Introduction

One of the main needs for the US Department of Energy (DOE) is the training of students with advanced degrees in radiochemistry to maintain ongoing and new programs in radioactive waste management, nuclear fuel cycle, nuclear medicine, non-proliferation, and the new areas of homeland security. In the past two decades, the number of students choosing radiochemistry has dramatically fallen to the point where there is a dearth of qualified personnel to work in above mentioned areas. Traditionally nuclear and radiochemistry was taught in chemistry departments. But as research funding decreased and radiochemistry was considered to be “old chemistry”, the vast majority of academic institutions ceased to hire young faculty in this area. This inadvertently led to fewer courses taught resulting in small numbers of students being exposed to even basic nuclear and radiochemistry concepts. As the demographics of US DOE National Laboratories show signs of its employees getting older and retiring, there remains this critical need to revitalize nuclear and radiochemistry, particularly at the graduate level. In 1999, The DOE Office of Nuclear Energy, Science and Technology (NE) established the "Radiochemistry Education Award Program" (REAP) to provide matching funds to universities interested in improving the educational aspects of their radiochemistry education programs. The key to this 3-year program is the matching funds provided by the respective University, thus expressing support for the development of radiochemistry on their campus. Three universities were initially funded; Washington State University, Clemson University and University of Missouri at Columbia. In 2001, three more universities were funded that included University of Texas at Austin, Colorado University and Washington State University.

Many engineering courses throughout North America are experiencing paradigm shifts in
their content and delivery of material, primarily through web based teaching and interactive modules. Pedagogically, the teaching of traditional chemistry courses to engineers, other than chemical engineers, poses a unique challenge. This is even further taxing in trying to employ proper teaching methodologies to elucidate basic concepts in nuclear and radiochemistry at the graduate level. Based on our previous experience in teaching a highly successful one hour introductory course called Introduction to Nuclear and Radiation Engineering Concepts that included many flash animations, we are in the process of incorporating these techniques to be used as part of our new Nuclear and Radiochemistry course to be offered in fall 2003.

Course Design

In the past two decades several books have been published dealing with the subject matter of nuclear and radiochemistry. Several of the books have chapters that are written with the presumed prerequisite of having a fundamental understanding of nuclear physics. Ultimately, these books do not serve well the novice engineering or chemistry student wanting to get involved in graduate work in nuclear or radiochemistry. Very recently, a new English version of a book was published entitled Nuclear and Radiochemistry: Fundamentals and Applications by K. H. Leiser (John Wiley). The modern format, style and content of the book are very well suited for graduate instruction. It contains the following chapters:

- Radioactivity in Nature
- Radioelements, Isotopes and Radionuclides
- Physical Properties of Atomic Nuclei and Elementary Particles
- Radioactive Decay
- Decay Modes
- Nuclear Radiation
- Measurement of Nuclear Radiation
- Nuclear Reactions
- Chemical Effects of Nuclear Reactions
- Influence of Chemical Bonding on Nuclear Properties
- Nuclear Energy, Nuclear Reactors, Nuclear Fuel and Fuel Cycles
- Radioanalysis
- Radiotracers in Chemistry
- Radionuclides in the Life Sciences

The first lecture is of a historical nature on the impact of pioneers in physics and chemistry in the field of nuclear and radiochemistry. Extensive usage of the Web for historical accounts and images is integrated into the lecture format.

Our main goal with creating the animation is to supplement the traditional teaching format and enhance the learning experience, thus, giving the student the ability to independently revisit the nuclear processes they learned in class. Most of the animations are based on already developed well-known scientific figures and tables in the book. Thus there is no need to “re-invent
the wheel”. Along with each animation, power point lectures are given to explain the processes in a more traditional teaching fashion.

To augment the offering of traditional lectures we have developed sophisticated animations using Flash MX to better explain the fundamentals of many of the concepts. Flash provides the ability to integrate multimedia elements into existing Web pages with the use of a simple player (plug-in). Flash content allows more interactivity and slicker graphical presentation than straight HTML (HTML is the basic form that delivers text information over the Internet). Graphics and animations anti-alias and scale based on the viewer’s screen size, providing high-quality viewing. Flash players are lightweight (easily downloadable) and widely installed on various user systems (1). In the past years Flash has grown into the de facto technology for simple Web interactivity.

Work Process

The work process of transforming static graphics to web animation consists of five steps:

1. Lecture preparation and identifying the elements (graphs, concept, scheme, etc.) to be transformed to animation.
2. Conveying the information to the animation designer.
3. Creating the animation using flash.
4. Correction session.
5. Approval of final animation and incorporating the animation in the class website.

One of the challenges was to bring together the theoretical knowledge of nuclear and radiochemistry and the multimedia specialties of web design. Different personnel with varying backgrounds and expertise usually preform these two functions. The successful development of the online program had to be based on a team effort with a good communication process between the involved parties.

A series of animations have been developed under the following categories.

Naturally Occurring Radioactivity and Radiation

- Electromagnetic spectrum
- Ionization
- Distribution of Natural Radiation
- $^{238}$U Decay Series
- Radiation in Space
- DNA and Radiation
- Cancer Risk and Radiation Exposure
Table of Isotopes

- Chart of Nuclides
- Stable Nuclides and the Line of Beta Stability

Radioactive Decay and Equilibrium

- Decay of the Daughter Nuclide and its Formation from the Mother Nuclide
- Secular Equilibrium
- Transient Equilibrium
- Half-life of Mother Nuclide Shorter than that of Daughter Nuclide - No Radioactive Equilibrium
- Several Successive Transformations: Decay of $^{218}$Po

Alpha, Beta and Gamma Decay Modes

- Decay Scheme of $^{198}$Au
- Decay Scheme of $^{210}$Po
- Beta Spectrum of $^{147}$Pm

Cross-Sections and Nuclear Reactions

- Schematic Explanation of the Cross Section of a Nuclear Reaction
- Cross Sections for Ag for Neutron Absorption as a Function of the Energy of the Neutrons
- Cross Sections of Several Nuclear Reactions of Protons with $^{63}$Cu as a function of their Energy
- Survey of Transmutations of Nuclides by Nuclear Reactions
- Nuclear Reactions with $^{238}$U
- Nuclear Reactions with $^{232}$Th
**Fission Process**

- Neutron Excess of the Fission Products due to the Neutron Excess of Heavy Nuclei
- The Phases of Low-Energy Nuclear Fission
- Fission Yields for the Fission of $^{233}\text{U}$ and $^{239}\text{Pu}$ by Thermal Neutrons
- Fission Yields for the Fission of $^{235}\text{U}$ by Neutrons of Various Energies

**Gamma-Ray Interactions**

- Photon Interaction
- Gamma-Ray Interactions with Germanium Detectors
- The "Small Detector" Extreme in Gamma-Ray Spectroscopy - The Case of Intermediate Detector Size in Gamma Ray Spectroscopy
- The Case of Intermediate Detector Size in Gamma Ray Spectroscopy - Influence of Surrounding Materials on Detector Response
- Influence of Surrounding Materials on Detector Response
- Variation of Scattered Gamma-Ray Energy with Scattering Angle

**Statistics**

- Distribution Function
- Distribution Functions for Two Sets of Data with Differing Amounts of Internal Fluctuation
- Binomial Distribution
- Poisson Distribution for Mean Value
- Discrete Gaussian Distribution for a Mean Value
- Plot of the Corresponding Continuous Form of the Gaussian
Nuclear Reactor

- Pressurized Water Reactor (PWR)
- Reprocessing Separations

A complete illustration of all the animations is not feasible. However, several animations can be illustrated by a series of screen captures (Figures 1-5). These include parent decay and daughter formation, beta decay and gamma ray transitions, fission, photon interactions, and successive decay transformations. The animations are clearly defined and visually eye-catching to accentuate the main highlights of the processes.
Figure 1. Screen Captures of Radioactive Decay and Formation
Figure 2. Screen Captures of Beta and Gamma-Ray Emission of a Radioactive Nuclide
Figure 3. Screen Captures of Nuclear Fission
Figure 4. Screen Captures of Interaction of Photons and Atoms
Figure 5. Screen Captures of Successive Transformations of $^{218}$Po
Conclusion

The development of animation of nuclear processes is time-consuming. But our experience with animations for an introductory course has shown it be very effective in conveying nuclear and radiation engineering concepts to a diverse set of students, as well as helping out in recruiting. The section on Naturally Occurring Radioactivity and Radiation has already been given several times in a one-hour introductory course in Concepts of Nuclear and Radiation Engineering, Health Physics and Radioactive Waste Management, with very positive feedback from the evaluations of the three courses. It is envisaged that these animations will enormously help out in presenting concepts in nuclear and radiochemistry in our up-coming graduate level course in

References

1. In September 2002, NPD Research, the parent company of MediaMetrix, conducted a study to determine what percentage of Web browsers have Macromedia Flash preinstalled. The results show that 97.8% of Web users can experience Macromedia Flash content without having to download and install a player. Read the full study at: http://www.macromedia.com/software/flash/survey/whitepaper

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