LA-UR-16-20106
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Title: The ACS-NUCL Division 50th Anniversary: Introduction

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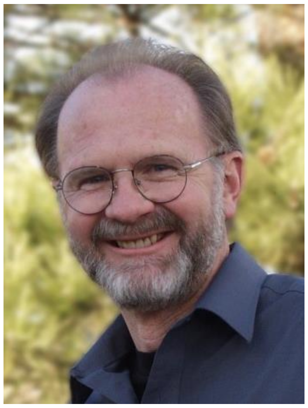
Intended for: Division of Nuclear Chemistry and Technology Newsletter

Issued: 2016-01-10

[Contribution to the Special Issue of the American Chemical Society, Division of Nuclear Chemistry and Technology (NUCL) NEWSLETTER]

The ACS-NUCL Division 50th Anniversary: Introduction



David E. Hobart graduated with his PhD in analytical chemistry from the University of Tennessee, Knoxville. He was a postdoc at Oak Ridge National Laboratory and later accepted a staff position at Los Alamos National Laboratory during which he served two years at DOE Headquarters, Washington D.C. He also worked at Lawrence Berkeley Lab. and later as a technical consultant to Sandia National Laboratories. Returning to Los Alamos, he later retired and is presently a guest scientist at Los Alamos, a courtesy faculty member at Florida State University and 2015 Chair of the ACS Division of Nuclear Chemistry and Technology. His focus areas are lanthanide and actinide chemistry, actinides in the environment and nuclear waste disposal.

The ACS Division of Nuclear Chemistry and Technology was initiated in 1955 as a subdivision of the Division of Industrial and Engineering Chemistry. Probationary divisional status was lifted in 1965. The Division's first symposium was held in Denver in 1964 and it is fitting that we kicked-off the 50th Anniversary in Denver in the spring of 2015. Listed as a small ACS Division with only about 1,000 members, NUCL's impact over the past fifty years has been remarkable. National ACS meetings have had many symposia sponsored or co-sponsored by NUCL that included Nobel Laureates, U.S. Senators, other high-ranking officials and many students as speakers. The range of subjects has been exceptional as are the various prestigious awards established by the Division. Of major impact has been the past 30 years of the NUCL Nuclear Chemistry Summer Schools to help fill the void of qualified nuclear scientists and technicians. In celebrating the 50th Anniversary we honor the past, celebrate the present and shape the future of the Division and nuclear science and technology. To celebrate this auspicious occasion a commemorative lapel pin has been designed for distribution to NUCL Division members.

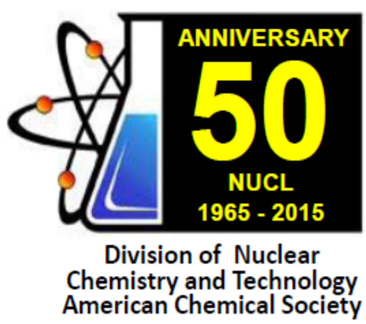


Figure 1. Anniversary lapel pin

Formal steps were initiated in 1962 by Subdivision chair Joseph Martin. Morton Smutz was the first chair of the probationary division with support from Bernice Paige. William Morris and Clark Ice organized the first symposium in Denver in 1964. J. L. Schwenneson chaired the sessions. This symposium entitled, "Production Technology of Np-237 and Pu-238," broke new ground in presenting previously classified technology to the public. The Division of Nuclear Chemistry and Technology was originally designated as DNCT but the abbreviation was later changed to NUCL. In the succeeding fifty years, the range of topics presented at national ACS meetings has been extensive, including fundamental nuclear research, creating new elements, nuclear physics, radiochemistry, analytical chemistry, environmental concerns, nuclear waste disposal, medical radioisotope production, nuclear fuels, etc. The longest-running symposium is Analytical Chemistry in Nuclear Technology which has been featured nearly annually for more than a decade. Most recently at the 2015 ACS National Meeting in Denver, the symposia convened were: The NUCL 50th Anniversary Symposium; The Seaborg Award Symposium in Honor of Heino Nitsche; Nuclear Forensics; and The Convergence of Theory and Experiment in Heavy Element Chemistry.

The many awards sponsored by NUCL over the years have included: The Glenn T. Seaborg Award in Nuclear Chemistry to recognize and encourage research in nuclear and radiochemistry or their applications; The W. Frank Kinard Distinguished Service Award recognizes NUCL members for outstanding service to the Division and the field of nuclear science; The Charles D. Coryell Award honoring undergraduate students who have completed research projects in nuclear or nuclear-related areas; and the Nuclear Summer Schools Outstanding Students Award.

Figure 2. Outstanding Brookhaven Nuclear Summer School Student Award recepient Aaron French as presented by J. David Robertson, ACS NUCL Division Summer School Director

Of significant impact in forging the next generation of nuclear scientists is the ACS NUCL Undergraduate Summer Schools. The first Nuclear Chemistry Summer School intended to educate students and help fill the void of qualified nuclear scientists and technicians was in 1984 at San Jose State University, CA. The subsequent 30 years of the Summer Schools has been highly effective and very successful by producing outstanding graduates. Present fellowships include a stipend of $4000, all tuition and fees, transportation to and from the Summer School location, housing, books, and laboratory supplies. Transferable college credit will be awarded through the ACS accredited chemistry programs at San Jose State University (7 units) or the State University of New York at Stony Brook (6 units). The course will consist of lectures and laboratory work including introduction to state-of-the-art instrumentation. In addition to the formal instruction, the course will include a Guest Lecture Series and tours of nearby research centers at universities and National Laboratories. Participants in the 2015 Summer Schools will be encouraged to join a research project during the following summer at a university or federal research institution. An "Outstanding Student" is selected from each summer school site. These students will be invited to attend the following spring national meeting of the American Chemical Society with all expenses paid.

Over the past five decades communications in the NUCL Division has tracked with the advance of technology. At all ACS national meetings the Division holds an Executive Committee Meeting and a Business Meeting followed by a Social Hour. The NUCL Division Newsletter is distributed quarterly by postal service and e-mail to all members that includes updates from the Division Chair, Program Chair, Treasurer, Summer School Director, and Award Nominations Committee. The Newsletter contains information on upcoming meetings, abstract deadlines, job openings, etc. More recently, the Division has maintained an Internet web site with extensive information about NUCL activities: http://www.nucl-acs.org/

In the last fifty years NUCL Division members have authored countless journal articles, book chapters, books and popular press articles. Important book publications to name a few examples include: The Chemistry of the Actinide Elements, Second Edition (Katz, Seaborg and Morss, Eds.); The Chemistry of the Actinide and Transactinide Elements, Third Edition (Morss, Fuger and Edelstein, Eds.); The Chemical Thermodynamics of Neptunium and Plutonium and The Chemical Thermodynamics of Americium (OECD Nuclear Energy Agency); Modern Nuclear Chemistry (Loveland, Morrissey and Seaborg); Radiochemistry and Nuclear Chemistry (Choppin, et al.); and Advances in Plutonium Chemistry 1967-2000 (Hoffman, Ed.). In progress is the rewrite of the classic text, The Plutonium Handbook (Clark, Geeson and Hanrahan, Eds.) dedicated to the 75th Anniversary of the discovery of plutonium by Seaborg and co-workers.

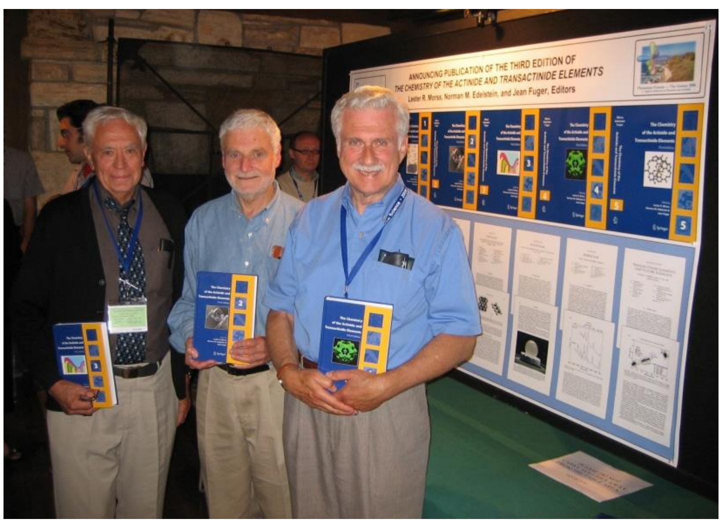


Figure 3. Editors of the *Chemistry of the Actinide and Transactinide Elements. Many NUCL Division authors are major contributors to this classic monograph.*

During the 50th Anniversary year it is useful to reflect on the many nuclear-related activities and incidents that have involved or affected members of the NUCL Division and the world at-large over the last five decades. For more than fifty years we have been living under the nuclear double-edged sword that offers the threat of devastating weapons of mass-destruction or the promise of unlimited power for future generations. There is no doubt that the Cuban Missile Crisis of 1961 was very close to initiating a nuclear world war. Calm political negotiations brought us back from the brink. The collapse of the Soviet Union in 1991 also lowered the nuclear crisis threshold, ushering in the end of the Cold War. With the end of the Cold War the United States had to change its nuclear weapons posture that ushered in the end of nuclear testing. No testing meant that we would then rely on science-based stockpile stewardship and computer simulation of weapons testing experiments. Treaties with the Russian Republic and other nations required a nuclear weapons stockpile reduction. With the lack of controlling and securing of special nuclear materials (SNM) in the Former Soviet Union, the US, other nations and the IAEA stepped up to secure these locations and safeguard the SNM from illicit activities and potential diversion.

Many nuclear scientists from the US and abroad supported the International Atomic Energy Agency in controlling the abandoned nuclear facilities and aided in accounting for SNM. Closer to home and more recently, the closure of the Rocky Flats Plant north of Denver, CO meant that Los Alamos National Laboratory would assume a major role in weapons production capability.

The threat of nuclear terrorism has become a major concern for nations world-wide. The US and other countries have established agencies and programs aimed at nuclear materials proliferation prevention. For this reason nuclear forensics has become an important science and a critical part of law enforcement. When illicit nuclear material is interdicted or suspected, law enforcement agencies need to answer very quickly the attribution questions: who, what, when, where, how, how much and why. Fission products uniquely identify a specific spent-fuel assembly for international safeguards to prevent and deter potential diversion and help to identify covert nuclear weapons programs. The nuclear fuel assembly power history is a distinct fingerprint and serves as the basis of a method for unique identification of attribution. Using fission product concentrations to characterize attribution seriously limits the ability of a proliferator to deceive law enforcement agencies.

For the first time in decades, less than 100 nuclear power reactors are operating in the US that are still producing 70% of the nation's electricity. Among the causes for this situation are safety concerns brought about by the 1979 Three Mile Island, 1986 Chernobyl, and 2011 Fukushima Daiichi reactor incidents. Furthermore, relatively inexpensive natural gas and oil prices and policies favoring renewable power resources such as wind, solar, etc. have slowed the nuclear power industry. One of the most pressing issues presently impeding the renaissance of nuclear power generation in the US is that of safe nuclear waste disposal. The problem of nuclear waste disposal is urgent. Leaving the radioactive waste issue unsolved creates permanent and tempting targets for terrorist and threatens our health and the environment. We have a moral imperative to solve this problem so we do not burden our children, grandchildren and untold future generations.

Present US Nuclear Regulatory Commission policy separates nuclear waste into two main categories. The first category is civilian nuclear waste generated as a by-product of electrical power generation. This consists mainly of high-level waste that is primarily spent nuclear fuel rods and fission products. The second category is defense nuclear waste resulting from national defense activities and this consists mainly of low-level waste including light actinides, fission products etc. Other minor miscellaneous waste categories include smoke detector Am-243, medical radioisotopes waste, X-ray, gamma ray and neutron sources for drilling exploration, industrial-scale metal production and plutonium-238 waste from space exploration programs.

The Yucca Mountain site adjacent to the Nevada Nuclear Test Site was the proposed site for civilian nuclear waste. The isolated location above the water table and in welded volcanic ash (tuff) the Yucca Mountain Site was thought to be adequate for containing nuclear waste for a million years. Recently however, concerns over potential volcanism and sooner than anticipated surface water infiltration prompted the Obama administration to cancel the project. This leaves the disposition of civilian nuclear waste in limbo at present. The disposition of defense nuclear waste has been addressed by the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico near Carlsbad. WIPP is a licensed permanent nuclear waste repository. A half-mile deep in a

Figure 4. Waste Isolation Pilot Plant near Carlsbad, NM

bedded salt formation was chosen because of its remote location, easy mining operations, long-term geologic stability and self-sealing properties. WIPP now holds more than 171,000 waste containers containing about 4.9 metric tons of plutonium and other nuclear waste elements. Aside from recent safety issues at the WIPP that resulted in temporary closure, it remains one of the best options for nuclear waste disposition. There has been recent discussion that a WIPP-II for civilian high-level waste may be a viable option as well.

Significant achievements have been made in the last 50 years in heavy element science. Mendelevium, element 101, was discovered by Seaborg and co-workers at Berkeley Laboratory in 1955 and in 1958 nobelium, element 102, was discovered at Berkeley. It was after much controversy and conflicting claims from various institutes that the first complete and incontrovertible report of its detection only came in 1966 from the Joint Institute of Nuclear Research at Dubna in the former Soviet Union. Earlier, in January 1958, the U.S. Atomic Energy Commission reviewed the status of transuranium isotope production in the US and built the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory with a fundamental focus on isotope research and production. Having gone critical in 1965, the in-core uses for HFIR have since broadened to include materials research, fuels research, fusion energy research, isotope production and research for medical, nuclear, detector and safety purposes. Additionally, the HFIR is providing targets for nuclear bombardment reactions to many countries around the world in the quest to discover new heavy elements. In the last fifty years 17 new elements have been discovered from Atomic Number 101 to 118, with only 4 remaining unnamed. The discovery of new elements has been a multi-national endeavor with many researchers working on the projects and involving multiple nuclear facilities. At the forefront of new element discoveries are Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, GSI Helmholtz Centre for Heavy Ion Research, Darmstadt, Germany, and the Flerov Laboratory Joint Institute for Nuclear Research, Dubna, Russia. Ongoing efforts to discover element 119 and 120 and the elusive “Island of Stability” are underway at present in a collaboration between these laboratories.

For more than five decades, radioisotope thermoelectric generators (RTGs) have played a crucial role in the exploration of space, enabling missions of scientific discovery to destinations across the solar system. Strontium-90, americium-241 and plutonium-238 are commonly used in RTGs with Pu-238 the most desireable power system. RTGs are useful where power from solar radiation is not a viable option because of large distances from the Sun. An RTG power system with no moving parts transforms the heat from alpha or beta decay directly into electricity using solid-state thermoelectric converters, which generate electricity using the flow of heat from the large temperature difference between the hot nuclear fuel and the cold space environment. Advances in computer controlled robotics have made long missions possible without jeopardizing human life. Pu-238 also keeps the electronics and computer systems operationally warm in the cold depths of space. These voyages revealed the nature of Earth's moon, icy geysers and sulfur volcanoes on moons of Saturn and Jupiter, and sustained long journeys to the outer reaches of our solar system. The Voyager 1, for example, has passed out of the Solar System. Voyager 1 was launched by NASA in September 1977 to study the outer Solar System. Operating for over 37 years, the spacecraft still communicates with the Deep Space Network to receive routine commands and return data. At a distance of about 130.62 AU (1.954×10 to the10th km), it is the farthest spacecraft from Earth. Voyager 1 has three radioisotope thermoelectric generators (RTGs) mounted on a boom. The RTGs generated about 470 watts of electric power at the time of launch, with the remainder being dissipated as waste heat. The power output of the RTGs does decline over time (due to the short 87.7-year half-life of the Pu-238 and degradation of the thermocouples), but the RTGs of Voyager 1 will continue to support some of its operations until 2025.

Cassini–Huygens is an unmanned spacecraft sent to the planet Saturn. Cassini has studied the planet and its many natural satellites since arriving there in 2004. Developed starting in the 1980s, the design includes a Saturn orbiter, and a lander for the moon Titan. The Huygens craft landed on Titan in 2005. The two-part spacecraft is named after astronomers Giovanni Cassini and Christiaan Huygens. The Cassini orbiter is powered by three radioisotope thermoelectric generators (RTGs), which use heat from the natural decay of about 33 kg (73 lbs.) of plutonium-238 as the dioxide to generate direct current electricity via thermoelectrics. The RTGs were designed to have very long operational lifetimes.

The Mars Science Laboratory Mission Rover named “Curiosity” is also powered by radioisotope power generators. This power source gives the mission an operating lifespan on Mars' surface of at least a full Martian year (687 Earth days) or more while also providing significantly greater mobility and operational flexibility, enhanced science payload capability, and exploration of a much larger range of latitudes and altitudes than was possible on previous missions to Mars.

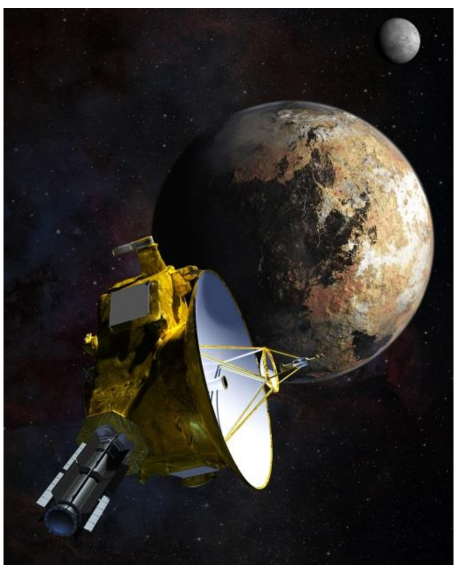


Figure 5. Artist's rendering of the New Horizons during its Pluto flyby. The RTG assembly is the boom at lower left.

The most recent NASA mission launched in January 2015 is the exploration of the planetoid Pluto, which is the origin of the name of the element plutonium named by Glenn Seaborg. Electrical power for the New Horizons is furnished by a single RTG. The compact, rugged General Purpose Heat Source (GPHS)-RTG aboard New Horizons, developed and provided by the U.S. Department of Energy, carries approximately 11 kilograms (24 pounds) of plutonium dioxide fuel. The New Horizons spacecraft was designed to make the first close-up study of Pluto and its moons and other icy worlds in the distant Kuiper Belt. The spacecraft has seven scientific instruments to study the atmospheres, surfaces, interiors and intriguing environments of Pluto and its distant neighbors.

Of major impact in the last few decades is the advent of the Information Age and the power of the Internet for instantly accessing chemical information (or any information for that matter). With a virtual library subscription, users can access nearly any book or journal article that has been made available digitally. Web sites like Wikipedia offer rapid access to a variety of science topics. Additionally, users can contribute their own knowledge to the information pool.

In conclusion, the ACS-NUCL Divisions impact has been remarkable over the last 50 years and it is expected that the Division will continue to serve its members, science and society over the next 50 years. Happy Anniversary NUCL!