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Nuclear Data for Non-destructive Assay Techniques

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1. Introduction:

Non destructive assay techniques have the advantage of being non obtrusive and quick and give the results with sufficient accuracy for many applications. Non destructive assay methods could be passive or active. Passive methods by its very nature are more elegant and can be achieved using relatively simple instrumentation hardware and are the best candidates for being adopted as field systems. But it is not always possible to get all the required characteristics of fissile and fertile materials using these methods. It is necessary in many situations to augment the methods using active interrogation.

Many of the methods make use of the nuclear and atomic data for arriving at the results of assay from the measurements, thus eliminating the need for standards. This is discussed for some typical methods in this paper. The precision with which the results of assay can be declared is dependent on the precision with which the relevant nuclear and atomic data are known. Currently a large number of compilations are available, at times conflicting with each other which leaves the user confused. The need for such a compilation has been felt for a long time by the safeguards R&D personnel. It is commendable that the Agency has now embarked upon a programme to consolidate the available data. The Agency should also form an intercomparison group for evaluating the data from the standpoint of safeguard applications and recommend the best set of data.

The various NDA methods generally adopted can be broadly classified as follows:

Passive gamma methods	poor resolution detectors high resolution detectors
Passive neutron methods	total neutron fission neutron
Active methods	x ray fluorescence fission product gammas delayed neutrons

2. Passive gamma methods:

The best field application of passive gammas is demonstrated by the use of high resolution gamma spectrometry for the assay of plutonium isotopic composition. In this method the atom ratio of two isotopes is related to the peak intensity ratio of two selected gamma lines from the two through nuclear data after correction for the difference in the relative efficiencies. The relative efficiency function takes into account the difference in efficiency due to the detector, detector-sample geometry and the self attenuation in the sample material and is a sample dependent parameter which has to be generated from the measurements on the sample itself. This makes the method independent of any standards. Using this method it is possible to achieve a precision of about 2%. Most of the data on half-lives, branching intensities are available to enable the results to be arrived at with this precision. But during the course of our work[1,2] we found many gamma ray intensities have uncertainities not acceptable to attain the required precision in the results. Further they should be continuously upgraded to improve the precision that can be obtained using this method. As an example the intensity of 43.40 keV gamma line from ^{241}Am as obtained from published literature was found to be inconsistent with other gamma lines in the region and was re-evaluated[3]. This shows the need for evaluation of the data from the standpoint of safeguards applications.

For the estimation of ^{242}Pu composition no suitable gamma signature is available and isotopic correlation method has to be adopted. The correlation data for different reactor

systems for this purpose may be included in the compilation.

Similar methods have now been applied for analysis of ^{233}U composition[4]. The situation is compounded in this case by the presence of significant daughter product activity build-up of uncertain equilibrium both from ^{233}U and ^{232}U. But the gamma signatures are more intense than in the case of plutonium isotopes. The required data on half-lives and branching intensities of ^{232}U and ^{233}U and their daughter products should also find a place in the compilation. The data on these with sufficient precision are not as abundantly available as for plutonium isotopes.

Recently we developed a similar method[5] for the isotopic composition of natural uranium isotopes ^{234}U, ^{235}U and ^{238}U in depleted and enriched uranium samples. This involved the analysis of low energy gamma lines from these isotopes and their daughter products. Our experience is that the data on these have not the same accuracy as in the case of plutonium isotopes.

An intercomparison for assay of plutonium isotopic composition was organised by KFK[6] which arrived at certain conclusions regarding the accuracy of available data. No such studies have been carried out either for naturally occuring uranium isotopes or for artificially produced uranium isotopes.

3. Passive Neutron Methods:

We have some experience with neutron coincident counting systems[7]. Though the nuclear data do not enter directly to declare assay results, they are needed for its standardisation. In particular data on the average number of neutrons ($\bar{\nu}$) emitted in various spontaneous fissions, the ν vs $P(\nu)$ distribution, the neutron yield from these and the neutron yields from (α,n) reactions are the data needed for this application. In certain situations gross neutron counting making use of the data on neutron yields gives valuable information[8].

4. Active Methods:

A system to characterise the Pu/U ratio[9] has been recently developed using x ray fluorescence with a ^{57}Co source. When published data on photo-absorption cross sections, fluorescent yields and branching intensities were used a constant bias of about 5% was observed in the results. When the bias was removed by fitting the data using standards, the method gave excellent self-consistent results. On referring back to the data, it was found to have an uncertainity of about 10% and this explained the bias. In the proposed compilation such atomic data should also be included. This is an instance for the necessity of including non-nuclear data in the compilation.

The k edge absorptiometry [1,10] is another method which has been well developed in recent years for measurement of U and Pu concentration in solutions. The method is capable of very high precision. A search for nuclear data on photon cross sections matching this precision is needed.

A number of years back we developed an activation method [11] for estimation of Pu/U ratio in samples, using a reactor.The method essentially consisted of measuring the delayed gamma spectrum and delayed neutron intensity after short neutron irradiation of the samples (mgm quantity) to arrive at the results. Since it is known that hard gammas are a characteristic of short lived fission products and since we used only a poor resolution NaI detector, we set up a gate above 2.2 MeV and found significant difference in the ratio of gammas with another lower energy group for the different fissile materials. Different delayed neutron to gamma ratios were also established for the three fissile materials. These ratios were exploited to try a method for assay of Pu/U ratio in samples. With the availability of high resolution detectors it should be possible to refine the method if data on short lived fission products (seconds half lives) are available. A compilation of gamma spectra of short lived fission products would be useful. The delayed neutron yields and spectra for

different fissile and fertile materials should also be included.

5. Conclusion:

The discussion of some of the non-destructive assay methods with which we have the experience of either developing or using described above shows that there exists an urgent need for an evaluated compilation of nuclear data for application to non destructive assay methods. It would go a long way to make the compilation successful if it is followed up by an effective evaluation programme in its application to NDA methodology.

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