Development of a PhD Radiochemistry Program at the University of Texas at Austin

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Introduction

The latter half of the 20th century witnessed an unprecedented amount of research and development in the use of radiochemistry in the United States spearheaded by cold war defense needs, the emergence of the new areas of nuclear medicine and its requirements for novel radioactive isotopes, and the 1954 Atoms for Peace initiated by former President Dwight Eisenhower. Equally important was the establishment of the International Atomic Energy Agency in 1956, which promoted worldwide usage of nuclear applications including various aspects of radiochemistry. In the US, radiochemistry programs traditionally resided in chemistry departments, although many geochemists judiciously employed these techniques in their research areas. In the 1960's and 70's, the Department of Energy actively supported many university programs involving radiochemistry research and the Atomic Energy Commission gave out many fellowships in the nuclear chemistry. Training of radiochemists at the graduate level was easily achievable through the existence of funded research programs at various US universities. However, by the mid 1970's with fewer opportunities for funded research and the appearance non-destructive techniques that did not require sophisticated radiochemistry techniques, many chemistry departments began to down-size or eliminate graduate research in radiochemistry. At first, the reduction in trained radiochemists to meet DOE and general nuclear medicine needs did not appear alarming. By the early 1990's with the retirement of many traditional radiochemists at the national laboratories and universities, the national critical needs in a variety of radiochemistry areas were not, and still are not effectively being met. This effect was compounded by fewer opportunities from the National Science Foundation except in a very few specific areas of research. The DOE continued to have very good success of undergraduate summer programs in nuclear chemistry at San Jose State University and Brookhaven National Lab. However, an overall focus in radiochemistry at the graduate level did not materialize until the first DOE REAP program came into existence in the late 1990's. More recently, the DOE has initiated the Advanced Accelerator Applications University Fellowship Program, which also has several areas in radiochemistry research. The continued awareness of the needs for trained radiochemists, particularly US citizens, in a variety of national laboratory objectives, nuclear energy security and nuclear medicine, has given the implementation of comprehensive graduate radiochemistry programs a high priority.

Goals and Objectives

In decades past, the trained radiochemist was one who excelled in one or more radioanalytical techniques for specific applications. DOE needs in radiochemistry include waste disposal, nuclear fuel cycle, nuclear medicine, and environmental remediation issues. The modern day radiochemist is expected to understand and to be acquainted with a wide variety radiochemistry and nuclear chemistry aspects. However, a large fraction of DOE staff members and contractors working in nuclear environmental areas possess little training in traditional radiochemical techniques. Today, integrative training of graduate students is an absolute necessity if we hope to solve the complex environmental issues facing DOE. For instance, graduate radiochemists should possess a good knowledge of the nuclear fuel cycle, statistical analysis, chemical engineering flow processes, modern detection systems, new separation science technologies (e.g.; magnetic particle separation for radionuclides), geochemistry, surface science and ground water flow, and soil chemistry leaching dynamics, and have extensive hands on laboratory experience. These aspects are equally important as the usual academic training in fundamentals of nuclear chemistry such as q-values, alpha and beta decay, introductory nuclear physics processes, activation analysis, etc.

The challenge lies in training chemists, chemical, nuclear or environmental engineers in the above mentioned areas so they have the broad-based expertise to solve many of the DOE radiochemistry problems. A close perusal of many national programs having the remaining radiochemistry programs reveals that a comprehensive integrative modern-day approach between universities and national labs is almost non-existent. We have begun to develop an interdisciplinary graduate radiochemistry program in conjunction with three academic areas at the University of Texas (Nuclear Engineering Teaching Lab, Mechanical Engineering Nuclear and Radiation Engineering Option, and Environmental and Water Resources Engineering), and DOE Laboratories. An overview is presented in Figure 1. The program will be comprised of four core areas: (1) Radiochemistry and the Nuclear Fuel Cycle, (2) Geochemistry, Groundwater and Soil Leaching Dynamics, (3) Radioactive Waste Management and Health Physics and (4) Laboratory Techniques.

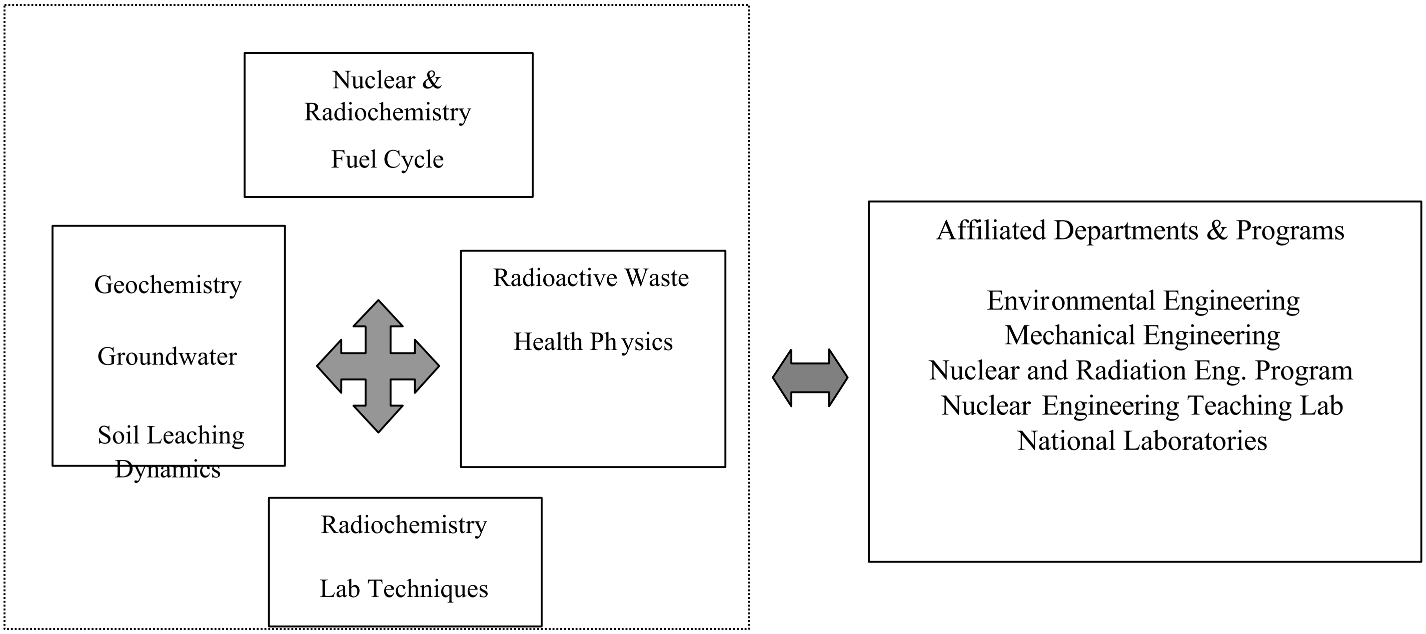

Figure 1. Overview of Interdisciplinary Graduate Radiochemistry Program

Specific objectives of the proposed program include:

1. Develop an integrated curriculum that offers courses within three programs and exposes graduate students to a variety of technical areas in nuclear and radiation engineering, environmental and water resources engineering and geology.

2. Develop an interdisciplinary research program in radiochemistry that involves the active participation of academia and Argonne National Lab.

3. Establish an internship program for graduate students to gain more in-depth experience in radiochemistry with the hope of eventual employment at a DOE national lab.

4. Ensure that our future leaders in radiochemistry represent an interdisciplinary and diverse population and have the skills needed to address the many important DOE issues.

5. Develop a web-based radiochemistry and nuclear fuel cycle course to disseminate the content and results in order to promote the concept of interdisciplinary research and training. Animation and the latestest techniques such as Flash will be used to enhance the understanding of basic radiochemistry concepts.

6. Develop a set of seven in-depth laboratories to train and better prepare radiochemists in

applying radiochemical methods to “real-life” situations.

Multidisciplinary Academic Theme

The major academic thrust is to offer a wide variety of technical courses to better enhance radiochemistry fundamentals both in the classroom and in the laboratory environment. A series of eight courses including a PhD dissertation will be chosen from below. Typically, there are 14-16 courses to take for MS and PhD degrees. The taking of the eight courses in the Radiochemistry Program will still allow the required courses to be taken for the Nuclear and Radiation Engineering Program or the Environmental and Water Resources Engineering Program. It is strongly felt that proper training in environmental radiochemistry can best obtained at the PhD level, with other fundamental technical courses in a major program. All the students are required to take all four courses in the Nuclear and Radiation Engineering Program, two from Environmental and Water Resources Engineering, and two out three from Geology. The courses are listed and briefly described in the next section. All MS and PhD graduate students in the regular Nuclear and Radiation Engineering Program will be highly encouraged to take the courses to be developed: Radiochemistry and the Nuclear Fuel Cycle, and Radiochemistry Laboratory. Currently PhD Nuclear and Radiation Engineering students in environmental research are taking courses in Environmental and Water Resources Engineering. More experience in hands-on experimentation for nuclear and radiation engineers will only strengthen their academic preparation. Currently almost all US nuclear engineering programs have virtually no wet chemistry laboratories involving handling of radioactive materials.

Nuclear and Radiation Engineering Program

Nuclear Health Physics

Atoms and x-rays, nuclei and nuclear radiations; radioactivity; nuclear reactions; interaction of radiation with physical and biological matter; radiation dosimetry; biological effects of radiation; radiation protection and regulatory standards.

Radioactive Waste Management.

An introduction to radioactive waste management covering the topics of waste forms; regulations and repository siting; public health and environmental issues; remediation and stabilization; low and high-level waste management; air dispersion; and radioactive groundwater transport.

Nuclear and Radiochemistry (to be developed)

Basic concepts in nuclear and radiochemistry processes, fundamental principles of decay and transformations, parent-daughter relationships, production of actinides and fission products, and their chemistry, ORIGEN code for calculating and predicting activities of fission and actinide products.

Radiochemistry Laboratory (to be developed)

Seven in-depth laboratories to be developed: statistics of low level counting, neutron activation analysis and the nuclear fuel cycle, solvent extraction of radionuclides, alpha counting, low-level gamma-ray counting with Compton suppression methods and thin window detectors for low energy gamma and x-rays, and radioactivity leaching dynamics of soils, adsorption of radioactive species in soil environments.

Environmental and Water Resources Engineering

Environmental Analysis

Advanced analytical procedures for the sampling, monitoring, and analyses of air, liquid, and other wastes.

Groundwater Pollution and Transport.

Advection, diffusion, and dispersion; advection-dispersion equation and analytical models; transport in the vadose zone; multiphase partitioning; multiphase flow and free product recovery; numerical modeling.

Surface and Soil Chemistry

Studies in the relationship between surface water chemistry and soil, leaching dynamics and absorption properties.

Department of Geology

Chemical Hydrogeology.

Introduction to the chemistry of water in the subsurface. Topics include basic thermodynamics and kinetics of rock-water interaction, acid-base theory, redox, and coordination chemistry. Three lecture hours and two laboratory hours a week for one semester.

Environmental Isotope Geochemistry.

The application of the isotope and trace element geochemistry of natural waters and sediments to studies of the hydrologic cycle. Stable, radiogenic, and cosmogenic isotopes are used as tracers of the evolution of groundwater, surface water, and ocean water. Three lecture hours a week for one semester, with laboratory hours to be arranged.

Isotope Geology.

Relation of isotope fractionation to earth processes; age determinations from ratios of unstable isotopes to daughter products; techniques of mass spectrometry.

Internships

It is expected that graduate students will perform their first year's summer internships at National Laboratories. Research objectives will be determined in conjunction with radiochemistry needs. After the course work is completed, the graduate student will be located at the National

Laboratory until the degree is completed. Funding is sought to recruit two new graduate students per year with the anticipation that the National Laboratories will then fund the student after the first year is completed or funding will be found from other radiochemistry or nuclear chemistry research projects. In such a way, funding will be used to maximize the number of graduate students receiving graduate degrees in radiochemistry, thus being a pipeline to DOE labs. Undergraduate students will also be recruited and encouraged to apply for summer internship programs. This will allow easier recruiting of graduate students. Adequate training will be given at the University of Texas so that "down-time" is minimized. The National Laboratories have excellent facilities in a wide range of radiochemistry and actinide research including state-of-the-art instrumentation for characterization of radioactive species.

Conclusion

It envisaged that this program will have the ability to provide trained PhD graduates to DOE and its contractors helping to alleviate the current and future shortage of radiochemists. Graduates from this program will have strong interdisciplinary skills in nuclear radioanalytical and environmental techniques that can be obtained in either the Nuclear and Radiation Engineering or the Environmental and Water Resources Programs. This program will open up new collaborative opportunities with DOE in other related radiochemistry areas, and thus will be a catalyst for future PhD training. The several students funded through this project and the development of the environmental chemistry laboratory course will provide the framework for a new era in environmental radiochemistry education.

Sheldon Landsberger is a Professor and Coordinator of the Nuclear and Radiation Engineering Program within the Department of Mechanical Engineering at the University of Texas at Austin. He received his PhD from the University of Toronto in the Department of Chemical Engineering and Applied Chemistry in 1982. He has spent the last five years instituting a complete web-based distance learning program at the MS and PhD level.

Donna O'Kelly is Manager of the Nuclear Analytical Services at the Nuclear Engineering Teaching Lab at the University of Texas. She received her PhD in 1996 from Texas A&M in nuclear chemistry. She has had several years of experience in heavy ion nuclear interactions and accelerator development. Her current interests include neutron activation analysis of environmental samples, positron research and radiochemistry education.

Lynn Katz is Associate Professor in the Environmental Engineering Program at the University of Texas. She has over fifteen years of experience examining reaction phenomena at interfaces and evaluating the impact of these processes on the fate and transport of organic and inorganic contaminants in the environment. Her research has involved both fundamental and applied research in this field and has included the development of in-situ remediation and ex-situ treatment processes for contaminated water. Her current interests include surface complexation modeling of the adsorption of radionuclides and metal ions to clays and clay minerals, adsorption of

radionuclides by engineered soils beneath low-level radioactive waste disposal facilities and development and evaluation of engineered treatment systems for in-situ and ex-situ remediation of contaminants.