Summer 1997

Los Alamos National Laboratory • A U.S. Department of Energy Laboratory

The Actinide Research Quarterly

of the Nuclear Materials Technology Division

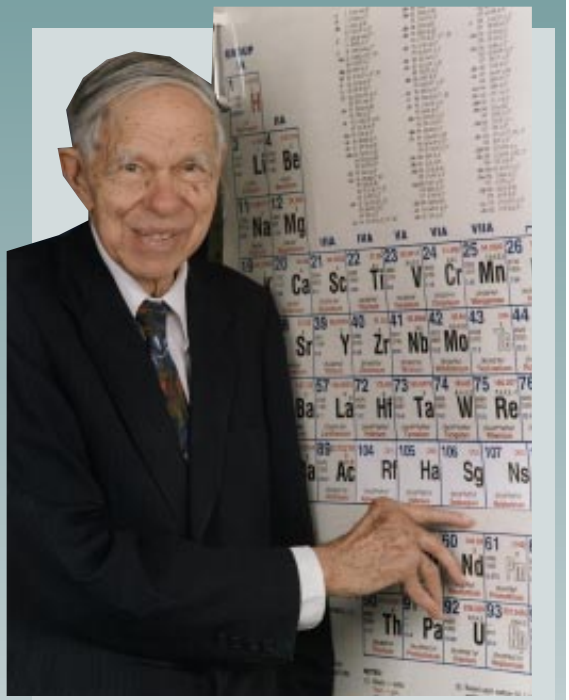
In This Issue

Source of the Actinide Concept

by Dr. Glenn T. Seaborg

This issue of the ***Actinide Research Quarterly*** *is blessed with the guest article "Source of the Actinide Concept" by Dr. Glenn Seaborg. One could not ask for a more significant and timely introduction to the "Plutonium Futures—The Science" conference than the personal perspective of the discoverer of the element. The Santa Fe conference will also feature Dr. Seaborg's plenary lecture videotaped in April this year. In reminiscing about the past and anticipating the future, we hope that this conference helps to herald a new beginning in the future science of actinides.*

K. C. Kim



XBC 942-905
Lawrence Berkeley National Laboratory

My romance with the transuranium elements started 63 years ago, in 1934, soon after I became a chemistry graduate student at the University of California, Berkeley. These were the undiscovered elements with atomic numbers greater than 92 (the atomic number of uranium), the heaviest naturally occurring element.

We (the transuranium elements and I) were first introduced at the weekly chemistry seminar on nuclear science held in venerable Gilman Hall. Actually, I was introduced to what were *thought to be* the transuranium elements. I read articles by Enrico Fermi and coworkers about the induced radioactivities observed when elements such as uranium were bombarded with neutrons. Since some were published in their native Italian, they were a challenge to decipher.

These induced radioactivities were, of course, produced in trace (unweighable) quantities, so radiochemistry methods were needed. For guidance, researchers predicted the chemical properties using the periodic table as it was then known. The heaviest natural elements, thorium, protactinium, and uranium (atomic numbers 90, 91, and 92), were placed in that table just below the sixth-period "transition elements"—hafnium, tantalum, and tungsten (in these elements, the "5d" electron shell is being filled). Thus it was assumed that the 6d electron shell was being filled in these heaviest elements, and the chemical properties of the transuranium elements, the undiscovered elements 93, 94, 95, and 96, would be homologous with the 5d elements immediately above them in the periodic table, rhenium, osmium, iridium, and platinum.

90 232.0381	91 231.0359	92 238.029	93 237.0482	94 (244)	95 (243)	96 (247)	97 (247)	98 (251)	99 (252)	100 (257)	101 (258)	102 (259)	103 (260)
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Thorium	Protactium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Medelevium	Nobelium	Lawrencium

Dr. Glenn Seaborg

The limited chemical identification experiments of Fermi and coworkers seemed consistent with this view. The work of Otto Hahn, Lise Meitner, and Fritz Strassman in Berlin seemed to further confirm it.

Little did we know then how we were being misled by accepting what was easiest to accept. I bought this interpretation "hook, line, and sinker." In the fall of 1936, I described the work and interpretation of Otto Hahn and coworkers during a required graduate student talk to the chemistry faculty, staff, graduate students, and visiting scientists.

Then in January 1939, the bubble burst! At the physics journal club meeting, we heard something extraordinary. Niels Bohr, who had arrived in New York the previous week, brought news from Otto Hahn's laboratory that the neutron-bombardment of uranium produced isotopes of light elements, like barium and lanthanum. The meaning was simple: the uranium had been split approximately in half, and all the radioactive "transuranium" isotopes studied by Hahn, Strassman, and Meitner during the previous four years were actually isotopes from the middle of the periodic table.

This was exciting! After the seminar, I walked the Berkeley streets for hours, chagrined that I hadn't recognized that the "transuranium elements" in which I had been so interested were nothing of the kind. I felt stupid for failing to admit the possibility. Subsequent work showed that the radioactivities that had been ascribed to transuranium elements were actually due to fission products!

With poetic justice, the actual discovery of the first transuranium element resulted from experiments aimed at understanding the fission process. In 1940, Edwin M. McMillan and Philip H. Abelson showed that a radioactive product of the bombardment of uranium with neutrons was an isotope of element 93, with a mass number 239 (^{239}93). The isotope ^{239}93, a negative beta-particle emitter, should decay to the product ^{239}94, but they were unable to observe this daughter product because of its long half-life.

McMillan then started looking for a shorter-lived isotope of element 94 through the deuteron bombardment of uranium. When McMillan was called to MIT for war work, I continued this quest with the help of my graduate student Arthur C. Wahl and another instructor in chemistry at Berkeley, Joseph W. Kennedy. We succeeded on the night of February 23–24, 1941, in chemically identifying (i.e., discovering) element 94 (the isotope ^{239}94) in room 307, Gilman Hall (designated as a National Historic Landmark on the 25th anniversary of the discovery). Most importantly, we found that the chemical properties of element 94 weren't like those predicted from the periodic table of that time (i.e., not like osmium), but were chemically similar to uranium. Joined by physicist Emilio Segrè, we soon identified ^{239}94 and, most importantly, demonstrated that it was fissionable by slow neutrons.

Following McMillan's suggestion for naming element 93 "neptunium" (after Neptune, the first planet beyond Uranus), with the chemical symbol Np, Wahl and I suggested "plutonium" (after Pluto, the next planet) for element 94. We first debated whether the name should be "plutium" or "plutonium," the sound of which we liked better. Although the chemical symbol might have been "Pl," we liked the sound of "Pu," for the reason you might suspect, and therefore decided on "Pu."

I had the pleasure of meeting for the first time Clyde Tombaugh, the discoverer of the planet Pluto, in Albuquerque, New Mexico, on June 9, 1991. At that time, he told me he had also considered naming his planet after the Greek god Cronus or Roman goddess Minerva (rather than after Pluto). In that case, I suppose we would have given element 94 the name "cronium" or "minervium," and therefore, people throughout the world would never have heard the word "plutonium" which is so much in the news today.

The chemical properties of neptunium and plutonium were found to be similar to those of uranium and quite unlike those of rhenium and osmium, which, according to the existing periodic table, they should have resembled. Thus we concluded that a new series of 14 rare-earth-like elements, starting at uranium, would be the "uranide" (uranium-like) series, just as the 14 rare-earth elements were known as the "lanthanide" (lanthanum-like) series.

Wrong again!

Soon after Pearl Harbor and the U.S. entry into World War II, I moved to the wartime Metallurgical Laboratory of the University of Chicago. Here, we solved many of the problems attendant with plutonium-239 production, and I turned my attention to the quest for the next two transuranium elements, 95 and 96. I was joined in the endeavor by my colleagues Albert Ghiorso, Ralph A. James, and Leon O. (Tom) Morgan. But when we predicted the chemical properties on the basis of the "uranide" concept, we failed to make any identification of our transmutation products.

We weren't successful until I suggested that we needed a bold revision of the periodic table in order to make correct predictions of the chemical properties of elements 95 and 96. I wrote a secret report in July 1944, suggesting that thorium, protactinium, and uranium be removed from the body of the periodic table and placed as the beginning of a "transition" series, analogous to the lanthanide (rare-earth) elements, in a separate row at the bottom. Thus the 14 elements beginning with thorium (elements 90–103), would become the "actinide" elements (by analogy with the "lanthanide" elements). They would then show the necessary element-by-element analogy with the lanthanide elements (58–71).

Thus element 95 would be chemically similar to the lanthanide element europium (63) and element 96 would be chemically similar to gadolinium (64). Using this concept, in 1944 and 1945, we synthesized and chemically identified elements 95 and 96, by analogy with their rare earth homologues, europium (element 63) and gadolinium (element 64). The new elements were subsequently named americium (95) and curium (96) by analogy with the naming of their homologues.

This bold revision of the periodic table was a hard sell. When I showed it to some world-renowned inorganic chemists, I was advised not to publish it—such an act would "ruin my scientific reputation."

However, I did publish it after the war, and it became a guide for the chemical identification of most of the subsequent members of the actinide series. The series was predicted to end at element 103, and the subsequent investigations confirmed this.

At element 104 (now known as rutherfordium), we jumped back up to the body of the periodic table, and rutherfordium took its place under hafnium (element 72). (This spot had been occupied by thorium before I moved it to a separate row at the bottom of the periodic table). Then we proceed across the periodic table along now-known elements 105–112, to undiscovered elements 113–118; element 118 will be a noble gas.

This form of the periodic table is accepted throughout the world and is now ubiquitous in wall charts and chemistry books. I am, needless to say, proud that U.S. chemists recommended that element 106, which is placed under tungsten (74), be called "seaborgium." I am looking forward to the day when chemical investigators will refer to such compounds as seaborgous chloride, seaborgic nitrate, and perhaps, sodium seaborgate. Fortunately, this name, after initial rejection, is now being accepted by the Commission on Nomenclature on Inorganic Chemistry of the Union of Pure & Applied Chemistry (IUPAC).

This, then, is a brief account of the origin of the *actinide concept* for the placement of the fourteen elements beyond actinium (atomic numbers 90–103) in the Periodic Table.

This bold revision of the periodic table was a hard sell. When I showed it to some world-renowned inorganic chemists, I was advised not to publish it—such an act would "ruin my scientific reputation."

NMT Division Recycles, Purifies Plutonium-238 Oxide Fuel for Future Space Missions

ballmill.eps

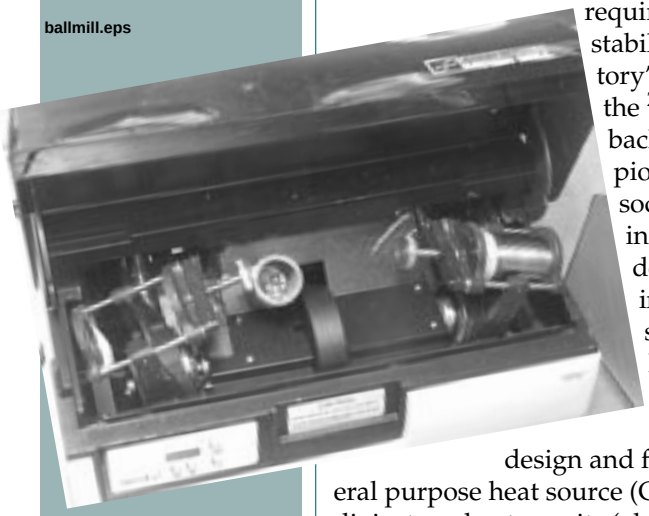


Figure 1: High-energy ball mill used in preparing plutonium-238 dioxide feed for dissolution. Because ^{238}Pu, used for space power applications, is no longer available from DOE nuclear reactors, NMT proposes to recycle old sources of ^{238}Pu in the DOE complex to make the necessary fuel.

Plutonium-238 (^{238}Pu) has proven to be an excellent radioisotope for space power applications because of its availability, power density, useful lifetime, minimal shielding requirements, and oxide stability. The Laboratory's experience with the ^{238}Pu isotope goes back many years to pioneering efforts associated with developing pacemakers and designing, fabricating, and testing heat sources for space. More recent LANL work has been associated with the design and fabrication of general purpose heat source (GPHS) units and radioisotope heater units (also known as RHUs) to support the Cassini mission to Saturn (Reported in *Actinide Research Quarterly*, Fall 1996).

Plutonium-238 is made in a nuclear reactor by neutron irradiation of neptunium-237 to form neptunium-238. Short-lived neptunium-238 (half-life of 2.35 days) then decays by beta emission to ^{238}Pu (half-life of 87.74 years). The shutdown of most DOE nuclear reactors has raised doubts about the production of new ^{238}Pu for future space missions. The NMT Division proposes to recycle old sources of ^{238}Pu that exist in the DOE complex to make highly purified fuel. Recycled fuel could also be mixed with higher-isotopic fuel obtained from the Former Soviet Union, England, France, or Canada.

The purity specifications for ^{238}Pu to be used in heat sources are rigorous. Small amounts of impurities in ^{238}Pu fuel could interfere with the function of heat sources in several ways, including grain growth in the iridium used in the inner clad layer to encapsulate the fuel; plugging of the fueled clad vent, leading to potential pressurization and rupture; and interference with instrumentation onboard the spacecraft from emitted radiation, primarily from neutrons produced by (α,n) reactions with light elements.

Our initial effort has focused on purification of $^{238}PuO_2$ fuel that fails to meet GPHS specifications because of impurities. The most notable nonactinide impurity was silicon, but aluminum, chromium, iron, and nickel were also near to or in excess of limits specified by GPHS fuel powder specifications. The ^{234}U was by far the largest actinide impurity observed in the feed material because it is the daughter product of ^{238}Pu by alpha decay. Older heat sources to be reclaimed would have relatively large amounts of ^{234}U ingrowth (half-life of 24,500 years), a valuable isotope that could be recovered for use in tracer studies of U.

Chemical processing of ^{238}Pu fuel offers several unique challenges. One step in making $^{238}PuO_2$ fuel extremely stable for heat sources is high-temperature firing of up to 1600°C. Unfortunately, this makes the material very hard to dissolve by usual methods should additional purification be required. We have observed a marked improvement in dissolution efficiency when the $^{238}PuO_2$ feed is first milled in a high-energy ball mill. The very fine powder obtained dissolves at an acceptable rate in a mixture of refluxing nitric and hydrofluoric acids.

Plutonium (III) oxalate precipitation was selected for this portion of the demonstration because of its simplicity, speed, and adequacy of purification. In particular, plutonium (III) oxalate precipitation requires no temperature control, shows little detrimental effect from excess oxalic acid, and has a rapid reaction, precipitation, and filtration time. Reagent-grade chemicals were used to minimize introduction of contaminants. Teflon or polypropylene apparatus was used for ^{238}Pu solutions in this demonstration to avoid leaching silicates from glassware.

Plutonium exhibits some of the most complex and interesting chemistry of any element, with several oxidation states possible in solution. Controlling the oxidation state of plutonium is challenging under any circumstances, but it is particularly so in the presence of so much alpha radiation. As ^{238}Pu has an alpha activity of 17.1 Ci/g, even a moderate batch size (80 g) of ^{238}Pu can have over 1000 Ci of

alpha in a single small solution. To mitigate effects of radiolysis caused by this level of radioactivity, combinations of reducing agents were used in excess, and all steps were performed as rapidly as possible. Our best results to date combined hydroxylamine nitrate with either sulfamic acid or urea.

Decontamination factors for uranium, silicon, chromium, iron and nickel were very good using the plutonium (III) oxalate precipitation method employed. Up to 96%–99% reduction in impurities was noted. The purity of the $^{238}PuO_2$ recovered from this demonstration was significantly better than GPHS specifications, and in fact better than that of any fuel material received at LANL for use in the Cassini mission to Saturn.

NMT Division has expertise and facilities that make larger-scale recovery and purification of ^{238}Pu for oxide fuel a practical option. Additional supplies of ^{238}Pu oxide fuel from many existing sources can be recovered in a glove box facility like PF-4. Plutonium-238 materials targeted for recovery include impure oxide and scrap items. For many $^{238}PuO_2$ feeds, including those with significant ^{234}U ingrowth, the plutonium (III) oxalate precipitation procedure is adequate to meet the GPHS fuel standard. For scrap items that are lean in ^{238}Pu values, anion exchange separation offers a method to concentrate and purify additional amounts of the isotope.

Efforts continue to develop the capability for efficient, safe, cost-effective, and environmentally acceptable methods to recover and purify $^{238}PuO_2$ fuel in a glove box environment. Los Alamos is the Department of Energy's "Lead Lab" for plutonium, and NMT Division has the resident plutonium experience and required infrastructure to complete this project successfully. One of the most valuable contributions is the waste minimization efforts underway in NMT to reduce the activity and volume of liquid and solid wastes associated with plutonium processing. Technology transfer of these capabilities to processing of $^{238}PuO_2$ will greatly support our ability to provide high-purity fuel for future space power applications.

tefpot.eps

Figure 2: After ball milling, the plutonium-238 dioxide feed is dissolved in a mixture of nitric and hydrofluoric acids in this apparatus consisting of a Teflon round-bottomed flask, Teflon reflux condenser, and Teflon-compatible heating mantle. The dissolution is one step in producing a ^{238}Pu fuel that meets the rigorous specifications for high purity to ensure proper performance for space applications.

Jacob Espinoza, Elizabeth Foltyn, and Gary Rinehart (NMT-9) and **Louis Schulte, Gary Silver, Larry Avens,** and **Gordon Jarvinen** (NMT-6) are the principal developers of this project. They acknowledge many contributors to this work: **Kevin Ramsey** and **Jim Jones** (NMT-9) for help with hardware and glove box development; **Charles V. Puglisi, Carlos D. Dozhier, Christina M. Lynch, Paul F. Moniz, Robert W. Mathews, Richard T. Romero,** and **Mary Severinghaus** (NMT-9) for the help with hot jobs and sample removal; **Tim George** (NMT-9), **Keith Fife, Steve Yarbro,** and **Steve Schreiber** (NMT-2), **Mark Dinehart, Jerry Lugo,** and **Randy Vaughn** (NMT-6) for helpful conversations; **Johnny N. Quintana** (CST-4), and **Margaret T. Trujillo** and **Nelson D. Stalnaker** (CST-8) for radiochemical analysis of solutions; and numerous others in LANL groups CST-8 and CST-9 for elemental and radiochemical analysis of the plutonium-238 oxide products.

Editorial

New Mexico Welcomes "Plutonium Futures—The Science" Conference








Pu in some of its many different forms

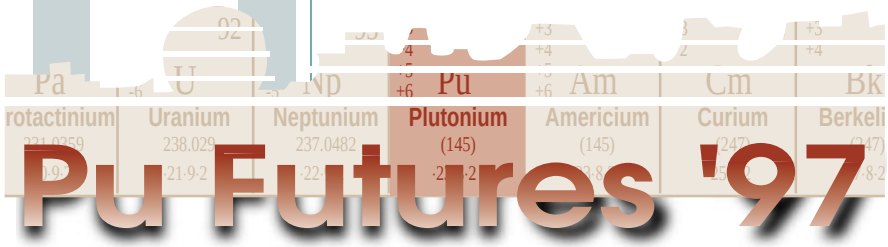
The field of actinide science has been shrinking for some time. While actinides, most prominently among them uranium and plutonium, are one of the most important energy sources worldwide, the adverse publicity resulting from the real or sometimes perceived nuclear danger has left this field in somewhat benign neglect from the scientific community. The public often recognizes the benefits provided by nuclear energy but does not wish to associate with the concomitant nuclear issues. Awakening the scientific community and the public interest to the need of dealing with the nuclear issues in such areas as nuclear waste, weapons dismantlement, contamination, and environmental cleanup is the first step toward solving some of the problems confronting us in the next several decades.

In August this year the Nuclear Materials Technology Division of the Los Alamos National Laboratory will sponsor an international conference on the subject of plutonium in cooperation with the American Nuclear Society. The idea of holding the "Plutonium Futures - The Science" conference locally was conceived well over a year ago, and the conference program presented in this issue of the *Actinide Research Quarterly* is a witness to the preparation and enthusiasm of the organizers and participants alike. Nuclear issues are broad-ranging, and many are of a nontechnical nature. By focusing on the science, however, the conference aims to achieve a degree of balance in the current debates on all things nuclear. Also, it is important to recognize that nuclear issues are worldwide issues and therefore require broad-based participation and cooperation.

The impact of plutonium on worldly affairs, both domestic and international, has been so great and profound for a half century that plutonium may garner the distinguished title of "the element of the 20th century." The conference organizers recognize that there are a multitude of issues surrounding plutonium and other actinides and that both short- and long-term solutions to reducing the nuclear danger rest ultimately on the scientific and technological knowledge base. Thus one of the main objectives of the conference is to provide an opportunity to present and assess our current understanding of plutonium and actinide sciences and to bring focus on the science needed for solving important national and international issues associated with plutonium. Another equally important objective is to inform the public, our stakeholders as well as the scientists, and to attract today's students who will carry on the task of solving the nuclear issues into the next century.

The topics covered in this conference (scientific program on following pages) are multidisciplinary and include separations chemistry, transuranic waste, isotopes/nuclear fuels, detection and analysis, materials science, noble actinides compounds and complexes, and environmental and biosphere chemistry. Plenary topics by invited speakers and technical presentations will highlight important issues and new developments. There also will be exhibits showing the Los Alamos Plutonium Facility at Technical Area 55, plutonium work at Savannah River Technology Center, and an introductory exhibit featuring the Glenn Seaborg Transactinium Institute.

K. C. Kim



Preliminary Program for the Plutonium Futures—The Science Conference

Sunday, August 24, 1997

Registration and Reception
Hilton, Chamisa Courtyard

Monday, August 25, 1997

Registration
Hilton, Promenade

Plenary Session

Session Co-Chairs: R. Bruce Matthews and Paul Cunningham
Hilton, Mesa Ballroom

Welcome, Dr. Sig Hecker, Los Alamos National Laboratory

SEABORG and PLUTONIUM: Retrospective and Perspective

The Role of Plutonium in Energy Production Outside the United States
Dr. Alan Waltar (Advanced Nuclear and Medical Systems)

Options for Plutonium Utilization: Sustainable Energy Development, Safeguards, and Nuclear Safety
Dr. Victor M. Mourogov (International Atomic Energy Agency)

Plus Additional Plenary Session Speakers

Lunch Hilton, Mesa Ballroom, New Mexican buffet
Exhibits on plutonium, TA-55, and the Seaborg Institute can be seen in the Aspen and Ortiz 1 and 2 siderooms during lunch and all conference breaks

Materials Science

Session Chair: Rodney Ewing, University of New Mexico
Hilton, Mesa Ballroom

Materials Science of Plutonium and Americium with Group IV Elements: Compounds and Solid Solution Relevant to Nuclear Applications
P. E. Raison, R. G. Haire, T. Sato (Oak Ridge National Laboratory)

Thermochemistry of Crystalline and Amorphous Phases Related to Plutonium Containment
A. Navrotsky (UC Davis)

Point Defects in the Solid Solutions of Actinide Oxides (M, An)O_{2+x} and Properties of Fuels (An=Np, Pu, Am, or Cm)
M. Beauvy, C. Duriez, T. Gervais, J. Larroque, J. M. Bonnerot (Commissariat a l'Energie Atomique, France)

Break Refreshments in the Promenade

Transuranic Waste Forms

Session Chair: Mal McKibben, Westinghouse Savannah River Company
Hilton, Mesa Ballroom

Immobilisation of Pu-Rich Wastes in Synroc
E. R. Vance,* A. Jostsons,* M. W. A. Stewart,* R. A. Day,* B. D. Begg,* M. J. Hambley,* K. P. Hart,* B. B. Ebbinghaus† (*ANSTO, Australia, †Lawrence Livermore National Laboratory)

Amorphous Zirconium Hydrosilicate (AZHS)—A Prospective Material for Pu Fixation
B. E. Burakov,* K. B. Helean†, E. B. Anderson,* R. C. Ewing,† A. F. Smetannikov*
(*V. G. Khlopin Radium Institute, Russia, †University of New Mexico)

New Ceramics for Tetravalent Actinides: $Th_4(PO_4)_4P_2O_7$. Leaching Tests for U^{4+} and Pu^{4+}
N. Dacheux, R. Podor, V. Brandel, J. F. LeDû, B. Chassigneux, M. Genet (Nuclear Physics Institute, France)

Self-Radiation Effects in Glass and Ceramic Waste Forms for the Stabilization and Disposition of Plutonium
W. J. Weber,* N. J. Hess,* S. D. Conradson,† J. D. Vienna* (*Pacific Northwest National Laboratory †Los Alamos National Laboratory)

Tuesday, August 26, 1997

Nuclear Fuels/ Isotopes

Session Chair: Larry Newkirk, Lawrence Livermore National Laboratory
Hilton, Mesa Ballroom

Nuclear Pu-Based Fuels for the Future
H. Bernard (French Atomic Energy Commission)

Concepts for Advanced MOX Fabrication Technology
W. Stoll (Institute for Industrial Environment, Germany)

Inert Matrix Non-Fertile Fuels for Plutonium Transmutation in PWRs
F. Vettraino,* C. Lombardi†, A. Mazzola† (*ENEA-Nuclear Fission Division, Italy, †Polytechnic of Milan, Italy)

Development of Coated Particle Plutonium Fuel in Russia
V. M. Makarov,* A. S. Shenoy,† M. B. Richards,¥ D. W. McEachern¥ (*A. A. Bochvar All-Russian Scientific Research, Russia, †General Atomics, San Diego, ¥General Atomics, Los Alamos)

Break Refreshments in the Promenade

Separations

Session Chair: Gordon Jarvinen, Los Alamos National Laboratory
Hilton, Mesa Ballroom

Recovery of Plutonium or Conversion of Plutonium Containing Materials to Glass Using a GMODS Dissolution Glass
C. W. Forsberg (Oak Ridge National Laboratory)

Recovery of Surplus Weapons-Usable Plutonium for Mixed Oxide Reactor Fuels
T. R. Johnson, R. D. Pierce, C. C. McPheeters (Argonne National Laboratory)

Aqueous Processes for the Conversion of Metallic Plutonium into an Oxide Powder Suitable for MOX Fuel Fabrication
B. Zakharkin,* L. Borisov,* P. Brossard,† P. Bros,† A. Boesch,¥ E. Capelle¥ (*VNIIM, Russia, †CEA/DCC, France, ¥CEA/DAM, Bruyère-Le-Châtel, France)

Magnetic Separation for Nuclear Material Applications
L. A. Worl, D. Hill, D. Padilla, C. Prenger, E. Roth (Los Alamos National Laboratory)

Lunch (on your own in Santa Fe)

Poster Session

Sweeney Center (within walking distance of the Hilton Hotel)
More than 70 posters will be presented at the Poster Session (See Page 10)

Banquet Invited Speaker: Richard Rhodes, *Public Health, Public Knowledge, Public Peace*
Author of *The Making of the Atomic Bomb* and *The Dark Sun–The Making of the Hydrogen Bomb*
Hilton, Mesa Ballroom

Wednesday, August 27, 1997

Actinides in the Environment

Session Chair: Ann Gibbs, Westinghouse Savannah River Company
Hilton, Mesa Ballroom

Actinides in the Environment: Some Perspectives from an Aqueous Chemist
J. Bruno (QuantiSci SL, Spain)

Investigations of Microbial Systems in Radioactive Environments
M. E. Pansoy-Hjelvik,* B. A. Strietelmeier,* J. B. Gillow,† C. J. Dodge,† R. J. Sebring,* S. M. Kitten,* P. A. Leonard,* R. Villarreal,* I. R. Triay,* A. J. Francis,† H. W. Papenguth¥ (*Los Alamos National Laboratory, †Brookhaven National Laboratory, ¥Sandia National Laboratories)

Mediation of Actinide Mobility and Potential Actinide Remediation by Microbes in the Environment
J. R. Brainard, S. Thompson, L. Hersman (Los Alamos National Laboratory)

Actinide Solubility and Speciation in YM and WIPP Aquifers: Experimental Data and Predictions Based on Thermodynamic and Geochemical Modeling
D. R. Janecky,* D. W. Efurd,* C. D. Tait,† W. Runde† (*Los Alamos National Laboratory, †Glenn T. Seaborg Institute for Transactinium Science, CA)

Break Refreshments in the Promenade

Detection and Analysis

Session Chair: Larry Avens, Los Alamos National Laboratory
Hilton, Mesa Ballroom

Advantages and Limitations of Oxidation State Analogs
G. R. Choppin (Florida State University)

Spectroscopic Study of Chelation Between Pu and Modified Siderophores
P. Zhao,* V. V. Romanovski,* D. C. Hoffman,* C. E. A. Palmer,* D. W. Whisenhunt, Jr.,* P. G. Allen,† D. K. Shuh,† J. J. Bucher,† N. M. Edelstein,† D. J. White,¥ J. Xu,¥ K. N. Raymond¥ (*G. T. Seaborg Institute for Transactium Science, Lawrence Livermore National Laboratory, †Lawrence Berkeley National Laboratory, ¥University of California, Berkeley)

Immobilization of Plutonium in Geomedia by Phytic Acid
M. P. Jensen, S. R. Friedrich, J. J. Hines, M. A. Schmidt, K. L. Nash (Argonne National Laboratory)

Characterization of Actinide Materials by Elemental and Molecular Imaging
G. J. Havrilla,* J. R. Schoonover,* F. Wesner,* C. Worley,* M. Sparrow,† P. J. Treado† (*Los Alamos National Laboratory, †University of Pittsburgh)

Lunch (on your own in Santa Fe)

Plutonium

Session Chair: Richard Bartsch, Texas Tech University
Hilton, Mesa Ballroom

Electron Localization in the Series of Actinide Metals and Pu_3X (X=Al, Ga, In, Tl) Compounds
M. Pènicaud (Commissariat a l'Energie Atomique, France)

Coordination Chemistry of Actinide Ions (U, Np, Pu) Under Highly Alkaline Conditions
D. L. Clark, S. D. Conradson, D. W. Keogh, M. P. Neu, P. D. Palmer, R. D. Rogers, W. Runde, B. L. Scott, C. D. Tait (Los Alamos National Laboratory and Glenn T. Seaborg Institute for Transactinium Science, CA)

Polymeric Plutonium(IV) Hydroxide: Formation, Prevalence, and Structural and Physical Characteristics
M. P. Neu,* R. K. Schulze,* S. D. Conradson,* J. D. Farr,* R. G. Haire† (*Los Alamos National Lab and Glenn T. Seaborg Institute for Transactinium Science, CA, †Oak Ridge National Lab)

Break Refreshments in the Promenade

Actinide Compounds and Complexes

Session Chair: Darleane Hoffman, Lawrence Berkeley National Laboratory
Hilton, Mesa Ballroom

The Los Alamos Tunable Light Source for Transuranic Photoelectron Spectroscopy: First Results for δ-Pu
A. J. Arko, J. J. Joyce, L. E. Cox (Los Alamos National Laboratory)

The Actinide Extraction Properties of 1,3 Para-Tert-Butyl-Acid-Diethyl Amide Substituted Calix[4]arene
G. P. Nicholson,* M. J. Kan,* G. Williams,* P. D. Beer,† P. Schmidt,† M. G. B. Drew,¥ P. D. Sheen¥ (*AWE, Aldermaston, †University of Oxford, ¥University of Reading; UK)

Conference Summary and Assessment
Rapporteur: G. R. Choppin (Florida State University)

Poster Session Presentations

Sweeney Convention Center (within walking distance of the Hilton Hotel)

Materials Science

The Activities of V. G. Khlopin Radium Institute, Russia, in the Field of Pu and Actinide Immobilization
E. B. Anderson (V. G. Khlopin Radium Institute, Russia)

Calculated Structural Relaxation in Pu-Ga
J. D. Becker,* B. R. Cooper,† J. M. Wills,* L. Cox* (*Los Alamos National Laboratory, †West Virginia University)

Electronic Structure and Theory of Bonding in δ-Pu
O. Eriksson, J. M. Wills (Los Alamos National Laboratory)

Gallium Interactions with Zircaloy Cladding
R. R. Hart,* J. Rennie,* K. Ünlü,† C. Ríos-Martínez† (*Texas A&M University, †The University of Texas at Austin)

Synthesis and Characterization of Solids in the $NA_{1-x}K_xCe_{2-y}U_y(PO_4)_3$ System
H. T. Hawkins,* D. K. Veirs,* J. A. Danis,* W. H. Runde,* B. E. Scheetz† (*Los Alamos National Laboratory, †The Pennsylvania State University)

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J. Y. Huang, D. R. Spearing (Los Alamos National Laboratory)

Glass and Glass-Ceramic Waste Forms Developed for Immobilizing Actinides
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Phase Separation in Borosilicate Glasses with P, F, and S and the Influence on Glass Durability in Aqueous Environments
H. Li, Y. L. Chen, J. D. Vienna (Pacific Northwest National Laboratory)

Glass Melter Development for Plutonium Immobilization
J. C. Marra,* K. Marshall,* R. Schumacher,* M. Speer,* J. Zamecnik,* R. T. Calloway, Jr.,* J. Coughlin,* R. Singer,* J. Farmer,† W. Bourcier,† D. Riley,† B. Hobson,† M. Elliott¥ (*Westinghouse Savannah River Company, †Lawrence Livermore National Laboratory, ¥Pacific Northwest National Laboratory)

A Statistically Designed Matrix to Evaluate Solubility, Impurity Tolerance, and Thermal Stability of Plutonium-Bearing Glasses
D. K. Peeler, T. F. Meaker, T. B. Edwards, D. S. McIntyre (Westinghouse Savannah River Co.)

Dissolution Studies of Plutonium Oxide in LaBS Glass
D. Riley,* W. Bourcier,* J. Vienna,† T. Meaker,† D. Peeler,¥ J. Marra¥ (*Lawrence Livermore National Laboratory, †Pacific Northwest National Laboratory, ¥Westinghouse Savannah River Co.)

Schoepite Weathering in the Presence of Calcium and Phosphate Bearing Water: Pathways and Products
A. G. Sowder,* S. B. Clark,† R. A. Fjeld* (*Clemson University, †Washington State University)

Alpha Radiation Damage in Plutonium Encapsulating Materials
K. Ünlü,* M. Saglam,* C. Ríos-Martínez,* R. R. Hart,† J. D. Shipp† (*The University of Texas at Austin, †Texas A&M University)

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The Raw Material and Waste Activity Balance in the Projected Nuclear Power of Russia
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Statistical Signal Processing and Artificial Intelligence Applications in the Nondestructive Assay of U/Pu Bearing Materials
S. E. Aumeier, J. H. Forsmann (Argonne National Laboratory—West)

Pu and Gd Chemistry of Zirconolite Polytypes in a Titanate Ceramic
A. J. Bakel,* E. C. Buck,* B. Ebbinghaus† (*Argonne National Laboratory, †Lawrence Livermore National Laboratory)

Microwave Vitrification of Radioactive Sludge and Residue in Container
G. B. Borisov,* A. V. Nazarov,* M. N. Molokhov† (*A. A. Bochvar All-Russia Research Institute of Inorganic Materials, [VNIINM] Russia, †Research and Development Institute of Construction Technology and Residues, [NIKIMT] Russia)

Microscopic Analysis of Pu-Contaminated Incinerator Ash: Implications for Immobilization
E. C. Buck (Argonne National Laboratory)

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J. G. Darab,* H. Li,* M. J. Schweiger,* J. D. Vienna,* P. G. Allen,† J. J. Bucher,† N. M. Edelstein,† D. K. Shuh† (*Pacific Northwest National Laboratory, †Lawrence Berkeley National Laboratory)

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J. A. Fortner, C. J. Mertz, D. C. Chamberlain, J. K. Bates (Argonne National Laboratory)

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E. M. Glagovsky, A. V. Kuprin (A. A. Bochvar All-Russia Research Institute of Inorganic Materials [VNIINM], Russia)

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S. G. Johnson,* T. P. O'Holleran,* S. M. Frank,* M. K. Meyer,* M. Hanson,* B. A. Staples,† D. A. Knecht,† P. C. Kong† (*Argonne National Laboratory—West, †Lockheed Martin Idaho Technologies Company)

Americium/Curium Bushing Melter Drain Tests
T. M. Jones, B. J. Hardy, M. E. Smith (Westinghouse Savannah River Company)

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O. H. Krikorian, R. H. Condit (Lawrence Livermore National Laboratory)

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C. Mahan, D. Wayne, D. Figg, D. Cremers, A. Koskelo, R. Drake, Y. Duan, J. Olivares (Los Alamos National Laboratory)

Liquidus Temperature and Durability of Pu Loaded Lanthanide Borosilicate (LaBS) Glass as a Function of Feed Stream Variation
T. F. Meaker, D. K. Peeler, C. M. Conley, J. O. Gibson (Westinghouse Savannah River Company)

Determination of Solubility Limits of Individual Pu Feeds into a Lanthanide Borosilicate (LaBS) Glass Matrix Without Preprocessing
T. F. Meaker, D. K. Peeler, C. M. Conley, J. O. Gibson (Westinghouse Savannah River Company)

Speciation and Surface Interactions of Actinides on Aged Ion-Exchange Resins
D. E. Morris, C. T. Buscher, A. R. Wheeler, R. J. Donohoe, C. D. Tait (Los Alamos National Laboratory)

Application of Freeze Drying Technology to Liquid TRU Waste Minimization
J. A. Musgrave,* D. W. Efurd,* J. C. Banar,* S. Boone,* R. A. Podkulski,† E. Renzi,† P. Stewart† (*Los Alamos National Laboratory, †BOC Edwards Calumatic)

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A. K. Nardova,* E. A. Filippov,* E. G. Kudriavtsev,† E. G. Dzekun,* K. K. Korchenkin,* A. N. Mashkin* (*Russian Research Institute for Chemical Technology, Russia, †Ministry for Atomic Energy of Russian Federation, Russia, *"Mayak" Production Association)

Vitrification of Rocky Flats Incinerator Ash
T. S. Rudisill, J. C. Marra, D. K. Peeler (Westinghouse Savannah River Company)

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T. E. Sampson, T. L. Cremers (Los Alamos National Laboratory)

Stabilization of Plutonium Contaminated Wet Combustible Residues
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Colloids in TRU Waste Contaminated Saturated Brine
R. K. Schulze, M. P. Neu, J. D. Farr, S. D. Conradson (Los Alamos National Laboratory)

Solution of the Problem of Recovery Transuranium Elements from Basin-Storage of Radioactive Waste and Equipment of Plants
N. E. Shingarjov, A. S. Polyakov, L. S. Raginsky, I. V. Mukhin (A. A. Bochvar All-Russia Research Institute of Inorganic Materials [VNIINM] Russia)

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K. Smith, A. Montoya, R. Wieneke, D. Wulff, C. Smith, K. Gruetzmacher (Los Alamos National Laboratory)

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J. D. Vienna,* M. L. Elliott,* H. Li,* J. K. Luey,* G. Veazey,† R. Nakaoka† (*Pacific Northwest National Laboratory, †Los Alamos National Laboratory)

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F. C. Dimayuga (AECL, Canada)

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E. I. Grishanin, L. N. Phalkovsky (All-Russia Nuclear Power Engineering Research and Development Institute [VNIIAM], Russia)

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E. I. Grichanin, P. N. Alexeyev, P. Fomichenko, L. N. Phalkovsky, S. A. Subbotin (All-Russia Nuclear Power Engineering Research and Development Institute [VNIIAM], Russia)

The Role of Chemical Reactions in the Chernobyl Accident
E. I. Grishanin, O. V. Konovalova, L. N. Phalkovsky (All-Russia Nuclear Power Engineering Research and Development Institute [VNIIAM], Russia)

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O. V. Konovalova (All-Russia Nuclear Power Engineering Research and Development Institute [VNIIAM], Russia)

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J. van Vliet, E. Pelckmans, A. Vandergheynst (BELGONUCLEAIRE)

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New Bifunctional Anion-Exchange Resins for Plutonium Separations
R. A. Bartsch,* J. S. Kim,* J. Nam,* S. F. Marsh,† G. D. Jarvinen† (*Texas Tech University, †Los Alamos National Laboratory)

Effects of Coprecipitation on Uranium and Plutonium Concentrations in Alkaline Salt Solutions
D. T. Hobbs (Westinghouse Savannah River Company)

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A. Osipenko,* A. Bychkov,* O. Skiba,* J. Lacquement,† JM. Adnet,† P. Brossard† (*SSC RIAR, Russia, †CEA/DCC, France)

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V. V. Romanovski,* P. Zhao,* D. C. Hoffman,* D. W. Whisenhunt, Jr.,* D. White,† X. Jide,† K. N. Raymond† (*Lawrence Livermore National Laboratory, †University of California at Berkeley)

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S. B. Clark, S. M. Loyland (Washington State University)

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A. J. Francis (Brookhaven National Laboratory)

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M. D. Hoover, G. J. Newton, B. R. Scott (Lovelace Respiratory Research Institute)

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G. R. Kolonin,* G. R. Choppin† (*United Institute of Geology, Geophysics and Mineralogy, Russia, †Florida State University)

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P. Longmire, C. R. Cotter, I. R. Triay, J. J. Kitten, A. I. Adams (Los Alamos National Laboratory)

Iron Oxide Colloid Facilitated Plutonium Transport in Groundwater
N. Lu, C. R. Cotter, H. D. Kitten, I. R. Triay (Los Alamos National Laboratory)

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E. S. Lyman (Nuclear Control Institute)

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C. F. V. Mason, N. Lu, H. D. Kitten, P. Longmire, W. R. J. R. Turney (Los Alamos National Laboratory)

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C. M. Steele, T. L. Wald, D. I. Chanin (Department of Energy, Los Alamos Area Office)

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Determination of Actinides in WIPP Brines by Inductively Coupled Plasma Mass Spectrometry
S. L. Bonchin, J. A. Eyre, L. A. Gallegos, T. M. Yoshida (Los Alamos National Laboratory)

A Method for Size and Activity Measurement of Minute Alpha Emitting Particles of Dispersed Reactor Fuel
O. A. Bondarenko (Radiation Protection Institute, Ukraine)

A New Principle of Alpha Particle Spectrometry Using SSNTD
O. A. Bondarenko (Radiation Protection Institute, Ukraine)

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J. Cross, D. J. Figg, C. Brink (Los Alamos National Laboratory)

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D. J. Gerth (Los Alamos National Laboratory)

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J. W. Grate,* O. B. Egorov,*† J. Ruzicka† (* Pacific Northwest National Laboratory, †University of Washington)

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D. W. Gray, D. L. Wannigman, P. S. Hoover (Los Alamos National Laboratory)

Neutron Source Processing—Managing Radiation without Using a Hot Cell
D. W. Gray (Los Alamos National Laboratory)

Characterization of Plutonium Irreversibly Bound to Ion Exchange Resins Using X-Ray Absorption Spectroscopy
D. K. Veirs, C. A. Smith, S. D. Conradson, M. P. Neu, L. A. Morales (Los Alamos National Laboratory)

Novel Plutonium Actinide Compounds and Complexes

Spectroscopic Investigations of Np, Pu, and Am in Selected Immobilization Glasses
Z. Assefa,* R. G. Haire,* N. Stump† (*Oak Ridge National Laboratory, †Winston-Salem State University)

Ionic Strength and Acid Concentration Effects on the Thermodynamics and 5f Electronic Structure of Plutonium(IV) Nitrate and Chloride Complexes in Aqueous Solution
J. M. Berg, R. B. Vaughn, M. R. Cisneros, D. K. Veirs (Los Alamos National Laboratory)

Synthesis and Structural Characterization of Uranium (IV, VI) and Plutonium (IV, VI) Phosphates
J. A. Danis,*† H. T. Hawkins,† W. H. Runde,† D. K. Veirs,† B. W. Eichhorn* (*University of Maryland, †Los Alamos National Laboratory)

Electronic Structure and Phase Stability of Pu-Ga Alloys
A. Gonis,* P. E. A. Turchi,* N. Kioussis† (*Lawrence Livermore National Laboratory, †California State University at Northridge)

Crown Ether Complexation of Transuranic Ions (Np, Pu) Factors Influencing Inner-Sphere Versus Outer-Sphere Complexation
D. W. Keogh, D. L. Clark, P. D. Palmer, B. L. Scott, C. D. Tait
(Los Alamos National Laboratory and the Glenn T. Seaborg Institute for Transactinium Science, CA)

Plutonium Coordination Chemistry with Oxygen Donor Ligands
M. P. Neu, D. L. Clark, S. D. Conradson, P. D. Palmer, S. D. Reilly, W. H. Runde, B. L. Scott, C. D. Tait (Los Alamos National Laboratory and the Glenn T. Seaborg Institute for Transactinium Science, CA)

Thermodynamic Studies of Nuclear Waste Ceramic Materials: Enthalpy of Formation for Zirconolite, $CaZrTi_2O_7$
R. L. Putnam,* A. Navrotsky,* B. Ebbinghaus,† M. A. Williamson,¥ J. Y. Huang¥
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Characterization and Stability of Actinide (U, Np, Pu, Am) Carbonates
W. Runde,* D. L. Clark,* S. D. Reilly,* M. P. Neu,* P. D. Palmer,* C. D. Tait,* B. W. Eichhorn†
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Chloride Complexation of Actinide Ions (U, Np, Pu, Am)
W. Runde, M. P. Neu, D. L. Clark, P. D. Palmer, S. D. Reilly, C. D. Tait
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Synthesis and X-Ray Investigation of New Compounds in the U-Nd-Au-Si System
P. S. Salamakha (L'viv State University, Ukraine)

Determination of Thermodynamic Properties of Actinide Elements in Room Temperature Molten Salts
W. H. Smith, D. Costa, F. deRege (Los Alamos National Laboratory)

Synthesis and Structural Chemistry of New Quaternary Germanides and Silicides of Uranium
O. L. Sologub (L'viv State University, Ukraine)

X-Ray Absorption Spectroscopy of Plutonium in Different Oxidation States
C. D. Tait, D. L. Clark, S. D. Conradson, M. P. Neu, P. D. Palmer, S. D. Reilly, W. H. Runde
(Los Alamos National Laboratory and the Glenn T. Seaborg Institute for Transactinium Science, CA)

NEWSMAKERS

A Laboratory-Directed Research and Development (LDRD) proposal put forward by NMT Division has been funded at $900k each year for five years. The proposal, "A New Paradigm in Separations: Molecular Recognition Membranes," was entered in the Competency Development (CD) component of LDRD. This CD proposal spokesperson was **Gordon Jarvinen,** who is collaborating with **Mary Barr** and **Daniel Kathios,** also of NMT; **Kent Abney, Rebecca Chamberlin, Benjamin Mattes, Mark McCleskey, Nancy Sauer, Norman Schroeder,** and **Barbara Smith** of CST Division; **Robert Dye** and **Betty Jorgensen** of MST; and **Antonio Redondo** of T Division.

Dana Christensen, NMT Deputy Division Director, received his Ph.D. from the Department of Chemical Engineering, New Mexico State University in May this year. His dissertation was titled "Decision Making in a Non-profit Engineering Environment."

David Kolman (NMT-6) was the recipient of the 1996 Morris Cohen Award from The Electrochemical Society in recognition of outstanding graduate research in the field of corrosion science and/or engineering. The award was for his Ph.D. research performed at the Center for Electrochemical Science and Engineering at the University of Virginia. The research focussed on the passivity and bare surface kinetics on β-titanium alloys in aqueous chloride solutions and their relevancy to environmentally assisted cracking. The award will be presented in September at the 192nd meeting of the Electrochemical Society in Paris, France.

Plutonium Futures The Science

Santa Fe, NM, on August 25–27, 1997. Conference information is available by visiting the World Wide Web at http://www.lanl.gov/PuConf97, sending e-mail to puconf97@lanl.gov, or calling 505-667-8663.

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