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CURRENT STATUS AND FUTURE NEEDS OF NUCLEAR ANALYTICAL TECHNIQUES AND THEIR APPLICATIONS

For the purpose of this course, we define nuclear analytical techniques (NATs) as those that use nuclear reactions, radioactive decay, or nuclear instrumentation to investigate properties of matter. This definition extends from the well-established radiochemistry, neutron activation analysis (NAA), and prompt-gamma activation analysis (PGAA) to advanced methods at the limits of science and technology, and includes the applications of these techniques to the determination of composition and structure of matter for science and technology.
The broad range of nuclear analytical techniques share a set of advantages over competing methods: (i) highly penetrating probe and response radiation; (ii) independence of chemical state and of analytical blank; (iii) non-destructive character, and (iv) sensitivity. NAA in particular is in regular use worldwide to perform elemental analysis of as many as forty elements in a variety of materials important to industrial process development and control, human health, environmental protection, and cultural heritage. NAA is especially valuable in the case of large samples, complex matrices, solid materials that are difficult to dissolve, and QA/QC. Although NAA is mature, several developing extensions to the method promise greater applicability to the analysis of large ultrapure solids and extremely heterogeneous samples. There is an urgent demand for the determination of ultra-fine particles in environmental studies and an understanding of their health impact. NAT's are and will continue to be applied in studies of atmospheric particulates and the developing field of engineered nanoparticles. The broad elemental coverage and high throughput of NAA have made the technique a dominant one in archaeometry.
Several obstacles stand in the way of further use of NATs. Foremost among them are the decline in the number of research reactors in the developed world. This problem may be partly offset by a number of new research reactors in the developing world but also by new developments in DD and DT neutron generator technology. Higher fluence rates, longer life-time and reduced size of the tubes make them attractive as a source of neutrons for analytical purposes when combined with appropriate moderator/shielding and counting equipment.
New developments in analytical techniques and applications:
Over 200 small and medium charged-particle accelerators are in use in many countries for PIXE and other ion beam analysis techniques. Their applications in materials and life sciences are expanding, especially with microbeam facilities which allow imaging in two or three dimensions (more than 40 operational μ-beam facilities available at this moment). Charged-particle activation analysis (with or without radiochemistry) can be a complementary technique to NAA for the determination of particular elements in different matrices (biological, environmental, and certain technologically advanced materials). In the version of TLA (thin layer activation) this technique is effective for wear and corrosion studies on moving mechanical equipments for industrial applications and the assessment of the performances with time of human prostheses as well.There is a remarkable growth in the number and availability of particle accelerators related to the rapid expansion of diagnostic and therapeutic nuclear medicine procedures, notably positron emission tomography (PET), single-photon emission tomography (SPET), (including hybrid systems with CT or MRI), functional diagnosis, molecular imaging, and metabolic radionuclide therapy. For example, more than ten million tests are made with 99mTc annually in North America alone. The number of qualified and experienced professional nuclear scientists and engineers, in particular radiochemists and radiopharmacists, has not kept pace with this increase, leading to greater risks in these procedures. Analytical techniques based on synchrotron radiation are emerging which can provide qualitative and quantitative information on in-vivo elemental composition, structure, and molecular imaging. As many as ten of the new large facilities are dedicated to the biomedical sciences.
The role of trace elements in health and environmental studies:
NATs are playing a significant role in the three "new epidemics"(WHO 2000) of cancer, cardiovascular disease,

and diabetes. NATs have a unique role to aid in understanding the mechanism of brain-gut interactions related to satiety and obesity, which appear to be related to the new epidemics, and are in other ways an important health issue in rapidly developing countries. It is noted that a few investigations have commenced involving NATs in the determination of the composition of biological tissues in connection with HIV incidence in sub-Saharan Africa. According with the recommendations of the international and European pharmacopoeia, the quality assurance/control (QA/QC) of labelled compounds and radiopharmaceuticals for human and animal investigations is required making use of sophisticated and sometimes unusual radiochemical and radioanalytical methods of analysis and NATs,. The development of rapid methods of analysis and visualization of radioactive specimens would give a substantial improvement to these technologies. The stability with time of the labelled species and the evaluation of the expiration time is of paramount relevance for the performances of labelled species. Artificially produced radioactive tracers, characterized by short half-life and high specific activity, are finding several applications in the life sciences, in particular in occupational and environmental toxicology, in metallobiochemistry and nanotoxicology as well as in living organisms (cell cultures, plants, animals, and fishes).

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