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Training in Environmental Analyses for Safeguards

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TRAINING IN ENVIRONMENTAL ANALYSES FOR SAFEGUARDS

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ABSTRACT

Responding to recommendations of the DOE/NNSA's *Next Generation Safeguards Initiative*, a new course, *Training in Environmental Sample Analysis for IAEA Safeguards*, is being offered as a summer internship opportunity at Lawrence Livermore National Laboratory. The first students completed the 8 week program during the summer of 2008. Interns are given training in the analysis of bulk environmental samples for safeguards through hands-on experience working in a clean laboratory, purifying U and Pu from bulk environmental samples, and measuring U and Pu isotope ratios by multi-collector ICP mass spectrometry. A series of lectures by invited safeguards and non-proliferation experts gives the students a broad picture of the safeguards work of the IAEA. At the end of the course, the students prepare a poster of their work to showcase at LLNL's summer student poster symposium. Both undergraduate and graduate students are recruited and hired as paid interns under the aegis of the Glenn T. Seaborg Institute in the Physical and Life Sciences Directorate at LLNL. This training course seeks to introduce students to analytical and interpretive skill-sets that are not generally taught at universities, and to encourage them to pursue careers with the IAEA.

INTRODUCTION

The DOE/NNSA NGSI program is supporting a new summer course at LLNL that is designed to teach the skills necessary to make analyses of environmental samples for safeguards. The course is taught by Ross Williams and Amy Gaffney, staff scientists in the Chemical Sciences Division of the Physical and Life Sciences Directorate. Five students recruited from universities across the US are employed as summer interns for this two month program. They join a larger cohort of summer scholars at LLNL and are encouraged to take advantage of the multi-disciplinary educational opportunities offered by interaction with other students and with LLNL scientists, and have the opportunity to attend Lab-wide lectures. Administration of this program is supported by Glenn T. Seaborg Institute, which serves as a national center for the education and training of the next generation of scientists in the fields of nuclear chemistry, chemical engineering, materials science, environmental chemistry and chemical biology.

COURSE DESCRIPTION

The students receive training in the analysis of bulk environmental samples through hands-on experience working in a clean laboratory, purifying U and Pu from bulk environmental samples, and measuring U and Pu isotope ratios by multi-collector ICP mass spectrometry. To learn the basic skills, the students first make analyses of QA/QC samples prepared at LLNL for the DOE/NWAL and for other international round-robin comparisons, and learn how to interpret the analytical data. Then, a group analytical project is developed and the students collect and analyze unknown environmental samples, and prepare a poster of their work.

The following is a condensed version of the syllabus developed for summer 2009, which only gives the classroom instruction topics.

Week 1

Introduction to LLNL. Training, training, and training. Safety, safety and safety. The first group meeting will be on *Thursday, June 18 at 3:30 PM* in the Oujia Room Introductions and an overview.

Week 2

June 23: The IAEA NWAL. What is it? Why make "Analyses of Low-Level U and Pu in Bulk Environmental Samples"?
June 25: History of the development and application of isotope ratio measurements

Week 3

June 30: Inorganic isotope ratio mass spectrometry – Part 1: The fundamentals
July 2: Introduction to the LLNL mass spectrometers (IsoProbe, Nu Plasma and Triton); applications and operations

Week 4

July 7: Inorganic isotope ratio mass spectrometry – Part 2: Ion-counting and statistics
July 9: Data reduction and sources of uncertainty in analysis; Guide to the Expression of Uncertainty in Measurement (GUM)

Week 5

July 14: Application of software for GUM
July 16: Working with data – present results from QC samples; interpretations; troubleshoot problems with analyses and uncertainty estimates; what does it all mean?

Week 6

July 21: Gamma-ray spectrometry – an introduction and its role in safeguards
July 23: U-enrichment, reactor operations and interpretation of data from bulk environmental samples

Week 7

July 28: The cutting edge in isotope ratio measurements
July 30: Nuclear forensics and international safeguards

Week 8

Aug 4: Proliferation detection
Aug 6: Other applications of isotope ratio analyses (biomedical, environmental, and geological)

As work in the chemistry laboratory proceeds, the students are given problems to solve that dovetail with the lecture content and the data acquisition. For example, problems on the atomic weight of uranium and a spike calibration exercise are assigned in weeks 2 and 3, and exercises on the evaluation and propagation of uncertainties are assigned in weeks 4 and 5. Data from the students' analyses of the QC samples, and of the unknown environmental samples are used to illustrate isotope mixing relationships and teach interpretation skills during weeks 6 and 7.

INDEPENDENT PROJECTS

After learning the relevant analytical techniques through analysis of the QA/QC samples, and with an introduction to the range of applications of these analytical techniques through the classroom lectures and problem sets, the students devise independent projects to complete during the remainder of their summer internship. In 2008, one independent project quantified the separation factors for U and Pu relative to set of potential interfering elements (Hf, Ta, W, Re, Ir, Pt, Au, Tl, Pb and Bi) using different purification media (AG1-X8, U-TEVA and TEVA). This work demonstrated that anion exchange resin was more effective at separating U and Pu from elements that can form isobaric interferences on the U and Pu isotopes. For the 2009 summer course, students will be encouraged to undertake independent projects with an environmental application. For example, students may search for the presence of fallout Pu in sediment samples.

SKILL-SET TAUGHT

The specific skill-set that pertains to analyses of bulk environmental samples for safeguards consists of: 1) the isolation and chemical purification of U and Pu found in trace amounts in environmental samples; 2) analysis of the isotopic composition of purified U and Pu by inorganic isotope ratio mass spectrometry; and 3) the data reduction and interpretation of these isotope ratio analyses. One might think that there are plenty of isotope geochemists, cosmochemists and radiochemists being taught such skills in earth sciences, nuclear chemistry, and planetary science departments at many colleges and universities, but there are not. The lack of training is due to the fact that plutonium is generally of little academic interest. The scarcity of talent is also due to the cross-disciplinary nature of the skill-set; one needs to be a skillful chemist and a careful instrumentalist. For example, the young isotope geochemist learning the art of element purification in clean-labs might be preparing microgram samples for isotopic analysis, or a budding radiochemist might be purifying samples for a decay counting method. Both scientists seldom appreciate the purity requirements and the control of cross-contamination and processing blank necessary for low-level pulse counting analyses by mass spectrometry. For both scientists, plutonium samples at the femtogram level are in a different world, at an abundance rarely considered in most applications of isotope analysis and radiochemistry. Our training program opens the door to that world.

PURPOSE AND CONCLUSION

We attempt to introduce the students to a wide variety of topics and give them at least a glimpse of the myriad subtleties of each topic, and an appreciation of the depths that must be plumbed. In the short term, we are not manufacturing experts in environmental sample analysis. That would take years, but we believe these introductions are the first step for some students who ultimately will consider careers with the IAEA.

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