

RADIOACTIVATION ANALYSIS

The uses of nuclear radiation in scientific investigation are many and varied. Amongst these is the technique of radioactivation analysis of the constituents of a very small sample of matter by making the sample artificially radioactive. This method is finding increasing use in various fields of study.

The most obvious method of determining the nature and quantities of the constituents of a piece of matter is chemical analysis, but it has certain limitations. For example, if the sample being analysed contains only a very small trace of a particular element, the trace may easily escape chemical detection. Again, if the sample itself is very small, it may be difficult to subject it to chemical analysis. Thirdly, the process of chemical analysis itself may interfere with the nature of the constituents and make correct determination of small traces impossible.

These difficulties can, to a large extent, be overcome by radioactivation analysis which, though not a self-sufficient analytical technique for all purposes, can often be a valuable adjunct to broader methods of investigation. And in some specialized fields, it is the only available method of analysis.

Principles and Method

The first stage in radioactivation analysis is to make the sample radioactive by artificial means. Of the various ways in which this can be done, the most effective is to subject the sample to neutron bombardment. As is well known, a stable atom after capturing an extra neutron usually turns unstable. In other words, a stable isotope of an element becomes a radioactive isotope after absorbing extra neutrons from outside. For example, if an atom of cobalt 59, which is a stable isotope, captures an extra neutron it will turn into an atom of cobalt 60, which is radioactive.

Once the sample has been activated, or made radioactive, the next task is to analyze the radiations given off by the sample. This analysis would indicate the nature and quantities of the various elements present in the sample. The reason is that the radiation from a particular radioisotope is characteristic for that isotope. All radioisotopes do not emit the same radiation. Even where two isotopes give off the same type of radiation, the rate at which the two disintegrate is different and fixed for each isotope. In a given period of time, which is characteristic for each different radioisotope, half the atoms of any given amount of the isotope disintegrate. This period, known as the half-life of a radioisotope, is one of the distinguishing marks of a particular radioisotope. Furthermore, the energy of radiation varies from one isotope to another and these energy values for different radioisotopes are known.

This method of analysis is relatively new and is being increasingly employed and developed. There are various factors which tend to create uncertainties, and these can be resolved only with greater operating experience and assessment of results. The need has therefore been felt for a meeting where experts in the field could discuss their techniques and results, and an opportunity for such discussion was provided by a symposium organized in Vienna by the International Atomic Energy Agency and the Joint Commission on Applied Radioactivity (ICSU).

Vienna Symposium

At this symposium, which met from 1 - 3 June, leading experts in the field presented papers describing various aspects of their work and explaining the results achieved or the problems encountered. These introductory papers were presented by G.B. Cook (Atomic Energy Research Establishment, Harwell, UK), W. Herr (Max Planck Institute, Mainz, Germany), J. Hoste (University of Ghent, Belgium), G.W. Leddicotte (Oak Ridge National Laboratory, USA), J.M.A. Lenihan (Western Regional Hospital Board, Glasgow, UK), and P. Leveque (Centre d'études nucléaires, Saclay, France). On the basis of these introductory papers there was further detailed discussion by the participants in the symposium.

In a paper setting forth the general considerations of radioactivation analysis in reactors, Mr. G.B. Cook pointed out that the sensitivity of this technique depended on the fact that a readily determinable amount of radioisotopes could be induced in a microgramme or less of many elements. To overcome uncertainties, a known weight of the element sought was irradiated with the sample, from which a relationship between the radioactive disintegration rate and the weight of the element sought could be established. This could be applied to the determined disintegration rate of the element from the sample.

On the possible methods of subsequent analysis, Mr. Cook explained that if the main components of the sample had radioisotopes of short half-life, these could be allowed to decay, so that traces of the long lived radioisotopes of the impurities might be examined without interference from large quantities of other isotopes. In such cases, the gamma ray emission, if any, might be estimated using a scintillation spectrometer and the method was non-destructive. Such cases, however, were the exception rather than the rule and usually chemical treatment was necessary. The quantities of trace element, however, were too small to allow simple chemical manipulation, and special processes had to be adopted.

Mr. Cook also pointed out that this method might involve several sources of error and discussed these possibilities in some detail.

Mr. W. Herr drew attention to the fact that radioactivation analysis had proved a powerful tool in tackling fundamental problems in geo- and cosmo-chemistry, and gave a review of the recent work in this field. One of the main advantages of activation analysis was that it could often supply information simultaneously about quantity and isotopic composition of trace elements. Research dealing with the distribution and the abundance of trace elements and especially problems about the geological-age determination of minerals and meteorites were of growing interest. Valuable information could also be obtained on natural radioactivities and their applicability to geological problems. The various analytical data facilitated an understanding of the energy spectrum and the constancy of cosmic radiation during the ages.

Uses in Industry

Mr. P. Leveque's paper on radioactivation analysis in the service of industry pointed out that because of its extreme sensitivity radioactivation analysis had been principally employed for trace detection and its most extensive use had been in the control of semi-conductors and very pure metals. The need to activate the samples in an atomic reactor had, however, hindered its systematic utilization. Mr. Leveque maintained that the errors inherent in radioactivity measurements made it little suited for determining the main constituents of a sample. On the other hand, the utilization of radiation/matter interactions seemed to open the way to a whole series of non-destructive and rapid analyses which were worthy of note, although they were not, strictly speaking, activation analyses.

Mr. G. W. Leddicotte gave an account of the experience gained in the USA, where radioactivation analysis was being used by many investigators in various scientific fields as a practical and useful tool for elemental analyses. Much of this work had been concerned with determining submicrogramme and microgramme concentration of many different elements in samples of biological materials, drugs, fertilizers, fine chemicals, foods, fuels, glass, ceramic materials, metals, minerals, paints, petroleum products, resinous materials, soils, toxicants, water and other materials. In addition to these studies, radioactivation analysis had been used by other investigators to determine isotopic ratios of the stable isotopes of some of the elements.

Mr. J. M. A. Lenihan's paper dealt with radioactivation analysis in biochemistry and medicine. He thought that this technique, already practised successfully (though not very widely) in human and animal biochemistry, was likely to prove increasingly useful in both these sciences. The simplicity, quickness, sensitivity and accuracy of the activation method had been



Experts on radioactivation analysis at the Vienna symposium

employed to a limited extent in dentistry, forensic medicine and cancer research. In these and certain other fields of clinical investigation many interesting problems suggested themselves for future study. In biochemistry the activation technique had so far been used mainly in the analysis of tissue samples, not only for trace elements, but also for commoner constituents (such as sodium and potassium) where other methods were lacking in sensitivity or convenience. The metabolism of some elements (e.g. strontium) could be explained to only a limited extent by radioactive tracer tests or conventional biochemical techniques. In such cases, activation methods were useful in studying the distribution of the normal element in tissues and excreta. Mr. Lenihan pointed out that while most of the biochemical applications of radioactivation analysis needed access to a nuclear reactor, rapid and accurate routine measurements of blood sodium could be done with a portable neutron source suitable for hospital use.

Mr. J. Hoste stated that activation analysis was not only a valuable analytical tool in the determination of traces, but was also useful in the determination of minor constituents in highly complex materials. Results in some cases indicated that accuracy and precision were of the same order, or better than in chemical analysis, even when no chemical separation was used.

These papers and the discussions that followed, which will be of considerable interest to scientists, research workers and technicians in various fields, will be published jointly by IAEA and the Joint Commission on Applied Radioactivity.