IS ACTIVATION ANALYSIS STILL ACTIVE?

Zhifang Chai
Institute of High Energy Physics, Chinese Academy of Sciences,
Beijing, China

Abstract. This paper reviews some aspects of neutron activation analysis (NAA), covering instrumental neutron activation analysis (INAA), k_0 method, prompt gamma-ray neutron activation analysis (PGNAA), radiochemical neutron activation analysis (RNAA) and molecular activation analysis (MAA). The comparison of neutron activation analysis with other analytical techniques are also made.

1. INTRODUCTION

Over sixty years have passed since Hevesy and Levi first utilized a neutron source to analyze dysprosium in Y_2O_3 by NAA in 1936. No doubt, the NAA has played a very important role in science and technology, especially at its early development stage as a unique analytical arsenal characteristic of nuclear properties. Its extremely high sensitivity for most elements in the periodical table, good accuracy and precision, non-destructiveness, less matrix effect and multi-elemental analysis ability, etc. are so fascinating that the NAA has become an authorized method in the trace elemental analysis, even the sole selection in some cases, e.g. activable stable isotope tracing, in vivo analysis, fine solid particle (cosmic dust and atmospheric aerosol) analysis, etc. However, with the development of other non-nuclear analysis methods in recent years, e.g. Inductively-Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), Inductively-Coupled Plasma-Mass Spectroscopy (ICP-MS), Laser Photoionization Spectroscopy (LAPIS), the NAA seems to lose the past eminence. Naturally, a question arises: *Is Activation Analysis Still Active?*

2. INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS (INAA)

With the advent of high purity Ge detector, the INAA has become a main member in the nuclear analysis field. Due to its simplicity and good accuracy it has been accepted as a recommended method in certifying the reference materials and applied in multidisciplinary studies, from extraterrestrial matter to deep-sea sediment, from large archaeological relics to very fine atmospheric particles, etc. However, some major obstacles which hinder its development as follows:

— sophisticated hardware. Most reactors used for INAA in the world are so huge and expensive that it is very difficult to access for non-nuclear scientists;
— radiation damage and radioactive waste;
— time-consuming and relatively expensive.

To overcome the first obstruction, a compact reactor, like the Canadian SLOWPOKE or Chinese Miniature Neutron Source Reactor (MNSR), should be exploited. In fact, they can be more or less regarded as a neutron source, instead of a true reactor, which are so safe that they are permitted to be installed at hospitals, universities, even in the downtown area.

To solve the second and third problems, the INAA based on short-lived radioactive nuclides should be thoroughly studied. As an alternative, it can be combined with simple preconcentration procedure to improve its sensitivity and selectivity. Consequently, the INAA is still a unique analytical tool in the fields of major, minor, trace and ultratrace elements.

3. K_0 METHOD

In the past twenty years a number of NAA groups, mostly in Europe, are involved in establishing this method, which is regarded to hold the following merits:

— the troublesome preparation of chemical standards can be avoided;
— the radioactivity counting time for standards can be saved;
— quantitative results for elements, but absent in chemical standards, can be obtained;
— some nuclear parameters, e.g. the cross section of neutron capture reaction and the branching ratio of the gamma-ray emitted by the radioactive nuclide, can be re-evaluated.

In fact the main purpose of this method is to simplify the routine NAA, which benefits the extension of utilization of NAA in non-nuclear fields.

4. PROMPT GAMMA NEUTRON ACTIVATION ANALYSIS (PGNAA)

Although its poor sensitivity for most elements, high radioactive background and complicated gamma spectrum, the PGNAA is developing rapidly due to the improvement of the facility, use of cold neutron and alleviation of background level, which has made it as a unique supplement to the conventional NAA, especially for analysis of H, B, Cd, Sm and some others.

It is worthwhile to mention the related work performed in Japan, USA, Germany, Canada and other countries. The very fascinating feature of PGNAA is to be able to non-destructively analyze large samples, and this method will find a broad application in archaeology. Another potential application field of PGNAA will be in radiotherapy via a boron-containing complex selectively absorbed by cancer tissue.

5. RADIOCHEMICAL NEUTRON ACTIVATION ANALYSIS (RNAA)

The use of RNAA is unlikely to expand significantly in near future, but will remain in specialized areas, e.g. determination of platinum group elements (PGEs) and biologically essential trace elements at low level. Up to now the RNAA is still the only way to be able to analyze all 6 PGEs in various matrices, although the ICP-MS and NTIMS (Negatively Thermolized Ionization Mass Spectroscopy are constituting a true threat to RNAA.

The role of RNAA in the analysis of REEs is fading, but it is still superior to other techniques for small sample analysis. The determinations of some essential trace elements, e.g. Cr, I, V, Mn, Co, etc. highly rely on RNAA, especially at ultratrace level, e.g. serum and sub-cell fractions.

6. MOLECULAR ACTIVATION ANALYSIS (MAA)

The term of MAA refers to an activation method that is able to give information about the chemical species of trace elements in systems of interest, though its definition has remained to be assigned. Its development is strongly stimulated by the urgent need to know the chemical species of elements. Total concentrations are often without any meaning when assessing health or environmental risks or in the explanation of geochemical processes. Recently the study of chemical species is implicitly increasing.

The critical point in the MAA is that it is not permitted to change the original chemical species of elements in systems, or the change has to be under control; in the meantime not allowed to form the "new artefact" originally not present in systems.

Some latest practical examples of the MAA are in the studies of the essential elements (Cr, Fe, Co, Se, I), toxic elements (Hg, As) and unknown elements (REEs, PGEs) in life science.

The important biological effects of chemical species of essential and toxic elements in environmental and biological systems have given a strong impetus to develop the MAA and will further enhance its necessity, and for the foreseeable future it is difficult to imagine how such studies can be pursued without a heavy reliance on the MAA.

Although there are some similarities between the MAA and preconcentrating NAA, the ultimate purpose is quite different. The MAA is aimed at chemical speciation of trace elements in samples of interest, whereas the latter is only to overcome matrix interference or to enhance the analytical sensitivity.

7. COMPARISON OF NAA WITH OTHER ANALYTICAL TECHNIQUES

Comparing analytical methods for trace elements is always very difficult. In fact, each coin has two sides and every method has its own merits and drawbacks. One has to take account of the following factors while doing this comparison:

- sample matrix;
- sensitivity and accuracy;
- contamination danger and blank correction;
- available sample amount;
- speed and cost;
- multi-elemental analysis ability;
- possibility of chemical species study, etc.

Another important factor in the selection of analytical methods is the personnel expertise. Some practical examples for this comparison will be given in this paper, especially in the analysis of platinum group elements, rare earth elements and other interesting elements.

Anyhow, the NAA is a valuable technique due to its nuclear-oriented character, unlike other techniques based on the atomic behaviors. Thus, as an independent arsenal, it will continue to occupy a reasonable position in the analytical kingdom. As a conclusion, what we can say is that activation analysis will still be active , even though it is not like before.

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