This will be a collaborative effort with Drs. B. L. Berman and J. C. Browne, Livermore, and Dr. M. Meier, of the NBS in Washington, D.C. The other approach will make use of the rapid decrease (the Wigner Cusp) in the $^{187}\text{Os}(n,\gamma)$ cross section as the inelastic channel opens.

The tellurium isotopes are also of interest to nucleosynthesis and analysis of the capture data is presently on-going.

Previous work with ^{205}Tl has given some evidence that a large fragment of the giant dipole resonance is located near 500 keV. Better determinations of the parities of many resonances above 200 keV are needed in order to more carefully test this suggestion. This work will be done in collaboration with J. A. Harvey and Dan Horen of ORELA.

Duke University

Triangle Universities Nuclear Laboratory (TUNL)

Studies of Nuclear Structure Using Neutron and Charged Particles

AK-01-01-01-1 FY 1978 \$540,000

AK-01-01-01-2 FY 1978 \$190,000

H.W. Newson, E.G. Bilpuch, N.R. Roberson, R.L. Walter

The Triangle Universities Nuclear Laboratory was initiated and continues to operate as a cooperative research facility of Duke University, the University of North Carolina at Chapel Hill, North Carolina State University at Raleigh and the United States Department of Energy. The Laboratory is located on the campus of Duke University and the major funding for the operation of the installation is through the Duke contract which also supports the research programs directed by the four Duke faculty members. The Duke contract accounts for 75 percent of the total Department of Energy support for TUNL and it provides for new equipment, replacement parts, maintenance, and the technical support personnel. Approximately 20 students pursuing their Ph.D. degrees in nuclear physics are in training at TUNL. The facility consists of a Cyclo-Graaff accelerator (a 31-in AVF cyclotron that injects a 15 MeV proton or 8 MeV deuteron beam into an FN tandem Van de Graaff) which provides 31 MeV protons or 24 MeV deuterons, and two single-stage Van de Graaffs with terminal voltages of 4 MV and 3 MV respectively. Most of the major research projects utilize the wide selection of ion sources available for injection into the tandem Van de Graaff: a nanosecond pulsed beam for neutron time-of-flight measurements, a source capable of providing polarized proton and deuteron beams of moderate intensities, and three conventional sources for providing heavy ions, helium ions and intense proton and deuteron beams. The 3 MeV accelerator laboratory is a unique facility providing intense beams of proton for very high resolution studies. While the TUNL research programs are characterized by considerable variety, reflecting the interests of a large permanent staff from the three universities, the major emphasis is on light ion induced reactions. These reactions involve light, intermediate and heavy target nuclei in an attempt to discover regularities in behavior which will cast more light on the structure of nuclei and the fundamental nature of nuclear forces. Research programs currently underway are: (1) fast neutron differential cross section measurements relevant to controlled thermonuclear fusion and fission physics, (2) neutron polarization studies, (3) high resolution studies of analogue states, (4) radiative capture reactions using both neutrons and charged particles in the giant resonance region, (5) charged particle reactions induced with polarized beams (6) physics of atomic collisions between heavy ions, (7) applications of nuclear techniques to trace element studies and production of radioactive ^{150}Pm for medical studies and (8) theory of nuclear models and reactions and of nuclear phenomenology. Of the programs listed above the fast neutron measurements have the highest laboratory priority. TUNL has committed itself to devote a minimum of 25% of its effort to performing these experiments to obtain precision neutron data essential to the Division of Magnetic Fusion Energy in carrying out its mission. In summary, this contract continues to emphasize a fertile mixture of mission oriented programs with pure basic research, a mixture of great benefit to both fields and to the Ph.D. students trained at TUNL.

Florida State University
Department of Chemistry

Research in Actinide Element Chemistry AK-01-01-01-3 FY 1978 \$59,060

Gregory R. Choppin

Thermodynamic parameters for complexation of the actinide and the chemically analogous trivalent lanthanide cations by carboxylate, hydroxy and phosphate ligands and by humic acid and fulvic acids will be measured by solvent extraction, potentiometry and calorimetry in order to ascertain the complexing formation constants and the relative role of the enthalpy and entropy changes. ^1H and ^{13}C . NMR studies of the complexes of both diamagnetic and paramagnetic lanthanides will be used to obtain information on the structure of these complexes in solution. ^{89}Y and ^{139}La nmr will be investigated to ascertain the utility of these nuclei in solution structure studies. The study of the kinetics and mechanisms of solvent extraction of actinides and of their complexation by aminocarboxylates and humate will continue.

Massachusetts Institute of Technology
Spectroscopy Laboratory

Laser-Induced Nuclear Orientation Effects AK-01-01-01-1 FY 1978 \$65,000

M. Feld

Combining various aspects of laser spectroscopy and nuclear spectroscopy can lead to significant advances in both areas. The experiments underway in the MIT Spectroscopy Laboratory are based on the idea of using laser optical pumping to orient gamma-emitting nuclei in excited states. In these studies atoms whose nuclei are in excited isomeric states ("isomeric atoms") are subjected to intense resonant laser radiation. Since the atomic and nuclear states are coupled together by the hyperfine interaction, saturation of the optical transitions by the laser field can lead to alignment of the atomic nuclei. The extent of alignment is sizably enhanced by optical pumping effects. Therefore, when the laser frequency coincides with one of the hyperfine transitions of the isomeric atom, a sharp anisotropy in the angular distribution of the gamma rays occurs. By tuning the laser through the atomic resonance transition, hyperfine structure of the isomeric atom should manifest itself as a series of resonant changes in the gamma-ray angular distribution.

These resonances can be considerably narrowed by means of laser saturation methods such as Lamb-dip and laser-induced line narrowing techniques. In this way it should be possible to resolve the isomeric h.f.s. with extremely high precision, leading to new nuclear structure information. Most importantly, experiments of this type directly measure the isomer shifts in atomic spectral lines between ground and excited nuclear states. These shifts, being proportional to the difference in nuclear volumes between ground and isomeric nuclear states, give important information about nuclear deformation.

The initial experiments are studying the hyperfine structure of the isomeric atom ^{137m}Ba using a tunable dye laser. The parameters of the system are optimal for a demonstration of the effect, and the calculated laser-induced gamma ray anisotropy is quite large. Preliminary Lamb dip studies of ground state barium atoms indicate the occurrence of a considerable amount of optical pumping. The experimental results should give accurate values for the magnetic and quadrupole moments of the barium isomer and for the isomer shift, none of which are presently known.

Depending on the findings of the initial experiments, barium isomer separation experiments will be carried out. Theoretical studies of the effects of double quantum processes in the laser-nuclear system are in progress. Experimental and theoretical studies in other areas of laser-nuclear spectroscopy are also under consideration.

University of Michigan
Department of Nuclear Engineering

AK-01-01-01-2 FY 1978 \$110,000

G. F. Knoll

Extensive facilities have been developed in the Phoenix Radiation Laboratory at The University of Michigan for the irradiation, transfer, and calibration of photoneutron sources. They provide a unique capability to carry out absolute neutron cross section measurements in the technologically-important keV neutron energy range. Work has been completed on the fission cross sections of ^{235}U and ^{239}Pu at five energies ranging from 23 to 964 keV. Other fission cross section measurements now beginning will extend the same techniques to targets of ^{233}U and ^{237}Np . Absolute accuracies of 2% or less are our common measurement goals. We are also using the photoneutron sources in a nearly-completed measurement of the $^6\text{Li}(n,\alpha)$ cross section at 23 keV, and are extending our counting techniques to allow the investigation of the $^{115}\text{In}(n,\gamma)$ cross section.

SUNY/Albany
Physics Department

Measurement and Analysis of Neutron Cross-Sections AK-01-01-01-2
FY 1978 \$28,000

J.B. Garg

This research conducted under contract with the U.S. Government agencies such as ERDA, DOE (AK-01-01-01-2) FY 1978) is of great importance and value to the development of atomic energy. For reactor design it is essential to know accurate values of the average resonance parameters such as level spacing $\langle D \rangle$, neutron and capture widths (Γ_n, Γ_γ) and strength functions for difficult s -values in order to calculate the proper amount of shielding and combination of materials to be used in the reactor environment. These parametric values are obtained from a careful measurement of cross sections (total and partial) over a wide range of neutron energy with high resolution. The cross section measurements are being made with one of the world's best facility ORELA at Oak Ridge National Laboratory. The principal investigator of these research under this contract is Prof. J.B. Garg at University at Albany and the Scientific Collaborators are Drs. Jack Harvey, R. Macklin and J. Halperin of the Oak Ridge National Laboratory. In order for this program to be successful, analytical techniques based on known reaction theories are being developed and used by the application of large Computer Systems.

These programs have been developed over the past few years. Through the timely support of the U.S. D.O.E. we have been able to make a significant contribution by investigating and publishing the results on many nuclei such as ^{19}F , ^{24}Mg , ^{27}Al , ^{35}Cl , ^{40}Ca , ^{51}V , ^{55}Mn , ^{59}Co , ^{63}Cu , ^{65}Cu , ^{54}Fe , ^{56}Fe , ^{57}Fe , and ^{58}Fe , ^{66}Zn and ^{68}Zn and the results obtained from total capture cross section's in ^{63}Cu , ^{65}Cu , ^{55}Mn . This had involved the detailed analysis of more than 5000 resonances using a Multi-level R-matrix formalism. We hope to continue this research on many other nuclei of interest to the nuclear energy program as well as those nuclei which shed significant light on a better understanding of fundamental interaction of neutrons with nuclei. The nuclei to be investigated in future are Yttrium, the isotopes of chromium and scandium. Another aspect of these investigations are conducted by measuring the γ -ray spectra in (n, γ) resonances in nuclei by making use of the HFBR at the Brookhaven National Laboratory in collaboration with Dr. R.E. Chrien and his associates. To date we have completed the detailed studies in Erbrium isotopes. The average dollar support received from the U.S. Govt. for these investigations to the principal investigator has been \$25,000 per year with a similar amount provided by the University in the form of the principal investigator's salary and use of UNIVAC Computer.

University of North Carolina at Chapel Hill
Department of Physics and Astronomy

Studies of Nuclear Processes AK-01-01-01-1 FY 1978 \$115,000

E. Merzbacher, T. B. Clegg, E. J. Ludwig, S. M. Shafroth,
W. J. Thompson

The research of the Chapel Hill group is centered at the accelerators of the Triangle Universities Nuclear Laboratory (TUNL). Most experiments use proton or deuteron beams, either with high resolution or from a polarized ion source, but some measurements are made with beams of heavier ions. Isospin-forbidden resonances are studied in proton elastic scattering. One- and more-nucleon transfer reactions initiated by polarized deuterons give spins and parities of nuclear states and permit extraction of spectroscopic factors. The analyzing power of even-A selenium isotopes is investigated with polarized protons and sheds light on the isospin dependence of nuclear parameters in the vicinity of neutron shell closure at $N=50$. The experimental and theoretical program share the common goal of an improved understanding of spin-dependent features of optical potentials, which before the availability of strong polarized beams as at TUNL had to be inferred indirectly. Systematics of nuclear deformation in light nuclei will be determined and new data tables prepared.

The theory of the interaction of fast (MeV) ions with atomic electrons will be further developed. Calculations are underway of ionization, energy loss, and charge transfer phenomena, which can have an important bearing on the technology of ion beam physics (as in some proposed heavy-ion induced fusion schemes for energy production). The need is for moderately reliable predictions of ion-atom collision cross sections for arbitrary projectiles and targets and broad ranges of relative velocity.

A careful analysis is in progress of the effects of atomic electrons on nuclear measurements, such as Q values, beta endpoint energies, and resonance parameters.

A long-range program to improve the characteristics of the polarized ion source continues. Substantial increases in metastable beam intensities are expected, and many technical improvements are projected to upgrade the performance of the Lamb-shift polarized ion source both in intensity and beam quality.

North Carolina State University
Department of Physics

Nuclear Research at the Triangle Universities Nuclear Laboratory

AK-01-01-01-1 FY 1978 \$60,000

AK-01-01-01-2 FY 1978 \$40,000

L. W. SEAGONDOLLAR, A. W. WALTNER, D. R. TILLEY, G. E. MITCHELL, C. R. GOULD

At TUNL, the above faculty do research in collaboration with physicists from Duke University and the University of North Carolina at Chapel Hill. Gould and Seagondollar are in a group that measures neutron cross sections that are needed in proposed controlled thermonuclear reactors; using the improved TUNL time of flight system. Improvements just completed are a new accelerator beam leg exclusively for neutron work using t-o-f, a new 6-meter, massively shielded neutron detector (to supplement the previous 4-meter detector) and a tritium gas target system. The improvements are functioning, debugging is well underway, and data taking is started. Scattering cross sections of ^{10}B and ^{11}B are being measured. ^{208}Pb and perhaps other heavier nuclides will be investigated. Also, measurements will be made of continuum neutron emission spectra from B, Fe, and other isotopes contained in stainless steels. Mitchell (with Bilpuch of Duke) will continue high resolution studies of the fine structure of analog states. Analysis will be completed on the ^{44}Ca , ^{46}Ti , ^{56}Fe and ^{48}Ti data already obtained. New measurements on ^{54}Fe will be made to extend present methods of analysis to f- and g-wave resonances. Preliminary experiments will be done to evaluate empirically the feasibility of studying such analogues in ^{55}Mn , ^{59}Co and ^{63}Cu . Elastic scattering experiments have been done on ^{26}Mg and ^{91}Nb . Experiments are planned on ^{64}Zn and ^{66}Zn . Tilley (with Roberson of Duke) will do radiative capture measurements and giant resonance studies. Study of $^{13}\text{C}(p,\gamma)^{14}\text{N}$ will be continued; special emphasis will be placed on transitions to the $0^+ T = 1$ first excited state. Cross section and polarization analyzing power angular distributions will be studied for $^{13}\text{C}(d,\gamma)^{15}\text{N}$ with polarized deuterons at $E_d = 6.74 \text{ MeV}$, and 90° cross sections for $3.0 \geq E_d \geq 6.74 \text{ MeV}$. Waltner (with Shafroth of UNC-CH) will continue the heavy ion experiment $^{59}\text{Co}(^{16}\text{O},X)Y$ using stacked foils to obtain additional points in the excitation function and using in-beam spectroscopy to explore reactions resulting in short lived activities or in stable residual nuclei. Exploration of other projectile target combinations will be made using computer code OVERLAID ALICE. ^{35}Cl will be the first possibility investigated but other projectiles will be considered when the TUNL sputter ion source becomes available and its capabilities known.

Ohio University
Accelerator Laboratory, Physics Department

Structure Studies of Light Nuclei by Neutron Interactions
AK-01-01-01-2 FY 1978 \$85,000

R.O. Lane

The knowledge of interactions of neutrons with light nuclei is important to the nuclear energy program for fusion reactor design, proper shielding and blanket calculations, tritium breeding predictions and determination of accurate standard cross sections. Neutron interactions are also vital probes to study the structure of light nuclei and to establish valid theoretical models of these nuclei from which other needed but difficult-to-measure cross sections may be calculated. A large set of data on differential elastic scattering cross sections has already been measured for ${}^6\text{Li}$, ${}^7\text{Li}$, ${}^{10}\text{B}$, ${}^{11}\text{B}$, ${}^{12}\text{C}$ and ${}^{13}\text{C}$ for energies to date between 2 MeV and 8 MeV at angles from 20° to 160° using the unique subnanosecond pulsed beam facility at the Ohio University Tandem Accelerator Laboratory. A similar comprehensive set of measurements for differential inelastic scattering cross sections on these nuclides is now underway because these inelastic processes play a particularly prominent role in the effectiveness of shielding, blankets, and tritium breeding for fusion reactors. Both the elastic and inelastic scattering measurements will later be extended up to ~ 25 MeV where data from other laboratories are not available. Charged particles emitted from neutron interactions with the above nuclides and other structural materials in fusion reactors can produce serious damage and substantial radioactivity in those materials. To measure these cross sections up to ~ 25 MeV for these applications and for incorporation in more complete theoretical nuclear model calculations, plans together with some preliminary design work are moving ahead on a proposed quadrupole-triplet, charged-particle spectrometer to be installed at this Laboratory. An R-matrix program for the theoretical analysis and interpretation of the scattering data has been written and used to make extensive analyses on some of the above light nuclei to determine spins, parities, energies, widths and other nuclear properties. These results together with the subsequent inclusion of the inelastic and charged-particle cross sections into the R-matrix analysis will provide a much more complete theoretical study of the structure of these nuclides and of interaction of neutrons with them. Thus in addition to providing the nuclear energy program with many of the much-needed cross sections for applications, these results contribute to the improvement of our knowledge of fundamental models of the nucleus such as the shell model and optical model.

University of Pennsylvania
Department of Physics

Compilation of Information on the Energy Levels of the Light Nuclei
AK-01-01-01-1 FY 1978 \$60,000

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.

The second part of our work consists in collaborative, user-type research at P-9 at Los Alamos, using the 23 MeV triton beam and the very high resolution Q3D spectrometer, and at the 88" cyclotron at Berkeley using the QDDD spectrometer to study, most recently, $(\alpha, {}^8\text{He})$ reactions.

While the evaluation work is more immediately relevant, our work at Los Alamos and at Berkeley which is done with frontier-type equipment and analysis methods makes us able to better evaluate contemporary research papers. Further, the research has turned out some interesting scientific information.

Purdue University
Department of Chemistry

Radiochemical Investigations of Nuclear Properties
AK-01-01-01-1 FY 1978 \$62,000

P. J. Daly

Continued investigations of high-spin states in spherical and transitional nuclei by $(\alpha, xn\gamma)$ and (Heavy Ion, $xn\gamma$) reactions are proposed. Experiments at the Michigan State University cyclotron will involve studies of high-spin neutron hole excitations in ^{202}Pb , ^{201}Pb , and ^{200}Pb and of the level structures of the shape transitional nuclei ^{187}Pt and ^{189}Pt . Recoil distance lifetime measurements for the ^{186}Pt nucleus will be completed. The spectroscopy of Gd, Tb and Dy nuclei with a few nucleons outside the doubly-closed core ^{148}Gd will be intensively studied.

University of Tennessee
Department of Chemistry

Physical-Chemical Studies of the Transuranium Elements
AK-01-01-01-3 FY 1978 \$53,500

Joseph R. Peterson

The program provides for continuing investigations of the basic physical-chemical properties of the transuranium 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, and in general, the range of validity of the actinide hypothesis. Specific projects include: synthesis of Cm-248, Bk-249, and Cf-249 metals, chalcogenides, and pnictides for X-ray diffraction (vary temperature or pressure), magnetic susceptibility (SQUID magnetometer), and heat of solution (solution microcalorimeter) studies; determination of the stability constants of actinide cryptate complexes in aqueous solution and the crystal structures of the corresponding solid cryptate compounds; 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 $^{253}\text{Es} \rightarrow ^{249}\text{Bk} \rightarrow ^{249}\text{Cf}$; development of techniques for spectroelectrochemical studies of actinides to characterize Am(VII), Cf(V), and Es(IV); polarographic and cyclic voltammetric studies of the reduction of Cf(III) and Es(III).

University of Washington
Nuclear Physics Laboratory

Charged Particle Research AK-01-01-01-1 FY 1978 \$590,000

E. G. Adelberger, J. S. Blair, D. Bodansky, J. G. Cramer, 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 hypothesis 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.

III. Radiative Capture Reactions. This research program places major emphasis on the study of electric quadrupole strength, a subject about which very little was known a few years ago. Our purpose is to deduce through detailed studies of particular nuclei the strength distribution of electric quadrupole radiation produced in radiative capture, and from this to extract those features involving collective E2 strengths which are common to a wide variety of nuclei.

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.

University of Washington
Department of Nuclear Engineering

Neutron Yields from (α ,n) Reactions of Importance to Reactors
AK-01-01-01-2 FY 1978 \$26,000

G. L. Woodruff, D. L. Johnson (HEDL)

The yields of the neutrons produced by (α ,n) reactions important to reactors are to be measured. The range of incident alpha energies will be from 4 MeV to 8 MeV. Both the type of chemical compounds and the isotopic composition of the targets will be varied, but initial experiments will focus on 180 . The results will be important with respect to:

- (1) subcriticality reactivity measurements in reactors generally and in the Fast Flux Test Facility (FFTF) in particular,
- (2) the design and use of fuel shipping costs,
- (3) radioactive waste management practice and equipment design,
- (4) fabrication of alpha emitting reactor fuels, and
- (5) reprocessing of reactor fuels.

University of Wisconsin
Department of Physics

Research in Nuclear Physics and Atomic Collisions
AK-01-01-01-1 FY 1978 \$487,000

H. Richards, W. Haeberli, L. Knutson, P. Quin, L.W. Anderson

Supports the operation of the EN tandem Van de Graaff facility and a research program. The research program emphasizes the use of beams of polarized protons and deuterons. Polarized deuteron studies involving scattering and reactions have given new insight into the D-state of the deuteron, yielded many new spin-parity assignments, and shown inadequacies in both DWBA and in coupled-channel descriptions of direct reactions. A new precision deuteron tensor polarimeter gives absolute calibrations which permit measurements of t_{20} to 1%, t_{21} to 2% and t_{22} to 2%. A new method for determining absolute vector polarization standards was developed. The first quantitative fit of all three tensor analyzing powers for deuteron elastic scattering was obtained by using an optical model potential with an imaginary $\vec{l} \cdot \vec{s}$ term. Our $^{16}\text{O}(\alpha, \gamma)^{20}\text{Ne}$ data indicate that Coulomb forces adequately account for the isospin mixing. Studies in progress of a $T=2$ state in ^8Be should test the relevance of spin dependent forces to isospin mixing. Research continues on the direct production of polarized H^- or D^- ions from a polarized atomic beam of H^0 or D^0 atoms. This research should lead in the very near future to the development of a very intense source of polarized H^- or D^- ions for the tandem accelerator. A prototype source based on this principle has been constructed and yields polarized ion currents up to 3 μA . Cross sections for various charge changing collisions that are important in the production of fast negative ions or fast neutral beams will be measured. The negative ion equilibrium fraction when H^+ or D^+ are incident on alkali metal vapor targets will be studied. The maximum neutral fraction when fast H^- (or D^-) ions are incident on a large variety of targets has been measured, as well as the cross sections for various charge changing reactions important in the production of negative ions or fast neutral atoms.

University of Wisconsin
Department of Nuclear Engineering

Charged Particle Production Induced by 14-MeV Neutrons AK-01-01-01-2
FY 1978 \$42,000

H. H. Barschall, K. R. Alvar - University of Wisconsin-Madison
R. R. Borchers, University of Colorado-Boulder

Cross sections for the production of isotopes of hydrogen and helium by 14-MeV neutrons, of interest to the development of fusion reactors are being measured. A knowledge of these cross sections is essential to the choice of materials for the first wall of a fusion reactor, since the generation of hydrogen and helium affects the mechanical properties and hence the useful lifetime of the vacuum vessel. While previous attempts to measure these cross sections were in most cases limited to reactions that resulted in a measurable radioactivity, the present method can be used for any nuclide. An essential part of this research is the LLL Rotating Target Neutron Source. Charged particles, protons, deuterons, and alpha particles, from 14-MeV neutron bombardment of selected materials are focused by a magnetic quadrupole triplet lens onto detectors which are relatively far (~ 2.5 m) from the target material and the neutron source. Data have been obtained for stainless steel and its major constituent materials (Fe, Cr, Ni), and for aluminum, titanium, vanadium, and niobium. Other structural and blanket materials will be studied in the future. This is a joint project with the Lawrence Livermore Laboratory.

Yale University
Wright Nuclear Structure Laboratory

Fundamental and Applied Research in Nuclear Science AK-01-01-01-1
FY 1978 \$238,000

D. Allan Bromley

We continue a very active program of light charged particle induced reaction studies. In systematic studies on the (pt) reaction on tungsten isotopes, for example, we have discovered an entirely new collective pairing excitation appearing at constant neutron binding energy in all residual nuclei. Here, as in a large fraction of our total research, the ability to examine nuclear problems with the same instrumentation with both light and heavy ion projectiles pays handsome dividends in understanding. Using both hydrogenic and helium projectiles from the Yale tandem and the Princeton cyclotron we are extending our studies on the effective nucleon-nucleon interaction as it is manifested between valence nucleons outside of heavy lead cores. We have, for the first time, developed a quantitative, non-destructive nuclear technique for profiling hydrogen in solids; this has very far reaching fundamental and applied consequences. We have already used it to answer outstanding questions concerning the storage of ultracold neutrons and are developing a new neutron bottle for study of fundamental weak interaction phenomena; we have also resolved a long standing problem in showing quantitatively that the hydrogen content is responsible for variations of the transition temperature of the superconductor Nb₃Ge. Similarly we have shown that hydrogen in amorphous silicon converts it to a semiconductor with great potential in solar cells. In even more applied areas we have shown that helium ion induced damage appears to seal metals such as tungsten and stainless steel against hydrogen diffusion; this may have important consequences in the design of inner walls for fusion reactors. We have also examined a wide range of glasses now proposed for use in solidification of fission reactor wastes prior to disposal and have made quantitative measurements on their hydration rates under exposure to realistic temperatures and environments. An offshoot of our hydrogen profiling technique has been the recognition that it provides a quantitative, nondestructive dating technique for both natural and man-made glasses and we are exploiting this in a number of areas. We have also developed new sputtering models that have succeeded in reproducing, for the first time, the observed isotope fractionation observed in lunar samples returned during the Apollo missions and in the Martian atmosphere as observed during the Mariner missions. In both cases the fractionation is a natural consequence of long term bombardment by very low energy protons in the solar wind. We shall continue our activities in all these areas.

Yale University
Electron Accelerator Laboratory

Electron Accelerator Laboratory AK-01-01-01-2 FY 1978 \$165,000

F. W. K. Firk

The study of neutron interactions using a linear electron accelerator as a pulsed source of neutrons produced by nuclear photo-disintegration, was pioneered in the United States at Yale University in the late 1940's by the late Professor Howard Schultz and his students. Since that time, a program of such studies has continued at Yale without interruption. The present electron accelerator has been in use since 1961; it was the first accelerator to produce very high current pulses (peak current greater than ten amperes) in very short bursts (less than ten nanoseconds) at energies greater than fifty MeV. For more than a decade, this feature has been exploited in studies of neutron interactions at energies in the MeV range. Emphasis has been placed on studies of neutron polarization effects. We have developed a unique polarized neutron source using double-scattering that provides a continuous flux of highly polarized neutrons over a wide range of energy. High resolution investigations of the scattering of polarized neutrons by light nuclei have recently been completed, and the results have been analyzed to give detailed basic information of unprecedented quality in neutron reaction studies. Among the most interesting of these, from the point of view of the basic energy sciences programs, are the neutron elastic scattering from lithium - 6 (needed for fission and fusion reactor research) and from carbon - 12 (for use as an absolute standard for flux measurements and for polarization measurements). Our program has been developed recently to include studies of differential cross sections to provide data in those regions which have received scant attention in the past, and which are essential in our theoretical analyses. We are now studying the small-angle scattering of polarized neutrons from heavy nuclei in an attempt to set new limits on the polarizability of the neutron - a fundamental quantity that provides one of the few links between low-energy nuclear physics and the burgeoning field of meson physics.

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SECTION D

BUDGET CATEGORIES

INDEX BY BUDGET CATEGORIES

AK 01 01 01 1 CHARGED PARTICLE RESEARCH

Includes all costs associated with Low Energy Nuclear Science activities in which the primary beam particle is a charged particle or photon or in which a radiative source is used but not including investigations of nuclear fission or properties of heavy elements. This includes the operation of the accelerators required to provide the beams and the improvement of the accelerators and ancillary equipment.

2, 3, 7, 8, 9, 10, 13, 16, 17, 18, 19, 24, 32, 33, 43, 46, 48, 51, 52, 54, 55, 57, 59, 61.

AK 01 01 01 2 NEUTRON AND FISSION RESEARCH

Includes all costs associated with Low Energy Nuclear Science activities in which the primary research particle is a neutron. Includes experimental investigations of nuclear fission (spontaneous, neutron, and charged particle induced). This includes the operation of accelerators and reactors required to provide the beams and the improvement of the accelerators and reactors and ancillary equipment.

1, 4, 5, 10, 11, 12, 14, 15, 20, 22, 23, 25, 26, 27, 28, 29, 33, 34, 35, 36, 37, 38, 42, 44, 45, 46, 49, 50, 52, 53, 58, 60, 62.

AK 01 01 01 3 HEAVY ELEMENT RESEARCH

Includes costs associated with experimental research on the chemical and physical properties of the heavy elements (those with atomic number larger than 83).

6, 21, 30, 31, 39, 47, 56.

AK 01 01 02 1 ELECTROMAGNETIC ISOTOPE SEPARATION

Includes all new costs associated with the separation of isotopes by the electromagnetic process at the ORNL Calutron facility.

40.

AK 01 01 02 2 SPECIAL ISOTOPE PREPARATION

Includes all costs associated with the production of isotopes at the ORNL High Flux Isotope Reactor, the separation of isotopes at the ORNL Trans-uranium Processing Plant, and with the preparation of nuclear materials in forms required for research.

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