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**INTERNATIONAL NUCLEAR DATA COMMITTEE**

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IAEA Specialists' Meeting on  
THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES  
ON NUCLEAR DATA MEASUREMENTS

In co-operation with the  
Central Bureau of Nuclear Measurements (CBNM)

and

International Nuclear Target Development Society (INTDS)

Central Bureau of Nuclear Measurements Geel, Belgium  
21-24 September 1987

SUMMARY REPORT

Edited by  
K. Okamoto

January 1988

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IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA



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### Abstract

The IAEA Specialists' Meeting on "Influence of Target and Sample Properties on Nuclear Data Measurements" was convened by the IAEA Nuclear Data Section on 21-24 September 1987 at the Central Bureau of Nuclear Measurements (CBNM) Geel, Belgium.

Discussions on the topics for the target and sample properties related to nuclear measurements were held between the experimentalists (users) and scientists engaged in target fabrication (producers).

Specific recommendations were made for the organization of a planned joint Conference of the International Nuclear Target Development Society (INTDS) and IAEA-International Nuclear Data Committee (INDC), and the IAEA Advisory Group Meeting with the same title as this specialists' meeting, which will be held concurrently in the week of 5-9 September 1988 at Darmstadt, Federal Republic of Germany.

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## Introduction

In his opening talk at the 12th World Conference of the International Nuclear Target Development Society (INTDS) in Antwerp, Belgium, 1984, Dr. C. Wagemans (CEN/MOL) emphasized the point that more consideration should be given to fabrication and assaying of samples used for nuclear data measurements (Nucl. Inst. & Methods A236 (1985) 429). Obviously, in the area of nuclear standard measurements, the problem of accurate and reliable sample and target characteristics is a matter of vital importance for obtaining high accuracy of the resultant data.

There are many important sample characteristics, such as high purity, self-support, uniformity, strength or durability to the incident beam, which must be taken into consideration. The production and use of thin stripper foils with a long life time is essential for Tandem accelerator operation. In the study of highly excited states, the measurement of giant resonances by alpha inelastic scattering requires a minimum content of H, C, O for effective background subtraction. Atomic collision experiments use different geometric sample arrangements, different phases (gas, liquid, solid) for comparison and require targets with thin self-support. For high intense neutron sources, reliable Ti-T rotating targets are essential.

The IAEA also has an obligation to train scientists in developing laboratories in nuclear measurement techniques; pure supply of targets and samples is not enough to expect these scientists to achieve fruitful and useful results for the scientific community. They should get to know and to realise how sample fabrication and assaying are related to the accuracies of nuclear measurements.

However, no special efforts have been made so far to identify how sample and target characteristics are related to the final data. The results of successful measurements have been reported at many conferences, but never have the failures due to sample fabrication and assaying been mentioned.

The International Nuclear Data Committee (INDC), the Agency's permanent advisory body in the field of nuclear data, at its 15th Meeting in Vienna, 16-20 June 1986, strongly supported the proposal to convene this Specialists' Meeting in 1987 and a consecutive Advisory Group Meeting in 1988 concurrent with the 14th INTDS Conference at Darmstadt, Federal Republic of Germany, in 1988. This proposal was also endorsed by the 13th INTDS Conference in Chalk River, Canada, 17-19 September 1986.

The meeting was chaired by A. Deruytter, CBNM. General recommendations and the proposed organization of a joint INTDS/IAEA-INDC Meeting, Darmstadt, 5-9 September 1988, is given in Appendix I. The list of participants and the agenda of the meeting are given in Appendix II and III, respectively.

## Objectives of the Meeting

This small meeting between experimentalists (users) executing the measurements and the target suppliers (producers) was composed of six users and six producers.

The objectives of the meeting were:

- to discuss the organization of the planned joint INTDS/IAEA Advisory Group Meeting to be held concurrently with the 1988 INTDS Conference at Darmstadt, Federal Republic of Germany, 5-9 September 1988, and

- to select and propose topics and invite speakers for this meeting for the following items:

- (1) Exchange experiences which specialists have encountered with strange measurement results due to failures in sample fabrication and assaying.
- (2) Itemize and possibly quantify the influence of sample and target characteristics on the accuracy of the final results of nuclear measurements.
- (3) Underline the importance and the necessity of alternative methods for sample assay, especially for the mass-determination of nuclear samples.
- (4) Prepare recommendations to obtain "optimum" samples for specific experiments.
- (5) Discuss the need for a supplier's list and a user's request list for targets and samples.
- (6) Discuss the possibility to organize a training course in sample preparation techniques especially for scientists in developing countries.
- (7) Formulate specific guide-lines for the characteristics of samples and targets requested by developing laboratories.
- (8) Miscellaneous.

Experimental nuclear physicists attending this Specialists' Meeting were specially requested to prepare a paper either from their own or their colleagues' experiences on item 1 of the above-listed Topics for the 1988 Joint Meeting.

The selected papers presented at this meeting are attached to this report.

### Observations

The following summarizes some of the interesting presentations by nuclear data measurers.

Wagemans reported on the influence of sample characteristics on nuclear measurements, especially in the nuclear standard measurements and in high resolution spectroscopy. He summarized the problems as follows: 1) mistakes in assaying the sample characteristics, 2) technical and experimental limitations of the sample characteristics (such as backing material, layer thickness and homogeneity), 3) variation of the sample characteristics (such as variation of specific amount of isotope considered, e.g.  $^{41}\text{Ca}$ ,  $^{237}\text{Np}$ ,  $^{36}\text{Cl}$  and others), 4) influence from in-growth and impurities (in-growth of daughter product with high neutron cross-sections, e.g.  $^{243}\text{Am} \rightarrow ^{239}\text{Np} \xrightarrow{\beta} ^{239}\text{Pu}$ ;  $\sigma(\text{Am-243})=0.1\text{b}$ ,  $\sigma(\text{Pu-239}) = 740\text{b}$  at thermal neutron energy), 5) "Mysterious" finding (e.g. cross-section measurement of  $^{235}\text{mU}(n,f)$ ).

Liskien reported the efforts made in sample preparation for neutron metrology of hydrogen. He pointed to a possible lack of suitable tissue

equivalent material especially as the presently used A-150 material would be out of market. He specified the characteristics of appropriate hydrogen-containing sample as: 1) high hydrogen content, 2) well known concentration of hydrogen, 3) long-term stability, and 4) homogeneous non-crystalline distribution (at least for ionization chamber application). It would be very helpful to know the accuracy which the dosimetry scientists really need.

Winkler urged necessary improvement in sample and target fabrication and assaying in the fields of: 1) standards in monitoring of neutron fluences aiming at better than 1% uncertainties for various cross-section measurements, 2) induced activities paying attention to even unexpected impurities, 3) experimental situations approximating "ideal" by "optimum" conditions and 4) reliable energy scaling with careful consideration of sample thickness, absorption and impurities. He cited a discrepancy of 4% in the values reported for the  $^{238}\text{U}(n,f)$  cross sections at 14 MeV neutron energy. This situation would be improved by quality control of the fission material samples.

Mizumoto reported the problems related to sample and target properties in neutron activation and neutron capture experiments. In particular he pointed to the influence of water absorption in rare earth materials on neutron capture measurements. He referred to the preparation of actinide targets by electro-deposition using isopropyl alcohol as solvent. The highest electro-deposition yield of nearly 100% was obtained.

The participants discussed the suggested topics and speakers (users side) for the 1988 joint INTDS/IAEA-INDC Meeting at Darmstadt. It was understood that the topics to be proposed would refer to samples and targets. User contributions might not only come from neutron nuclear data laboratories but also from heavy-ion physics institutes and also from small accelerator groups at universities. Therefore some users might be dependent on the machine which they use. On the other hand, project-dependent target producers might also have user-relevant information. The attached Appendix IV is a selection of suggested topics (users' side) for the Darmstadt Meeting in 1988.

#### Acknowledgement

The scientific secretary of the meeting wishes to express his gratitude and appreciation to CBNM for their kind arrangement in hosting the meeting. He strongly believes that the success of this meeting was entirely due to CBNM's cooperation.



IAEA Specialists' Meeting on 'The Influence of Target and Sample Properties on Nuclear Data Measurements'.

Prof. W. Müller, Director of CBNM and myself are pleased to welcome the participants of the International Nuclear Target Development Society (INTDS) and the users of targets in nuclear measurements invited by the International Atomic Energy Agency, Vienna to this IAEA Specialists' Meeting on 'The Influence of Target and Sample Properties on Nuclear Data Measurements', organised by Dr. K. Okamoto.

We believe that this venue is well-chosen as CBNM has on the one hand a very active Group for the preparation of samples and targets for nuclear measurements of which Mr. Van Audenhove is the past and Mr. Pauwels the present Group Leader, both present, and who are at the same time very active members of the INTDS; on the other hand CBNM has an important project on nuclear measurements with subprojects on nuclear data and nuclear metrology respectively, that groups a number of experienced users of targets and samples for their respective measurements and represented by Dr. H. Liskien and myself. We think that the cross-fertilization of these two important aspects of nuclear measurements has been very beneficial to our work in general, and in particular to the work on standards data of this laboratory.

Reading the title of this Specialists' Meeting, a first reaction is that of 'déjà-vu', especially for scientists having worked over extended periods of their professional life in a 'metrological' laboratory. However, the broadening of the nuclear measurement community to laboratories in developing countries, firmly supported by the IAEA and its Nuclear Data Section and recommended by the International Nuclear Data Committee

(INDC) creates a duty for NDS to instruct these scientists on the importance of the sample fabrication and how sample characteristics influence the value of the reported results. This leads to one of the reasons for IAEA/NDS to look forward to the organisation of a joint INTDS/IAEA Advisory Group Meeting at the occasion of the INTDS Meeting in Darmstadt, 5-9 September 1988, where scientists from developing countries could participate and be convinced of the importance of the sample fabrication and definition for their results, as well as establish useful contacts in order to obtain the samples needed. A typical example is e.g. the availability of fission foils for cross-section measurements, or for calibration of detection equipment with well-characterized  $^{235}\text{U}$ -foils, question raised at several IAEA organised meetings.

The international nuclear measurements community has and will continue to have a multitude of requests in many areas of nuclear measurements, with ever shifting emphasis (neutron physics to heavy ion work).

A well recognized and very demanding area is that of the targets required for measurements of standard cross-sections as evidenced during the IAEA Advisory Group Meeting on neutron standard reference data held in Geel in November 1984: one example being the availability of thin homogeneous layers containing an accurately known amount of hydrogen, for use in  $2\pi$  "Frisch-gridded" ionization chambers, wanted for an efficient exploitation of the  $\text{H}(n,p)$  cross-section as a standard.

In that area of standards data the further progress, when requested, will depend in a decisive way on the possibility to improve the characterization of standard layers. Such an improvement of the characterisation is very demanding and only possible by a coordinated effort of sample preparation, analytical chemistry and mass-spectrometry together with the data measurer.

In the non-standard area of nuclear measurements many problems arise, ranging from the availability of the base material, to the "infinite" resolution required for spectroscopy of the emitted charged particles from a sample. A measurer may require a target of an isomer that is short-lived. He may want to use it in extreme conditions of temperature (polarisation experiments) or in the presence of very high radiation fields (inside a nuclear reactor). He may want to perform experiments in a  $4\pi$  geometry, requiring "infinitely thin" backings for the layers, to have them transparent for 'all' particles to be detected.

On the other hand the target producer has in-built limitations in the methods he uses. Quality (e.g. resolution of the charged particle spectra) will depend on the deposition method used for the target : e.g. for a fissile or  $\alpha$ -active layer large differences follow from using electro spraying or evaporation respectively. The elemental and isotopical purity of the base material, its chemical form, all have to be considered.

From such a very incomplete enumeration it is already evident that there should be an excellent communication between target producers and target users, in order to reach 'realistic' compromises for both, still enabling the user to obtain valuable physical information from his experiment. It is a 'conditio sine qua non' for success of a meeting like ours, to have both important partners available around the table to reach valuable discussions.

Discussions should also be kept as informal as possible to reach the objectives of this meeting which are enlisted as follows :

Objectives of the meeting :

- Discuss the organization of the planned joint INTDS/IAEA Advisory Group Meeting to be held concurrently with the 1988 INTDS conference at Darmstadt, 5-9 September 1988.

Select and propose topics and invite speakers for this meeting along the following lines:

1. Itemize and possibly quantify the influence of samples and target characteristics on the accuracy of the final results of nuclear measurements.
  2. Exchange experiences which specialists have encountered with strange measurement results due to failures in sample fabrication and assaying.
  3. Underline the importance and the necessity of alternative methods for sample assay, especially for the mass-determination of nuclear samples.
  4. Prepare recommendations to obtain "ideal" samples for specific experiments.
- Discuss the need for a suppliers' list and a users' request list for targets and samples.
  - Discuss the possibility to organize a training course in sample preparation techniques especially for scientists in developing countries.
  - Formulate specific guide-lines for the characteristics of samples and targets requested by developing laboratories.

We hope that this meeting will bring the appropriate people closely enough together to provide the necessary personal contact for fruitful discussions and a positive outcome.

C. WAGEMANS\*

Physics Department, S.C.K./C.E.N., B-2400 MOL (Belgium)  
and  
Nuclear Physics Laboratory, RUG, B-9000 GENT (Belgium)

### INTRODUCTION

In the present paper, the influence of sample characteristics on nuclear measurements is discussed from a neutron physicist's point of view. One has indeed to consider that sample problems may be different for spectroscopy measurements, cross-section measurements, (n,x)-reactions, (n, $\gamma$ )-reactions, heavy ion induced reactions, charged particle induced reactions, ..., although some aspects are certainly of common interest.

One can subdivide the impact of sample characteristics on nuclear measurements in two major categories:

1. Measurements where the sample is the determining or limiting factor on the accuracy or on the resolution of the measurement. Typical examples here are nuclear standard measurements where an accuracy better than 1 % is requested, and high resolution spectroscopy measurements where the resolution of the sample is larger than the resolution of the detection system used. In the latter case, the total experimental resolution is the sum of both components, so often one has the choice to invest (money and effort) in improved apparatus or in higher resolution samples in order to improve the nuclear data.
2. Measurements where the sample is not the determining or limiting factor. Typical examples here are simple counting experiments (e.g. a neutron flux shape monitor) and experiments where the sample resolution is better than the resolution of the detection system used (e.g. the older ionization chambers).

Moreover, one could subdivide the problems due to sample characteristics in five categories:

- I. Mistakes in the sample assaying.
- II. Technical or experimental limitations in the sample assaying.
- III. Variations in the sample characteristics after their determination.
- IV. Neglected aspects during the sample fabrication or assaying.
- V. Mysterious phenomena.

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## DISCUSSION AND EXAMPLES

These five headlines will be discussed at the hand of various examples.

### I. Mistakes

Mistakes may relate to one or more characteristics of the sample, starting with the composition and the thickness of its backing. E.g. erroneous values for the thicknesses of VYNS-layers have been observed in the past, advanced verification methods like spectro-photometry not being available at that time. As far as the layer itself is concerned, errors may occur in the chemical or physical composition quoted, the most sensitive characteristic being however the layer thickness. The thickness quoted for the isotope considered may be strongly smaller than the "true" layer thickness due to impurities collected during the sample fabrication. E.g. in the case of radio-active  $\alpha$ -emitters, the sample thickness is often determined via  $\alpha$ -counting. Here it is perfectly possible that the number of radio-active nuclei is accurately quoted, but that the layer thickness deduced from it is strongly underestimated since possible (stable) impurities are not observed in the  $\alpha$ -counting.

### II. Technical limitations

A few examples have been selected related to the backing and to the thickness and homogeneity of the layer.

Especially for very thin backings, one is often limited by what is commercially available, e.g. nickel foils (in which pinholes may be present) or aluminium foils (which may contain a few ppm of uranium, giving rise to unwanted fission events upon irradiation<sup>1)</sup>).

As will be demonstrated later, a sufficiently accurate determination of the layer thickness is sometimes hard to achieve due to the inherent limitations of the method used e.g. weight difference method,  $\alpha$ -counting (influenced by uncertainties on the isotopic composition, the half-life, the identification of peaks in the  $\alpha$ -spectrum, ...).

Also the sample homogeneity is limited by the fabrication method used, which can be arranged as follows in order of decreasing resolution: evaporation, electrolysis, electro-spraying, suspension spraying, spraypainting, droplet<sup>2)</sup>. A realistic problem in this respect could be that a sample with a very good homogeneity is needed, but that only a very small amount of material (or very active material) is available, so that evaporation is excluded. This may have severe consequences for the experimentalist, since a lack of sample resolution can hide or even

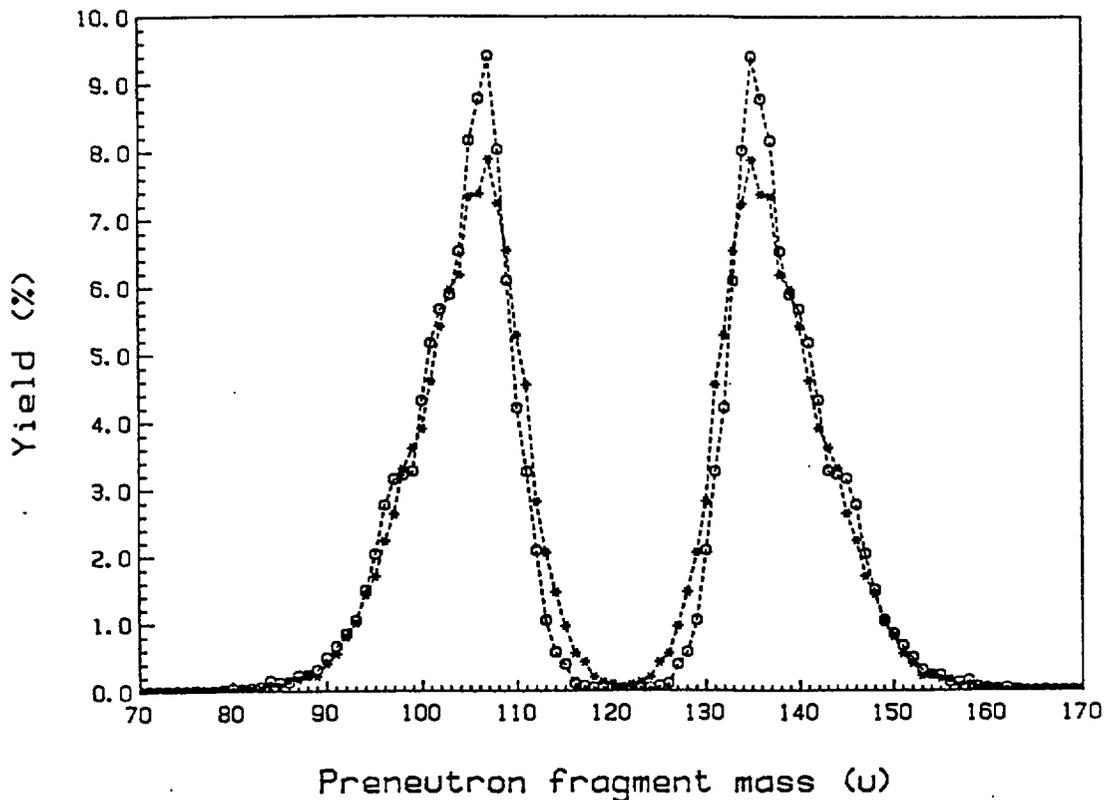


Fig.1  $^{242}\text{Pu}(\text{s.f.})$  fragment mass-distribution with an evaporated (o) and with an electro sprayed (\*) sample.

distort nuclear properties. This is illustrated in Fig. 1, which shows the fission fragment mass-distribution obtained<sup>3)</sup> for the spontaneous fission of  $^{242}\text{Pu}$ , using an evaporated layer (o) and a good quality electro sprayed layer (\*).

### III. Variations in sample characteristics

The sample characteristics may change after their determination due to phenomena like oxidation, hygroscopy, sublimation, crystallization, ...

Hygroscopy can strongly influence the experimental results, since water absorption (or adsorption) by the layer increases its thickness and changes its composition. It can even lead to crystallization. This increase in weight of the layer can have two consequences:

- (i) the energy loss in the sample increases and its resolution degrades;
- (ii) cross-section values can be wrong if the method used to determine the sample thickness is sensitive to the total layer thickness and not to the specific amount of the isotope considered.

A very nice example in this respect is the study of the  $^{41}\text{Ca}(\text{n},\alpha)^{38}\text{Ar}$  reaction, which has been done using samples with different chemical and isotopic composition<sup>4)</sup>.

A tricky situation for the experimentalist occurs when his sample slowly disappears during the experiment. This happens when the sample material sublimates. In such cases, the experimental results will obviously be wrong, which generally is reflected in strongly scattered values. A typical example are the  $^{32}\text{S}(n_{\text{th}},\alpha)^{29}\text{Si}$  and  $^{33}\text{S}(n_{\text{th}},\alpha)^{30}\text{Si}$  reaction cross-section values<sup>5)</sup> shown in Table 1. The problems encountered during the sulphur sample fabrication and assaying due to the sublimation of the sulphur have been described by Geerts et al.<sup>6)</sup>.

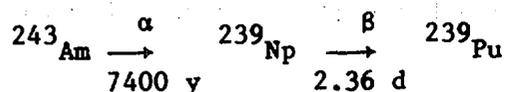
TABLE 1. The  $^{32}\text{S}$  and  $^{33}\text{S}(n_{\text{th}},\alpha)$  cross-section (mb)

Reference	$^{32}\text{S}(n_{\text{th}},\alpha)^{29}\text{Si}$	$^{33}\text{S}(n_{\text{th}},\alpha)^{30}\text{Si}$
Munnich (1958)	$6.8 \pm 0.11$	$180 \pm 80$
Benisz (1965)	$3.9 \pm 0.51$	$151 \pm 22$
Harris (1966)		$52 \pm 16$
Wagemans (1983)	$\leq 0.5$	$115 \pm 10$

#### IV. Neglected aspects

Some characteristics of the backing or of the sample material may be overlooked, since, at first glance, they seem to be irrelevant. This is e.g. the case for minor impurities, which, if their reaction cross-section is very high, may turn out to be very disturbing. Such a situation occurred e.g. in the study of the  $^{238}\text{U}(n_{\text{th}},f)$  reaction<sup>1)</sup>, which was initially performed with a  $^{238}\text{U}$  sample (containing 0.17 ppm of  $^{235}\text{U}$ ) deposited on a thin aluminium backing. It turned out that the aluminium contained an extremely small amount of uranium, resulting in a very disturbing  $^{235}\text{U}(n_{\text{th}},f)$  background. Even a contribution of 0.17 ppm of  $^{235}\text{U}$  (with its thermal fission cross-section of 587.6 barn) in the sample appeared to be too high, the  $^{238}\text{U}(n_{\text{th}},f)$  cross-section being only a few  $\mu$  barn. These problems were solved when a second sample was fabricated in which  $^{238}\text{U}$  containing only 0.012 ppm of  $^{235}\text{U}$  was deposited on an ultra-pure silicon slice.

Another frequently neglected phenomenon is the in-growth of daughter products with a high reaction cross-section. A typical example is the  $^{243}\text{Am}(n_{\text{th}},f)$  reaction ( $\sigma_f \approx 0.1$  barn). If one neglects the in-growth of  $^{239}\text{Pu}$  (with  $\sigma_f = 740$  barn) in the sample via



one will mainly measure the  $^{239}\text{Pu}(n_{\text{th}},f)$  characteristics instead of those of  $^{243}\text{Am}(n_{\text{th}},f)$ . Here obviously a Pu-Am separation is needed just before the sample preparation.

#### V. "Mysterious" phenomena

It sometimes happens that experimental results are strongly discrepant, the main difference in the experimental conditions being the characteristics of the samples used. A very recent example is the study of the  $^{235\text{m}}\text{U}(n,f)$  reaction<sup>7)</sup>, for which an almost two times higher fission cross-section has been observed with samples prepared via the recoil collection method compared to samples prepared via chemical separation techniques. Both methods being in principle correct, the explanation for the discrepancy remains a mystery ...

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ON THE INFLUENCE OF SAMPLE AND TARGET PROPERTIES ON THE RESULTS  
OF ENERGY-DEPENDENT CROSS SECTION MEASUREMENTS

Gerhard Winkler  
Institut für Radiumforschung und Kernphysik  
der Universität Wien  
A-1090 Wien, Boltzmannngasse 3, Austria

Abstract:

The impact of sample and target properties on the accuracy of experimental nuclear cross section data is discussed in the context of the basic requirements in order to obtain reliable results from the respective measurements from the user's point of view. Special emphasis is put on activation measurements with fast neutrons. Some examples are given and suggestions are made based on experiences and recent investigations by the author and his coworkers.

1. Introduction

In the discussion of the influence of sample and target properties on the accuracy of the results of nuclear data, I will confine myself to the problem of quantitative measurements of cross sections for nuclear reactions, in particular for those induced by (fast) neutrons, of primary importance in fission and fusion reactor technology applications. But most of the points to be made are also valid in a more general context dealing with reactions induced by other particles or photons. The problems will be treated from the user's point of view and some examples from recent experimental investigations by the author and his coworkers will be given to several items.

A good starting-point is to think of the essential requirements for obtaining reliable cross-section data and to investigate then, where sample and neutron-producing-target specifications enter.

2. The number of sample nuclei

The number of reaction events  $R$  induced by an incident directed neutron fluence  $\phi_E$  (neutrons per  $\text{cm}^2$ ) is given in simplest form by

$$R = N \sigma_E \phi_E \quad (1)$$

with  $N_0$  the number of sample nuclei of the specific isotope on which the reaction is studied and  $\sigma_E$  the microscopic reaction cross section, provided that the sample is sufficiently small that a very small fraction of the incident neutrons experience interactions. The index E is attached to indicate the energy dependence of the cross section on the neutron energy assuming a monoenergetic or quasi-monoenergetic neutron fluence as the simplest case. The usual way to define  $N_0$  is to determine the sample mass using information on the chemical composition of the sample material and its isotopic composition.

The mass determination may be performed by weighing (or via weight differences), which is in general the simplest way if applicable, or by other more direct methods such as counting the emitted particles (or photons) in the case of unstable samples, or mass-spectrometric techniques (such as isotope dilution mass spectrometry) or other chemical or physical methods of quantitative analysis. Sometimes it is possible to determine the sample mass relative to a mass standard of the same or another material, e.g. by means of an irradiation experiment using well-known interaction cross sections, as demonstrated later on for the case of a fissile uranium deposit. Whenever possible and reasonable, alternative independent methods for sample assay should be applied in order to obtain a realistic estimate of the uncertainty of  $N_0$ . When relatively massy samples are used in an experiment, usually not the weighing errors are decisive, but the uncertainties in stoichiometry, impurities (including radiochemical purity), and isotopic abundance values.

Physical and chemical stability of the sample material - compound or pure element - under environmental conditions may lead to an erroneous determination of the mass and therefore of  $N_0$ . Hygroscopy, sublimation, oxidation (e.g. in the case of metal powder or thin metal foils) or chemical reaction with the  $\text{CO}_2$  from the air are the most frequent interferences. If the chemical stability of the sample material cannot be assured, additional tests are necessary. Variations of the total sample mass as a function of time are a strong indication of sample instability. For example, we have observed a change of  $\sim 1\%$  of the mass ( $\sim 0.5$  g) of an yttrium-oxide sample embedded in a thin perspex container, within 4 months; therefore a significant deviation from the formula  $\text{Y}_2\text{O}_3$  (as provided by the supplier) must be assumed and drastic changes in the chemical composition probably have taken place during or even before the filling procedure. Proper heating in an oven to get rid of constitutional water and to transform carbonate

into oxide with immediate weighing and checking for achieved constancy of mass after this procedure is necessary before using the above stoichiometric formula to determine the number of  $^{89}\text{Y}$  nuclei in an oxide sample. Neglecting these facts is a likely explanation why the measurement of the  $^{89}\text{Y}(n,2n)$  cross section by Vonach and Münzer (1959) resulted in a too low cross section value. Sometimes it is necessary to handle the sample material in a dry inert-gas environment (e.g. nitrogen or argon) before encapsulation. Metallic strontium samples for a neutron scattering experiment, for example, we have successfully cut under oil, and a thin oil film served to stabilize the sample before encasing it in a thin-walled aluminium container. Occasionally, with samples or sample backings of low electrical conductivity, problems due to electrostatic charges on the objects to be weighed were encountered, showing up as instability of the balance readings. These problems were frequently overcome by earthing the forceps and discharging source backings and empty vials by means of an ultraviolet lamp before weighing.

One should also be aware of the eventuality that the sample preparation technique chosen may lead to a change of the elemental and/or isotopic composition of the sample material, or that the analyzing procedure on an already fabricated sample may cause a diversification. Occasionally, one has to take care that the part of the sample material that is analysed is really representative of the material that is used in the experiment. Other examples and remarks concerning the problem of the definition of the number of sample nuclei were given previously e.g. by Wagemans (1985) and presently in other contributions to this meeting.

### 3. Choice of a suitable standard to monitor the neutron fluence

Most measurements of nuclear cross sections are in practice done relative to a cross section "standard", that means using a material and a specific reaction on it, the cross section of which is very well established, and using the measured reaction rates in a well-defined neutron field in order to determine the cross section in question. Or in other words: Equation (1) is not solved to determine  $\sigma_E$ , but to define  $\phi_E$ . But in most cases the problem is not the choice of this reference but its realization, that is employing a detector and reference material based upon, which can in fact exploit the accuracy to which the standard is known.

Employing chemically stable metal monitor foils that can be obtained with sufficient purity, and well-evaluated activation cross sections with radionuclides as reaction products that can be detected without interferences, is the simplest choice for such a reference. They may be typically used in a foil-sandwich arrangement. In the neutron energy range 13.4 - 14.8 MeV the reaction  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$ , for example, is one of the most convenient references of this type, and very accurately (uncertainties  $\sim 1\%$ ) known (Vonach, 1983). Other good examples are iron, gold, copper or niobium foils (Winkler and Ryves, 1983); the respective cross section data have been updated recently (Ryves, 1987).

A more "fundamental" reference is the hydrogen elastic scattering cross section, which is currently the best-known cross section over a wide energy range. (Nuclear Data Standards, 1983; Bödy, 1987). But that does not mean that the measurement using the hydrogen cross section is preferable to any other one, because the cross section is not the only quantity involved; the accuracy of the efficiency of the counter incorporating the hydrogen-containing substance is another important parameter. When observing the proton recoils from an organic radiator foil (e.g. polyethylene) with a telescope counter, for instance, the uncertainty in the areal density of H-atoms is still the limiting factor, since the hydrogen content of such foils can obviously not be determined to better than  $\sim 1.5\%$  (equivalent standard deviation) and this is the largest uncertainty contribution in such measurements. The overall uncertainty of such recoil telescopes is typically  $\sim 2.5\%$  as recent fluence intercomparisons, and comparisons relative to  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  in the 14 MeV region, have shown. The question is still open: what is the best method to determine the H contents, what material, which should have a high H content and be homogeneous, is best suited as for long-term stability for the various energy regions. (See also the contribution by H. Liskien at this meeting!)

The fission reactions  $^{235}\text{U}(n,f)$  and  $^{238}\text{U}(n,f)$  are among the most important references over a wide energy region and can be implemented relatively easily.  $^{235}\text{U}$  is considered as the reference isotope for precision fission cross section measurements and  $^{238}\text{U}$  is most useful as a reference in the fast-neutron energy region ( $\geq 2$  MeV, when the cross section reaches the first plateau) (Nuclear Data Standards, 1983). Due to the quasi-threshold behaviour of the excitation function for  $^{238}\text{U}(n,f)$ , a detector based on this process is less sensitive to

neutrons lower in energy than those of interest, which may stem from interaction processes on construction materials, samples and the environment. Prompt detection of fission fragments using a low-mass ionization chamber (e.g., Wagner et al., 1988) and a well-defined enriched fission deposit provides a sensitive and reliably working fluence monitor. The available accuracy depends on the knowledge of the fission cross sections (which seems to approach the 1 % region according to current evaluations) and on the physical (mass, thickness, uniformity, roughness, ...), chemical and isotopic specification (enrichment grade, abundances of minor isotopes) of the fissile deposit. A laboratory involved in neutron data measurements should have in his repertoire  $^{235}\text{U}$  and  $^{238}\text{U}$  deposits, well-defined with respect to physical, chemical, and isotopic properties, of different sizes and different areal densities on suitable backings (support foils) and of sufficient uniformity ( $\pm 2$  to  $\pm 5$  %). As for long-term stability the uranium layer should be in the chemical form of an oxide or fluoride and the deposition technique should guarantee a firm sticking of the layer to the backing. The choice of the backing material depends to some degree on the characteristics of the experiment in which the device is applied; it should have a relatively smooth and sufficiently known cross section in the energy region to be used. Likely possibilities are platinum, stainless steel and aluminium of thicknesses 0.1 - 0.2 mm. The backing should extend at least 5 mm beyond the deposit to enable safe and easy handling. It should be highly polished to reduce roughness (microscopic nonuniformity) of the layer in order to reduce uncertainties in fission fragment counting (see below!). Different deposit sizes permit different geometrical sample arrangements (also for comparison) and different areal densities permit measurements with different fragment energy losses in the deposit to test corrections for total fission-fragment-absorption losses or to perform measurements with different energy resolutions. For activation experiments with a quasimonoenergetic accelerator-neutron-source (neutron generator), for instance, deposits  $\sim 20$  mm in diameter (areal density 150 - 200  $\mu\text{g}/\text{cm}^2$ ) and  $\sim 10$  mm in diameter (areal density 300 - 400  $\mu\text{g}/\text{cm}^2$ ) seems to be a proper choice to operate a neutron fluence monitor.

The main contributions to the uncertainties of fission counting are stemming from:

extrapolation of the fission fragment pulse-height spectrum to zero energy,

loss of fission fragments,  
sample assay, especially the mass and abundance of the major isotope and the abundances of the minor isotopes.

In any case at least two alternative independent procedures for sample assay should be used and whenever possible the essential characterization given by the supplier should be checked and verified independently. As an example, for a recent measurement program we checked the mass characterization of an  $^{238}\text{U}$  deposit ( $\sim 210 \mu\text{g}/\text{cm}^2$   $\text{UF}_4$ , diameter 10 mm) in a separate irradiation experiment with 14.8 MeV neutrons employing a 200 keV Cockcroft-Walton generator with an air-jet cooled low-mass target construction to achieve a very clean neutron field. In this experiment the mass of the  $^{238}\text{U}$  deposit, used as a fluence monitor in an ionization chamber, was determined relative to the mass of an aluminium foil, thus relying on the well-known  $^{238}\text{U}(n,f)/^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  cross section ratio at this energy (ENDF-B/VI, 1986; Nuclear Data Standards, 1983). The  $^{24}\text{Na}$  activity induced in the Al foil, which had been mounted back-to-back with the fission-layer-support foil, was measured by the  $4\pi\gamma$  technique employing a NaI(Tl) well-type detector (Winkler and Pavlik, 1983; Pavlik and Winkler, 1983) with an accuracy of  $\pm 0.3\%$ . The fluence attenuation in all material between the Al reference foil and the U deposit was corrected for. Different runs were performed under different experimental conditions, choosing different distances between the accelerator beam spot and the irradiated samples. The reproducibility of the results for the mass of the fission deposit was very satisfactory, which proved that there was no influence of an eventual room-return background on the number of recorded fission events. Separate irradiation runs with the  $^{238}\text{U}$  layer removed and without any neutron source showed no other significant background. The increase of the number of recorded fission events due to lower-energy neutrons produced by (n,2n) reactions and inelastic scattering in the target backing, the fission chamber wall, the Al backing of U deposit, the Al reference foils and the brass electrode of the chamber was estimated (+ 0.65 %). The enhancement of the induced  $^{24}\text{Na}$  activity caused by elastic scattering of neutrons in the Al foil itself and from in-scattering of neutrons by material adjacent to the sample was similarly estimated (+ 0.21 %).

The fission-fragment pulse-height spectrum, clearly separated by a flat minimum from the pulse-height distribution caused by noise,  $\alpha$  particles and other charged particles produced by neutron-induced

reactions in the chamber, was horizontally extrapolated to zero energy from that minimum as recommended, e.g. by Meadows (1986). The extrapolation correction amounted to  $(1.09 \pm 0.36)\%$  of the total number of recorded fission events.

As mentioned above, a serious problem is the correction for fission products that do not escape the deposit, taking into account reaction kinematics and the angular distribution of the fragments. Assuming an uniform  $^{238}\text{UF}_4$  deposit, this self-absorption correction can be calculated according to Meadows (1978) and resulted in  $(0.3 \pm 0.1)\%$  for 14 MeV incident neutrons and  $\sim 200 \mu\text{g}/\text{cm}^2$  thickness of the deposit. With studies on  $^{252}\text{Cf}$  deposits, decaying by spontaneous fission, it has been demonstrated that depending on the quality of the sample, especially on the evenness of the backing, the loss of fission fragments can be significantly higher than anticipated assuming an uniform layer, due to the microscopic roughness of the layer following the structure of the backing. The efficiency for fragment detection, measured by means of coincidence counting of fission events and events in a scintillator detecting the associated neutrons, showed a clear dependence on the position of the coincident neutron detector relative to the orientation of the fissile deposit (e.g., Böttger et al., 1983). Budtz-Jørgensen and Knitter (1984) used a gridded ionization chamber for the investigation of fissile layers. Both the energy (E) of the charged particles emitted from the sample positioned coplanar with the cathode and the cosine of emission angle ( $\theta$ ) with respect to the normal of the cathode was determined. For  $\cos\theta$  values close to zero, i.e. for very flat emission, the  $\cos\theta$  distribution exhibited a pronounced depression stemming from enhanced absorption of fission fragments emitted in the corresponding direction, and showed a clear trend with the areal density of the layer ( $15 \mu\text{g}/\text{cm}^2$  up to  $500 \mu\text{g}/\text{cm}^2$ ). The region of the  $\cos\theta$  distribution showing isotropic angular distribution (in the case of thermal incident neutrons) is obviously unaffected by self-absorption (and backscattering) and can be used for extrapolation to  $\cos\theta$  equal zero. This technique thus permits to correct automatically for losses and to determine the total number of fission events (to better  $\sim 0.5 \%$ ), leaving no doubts on the magnitude of fragment absorption, requiring no assumptions on fragment ranges and loss mechanism, working independently of sample quality. The disadvantage of this technique is that it requires a considerably larger instrumental effort and experience than a simple ionization chamber.

At higher incident neutron energy in the several MeV region, the problem of self-absorption is not as severe as for spontaneous fission or for thermal-neutron-induced fission. Due to reaction kinematics, i.e. due to the transfer of momentum from the incident neutron, the fragment angular distribution being symmetric about  $\pi/2$  in the center-of-mass system, becomes slightly forward-peaked in the laboratory system, where half the fragments will have angles between 0 and  $(\pi/2-\gamma)$  and half between  $(\pi/2-\gamma)$  and  $\pi,\gamma$  corresponding to 0.5 - 1.3 degrees in the neutron energy range 3 - 20 MeV. If the plane of the fissile deposit is at a right angle to the direction of motion of the bombarding neutrons, in the forward direction there is even the possibility of detecting both fragments from some fissions if the layer is thin enough. In this case there will be no loss at all for an uniform layer. Surely, an efficiency more than 100 % cannot be realized since both fragments from a fission event are in coincidence. The kinematic effect together with a nonisotropic angular distribution is responsible for the small calculated absorption correction as mentioned above for our 14.8 MeV neutron experiment. Kinematics and angular distribution will certainly also diminish the effect of microscopic nonuniformity, i.e. roughness, of the layer.

Another way to determine the mass of the uranium deposit was by counting the emitted  $\alpha$ -particles and converting the measured activity into a mass using the  $^{238}\text{U}$  half-life. Since the total  $\alpha$ -emission rate was very low ( $\sim 2$  Bq) a  $2\pi$  counter was employed. The  $^{238}\text{U}$  mass derived from  $\alpha$ -particle counting was (after correction for an activity contribution of  $\sim 2$  % from  $^{234}\text{U}$  in the deposit) significantly lower and in disagreement with the result from the neutron irradiation experiment. The accuracy of  $2\pi\alpha$  counting is probably hampered by the necessity to estimate self-absorption and backscattering corrections. As the next step we intend to perform an, unfortunately long-lasting, small-solid-angle (or medium-solid-angle) counting experiment with the same sample, which should largely reduce absorption and backscattering problems. It should additionally permit testing the isotopic purity of the sample by  $\alpha$ -particle spectroscopy.

By means of the usual  $2\pi$  counter it is not possible to see absorption and backscattering effects directly. This would be possible again with  $\alpha$ -particle counting using the method of Budtz-Jørgenson and Knitter as described above. Its capability has been clearly demonstrated for assaying of targets and samples (Budtz-Jørgenson et al., 1985). The emission of  $\alpha$  particles into a large solid angle close to

$2\pi$  can be considered, the problem to estimate sample absorption and scattering effects can be circumvented, and the latter effects are directly seen by recording the emission angle information ( $\cos\theta$ ) of the emitted  $\alpha$  particles. Thus this technique also directly shows the quality of the sample layer. Therefore this technique using a gridded ionization chamber can obviously be strongly recommended to routinely perform a quality assurance check of sample layers emitting charged particles, e.g. from  $\alpha$ -decay or fission.

I want to mention only in this context that the demands for the quality of the sample layer are particularly high when the time-correlated associated particle method is used to perform absolute precision fission cross-section or charged-particle-emission cross-section measurements (see e.g. Arlt et al., 1980; Cancé and Grenier, 1978; and references cited therein). With this technique the sample under investigation completely covers the cone of neutrons defined by the opening angle of the source-reaction associated particle detector which is operated in coincidence with the detector incorporating the sample. The knowledge of the total number of sample atoms is not sufficient. A good determination of the areal density in atoms per  $\text{cm}^2$  together with a small nonuniformity is required. The uniformity can be tested by scanning the layer with a small-aperture detector.

Coming back to the problems with the special fission layer dealt with above, we decided for the present to use the result for the  $^{238}\text{U}$  mass as determined by the above mentioned irradiation experiment for the following reasons:

- The precision and accuracy of  $\alpha$ -particle counting and spectrometry is limited due to the low emission rate and the necessity to estimate self-absorption and backscattering corrections.
- The fissile deposit is used in the cross section measurements in the same way as in the irradiation experiment performed to determine the fissile mass. Therefore, systematic errors, e.g. due to the loss of fission fragments because of the roughness of the deposit and due to the extrapolation of the pulse height distribution, will cancel to a certain degree.
- Eventual new or more reliable information on the  $^{238}\text{U}$  fission cross section can easily be inserted in a traceable way to renormalize our cross section results. The mass of fissile material determined in the irradiation experiment is proportional to the ratio of the  $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$  cross section to the  $^{238}\text{U}(n,f)$  cross section, both taken at  $\sim 14.8$  MeV.

On the other hand, if the mentioned fission layer would be assayed reliably by another independent method (see above), the 14 MeV irradiation experiment would provide an interesting comparison of the  $^{238}\text{U}(n,f)$  and the  $^{27}\text{Al}(n,\alpha)$  cross section in the 14 MeV range with regard to the Nuclear Data Standards File.

### 3. Accurate determination of the relevant activity induced in the sample foils

If the reaction product is a radionuclide of proper decay characteristics the activation method is applicable. In any case it is advisable to record full  $\gamma$ -ray spectra by means of a high-resolution Ge spectrometer, at least. Thus some kind of activation analysis checking the sample characterization is automatically provided.

Impurities and interfering activities may be located.

High-efficiency  $\gamma$ -ray detectors with (almost)  $4\pi$  geometry, e.g. a large well-type NaI(Tl) detector, have proven to be a very powerful instrument, in particular for the metrology of radionuclides with complex decay schemes incorporating coincident photon transitions, exploiting the summing properties of such a detector. Accuracies down to tenths of a percent can be achieved just by single integral counting above a low discrimination level, widely independent of a knowledge of the precise values of the decay-scheme parameters (Mannhart and Vonach, 1976; Winkler and Pavlik, 1983). As often necessary for applied purposes, also the activity of thicker and extended samples can be readily measured without much loss in accuracy. (The  $4\pi$  geometry and the rather small dependence of the efficiency on the photon energy keeps corrections for sample-scattered radiation small. The efficiency is also rather insensitive to the source position). A drawback of this technique is that it has no energy-discriminating capabilities and is therefore sensitive to interfering activities. Adequate timing of the measurements often helps to circumvent these problems. The subtraction of pulse-height distributions belonging to interfering activities on the basis of a  $\gamma$ -ray pulse-height-distribution library is not successful in most cases without losing much of the accuracy, since the summing feature of such a detector distorts the respective pulse-height distributions depending on the presence of coincident radiations.

"Never blindly believe the sample characteristics quoted by the supplier" (Wagemans, 1984) should never be ignored. For example, in a

recent irradiation experiment with chromium samples in order to measure the  $^{52}\text{Cr}(n,2n)^{51}\text{Cr}$  cross section for fast neutrons, we have found  $\sim 400$  parts per million antimony identifying the corresponding  $\gamma$ -ray peaks by means of a HP Ge detector (15 % relative efficiency). The supplier had stated a purity of 99.99+ %. The influence on the  $4\pi\gamma$ -counting result for the produced  $^{51}\text{Cr}$  would have amounted to several per cent unless a proper waiting time would have been chosen.

Occasionally, a careful analysis of the induced activities may guard from large errors due to unexpected events. For example, we experienced the production of  $^{52}\text{Mn}$  in the course of Cr irradiations by fast neutrons in the 16-20 MeV range: The neutrons were produced by the  $\text{T}(d,n)^4\text{He}$  source reaction at a Van-de-Graaff accelerator employing 3 MeV deuterons and a thin titanium target ( $\sim 4 \text{ mg/cm}^2$ , incorporating the tritium) on a silver backing. In addition to the neutrons, protons were produced predominantly in the forward direction by (d,p) reactions in the  $\sim 0.25$  mm thick silver target backing, which was obviously not thick enough to stop these protons, which on their part initiated the reaction  $^{52}\text{Cr}(p,n)^{52}\text{Mn}$ .

A wide variety of interference eventualities may show up in actual experiments depending on the measurement tasks, in particular when low-yield reactions are studied. Secondary neutron groups from the source reaction, neutrons from beam-line contamination, or lower-energy neutrons produced by elastic and inelastic scattering, (n,2n) processes, and moderation, may lead to further complications and make high demands on the quality of samples, backings or sample containers. The cross sections of impurities or minor isotopes may be much larger in the respective neutron energy ranges than the ones to be measured (e.g., for (n,t), (n, $^3\text{He}$ ), (n, $\gamma$ ) reactions with fast neutrons). (Working under dust-free conditions could be necessary in some cases.)

Strong interferences may arise when characteristic x-rays from internally converted transitions have to be measured. A typical example is the reaction  $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ , most important in reactor dosimetry. Sample impurities with large cross sections (typically Ta in this case) will enhance the Nb K x-ray count rate from the activated Nb foil due to x-ray fluorescence. Knowing the amount of impurity this enhancement can be estimated on the basis of the  $\gamma$ -ray emission spectrum of the produced radionuclide ( $^{182}\text{Ta}$  in this example), the fluorescence yield of the sample material and the attenuation of the photon radiation in the sample foil (see e.g., Wagner et al. 1988). In the course of a recent activation cross

section measurements of the reaction  $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$  with a Si(Li) x-ray detector it was in addition essential to measure the background spectrum using a Nb foil of the same dimensions as the irradiated foil, but not activated by neutrons. Since the emission rate of the characteristic Nb K x rays produced by the irradiation was rather low ( $\sim 1.7$  counts per minute), x-ray fluorescence in the corresponding peak caused by the background radiation rendered a significant contribution as compared to the background effect without such a sample in place - a striking example how the background effect may be changed by the sample itself.

A typical sample effect which may have to be considered is the loss or transfer of recoil nuclei ejected from the sample or from material adjacent to the sample. In the case of thin metal foils with thicknesses of a few microns there may be a noticeable loss of activity (depending on the range of the recoil atoms relative to the foil thickness). In other cases, especially when low-yield reactions are studied, the sample may be contaminated by reaction products stemming from interactions in adjoining material such as containers, sandwich foils, or the housing (chamber wall) of the fluence monitoring detector. The effect is very well observed when considerable momentum can be transferred, e.g. in  $(\alpha,n)$  reactions (H. Vonach et al., 1983), but also with  $(n,\alpha)$  reactions. For example, when aluminium foils as fluence monitor are used in a sandwich arrangement for irradiation with 14 MeV neutrons, some activity of  $^{24}\text{Na}$  from the reaction  $^{27}\text{Al}(n,\alpha)$  will be implanted and found in the adjacent sample if no precautions, such as a separating thin catcher foil, are taken.

#### 4. Optimizing experimental (irradiation) conditions and/or correcting for effects of sample-size, target-size and other environmental conditions

An ideal experiment would, if possible, employ an (almost) massless sample on an (almost) massless backing, combined with an extremely low-mass neutron producing target construction. In practice one has to deal with possible approaches to the ideal situation, and use, for example, samples as thin, as pure, as uniform as available and reasonable. Intensity problems can put a lower limit on the sample mass. Therefore, often corrections have to be applied to take into account changes of the total response due to influences on the incident neutron field or on the radiation to be detected, e.g. by

scattering processes, attenuation, production of secondary neutrons or other radiation, in the sample material itself, in components of the target set-up, beam-line, and any material in the surroundings of the sample or the target. In most cases energy-dependent cross-section data are required for these corrections. Both the composition (including impurities) and the geometrical characterization of sample or target materials will enter. A typical example is the interference by impurities with relatively high cross sections for the production of unwanted neutrons, in the backing, beam stop or entrance window of the target arrangement. In the 14 MeV region, for instance, copper as an impurity in an aluminium target support may lead to a significantly increased background of lower-energy neutrons due to (n,2n) processes in copper. As another example, material instability, e.g. due to hygroscopy, may lead to wrong energy-loss or attenuation estimates for charged particles or neutrons, respectively. The influence of the structural target components on the sample response can be investigated by means of a measurement with the medium of the primary neutron source being not present (e.g. in the gas-out condition in case of a gas target).

##### 5. Reliable energy scale

Every "differential" experiment is actually an "integral" experiment with somewhat tighter limits on the experimental parameters. An energy-dependent cross section cannot be measured at a single discrete energy, but the experimental result is to be interpreted as an average of the microscopic cross section over the parameter space, typically the effective neutron energy profile, of the experiment. In case that the excitation function exhibits a nonlinear behaviour, the experimentally determined cross section will in addition more or less differ from the real cross section at the average energy (Winkler et al., 1980). Paying attention to a reliable energy scale is particularly important when the excitation function shows structure or a steep slope as close to the reaction threshold. This means, among others, careful determination of the effective beam energy for the particles used to initiate the source reaction. Effects of uncertainties in the thicknesses and uniformity of the neutron producing target layer, an eventual entrance window or another absorption layer have to be estimated, as well as uncertainties in the stopping power data for energy loss calculations (and therefore also in the composition) of

such layers. Impurities in windows, target layer and beam stop may cause a contamination of the primary energy spectrum by unwanted neutron groups as mentioned above. On the basis of a good specification of the relevant target components with regard to dimensions and composition, energy distribution profiles can be calculated, e.g. by means of a Monte Carlo simulation (Pavlik and Winkler, 1986), simultaneously taking into account the relevant interaction processes including correlations. In this way reliable estimates of the effective average neutron energy and the energy spread and the uncertainties of these experiment parameters can be derived. For example, for the production of neutrons with energies above 14 MeV by means of the  $T(d,n)^4\text{He}$  reaction with solid-state targets, thin titanium layers (in the  $\text{mg/cm}^2$  range, with the tritium occluded in them) are employed, where the incident deuterons lose only a small part of their energy, in order to keep the energy spread small. The thickness uncertainty of these layers has typically to be assigned to  $\sim 10\%$  for commercially available targets, which enters in the uncertainty of the average neutron energy accordingly.

Another point to be mentioned which is in most cases not directly related to the target fabrication but to the usage of targets, is cleanness. For example, an oil layer on a solid-state neutron production target will confuse the energy definition acting as absorption layer for the incident charged particles; the beam will likely crack such layers into firmly sticking carbon layers. At low incident energies, e.g. with a 200-keV Cockcroft-Walton neutron generator, unclean conditions may show up as a drastic reduction in the neutron yield from the respective targets. The shifts in energy scale can be verified by observing the spectra of charged particles produced by neutron reactions in a Si detector or by a pair of monitor reactions with very different slopes of their excitation functions (see e.g., Ryves and Zieba, 1979; Lewis, 1984).

## 6. Fulfilment of the requirements on experiment reporting

Last not least, I should like to mention that a successful experiment should end up listing all significant uncertainty contributions that are used to form the total error of the final result, distinguishing between correlated and uncorrelated (random) contributions (see e.g., NEANDC-A-134, 1981). This information should also include uncertainties in the sample and target specifications. The

uncertainties resulting therefrom will be correlated or partly correlated over the energy range of the measurements, if cross sections are measured at several energies using the same sample or the same sample material and/or the same target arrangement. All uncertainties stated should represent standard deviations or equivalent standard deviations (see e.g., Giacomo, 1981; Müller, 1979).

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**GENERAL COMMENTS ABOUT THE INTERNATIONAL NUCLEAR  
TARGET DEVELOPMENT SOCIETY WITH EMPHASIS ON INFLUENCES  
OF TARGET AND SAMPLE PROPERTIES ON NUCLEAR DATA MEASUREMENTS**

A.L. ADAIR  
OAK RIDGE NATIONAL LABORATORY

**I. Introduction**

The International Nuclear Target Development Society (INTDS) has been concerned for many years with sample preparation and influences preparative techniques will have on experimental results. The purpose of this presentation is to give a general description of INTDS, cite specific examples of papers presented at previous INTDS meetings that detailed experimental anomalies resulting from target fabrication or assay problems, and detail reasons for conducting a joint INTDS/IAEA meeting in Darmstadt in 1988.

**II. General Background of INTDS**

The INTDS was officially formed at a meeting at the University of New York at Stony Brook in 1973. Earlier meetings dealing with sample fabrication and characterization had been held at the Central Bureau of Nuclear Measurements (CBNM) in 1963, at Harwell in 1965, at the Oak Ridge National Laboratory (ORNL) in 1971, and at the University of Montreal in 1972. The purpose for forming the Society was to bring together, on a regular basis, those individuals interested in exchanging ideas relating to materials availability (typically highly enriched isotopic materials), sample fabrication techniques, sample characterization, and associated related subjects of interest. The INTDS has answered a need for communication of information in many areas of material science, including target and special nuclear materials preparation, through publication of newsletters and Conference proceedings.

One major goal of INTDS is to ensure that the information presented at the biennial INTDS conferences is published in a reputable journal in a timely manner.

Since 1973, annual meetings of INTDS were held until 1982 when it was decided to conduct biennial conferences. In 1983, an INTDS workshop was held at the Argonne National Laboratory (ANL), and the biennial format officially began in 1984. The specific INTDS conferences and locations are detailed in Table 1.

Table 1. INTDS conferences held annually until 1982 when a biennial format was adopted

Year	Location
1973	University of New York, Stony Brook, New York
1974	Atomic Energy of Canada Limited, Chalk River, Canada
1975	Argonne National Laboratory, Chicago, Illinois
1976	Los Alamos Scientific Laboratory, Los Alamos, New Mexico
1977	Lawrence Berkeley Laboratory, Berkeley, California
1978	University of Munich, Tech. University Munich, Garching, F. R. Germany
1979	New England Nuclear Corporation, Boston, Massachusetts
1980	ORNL, Gatlinburg, Tennessee

Table 1 (continued)

Year	Location
1981	Weizmann Institute of Science, Israel
1982	University of Washington, Seattle, Washington
1983	Argonne National Laboratory (workshop)
1984	CBNM, Antwerp, Belgium
1986	Chalk River Nuclear Laboratories, Chalk River, Canada

### III. Examples of Papers Presented at Previous INTDS Meetings Citing Experimental Anomalies Resulting from Target Fabrication or Assay Problems

Since the subject of this meeting is the influence of target and sample properties on nuclear data measurements, specific examples of papers presented at previous INTDS meetings discussing this topic should be of interest. This is by no means an all inclusive list but examples that should give some indication that a joint meeting of INTDS and IAEA would be very beneficial to both groups.

Table 2. Sample listing of papers presented at INTDS conferences that dealt with experimental anomalies that resulted from target fabrication and/or assay problems

Conference Year	Location	Title and Author	Comments
1971	Gatlinburg, Tennessee	Preparation of Targets of alpha - radioactive sources - G. Sletten	Deposits were contaminated with Ta and W. Experiment required contamination-free deposits to study fission isomerism by the recoil method.
1974	Chalk River, Canada	Tailoring of Targets for a Tandem Accelerator Laboratory - G. Sletten	Describes effects of target uniformity and target thickness on the study of fission isomers.
1975	ANL	Beam Heating of Target Foils - W. C. Corwin	Describes the use of a target rotator to reduce or eliminate beam-heating effects.
1979	Boston, Massachusetts	Methods to Reduce Contamination in Targets Prepared by Vacuum Evaporation - G. Thomas et al.	Describes sources of contaminants in targets, effects on experiments, and possible solutions to contamination problems.
1979	Boston, Massachusetts	Target Techniques Applied to Gamma Spectroscopy with Heavy Ions - G. Sletten	Presents experimental problems and how they relate to target design and fabrication. Specifications, target thickness, and target heating are addressed.

Table 2 (continued)

Conference Year	Location	Title and Author	Comments
1980	Gatlinburg, Tennessee	Potassium Targets from KI - G. Sletten	Describes fabrication technique for fabricating KI targets with minimal chlorine impurity. Experimental results are presented.
1981	Israel	Production of Thick Elemental Low-Oxygen Content Magnesium Targets - G. Hinn	Determining cross sections for Al-26 reaction where oxygen contamination in the magnesium targets would cause serious errors.
1984	Antwerp, Belgium	Some Users' Comments on the Fabrication, Assaying, and Use of Samples for Nuclear Measurements - C. Wagemans	Emphasized the point that more consideration should be given to fabrication and assaying of samples for nuclear data measurements.

#### IV. Joint INTDS/IAEA Meeting Can Be Beneficial to Both Groups

A meeting that brings both sample fabricator and experimenter together can be of mutual benefit. Such a meeting helps to further clarify the needs of the user and helps to identify sample fabrication and assay methods to meet those needs. Furthermore, it would help inform IAEA participants of the specific materials that are available and the sample fabrication technology that exists at various laboratories to convert the required materials into usable forms.



Influence of water absorption in a sample for  
neutron capture measurements

Motoharu Mizumoto and Masayoshi Sugimoto

Japan Atomic energy Research Institute  
Tokai-mura, Naka-gun, Ibaraki-ken, Japan

Abstract

The influence of water absorbed in oxide samples was estimated for the measured neutron capture yields in the keV region. The calculation of correction factor was made with a Monte Carlo method taking into account neutrons slowing down by hydrogen atoms to the resonance region.

I. Introduction

The neutron cross section measurements of fission product nuclei have been carried out systematically at the JAERI linac for last several years. In neutron capture experiments, the sample-related corrections such as self-shielding and multiple-scattering corrections are always very important. For fission product nuclei in the keV region, chemical compound samples such as oxide, carbonate or nitride are often used. In particular, oxide samples are highly hygroscopic. Due to the hydrogen in the water, neutrons are easily slowed down by neutron multiple scattering to the low energy region where the capture cross section values are usually high and are fluctuated in the resolved resonance region. This effect causes large effective cross section values. The proper correction is needed to obtain the accurate cross section values.

In the course of  $^{149}\text{Sm}$  capture cross section analyses<sup>(3)</sup>, we realized the serious problem of the water absorption in the oxide sample. Our  $^{149}\text{Sm}_2\text{O}_3$  (33.7 g) was found to absorb 5.2 % water. The estimated correction to the cross section was 3 % at 3 keV to 17 % at 100 keV. Such another example is emphasized in Fig. 1 in the case of Tantalum sample ( $\text{Ta}_2\text{O}_5$ ). In the figure, comparison is made between the data for the metallic sample and oxide sample. The water absorbed in the oxide sample is about 10 % in weight. Effective cross section

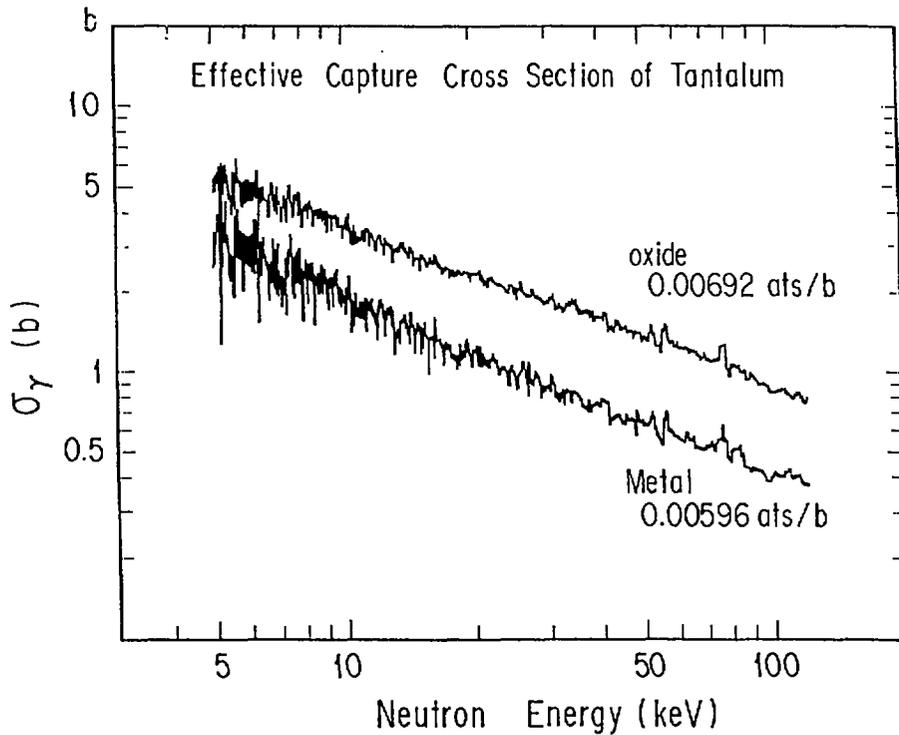


Fig. 1 Effective capture cross sections of Tantalum. In the oxide sample, water of 20 % in weight is absorbed in the sample.

obtained from the oxide sample is almost 100 % larger than the metallic sample if any correction is not made.

## II. Methods

The resonance self-shielding and multiple scattering correction due to the sample thickness have been estimated by a statistical technique originally developed by Dresner<sup>(1)</sup> and reformulated by Macklin<sup>(2)</sup>. But this methods do not include the effects of the neutron energy degradation due to the neutron scattering from light mass elements of hydrogen and oxygen.

In our experiments, the sample thickness correction was carried out for an oxide sample by semi-analytical method. The primary capture yield from the sample was calculated by the same analytical way as Dresner-Macklin method. The capture yields after the multiple scattering were then estimated by a Monte-Carlo method. The calculation took into account the change of neutron energy caused by the large recoil energies from light mass elements of oxygen and hydrogen in the sample materials.

The capture cross section in the low energy region are highly fluctuated due to the resonance levels. Average neutron cross sections were calculated from the single-level Breit-Wigner formula, including the Doppler broadening effect, which used the average resonance parameters obtained from the resonance region. In each history of Monte Carlo calculation, the contribution to the capture yield was calculated at each collision and weight by the probability of prior scattering events. The neutron was scattered at a position and in a new direction which were chosen by the random number methods, assuming isotropic scattering in the c.m.s. All weighted capture contributions were summed until the weight dropped below a preset minimum.

### III. Results

The calculated correction factor is shown in Fig. 2 for the metallic and oxide sample. The correction factor calculated by the analytical method is also shown, where no effect by water is included. The corrected capture cross sections are shown in Fig.3 together with the evaluated values of JENDL-2 data (Japanese Evaluated Nuclear Data Library-2). We obtained very good agreement between two data.

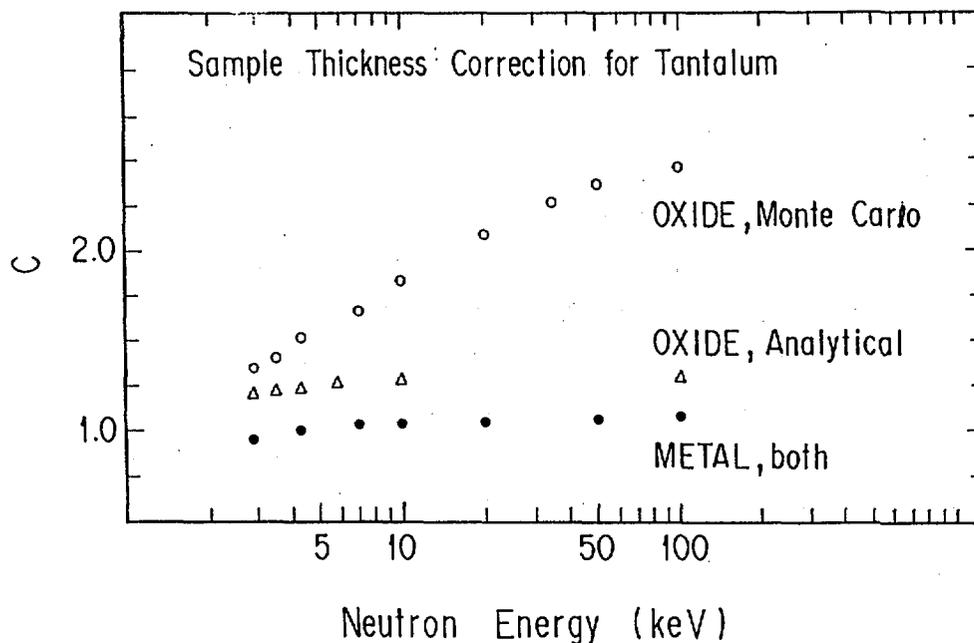


Fig. 2 Sample thickness correction factor for Tantalum sample. The data points are calculated both by the analytical (Ref.2) and Monte Carlo method.

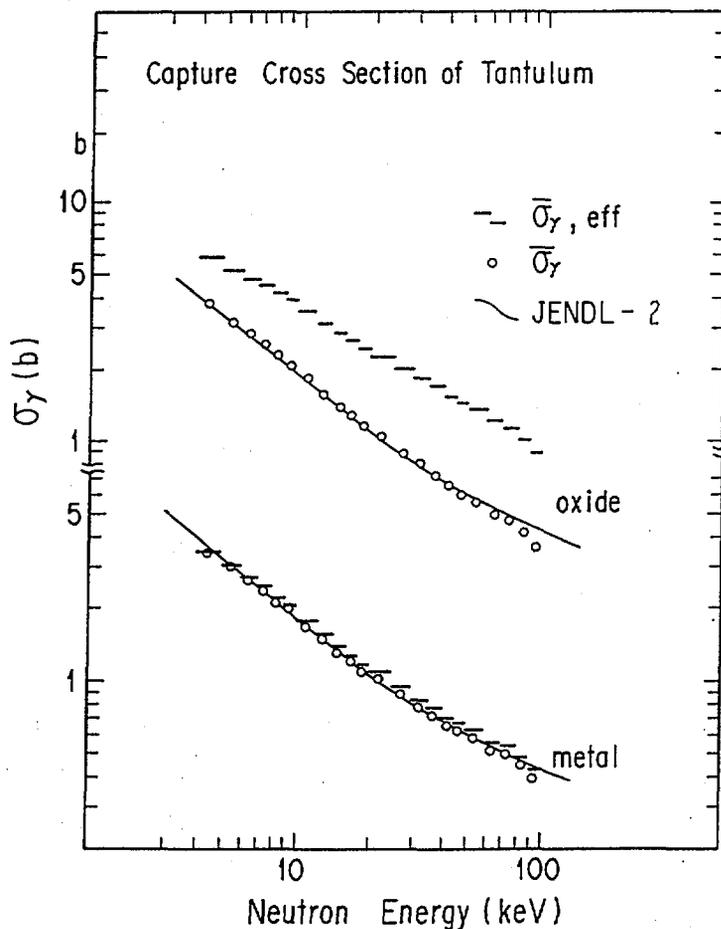


Fig. 3 The capture cross sections which are corrected for the sample thickness and water absorption. The lines show the evaluated values of JENDL-2.

From these results, we made the same correction to the fission product nuclei of Sm isotopes. Though the capture cross section and water absorption rate (5.2 %) of the Sm sample are different, the Monte Carlo calculation including narrow resonance approximation was assumed to be adequate. We concluded that the data have an uncertainty from the correction reached as much as 15 % at 100 keV.

This typical example shows that the water absorption in oxide samples has to be carefully avoided in the neutron capture experiments even though some correction can be made

#### References.

- (1) L. Dresner, Nucl. Instrum. Methods 16 (1962) 176
- (2) R.L. Macklin, Nucl. Instrum. Methods 26 (1964) 213
- (3) M. Mizumoto, Nucl. Phys. A357 (1981) 90

# Influence of target thickness and isotope in the sample in the measurement of neutron activation cross section

T. Katoh, K. Kawada, H. Yamamoto

Department of Nuclear Engineering, Nagoya University

## Abstract

Influences of sample thickness to the measured activation cross sections were discussed in the case of Mo isotopes at 14 MeV. For the measured cross section ( $1.60 \pm 0.11$  mb) of  $^{96}\text{Mo}(n,n'p)^{95m}\text{Nb}$ , the influence of  $^{95}\text{Mo}$  (0.94% in the enriched sample) was found to be 6.7%. The rates of neutron flux reduction were also examined for the various 1 mm thick samples.

### 1. REDUCTION OF NEUTRON FLUX IN THE SAMPLE

For the measurement of neutron activation cross-section, the sample is irradiated together with flux-monitor sample. Since the reduction of neutron flux is caused in the sample due to scattering and so on, the true flux at the sample is different from the monitor sample. Fig. 1 shows results of measurements of flux reduction.

The broken line shows the spatial neutron flux without sample, and closed circle with bars show measured flux with sample (natural molybdenum). Table 1 shows rate of flux reduction for thickness of 1 mm of various samples. We set monitor samples at the front and back of sample to be measured, and take an average value of fluxes at both monitors as the flux at the sample.

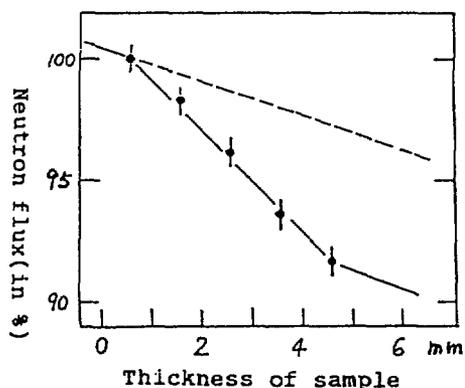


Fig. 1, Influence of sample thickness

Table 1, Rate of flux reduction for 1 mm of sample

sample	%/mm
Al	0.8
Ni	1.4
Nb	0.9
Mo	1.0
Zr	0.9
Au	1.5

## 2. INFLUENCE OF ISOTOPE IN THE SAMPLE

Since  $^{96}\text{Mo}(n,p)$  and  $^{96}\text{Mo}(n,n'p)$  reactions produce same nuclide, the influence of the adjacent mass elements must be considered for the measurement of activation cross-sections.

We measured this effect by using samples with different enrichment.

In case of  $^{96}\text{Mo}(n,n'p)$ , a sample of 96.8% enrichment in mass 96 and a natural Mo sample(16.7% in mass 96) were used, and yield of induced activity( $^{95}\text{Nb}$ ) in both samples were compared. As a results of experiment, it is found that the influence of  $^{96}\text{Mo}$ (0.94% in the enriched sample) on the measured cross-section( $1.60 \pm 0.11$  mb) of  $^{96}\text{Mo}(n,n'p)^{95}\text{Nb}$  was 6.7%.

Since, the activation cross-section of  $^{96}\text{Mo}(n,p)^{95}\text{Nb}$ ( $\sigma = 5.81 \pm 0.39$  mb) is larger than that of  $^{96}\text{Mo}(n,n'p)$ reaction, the influence becomes large even though the amount of residual isotope in the enriched sample is small.

In case of  $^{96}\text{Mo}(n,n'p)$  reaction, the influence of  $^{96}\text{Mo}(n,p)$  reaction by residual  $^{96}\text{Mo}$ (0.63% in the enriched sample) was 3.2%.

# Preparation of Actinide Targets by Electrodeposition using Isopropyl Alcohol

N. Shinohara and N. Kohno

Department of Chemistry, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken, 319-11 Japan

## Abstract

A preparation method of actinide targets ( U, Np, Pu, Am and Cm) by electrodeposition using isopropyl alcohol is described. The actinides can be deposited quantitatively on a platinum disk within 15 to 20 minutes, and the resolution of alpha-ray spectra of the electrodeposited sources are within the range of 14 to 18 keV (FWHM).

## 1. INTRODUCTION

For the purpose of the determination of actinides in spent fuel, we have studied the electrodeposition of the actinides using various kind of organic solvents because the electrodeposition rate by the organic solution is usually rapid more than by aqueous one<sup>1)</sup>. It has been found that isopropyl alcohol as a solvent is very suitable for the electrodeposition of the actinides, and several sources of  $^{235}\text{U}$ ,  $^{237}\text{Np}$ ,  $^{238}\text{Pu}$ ,  $^{242}\text{Pu}$ ,  $^{243}\text{Am}$  and  $^{244}\text{Cm}$  isotopes with splendid alpha-ray energy resolution have been prepared by the present method.

The electrodeposition method using isopropyl alcohol has been applied to the preparation of the actinide targets for the various purposes, i.e. targets of uranium, neptunium, plutonium, americium and curium isotopes for fission chambers used in the Fast Critical Assembly of JAERI<sup>2)</sup>, targets of uranium and plutonium for accerelator experiments<sup>3)</sup>, source

of  $^{242}\text{Cm}$  for measuring the spontaneous fission<sup>4)</sup>, and standard sources of  $^{238}\text{Pu}$  and  $^{243}\text{Am}$  for calibration of detector efficiency<sup>5)</sup>. These targets have a variety of the areas deposited and their diameters are from 2.0 to 25.0 mm.

This paper describes the details of the electrodeposition method using isopropyl alcohol for the actinide targets.

## 2. EXPERIMENTAL

### 2.1 Preparation of sample solution

The solution of actinides isotopes,  $^{235}\text{U}$ ,  $^{237}\text{Np}$ ,  $^{238}\text{Pu}$ ,  $^{242}\text{Pu}$ ,  $^{243}\text{Am}$  and  $^{244}\text{Cm}$ , were purified by ion-exchange method by using HCl solution<sup>6)</sup>. Each purified actinide solution was evaporated under infrared lamp and dissolved with 50  $\mu\text{l}$  of 0.2 M HCl and 2 ml of twice distilled water. The solution was transferred into small polyethylene bottles and provided as a stock solution for the electrodeposition after standing for a week. After a definite amount of the stock solution was mounted on a platinum disk and dried by infrared lamp and gas burner, the specific activity of the solution was determined by measuring the alpha-ray activity of the disk with  $2\pi$ -gas flow proportional counter.

### 2.2 System of the electrolysis

The electrodeposition cell is shown in Fig. 1. The cell, which is made by pyrex glass, consists of jacket for cooling the electrolyte solution and a stainless steel base. For stirring the solution a platinum wire (anode, 10 mm diameter) is rotated by a motor at about 100 rpm. A platinum disk (cathode, 24 mm diameter, 0.05 mm thickness) was used as a backing material for the electrodeposition after washing with trichloroethylene, acetone, distilled water and 7 M  $\text{HNO}_3$ .

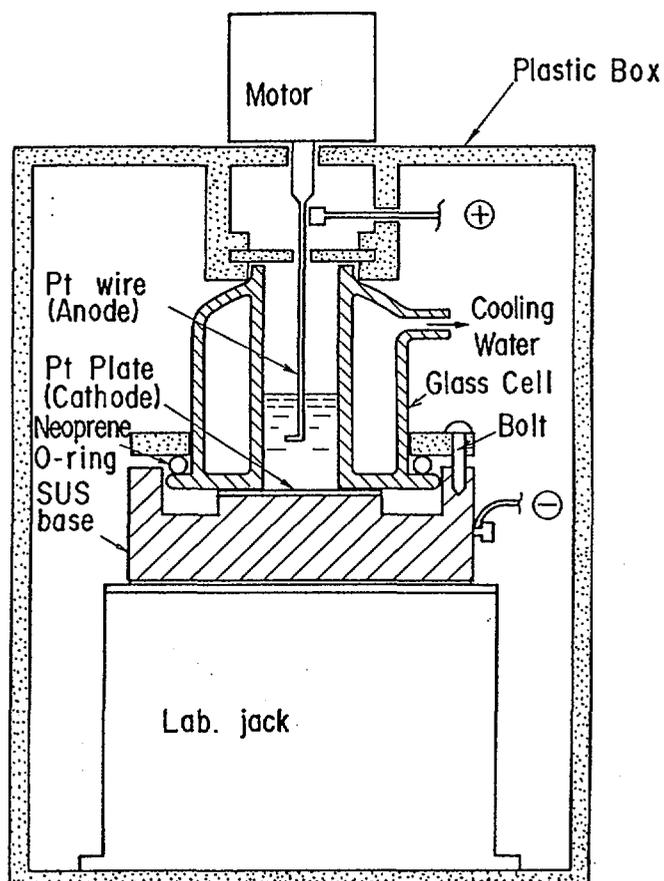


Fig. 1 Electrodeposition cell assembly.

### 2.3 Condition of the electrolysis

The cell was filled with 4 ml of isopropyl alcohol, 5  $\mu\text{l}$  of 0.005 M HCl and 0.5  $\mu\text{g}$  of  $^{242}\text{Pu}$ . Effect of the acidity of the solution on the yield of the plutonium electrolyzed for 20 minutes was investigated by further adding 0.1 M NaOH (0-100  $\mu\text{l}$ ) or 0.1 M HCl (0-35  $\mu\text{l}$ ) into the cell. The yields of the actinides electrodeposited on the disks were investigated as a function of acidity of the solution, the voltage and the current density for electrolysis. The yield was determined by measuring the alpha activity of 5-10  $\mu\text{l}$  of the solution before, during and after the electrolysis with  $2\pi$ -gas flow proportional counter. Effect of the voltage on the electrodeposition yield of  $^{242}\text{Pu}$  was also examined under the

condition of 4 ml of isopropyl alcohol, 20  $\mu\text{l}$  of 0.1 M HCl and 5-100  $\mu\text{l}$  of sample solution.

### 3. RESULTS AND DISCUSSION

The electrodeposited yields of  $^{242}\text{Pu}$  is shown in Fig. 2. As increasing the acidity of the solution, the yield raises and reaches the maximum at 5-25  $\mu\text{l}$  of 0.1 M HCl added. The

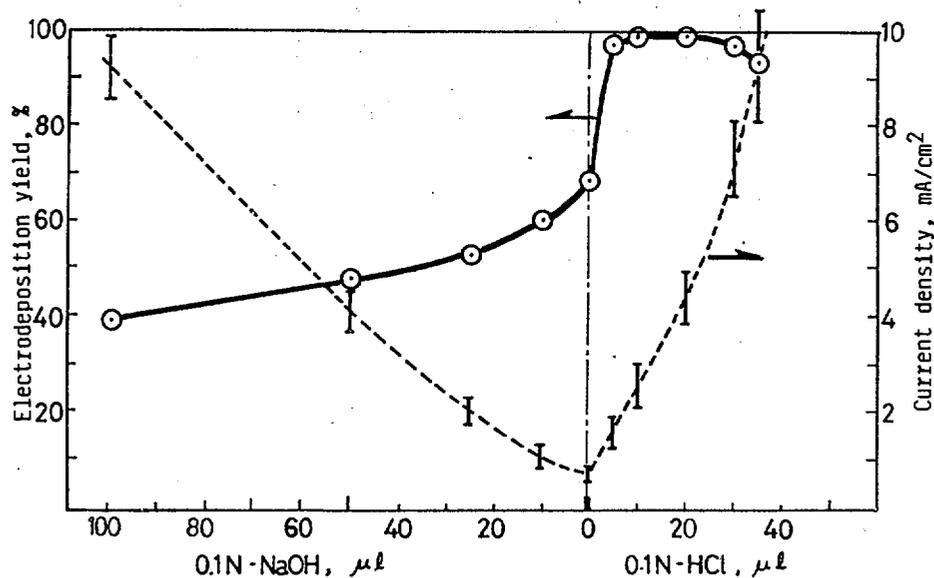


Fig. 2 Effect of the addition of acid and alkali in the electrolyte on the electrodeposition of  $^{242}\text{Pu}$ .

Electrolyte; 5  $\mu\text{l}$  of 0.005N HCl, 4 ml of isopropyl alcohol and 5  $\mu\text{g}$  of  $^{242}\text{Pu}$ .

current density rises in proportion as the volume of HCl increases.

Figure 3 shows the results of the yield and the current density with controlled-voltage electrolysis (360, 530, 700 and 1000 V). After electrolysis for 20 minutes the yields are 80, 98, 99 and 96 % at 360, 530, 700 and 1000 V, respectively. The electrolysis at 700 V subscribes highest yield and the current density varies from 3.5 to 5  $\text{mA}/\text{cm}^2$ . The result under constant current electrolysis of  $^{242}\text{Pu}$  is given

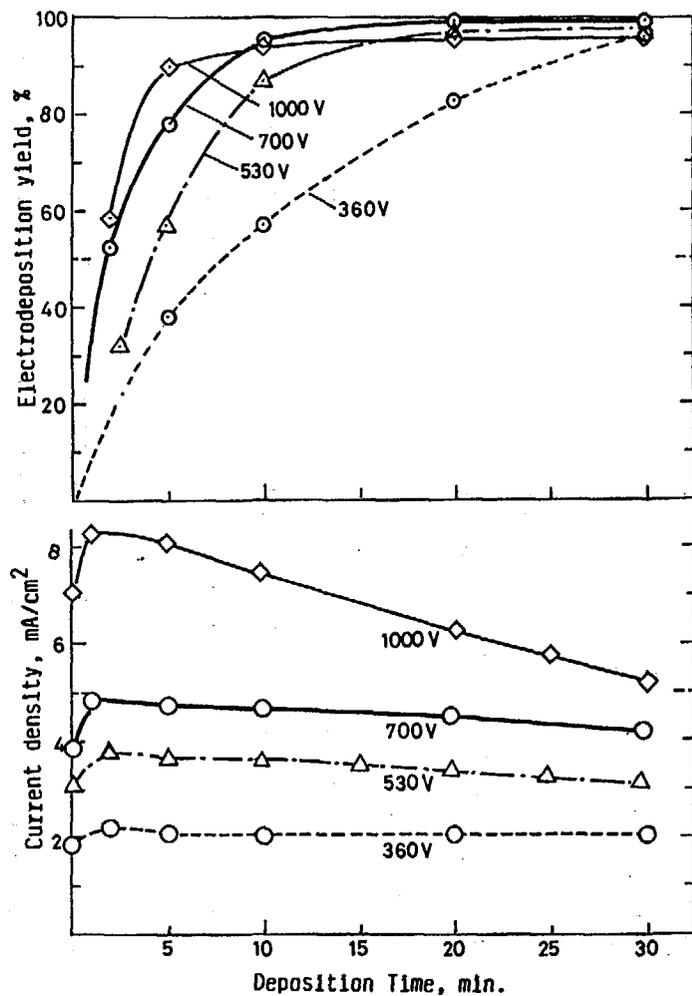


Fig. 3 Deposition yields and current density as a function of the time for the controlled-voltage electrolysis of  $^{242}\text{Pu}$ . Electrolyte: 4 ml of isopropyl alcohol, 5  $\mu\text{l}$  of 0.005N HCl, 0.5  $\mu\text{g}$   $^{242}\text{Pu}$  and 20  $\mu\text{l}$  of 0.1N HCl.

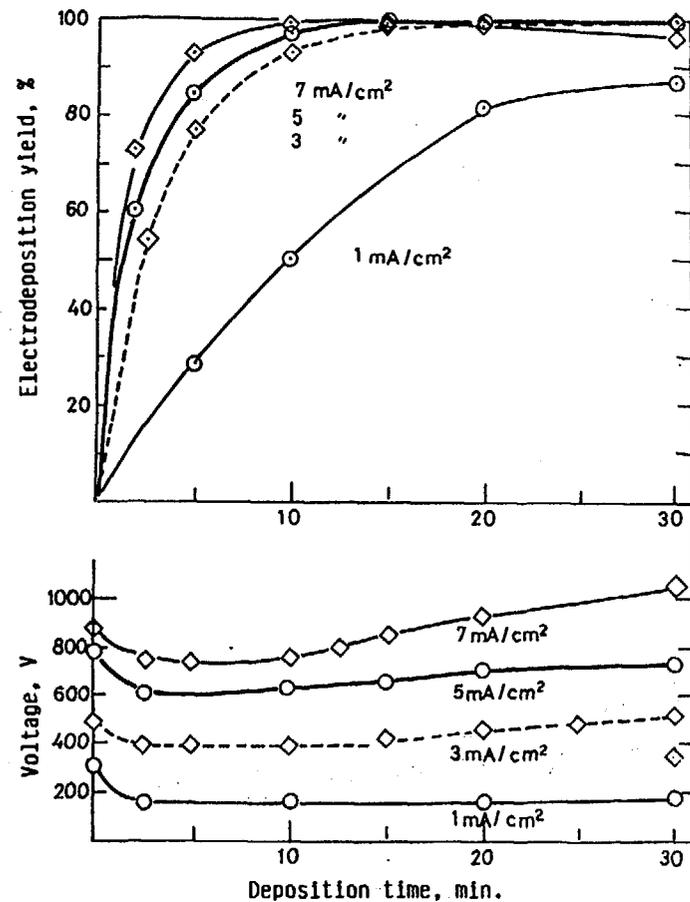


Fig. 4 Deposition yields and voltage as a function of the time for constant current electrolysis of  $^{242}\text{Pu}$ . Electrolyte: 4 ml of isopropyl alcohol, 5  $\mu\text{l}$  of 0.005N HCl, 0.5  $\mu\text{g}$   $^{242}\text{Pu}$  and 20  $\mu\text{l}$  of 0.1N HCl.

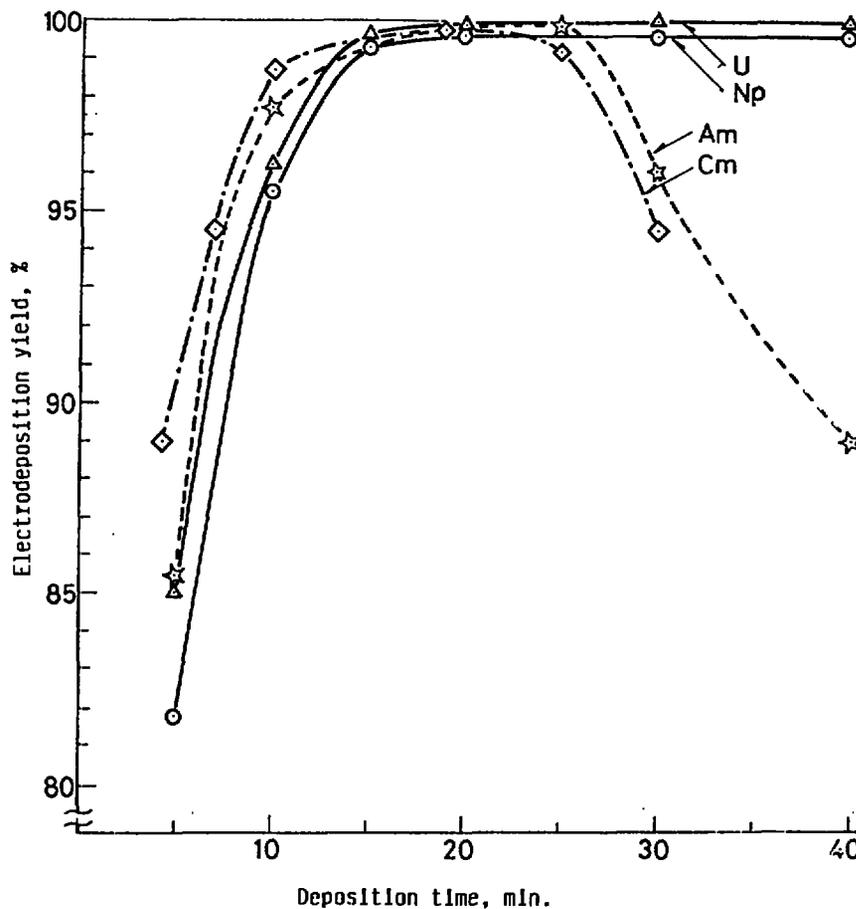


Fig. 5 Deposition yields of U, Np, Pu, Am and Cm by constant current electrolysis.

Electrolyte: 4 ml of isopropyl alcohol, 20  $\mu$ l of 0.1N HCl.

Current density: 3.5 mA/cm<sup>2</sup>.

in Fig.4. The highest yield over 99% is obtained in the case of 3 mA/cm<sup>2</sup> (400-500 V) and 5 mA/cm<sup>2</sup> (600-800 V) for 15-30 minutes-electrolysis.

Considering the results mentioned above it is found that highest electrodeposition yields of plutonium is achieved under the condition of 3-5mA/cm<sup>2</sup> of current density and 400-800 V of voltage.

The deposition yield curves for uranium, neptunium, americium and curium by constant current electrolysis is shown in Fig. 5, where current density is 3.5 mA/cm<sup>2</sup>. Uranium and neptunium is quantitatively deposited for 15-40 minutes elec-

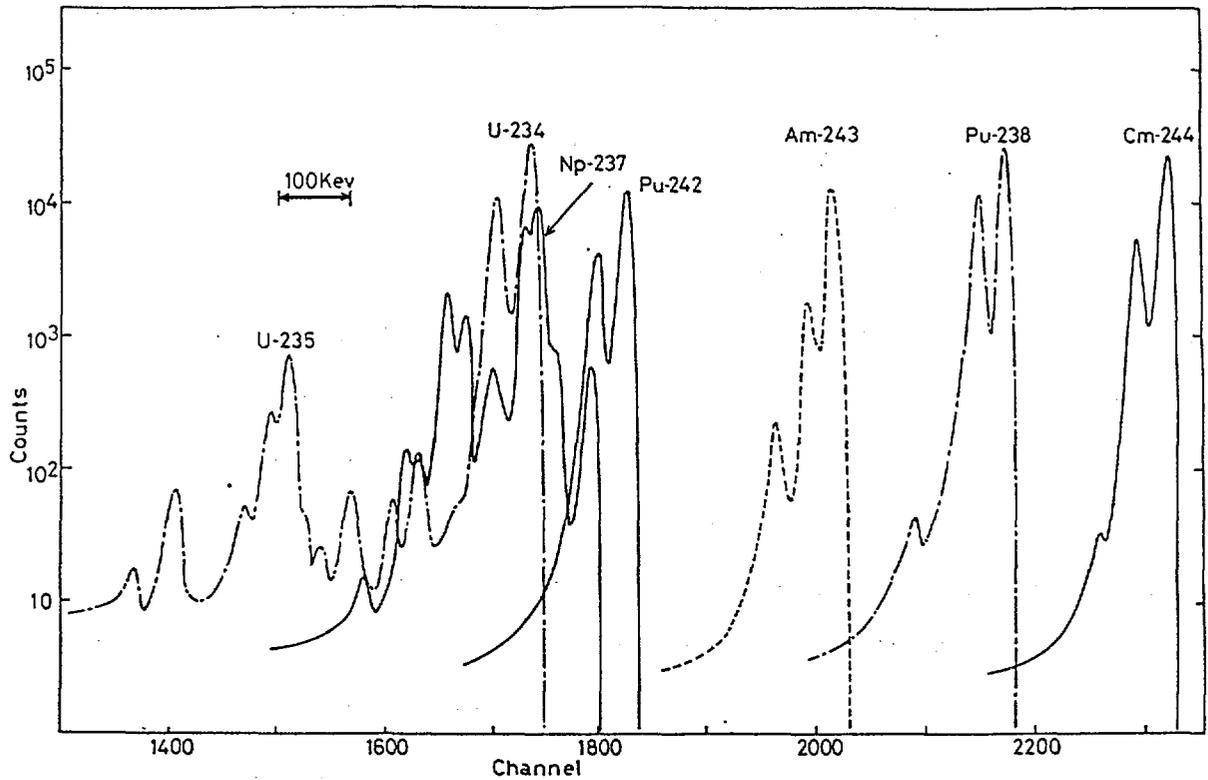


Fig. 6 Alpha-ray spectra of the U, Np, Pu, Am and Cm sources prepared by the electrodeposition.

Table 1. Electrodeposition yields of the actinides and the energy resolution of alpha-ray spectra.

Isotope	Deposition yield	Thickness $\mu\text{g}/\text{cm}^2$	Resolution keV (FWHM)
$^{235}\text{U}$	99.7	13	17.0
	99.9	25	17.9
$^{237}\text{Np}$	99.1	10	16.2
	99.6	23	16.9
$^{238}\text{Pu}$	99.2	0.004	14.2
	99.1	0.007	14.0
$^{242}\text{Pu}$	99.4	1.8	15.0
	99.7	2.9	15.8
$^{243}\text{Am}$	99.2	1.7	15.3
$^{244}\text{Cm}$	99.3	0.007	14.9

trolysis, whereas the maximum yields of americium and curium are accomplished for 15-20 minutes electrolyses. In the case of americium and curium, the yields are decreased as the duration of the electrolyses becomes over 25 minutes.

Alpha-ray spectra of the actinides measured with silicon-surface-barrier detector are summarized in Fig. 6, and Table 1 gives the yields of the actinides deposited under the condition of  $3.5 \text{ mA/cm}^2$  for 20 minutes. The thickness of the actinides deposited and the resolution of the spectra (FWHM) are also shown in the table. The sources have a resolution of 14-18 keV (FWHM) for the uranium, neptunium, plutonium, americium and curium isotopes. The electrodeposition using isopropyl alcohol makes excellent sources for alpha spectrometry.

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- 3) N.Shinohara, et al.; Phys. Rev. C34, 909 (1986).
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- 5) N.Shinohara and N. Kohno; to be published.
- 6) H.Natsume, et al.; J. Nucl. Sci. Technol. 9(12), 737 (1972).

IAEA Specialists' Meeting on  
THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES ON  
NUCLEAR DATA MEASUREMENTS

in co-operation with the  
Central Bureau of Nuclear Measurements (CBNM)  
and the  
International Nuclear Target Development Society (INTDS)

CBNM, Geel, Belgium, 21-24 September 1987

SUMMARY and RECOMMENDATIONS

1. The IAEA Specialists' Meeting on "The Influence of Target and Sample Properties on Nuclear Data Measurements" (in the following: IAEA Specialists' Meeting) agreed on the following boundary conditions for the INTDS Conference at GSI (Gesellschaft für Schwerionenforschung) in Darmstadt:

1) Label: The Fourteenth World Conference of the International Nuclear Target Development Society organized in cooperation with the IAEA-International Nuclear Data Committee at the Gesellschaft für Schwerionenforschung, Darmstadt, FRG, Sept. 5-9, 1988.

A session (e.g. 1/2 day) on user relevant topics will be organized, preferentially at the beginning of the conference, however, details (grouping or spreading) are left to the discretion of the organizing committee.

All accepted papers will be published as INTDS report in Nuclear Instruments and Methods.

Submitted and invited papers are considered by the INTDS conference programme committee. Invited talks on selected user oriented topics suggested by the IAEA should be considered by this agency in cooperation with the INTDS programme committee. The presentation time for both invited and contributed papers will be approximately 20 minutes. It is expected that the number of user oriented papers will be about 10.

An IAEA Advisory Group Meeting (2 evenings + 1 day) will take place during the conference, assuming that the invited experts have attended the whole conference. Also INTDS members are expected to participate as experts.

The advice is formulated and published as an INDC report, not publishing papers, but referring to titles and abstracts of the "user session" and making reference to the entire conference.

H. Folger will send to K. Okamoto the text of the 1st announcement of the conference before October 15, 1987. This announcement will be attached to the IAEA invitations for its Advisory Group Meeting.

2. The IAEA Specialists' Meeting agreed that the following specific topics should be discussed at the IAEA Advisory Group Meeting:
  - 1) the need of a target supplier's list to serve the IAEA for answering requests from developing countries;
  - 2) the need of a user's "wish"-list that might give a challenge to target producers, and
  - 3) the organization of proposed training courses related to sample and target preparation by the IAEA with support from the INTDS.
  
3. The IAEA Specialists' Meeting suggests that INDC forms a small ad-hoc sub-committee to deal with requests, mostly from developing countries on the matter of target and samples for nuclear measurements.
  
4. The IAEA Specialists' Meeting recommends in response to action 27 of INDC, that for IAEA administered fission foils, the producer laboratory should store, check and dispatch the foils on request of IAEA. The IAEA has the responsibility of coordinating and administrating this effort.

CBNM would be willing to prepare such foils based on conditions and specifications to be determined.
  
5. The IAEA Specialists' Meeting suggests that the subject of tritium target handling be presented at the INTDS conference or at least discussed during the IAEA Advisory Group Meeting in Darmstadt.

IAEA Specialists' Meeting on  
THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES ON  
NUCLEAR DATA MEASUREMENTS

in co-operation with the  
Central Bureau of Nuclear Measurements (CBNM)  
and the  
International Nuclear Target Development Society (INTDS)

CBNM, Geel, Belgium, 21-24 September 1987

LIST OF PARTICIPANTS

ADAIR, H.L.	Oak Ridge National Laboratory Operations Division P.O. Box X Oak Ridge, TN 37831, USA
DERUYTTER, A. (Chairman)	Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel, Belgium
FOLGER, H.	GSI-Gesellschaft für Schwerionenforschung mbH Postfach 11 05 41 D-6100 Darmstadt 11 Federal Republic of Germany
HANSEN, H.H. (Local Secretary)	Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel, Belgium
LESSER, R.	Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel, Belgium
LISKIEN, H.	Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel, Belgium
MIZUMOTO, M.	Nuclear Physics II Laboratory Japan Atomic Energy Research Institute (JAERI) Tokai-mura, Naka-gun Ibaraki-ken 319-11, Japan
OKAMOTO, K. (Scientific Secretary)	IAEA Nuclear Data Section Wagramerstr. 5, P.O. Box 100 A-1400 Vienna, Austria
PAUWELS, J.	Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel, Belgium
SLETTEN, G.	Niels Bohr Institute University of Copenhagen DK-4000 Roskilde, Denmark

VAN AUDENHOVEN, J.                   Central Bureau of Nuclear Measurements  
  Steenweg naar Retie  
  B-2440 Geel, Belgium

WAGEMANS, C.                         Centre d'Etude de l'Energie Nucléaire  
  C.E.N./S.C.K.  
  Boeretang 200  
  B-2400 Mol, Belgium

WINKLER, G.                         Institut für Radiumforschung und Kernphysik  
  Boltzmannngasse 3  
  A-1090 Vienna, Austria

IAEA Specialists' Meeting on  
THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES ON  
NUCLEAR DATA MEASUREMENTS

in co-operation with the  
Central Bureau of Nuclear Measurements (CBNM)  
and the  
International Nuclear Target Development Society (INTDS)

CBNM, Geel, Belgium, 21-24 September 1987

TENTATIVE AGENDA

Monday, 21 September

Opening

Introductory Address: A. Deruytter (Chairman)

Announcements: K. Okamoto

J. van Audenhoven

SESSION I: USERS' COMMENTS I

- Report by participants

C. Wagemans

H. Liskien

Tuesday, 22 September

Welcome Speech by Director of CBNM

SESSION II: USERS' COMMENTS II

- Report by the participants (cont.)  
and discussions on the items mentioned in the  
Information Sheet (1) to (4)

G. Winkler

M. Mizumoto

H. Folger

H. Adair

SESSION III: Discussion on the organization of joint INTDS/IAEA  
Advisory Group Meeting, Darmstadt, 5-9 September 1988.

(i) General

(ii) Selection of proposed topics (outline)

(iii) Selection of proposed topics for the users'  
interest and proposed speaker on the topics  
(users' side)

SESSION IV: Miscellaneous topics common to users' and producers'  
interest.

Wednesday, 23 September

SESSION V: Discussions on the need for a complete target suppliers' test and a users' request list for targets and samples

SESSION VI: Possibility of organizing a training course in sample preparation

SESSION VII: Detailed discussions on the selection of speakers (invited) from the users' side (cont. of SESSION III (iii))

SESSION VIII: Preparation of the summary and recommendations

Thursday, 24 September

SESSION VIII (Continued)

SUGGESTED TOPICS (Users' side)  
for the 1988 Joint INTDS/IAEA INDC Meeting

5-9 September 1988  
Darmstadt, Federal Republic of Germany

1. Review Talk.
2. Influence of target/sample impurities.
3. Fission foil characterization.
4. Environmental targets.
5. Hydrogen foils as part of standards.
6. Tissue equivalent and plastic samples.
7. Targets for isotope production.
8. Targets for with heavy ion physics.
9. Samples for decay data measurements with high accuracy.
10. Targets for the production of monoenergetic neutrons.
11. Tritium targets.
12.  $^{41}\text{Ca}(n,\alpha)$  reactions - an example for the need of alternative methods to determine the sample thickness.
13. Others