What Lies Ahead

by Darleane C. Hoffman

I have always enjoyed the intriguing mix of fundamental research and applied programs in our division. There is a synergistic effect in which the research sparks new applications, while the needs of our diverse interdisciplinary programs stimulate the research. And, as in the past, future challenges for the division are being generated from both our current applied programs and our research.

A particularly exciting challenge that promises to test the full range of our capabilities is how to attach radionuclides to monoclonal antibodies. Such tagged antibodies could be used both to help diagnose tumors with a technique known as tumor imaging or to deliver radiation to a specific diseased site in the body with minimal damage to healthy tissue. The trick will be to keep from destroying the biological activity of the antibody while, at the same time, "caging" the radionuclide securely enough so it won't get loose and go to the wrong place.

Jumping to another exciting area, that of heavy-element and fission research, I think we'll be able to produce many neutron-rich isotopes of the heavy actinide and transactinide elements by heavy-ion transfer reactions, that is, transfer of a neutron-rich portion of an accelerated ion to a heavy target nucleus. More importantly, we will have developed the techniques required to identify these short-lived isotopes as well as to measure their spontaneous fission properties. These advances should also permit resolution of the controversies surrounding the discovery of elements 104, 105, 106, and 107. Perhaps they'll even facilitate the discovery of element 108 which is expected to decay only by spontaneous fission.

We further predict that some of these new isotopes will live long enough to be separated by ingenious chemical techniques, such as centrifugally separated solvent extraction, gas transport, or thermochromotography. It should then be possible to study a number of exciting features that help refine our basic understanding of the atom. In particular, we may be able to observe marked deviations in chemical properties and reactions because of the greater influence of relativistic effects in these new very heavy elements compared to lighter homologs. We wish to compare the observed chemical behavior of the transactinide elements 104, 105, and 106 with their expected behavior as Group IV, V, and VI elements. These experiments will certainly not be easy, but understanding the architecture of the periodic table and its ultimate limits are worthy of our best efforts.

We will also not neglect the light-element region and plan to construct a time-of-flight isochronous spectrometer at LAMPF. We will measure the masses of two to five new isotopes of each of the elements from nitrogen to zinc produced in fragmentation and spallation reactions induced by 800-MeV protons. These measurements will enable us to explore the limits of nuclear stability in the light element region and will critically test the atomic mass models.

I foresee a renaissance of interest in separating isotopes by chemical exchange instead of by more sophisticated techniques such as electromagnetic, gaseous diffusion, or laser separation. Underdeveloped countries will be particularly attracted to such processes because they require only current chemical engineering rather than more sophisticated technology.

The recent progress in artificial intelligence, including robotics and microelectronics, could revolutionize how we handle radioactivity. In fact, techniques developed for radioactive materials will surely carry over into other laboratory operations for any type of hostile environment.

I expect recently developed very sensitive analytical techniques to have a far-reaching impact on many disciplines. For example, we have recently used accelerator-based mass analysis to investigate geochemical processes at much lower concentrations and rates than ever before (see "Migration of Radioisotopes in the Earth's Crust"). We have detected some atoms, such as chlorine-36 in groundwater, in concentrations of only 10^7 atoms per liter—one atom in 10^{19}! We are already applying nuclear microprobe techniques to analyze for surface and trace impurities in materials critical to our nuclear weapons, and we are developing resonance-ionization mass spectrometry for our weapons radiochemical diagnostics program. We anticipate applying these techniques to more fundamental problems, such as to study variations in the solar neutrino flux-or to examine rare modes of nuclear decay such as double beta emission—or to search for quarks and the very heavy X particles that have been postulated.

We are using our expertise in nuclear magnetic resonance to develop methods to follow the progress of metabolism and biochemical processes. We label biologically active compounds with stable carbon, oxygen, and nitrogen isotopes that have nuclear magnetic moments and then follow these compounds with NMR techniques (see "Metabolism As It Happens"). Similarly, NMR techniques can be applied to a variety of other problems, such as elucidating the structure of zeolites and how these minerals bind and hold various chemical species including the radioactive nuclides in nuclear waste. Or, when combined with x-ray and neutron diffraction and time-resolved spectroscopy, NMR can help show why one explosive is very sensitive to detonation while another, superficially very similar, is not.

The techniques we've developed to assess how well a geologic and hydrologic system will isolate radioactive waste will surely find use for nonradioactive waste, such as toxic chemicals. Our studies on rock-water interactions and the migration and fixation of elements in rocks are relevant to production of geothermal energy, ore body formation, and the exploration and development of mineral resources.

I've mentioned only a few of the things I can see for the future. If it sounds as though our division has a wide diversity of interests, that's true, it does. It keeps me hopping trying to keep up. But that's also what keeps it interesting and lets us make contributions that cross traditional, narrow disciplinary lines. ■