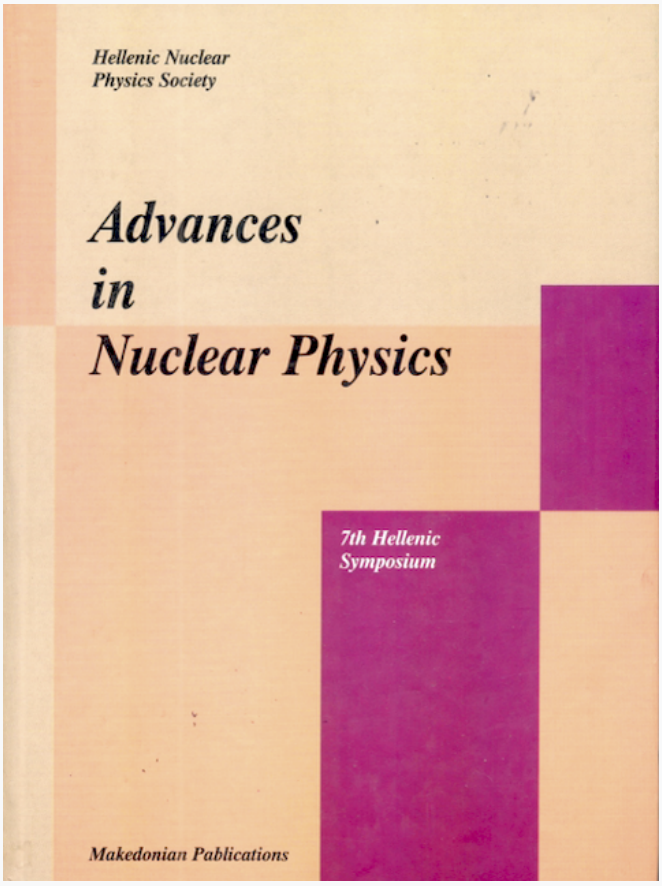
HNPS Advances in Nuclear Physics

Vol 7 (1996)

HNPS1996



Advanced Nuclear Physical Analytical Techniques

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doi: 10.12681/hnps.2401

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Abstract

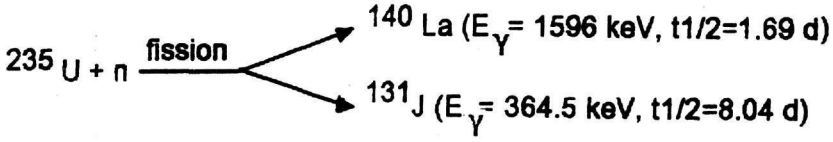
Among the modern analytical methods, the nuclear analytical techniques, and especially neutron activation analysis, pay an important role in accurate and sensitive analysis. The capabilities of this technique and its application range have broadened lately with the development and employment of a combination of special more or less novel sub-techniques. These techniques are (a) loss-free counting gamma-ray spectrometry, (b) radioactive decay compensation and (c) repeated activation and measurement. The first technique permits short-time measurements at high count rates in multielement activation analysis with a wide nuclide concentration and half-life range, while by the other two techniques the counting statistics can be improved considerably especially in short-lived nuclide analysis. Thus, because of the high throughput rate, more customers can be served even far from the reactor site by mailing the samples and getting the analytical results back.

1 Introduction

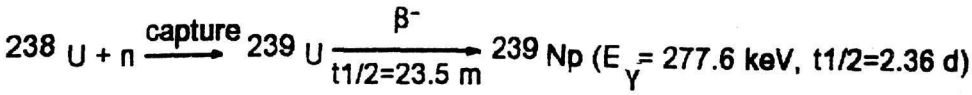
The advantages of neutron activation analysis, such as high accuracy, sensitivity, non-destructive sample preparation, negligible matrix interference, automation possibilities a.o., are limited in certain cases. Thus, in short-lived nuclide analysis, the irradiation, waiting and counting periods should be short, due to rapid radioactive decay, leading to low counting statistics and accuracy [1]. On the other hand, long-lived nuclides require long waiting times to reduce the count rate level from interfering short- and medium-lived nuclides. In general it is difficult to optimize timing if multielement samples with a broad concentration and half-life range have to be analyzed. To overcome these problems, novel special techniques have been employed which enhance the capabilities of neutron activation analysis broadening its application range.

2 The novel techniques

In order to permit instrumental activation analysis at high counting rates and dead times, loss-free counting has been employed, by which the lost counts are continously determined and added instrumentally to the multichannel analyzer for their compensation [2].Thus the waiting time in both short- and long-lived nuclid analysis can be reduced. Besides this short-lived nuclides can be measured in the presence of long-lived nuclides and vice versa without spectral interference even if the count rate is still high [3]. This permits also automation of the analytical system, since no adjustment of the experimental conditions for count rate optimization is required, even if a series of multielement samples with a wide nuclide concentration and half-life range has to be measured. However the loss-free counting technique does not improve the counting statistics, espcially in short-lived nuclide analysis where timing is limited. Therefore other techniques have been developed [4], such as the radioactive decay compensation technique, which is based on the counting efficiency increase during the measurement by source-detector approach, in order to keep the count rate constant and to permit prolongation of the counting period. Thus the total counts can be increased considerably. Besides this repeated cyclic activation of the same sample and cumulative activation of sub-samples can be employed to improve the counting statistics and thus the accuracy and sensitivity of the method. A special application of the above improved INAA techniques is the isotopic uranium determination in nuclear safeguards analysis [5]. The ^{235}U concentration can be derived from gamma spectrometry of the fission products ^{140}La, ^{131}I or others, according to the reaction:



while the ^{238}U concentration can be determined from the ^{239}Np gamma ray peak after beta decay of ^{239}U resulting from neutron capture, according to the reaction:



By plotting the ratio of the ^{140}La/^{239}Np peaks, after substructing the ^{238}U

contribution to fission and consequently to ^{140}La production versus to corresponding ratios of $^{235}U/^{238}U$ for some standards with known ^{235}U enrichment, a calibration curve can be drawn, from which the $^{235}U/^{238}U$ ratio of an unknown sample can be derived by measuring the corresponding $^{140}La/^{239}Np$ ratio. It should be noted that these ratios are independent of the sample mass. However, in order to determine the concentrations of ^{235}U and ^{238}U or total U the samples as well as the calibrants have to be weighed. Since these samples have high uranium concentrations no sensitivity problem exists. However the counting statistics should be high enough for sufficient high accuracy required in nuclear safeguards. Preliminary measurements gave promising results [6]. On the other hand, for trace element determination especially in short-lived nuclide activation analysis, the loss-free counting technique employed above for short-time measurements might not be sufficient but then the above mentioned compensation and repetition techniques might have to be employed for sufficient sensitivity.

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