International Atomic Energy Agency

INDC(NDS)-213/G+,M3

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES ON NUCLEAR DATA MEASUREMENTS

SUMMARY REPORT

IAEA Advisory Group Meeting
in co-operation with the
International Nuclear Target Development Society (INTDS)
Darmstadt, Federal Republic of Germany
5-9 September, 1988

Edited by

K. Okamoto
IAEA Nuclear Data Section

October 1988

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

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A b s t r a c t

The IAEA Advisory Group Meeting (AGM) on The Influence of Target and Sample Properties on Nuclear Data Measurements was held at the Gesellschaft für Schwerionenforschung mbH, Darmstadt, Federal Republic of Germany, during the week 5-9 September 1988. The AGM (hereafter "Meeting") was held concurrently during the 14th World Conference (hereafter "Conference") of the International Nuclear Target Development Society (INTDS) in co-operation with the IAEA-International Nuclear Data Committee (INDC).

The "Meeting"'s special sessions (5th, 7th and 9th September 1988) were held to review and prepare the summary of the papers presented to the "Conference" and recommendations on the objectives of the AGM.

The contributed papers to the "Conference" are to be published in the Journal Nuclear Instruments & Methods in Physical Research. The contributed notes to the "Meeting"'s special sessions together with the summary of the contributed papers by the Agency's invitees and the discussions during the "Meetings"'s special sessions and the recommendations are issued in this report.

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Introduction

For experimental nuclear physicists, it is necessary and quite obvious, to devote considerable efforts and to exercise great care in fabrication and assaying of samples used for nuclear data measurements. Needless to say, that in the area of nuclear standard measurements, reliable sample fabrication and accurate assaying are vital in order to obtain the high accuracy of the resultant data.

There are many important problems regarding the influence of sample characteristics on nuclear measurements, the negligence of which might cause erroneous results and lead to wrong conclusions. At the last IAEA Specialists' Meeting with the same title, held at the Central Bureau of Nuclear Measurements (CBNM), Geel, during the week from 21 to 24 September 1987, the specialists summarized the problems as follows: 1) mistakes in assaying the sample characteristics, 2) awareness of technical and experimental limitations of sample characteristics deviating from the ideal ones, 3) variations in sample characteristics after initial assaying due to phenomena like oxidation, hygroscopy, sublimation, crystallization and others, 4) influence from in-growth and impurities specifically relevant to the experimental process, and 5) "mysterious" phenomena which might occur from the sample, capsule, backing material or others but can as yet not be explained.

However, no special systematic efforts have been made so far regarding the influence of target and sample properties on the final results of nuclear data measurements.

There is still another important aspect to be considered. One of the basic tasks of the IAEA is to train scientists from developing countries in nuclear measurement techniques. Simple supply of target and sample materials is not enough to expect those scientists to achieve fruitful and useful results for the scientific community. It is very essential and obligatory to the IAEA as well as to scientists which IAEA supports for nuclear measurement techniques to know and to realise in detail how sample fabrication and assaying are related to the accuracies of nuclear measurements.

Therefore, the IAEA Nuclear Data Section, with strong support by the International Nuclear Data Committee (INDC), convened an Advisory Group Meeting on this topic during the 14th World Conference of INTDS which was held in co-operation with the IAEA-INDC, from 5 to 9 September 1988 at the Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Federal Republic of Germany. While the total number of 104 attendants was represented at the "Conference", twenty-one were invited by the Agency, mostly as target/sample users' representatives and in addition nine members of INTDS were invited to the "Meeting". These participants represented 13 IAEA Member States and one international ogranization (the European Community). All the invited participants by the Agency were requested to present their papers to the "Conference" sessions. The "Conference" was part of the IAEA AGM.

The "Meeting"'s special sessions (5th, 7th and 9th September 1988) were held to review and prepare the summary of the papers presented to the "Conference" and recommendations on the objectives of the AGM. The "Meeting"'s special sessions were chaired by C. Wagemans, CEN/SCK Mol, Belgium, and S.M. Qaim, KFA Jülich, Federal Republic of Germany, and K. Okamoto, the Scientific Secretary. There were also several observers present from INTDS.

The contributed papers to the "Conference" are to be published in the Journal Nuclear Instruments & Methods in Physical Research.

Objectives of the "Meeting"

While to present contributions to the 14th World Conference of INTDS held in co-operation with the IAEA-INDC, especially from the "users" point of view on the topic of the influence of target and sample properties on nuclear data measurements and to participate in the Conference presentations and discussions on nuclear target developments and problems, participants were requested to review and prepare summaries of conclusions and recommendations for the "Meeting" according to the following objectives:

(1) Identify 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 data measurements;

(3) Underline the importance and the necessity of alternative methods for sample assay, especially for the mass-determination of nuclear samples;

(4) Discuss the need for a supplier's list of targets and samples;

(5) Discuss the possibility to organize a training course in sample preparation techniques especially for scientists from developing countries; and

(6) Prepare the recommendations to the IAEA.

Acknowledgement

The scientific secretary of the IAEA AGM wishes to express his gratitude and appreciation to the Gesellschaft für Schwerionenforschung mbH, Darmstadt, for hosting the "Meeting". He extends his acknowledgement to the International Nuclear Target Development Society (INTDS) for the generous co-operation during the "Meeting".

Last but not least, the scientific secretary expresses his grateful appreciation for the work load on Dr. C. Wagemans and Dr. S.M. Qaim as Chairman and Co-chairman of the "Meeting", who finalized the Summary and Conclusions.

International Atomic Energy Agency
Advisory Group Meeting on
THE INFLUENCE OF TARGET AND SAMPLE
PROPERTIES ON NUCLEAR DATA MEASUREMENTS

in co-operation with the
International Nuclear Target Development Society (INTDS)
5-9 September, 1988
Darmstadt, Federal Republic of Germany

PROGRAMME

I. **FIRST MEETING (Monday, 5 September) - General presentation**

C. Wagemans:

(1) Some general considerations on the influence of sample characteristics on nuclear data measurements

O. Wasson:

(2.1) Time dependent neutron energy spectrum from natual Li target

(2.2) Changes in angular distribution of 14 MeV neutrons produced in D(T,n) reactions due to change of concentration of tritium

(2.3) Use of X-ray powder diffraction to determine the oxidation state of U oxide

R.A.P. Wiltshire: (oral presentation)

(3) Samples for decay data

H. Adair:

(4.1) General comments about target purity and substrate materials

(4.2) Impurity problems with an <neutron, gamma> experiment involving Mg isotopes, and

(4.3) Tritium impurity problems

H. Liskien: (oral presentation)

(5) Problems of hydrogen foils

S.M. Qaim:

(6) Targets and samples for nuclear data measurements relevant to medical radioisotope production

II. CONTRIBUTIONS TO INTDS & IAEA-INDC Conference

III. THIRD MEETING (Wednesday, 7 September)- Discussion on specific topics

III-1 Tritium Target Problems

E.H. Kobisk: The problem of tritium handling

K. Sumita: Tritium contamination from the target

D. Seeliger: Comments about the problems of absolute monitoring in experiments with (D,t) reactions

R. Böttger: Problems with D and T solid target

Conclusions and Recommendations on T-Targets
Chairmen: C. Wagemans and S.M. Qaim

III-2 Sample and target problems in general

S.M. Qaim: Sample problems for low-yield reactions

G. Winkler: Main comments on sample problems

S.M. Qaim: Summary and recommendations on
- neutron producing targets
- targets for heavy ion and charged particle work

C. Wagemans: Idem for samples for nuclear data measurements

III-3 Suppliers list

S. Soloviev (Leningrad), J. Pauwels (CBNM), H. Adair (ORNL), R.A.P. Wiltshire (Harwell)

III-4 Training Course

H. Maier: Comments on a training course for scientists from developing countries, and

Report on discussion during INTDS Business Meeting

L. Drapchinsky: Proposal for a training course at the V.G. Khlopin Radium Institute, Leningrad, in 1990

IV. FOURTH MEETING (Friday, 9 September)

IV-1 Standard Foil Exchange
L. Drapchinsky, G. Winkler, K. Okamoto, J. Pauwels

IV-2 Conclusions and Recommendations
Chairmen: C. Wagemans and S.M. Qaim

IV-3 Join the closing session of the Conference

SELECTED REPORTS OF THE MEETING

INTRODUCTORY TALK

SOME GENERAL CONSIDERATIONS ON THE INFLUENCE OF SAMPLE CHARACTERISTICS ON NUCLEAR DATA MEASUREMENTS

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The sample (target) is often the underestimated and unbeloved part of a nuclear data measurement. This becomes apparent in various ways.
In scientific papers e.g. or during seminars one can often read or hear statements which can be paraphrased as "We take a target and put it into the beam". In other words, the target is just bought (or borrowed) and no further attention is given to its possible (unwanted) influence on the experimental results.

The underestimation of the target can also be observed during visits of laboratories. Scientists are always proud about their accelerator or reactor, about their computers and sophisticated detection systems, which they are eager to show to their guests. They generally forget however to mention the excellent quality of their targets, which are merely locked into a cupboard (often not inventorized!).

The enormous impact of the sample characterization on cross-section measurements is clearly demonstrated by the simple relation:

$$Y = N \sigma \Phi \quad \text{or} \quad \sigma = Y / N \Phi$$

where N is the number of atoms /cm^3 on the sample, σ the reaction cross-section, Φ the reaction inducing flux and Y the reaction yield per sec.

It is very obvious that the uncertainty on N is fully propagated into the uncertainty on σ.

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* National Fund for Scientific Research

Simplifying one can subdivide the impact of sample characteristics on nuclear measurements into two groups:

- Measurements where the sample is the determining or limiting factor on the accuracy or on the resolution of the measurement.
- Measurements where the sample is not the determining factor.

Moreover, during the preparation of this meeting at Geel last year [1] I suggested to subdivide the problems due to sample characteristics into 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. Unexplained phenomena.

These items have been discussed in detail at the same occasion [1].

At present I want to highlight three special cases:

1. Standard cross-section measurements

In this type of measurements one often tries to realize allover accuracies of better than 1 %, which implies very exigent sample requirements. Here one reaches the limits of sample manufacturing and assaying. Besides a very accurate knowledge of the sample mass, also its homogeneity, its dimensions and possible edge effects need to be investigated.

2. Apparently simple cases

Samples that are apparently simple to manufacture and to assay sometimes turn out to be the most dangerous cases. In my talk [2] during the users' session at this conference I will discuss the stable isotopes ^{33}S and ^{50}V and the long-living (weakly active) ^{41}Ca. In all these cases, erroneous sample assays lead to very discrepant cross-section values.

3. Sample thickness

A frequently neglected aspect is the true sample thickness, which may be significantly different from the thickness determined via selective methods. This is due to the insensitivity of most of these methods to

various phenomena such as oxidation, hygroscopy, impurities, residues etc. Such a difference may have severe consequences for high resolution spectroscopy experiments, in which the energy loss in the sample is a prominent parameter [2].

These and many other aspects of samples and their impact on nuclear measurements will be discussed in detail during this conference. Since I am convinced that the French are right when they say "De la confrontation des idées jaillit la lumière", I wish you all a very fructuous and interesting meeting.

REFERENCES

[1] C. Wagemans, IAEA Specialists' Meeting on The influence of Sample and Target Properties on Nuclear Data Measurements, Geel (Belgium) 1987, Report INDC (NDS) - 200/G, MY p. 13.

[2] C. Wagemans, this conference.

STUDIES OF THE EFFECT OF THE PROPERTIES OF NEUTRON PRODUCING TARGETS AND SAMPLE BACKINGS ON NEUTRON CROSS SECTION MEASUREMENTS

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Abstract

The use of pulsed-beam time-of-flight techniques to monitor the time dependence of the distribution of the neutron energy spectrum from lithium metal targets produced from the $^{7}Li(p,n)^{7}Be$ reaction is reviewed. The effect on the 14-MeV neutron angular distribution produced by the $T(d,n)^{4}He$ reaction by changes in the tritium distribution in the TiT target is investigated. The influence of the crystalline properties of sample backings and the use of x-ray powder diffraction to determine the stoichiometry of uranium oxide material are studied.

1. Introduction

Examples of our experience in the measurement of the properties of neutron-producing targets using positive-ion beams are given. The importance of the properties of smple backings and the stoichiometry of uranium deposits are discussed.

2. Time Dependence of Neutron Energy Spectrum from Lithium Targets Using the $^{7}Li(p,n)^{7}Be$ Reaction

The shape of the neutron energy spectrum emitted from lithium targets using the $^{7}Li(p,n)^{7}Be$ reaction is strongly influenced by the condition of the target. The neutron energy distribution changes with time as the chemical composition of the lithium is changed during bombardment with the proton beam. This energy distribution needed to be known in order to determine the neutron-induced fission cross section of ^{235}U in the neutron energy region from 0.2 to 1.3 MeV [1].

Our experimental setup to do these measurements is shown in fig. 1. The target consisted of lithium metal evaporated onto a tantalum backing. The target thickness produced a neutron energy spread of approximately 40 keV. The pulsed-beam time-of-flight technique was used to measure the neutron energy distribution and to separate the neutrons from the γ rays. The proton beam from the 3-MV positive ion accelerator was pulsed at a rate of 1-MHz onto a 2 mm diameter beam spot. Proton energies from 1.9 to 3.0 MeV were utilized. The fission chamber was located at a flight path of 1.3 m while the thick plastic scintillator neutron fluence monitor was located at a flight path of 5.8 m. The neutron source was surrounded by a large shield in order to reduce the background at the detector positions.

The determination of the $^{235}U(n,f)$ cross section is complicated by the source spectrum of neutrons. The neutron energy distribution from the source is determined by the condition of the lithium target as is shown in fig. 2 for approximately 400-keV neutrons. The spectrum is from the time-of-flight measurement with the thick plastic scintillator. The energy spread increases and a low energy tail grows as the target conditions change during bombardment. The spectrum from a fresh target as well as that obtained after a 12-hour bombardment with a 3.5-μA proton beam is shown.

There is also an approximately 2% lower energy component caused by neutron scattering in the tantalum backing of the lithium target as is shown in fig 3,

which shows the time-of-flight spectrum for 1-MeV neutrons. The γ-ray peak is due mainly to 478-keV γ rays from inelastic proton scattering in the lithium target. For neutron energies greater than approximately 660 keV, the spectrum contains a lower energy neutron component from the $^{7}Li(p,n_1)^{7}Be^{*}$ reaction. This component, which increases to approximately 7% at 1.2 MeV, is indicated by N_1 in the figure.

It is thus necessary to use pulsed-beam time-of-flight techniques to carefully monitor the neutron energy spectrum for these cross section measurements in order to make corrections for background components as well as to determine the mean neutron energy.

3. Changes in the Angular Distribution of 14-MeV Neutrons Produced in the $T(d,n)^{4}He$ Reaction Due to Changes in Sample Tritium Concentration

Another example of the effect of the condition of the neutron-producing target on neutron cross section measurements is the $T(d,n)^{4}He$ reaction using TiT targets. The use of the time-correlated associated-particle technique with this reaction has produced the most accurate measurements of the $^{235}U(n,f)$ cross section at 14-MeV neutron energy [2]. The schematic diagram of this technique is shown in fig.4. The emitted α particle and corresponding neutron are shown. An electronic coincidence between the α particle and the fission event produced by the associated neutron eliminates the effects of the scattered neutron-induced background. The accuracy of the cross section measurement is limited by the uncertainty in the areal density of the fission deposit. It is also essential that the entire associated neutron beam hit the fission deposit.

The experimental geometry used in our measurements is shown in fig. 5. A monoenergetic, 500-keV D_2^{+} beam from the 3-MV positive-ion accelerator is incident on a thick tritiated titanium target. The direct current beam was collimated to a 3-mm diameter to provide an approximately 0.5-μA current on the target. The 2.8 mg/cm^2 thick titanium tritide target was much thicker than the range of the incident beam. The beam current was limited by the poor heat dissipation of the target in the vacuum chamber since no cooling was provided to the target in order to reduce neutron scattering corrections.

The 14.1-MeV neutron beam produced by the nuclear reaction was monitored by the detection of the associated 3.6-MeV α particle at an angle of 84 deg. A collimator limits the detector acceptance cone to a cone angle of 4.1 deg. A 2.3 mg/cm^2 thick nickel foil mounted over the face of the detector eliminated the large background level in the detector caused by scattered deuterons as well as the electrons from the decay of the tritium target. The detector and target were mounted in an evacuated 50-cm-diam, semicircular scattering chamber. The two fission deposits were mounted in a parallel plate ionization chamber which was mounted on the external wall of the scattering chamber. The fission deposits were centered in the 90-deg neutron beam and positioned 38 mm from the neutron source. The area subtended by the neutron cone was entirely enclosed within the area of the sample deposits.

A neutron detector, which was positioned 254 cm from the source and constrained to movement about the source center, was used to map the neutron beam profile. This detector consisted of a 2.5-cm-diam,8-cm-thick cylinder of NE110 plastic scintillator mounted on a 5-cm-diam photomultiplier tube. This detector was operated in coincidence with the α-particle detector to measure the angular shape of the neutron beam corresponding to the angular acceptance of the α-particle detector. Corrections for the finite size of the deuteron beam were then applied to deduce the linear dimensions of the neutron beam at the uranium sample position.

The spatial distribution of the 14-MeV neutron beam measured in coincidence with the associated α particle is shown in fig.6. The position of the uranium deposit is indicated at the bottom of the figure. Since the neutron detector is positioned 2.5 m from the source, the measured profile determines the

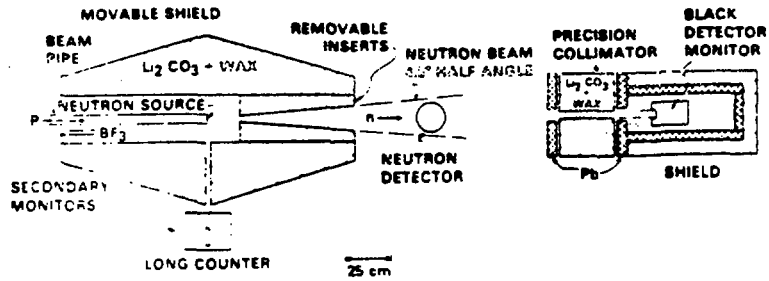


Fig.1 Experimental geometry used in fission cross section measurement.

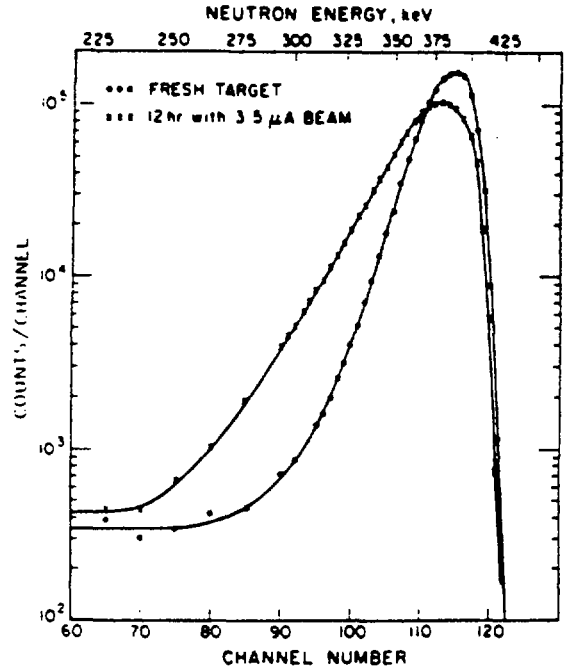


Fig.2 Time-of-flight spectra from different lithium target conditions for 400-keV neutrons.

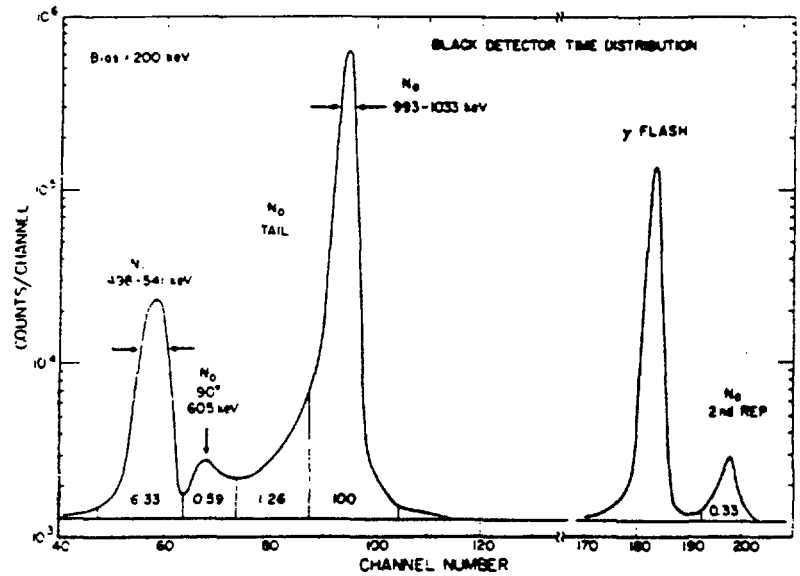
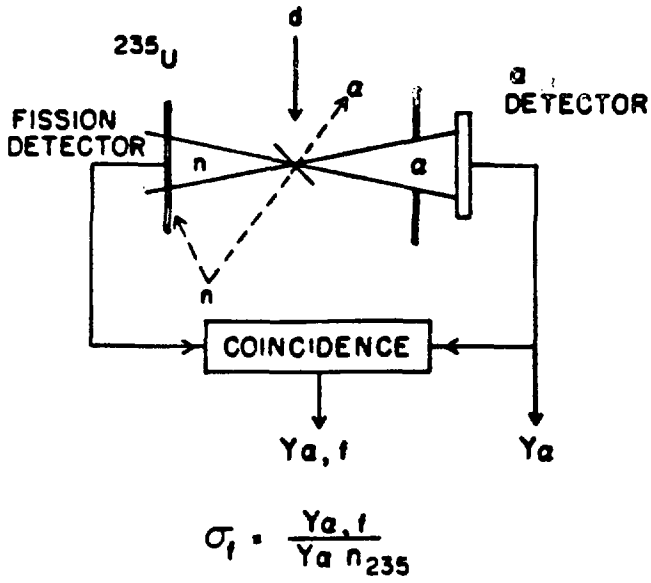


Fig.3 Time-of-flight spectrum for 1-MeV primary neutrons. The relative contributions of various components are shown.



$$\sigma_f = \frac{Y_{\alpha,f}}{Y_\alpha \, n_{235}}$$

Fig.4 Schematic diagram of the time-correlated associated-particle technique using the $^3H(d,\alpha)n$ reaction.

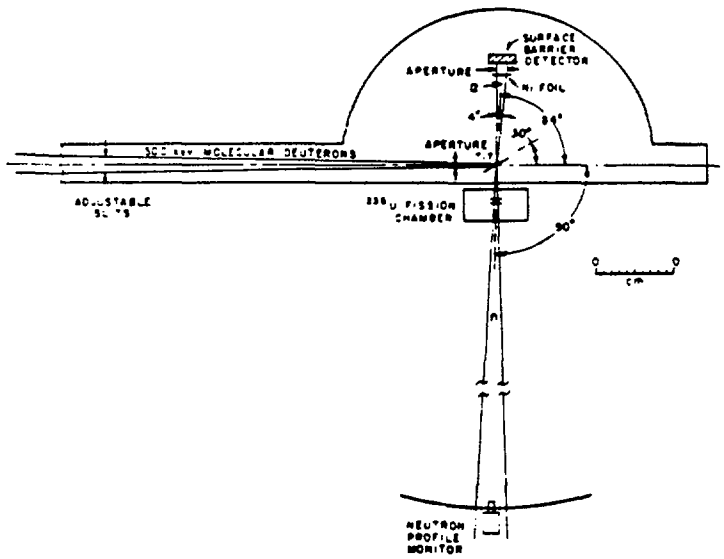


Fig.5 Experimental geometry used for fission cross section measurement at 14.1-MeV neutron energy.

angular spread of the neutron beam. The spacial distribution of the neutrons over the uranium deposit is obtained by combining the angular measurement with the deuteron beam spot size.

The spatial distribution of the neutron beam depended on the condition of the TiT target. As the distribution of tritium in the target changed during deuteron bombardment, the average energy of the interacting deuteron decreased, the width of the neutron cone decreased, and the centroid shifted to a larger angle. The two profiles shown in the figure represent the extreme positions of the neutron beam during the experiments. However, the uranium deposits intercepted essentially all of the neutron cone for all target conditions. It was observed that the beam profile labeled "old target" changed to that labeled "fresh target" after a night with no deuteron beam incident on the target. The tritium apparently migrated to the front surface during this time at lower temperature.

There was no shift of the neutron profile in the vertical direction where the shape was symmetrical and resembled that for the "old profile" shown in

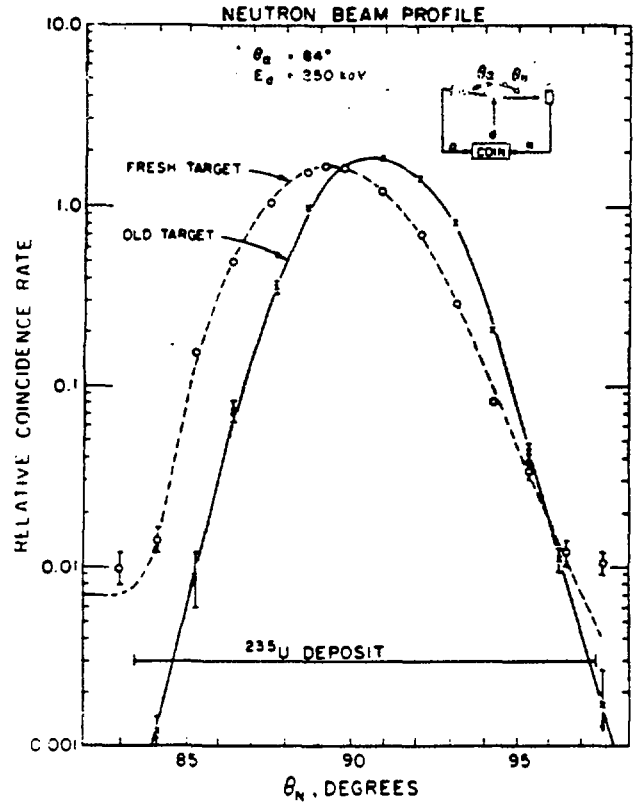


Fig.6 The shape of the neutron beam profile measured in the horizontal plane for two extreme conditions of the neutron-producing target. The position of the ^{235}U deposit is indicated at the bottom.

the figure. The angular spread of the neutron beam in the horizontal plane (θ_N plane) is limited by the scattering of the α particles in the TiT target in addition to the energy spread in the interacting deuteron beam. In the vertical profile (orthogonal to the θ_N plane) the deuteron energy spread does not contribute to the broadening. The useful continuous beam lifetime of each target spot was approximately 10 h.

The variation in the fission yield due to variation in the neutron cone shape and position was carefully studied by means of a computer program which calculated the fission yield for various shapes and positions. This variation introduced a 0.3% uncertainty (one standard deviation) in the $^{235}U(n,f)$ cross section measurement at 14.1 MeV.

4. Effect of the Crystalline Structure of Platinum Backing of Uranium Deposits on the Measurement of Uranium Masses Using Thermal Neutron-Induced Fission Fragment Measurements

The total mass of the ^{235}U deposits used in the 14-MeV cross section measurement was determined from a comparison of the fission rates with a standard reference deposit placed in a thermal neutron beam at the NBS nuclear reactor. The reference deposit consisted of approximately 500 $\mu g/cm^2$ of ^{235}U in the form of UO_2 evaporated onto a 0.127-mm-thick platinum backing. The total ^{235}U mass is (1546.1±1.6) μg. The fission deposits were mounted in a parallel-plate ionization chamber. The fission fragments were collected over a solid angle of approximately 2π sr. The neutron scattering from the platinum backing of the reference deposit increased the fission rate by approximately 2.0%. The calculation of this effect assumes that the neutron scattering in the platinum is isotropic. However, crystalline structure in the platinum can cause deviations in the angular distribution of the scattered neutrons in the thermal neutron energy region. The estimated uncertainty in the calculated fission rate due to this possible effect is 0.2%, which was not a significant

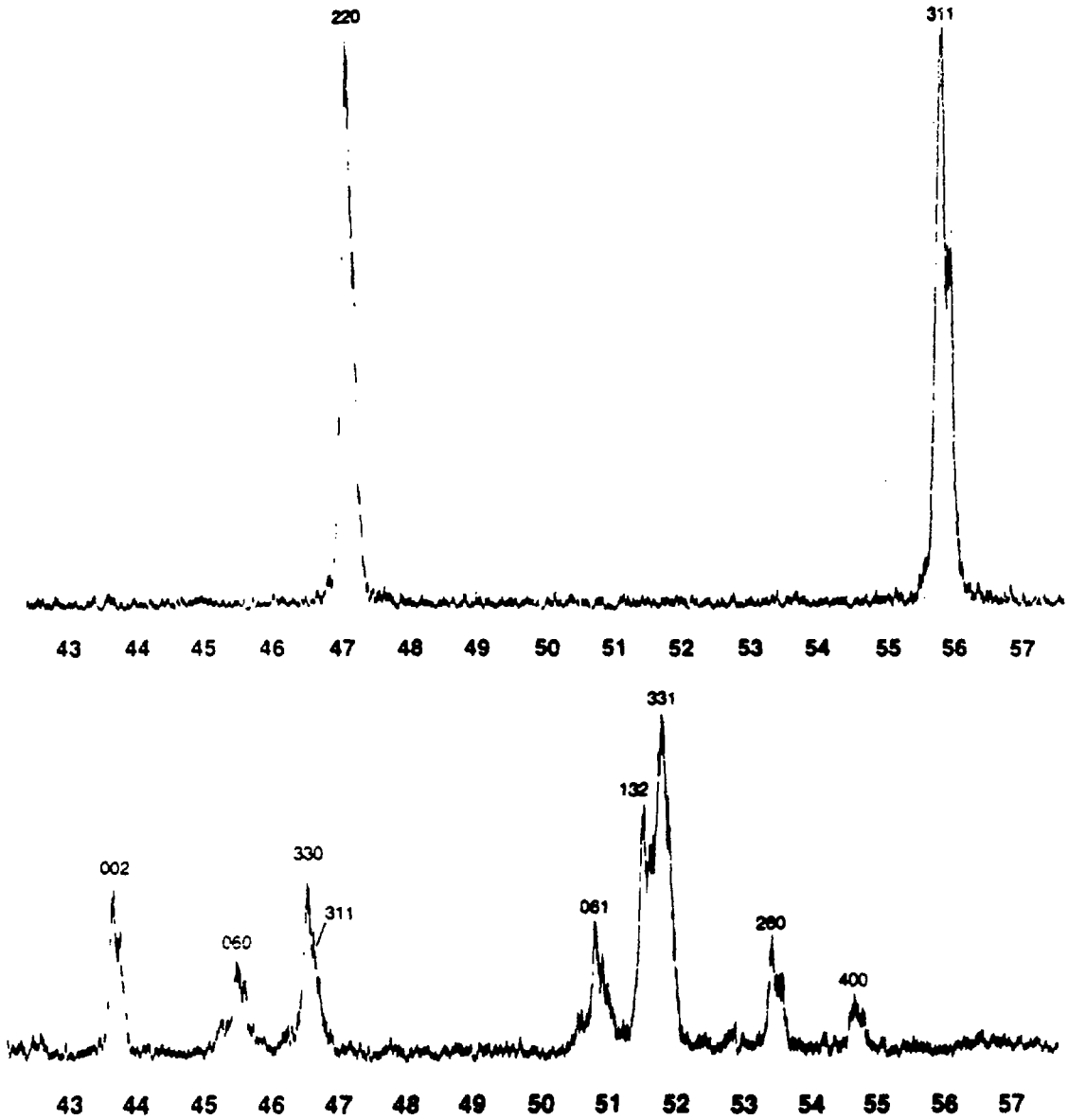


Fig.7 X-ray powder diffraction spectrum of U_3O_8 (top, sample before reduction) and UO_2 (bottom, sample after reduction).

contribution to the uncertainty in the $^{235}U(n,f)$ cross section at 14-MeV neutron energy. However, this will become an important consideration as the accuracy of the cross section measurements improve.

5. Use of x-ray powder diffraction to determine the oxidation state of uranium oxide samples

The characteristic x-ray diffraction pattern produced by crystalline materials has been utilized at NBS to determine the oxidation state of uranium oxide. In a study of the delayed neutron spectrum from neutron-induced fission in UO_2 and U_3O_8 it was important that the oxidation state and the purity of the samples be known [3,4]. The U_3O_8 was obtained as an NBS standard sample having well determined stoichiometry and isotopic composition. To ensure that the UO_2 sample had the same isotopic composition the U_3O_8 sample was reduced in a microbalance oven in a reducing atmosphere. The temperature of the oven was gradually raised until the weight reduction of the sample leveled off. The weight transition was that which was expected for a change from U_3O_8 to UO_2 but x-ray diffraction was used as a check to see if the original and transformed samples were completely in one oxidation state or the other.

Figure 7 shows the diffraction patterns obtained from samples of the uranium oxide before and after the reduction treatment. The original data was taken over a much larger wavelength region than is shown in the figures but has the same character, i.e., that the diffraction resonances found in one pattern are not found in the other. The strength of the resonances is such that one can easily see that contaminations on the order of a percent could be observed thus verifying that the transformation was complete and the original sample was not contaminated with UO_2.

References

[1] O. A. Wasson, A. D. Carlson and K. C. Duvall, Nucl. Sci. Eng. 80, 282 (1982).

[2] O. A. Wasson, M. M. Meier and K. C. Duvall, Nucl. Sci. Eng. 81, 196 (1982).

[3] R. A. Schrack and C. D. Bowman, Proc Int. Conf. on Nucl. Reactions and Tech., Knoxville,TN, 1979; NBS Spec. Pub. 594, pp 105-107 (1980)

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EXAMPLES OF PROBLEMS CAUSED BY IMPURITIES IN TARGETS AND/OR RESEARCH SAMPLES*

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1. Introduction

It is important that the fabricators of research or production samples understand what problems impurities will cause. Thus, it is necessary that those individuals requesting targets or other samples discuss, in detail, what is required with the individuals responsible for preparing the samples. This will permit proper preparation procedures to be selected which will eliminate or reduce the impurity content that might otherwise jeopardize the intended use of the sample. Examples of problems caused by impurities in research and production samples are detailed below.

2. General Comments about Target Purity and Substrate Materials

In determining the appropriate target design and composition, one of the major considerations in either light-ion or heavy-ion experiments is the attenuation of "noise" or incidental reactions which can mask or reduce statistical detection of desired events. In this regard, for heavy-ion experiments low-Z contaminants are particularly bad actors since they generate "structured" background signals that are not easily subtracted. However, high-Z materials produce a "smooth" background that is usually easy to subtract. The Coulomb barrier energies (E_B) shown in Table 1 were calculated for several projectile-target nuclide combinations using the equation[1]

$$E_B = \frac{(Z_1 e)(Z_2 e)}{R}$$

where $Z_1 e$ is the charge of the projectile, $Z_2 e$ is the charge of the target nuclide, and R is the distance of closest approach.

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*Based on work performed at the Oak Ridge National Laboratory, operated for the U.S. Department of Energy under contract DE-AC05-84OR21400 with the Martin Marietta Energy Systems, Inc.

Table 1. Coulomb Barrier Energies for Several Projectile-Target Combinations

Projectile	Target	Coulomb Barrier (MeV)
^{12}C	^{12}C	7.8
^{12}C	^{16}O	10.0
^{12}C	^{40}Ca	21.0
^{12}C	^{119}Sn	41.6
^{12}C	^{181}Ta	55.0
^{12}C	^{238}U	64.9
^{48}Ca	^{12}C	20.2
^{48}Ca	^{16}O	26.0
^{48}Ca	^{40}Ca	56.6
^{48}Ca	^{119}Sn	116.8
^{48}Ca	^{181}Ta	156.9
^{48}Ca	^{238}U	186.8
^{208}Pb	^{12}C	59.8
^{208}Pb	^{16}O	77.5
^{208}Pb	^{40}Ca	175.2
^{208}Pb	^{119}Sn	377.6
^{208}Pb	^{181}Ta	516.0
^{208}Pb	^{238}U	621.3

$$R = 1.44\ A_1^{1/3} + 1.44\ A_2^{1/3} \quad (A_x = \text{atomic radius})$$

As shown in Table 1, the lower the atomic number of the target nuclide, the lower the Coulomb barrier energy and the larger the cross section for the nuclear reaction with the incident beam. In addition, the energy loss of the heavy ion in the target increases with decreasing atomic number of the target nuclide as shown in fig. 1. Thus, inclusion of low-Z impurities in the target should be avoided if at all possible.

As a result of the heating effects and "noise," gold and lead are frequently used as heavy-ion target substrates when self-supported targets cannot be obtained or are too fragile. Target materials are most frequently used in their elemental form to avoid the presence of extraneous low-Z nuclides. Many times a compromise must be reached because other considerations such as chemical reactivity, material availability, and material cost may limit the target material to some compound form.

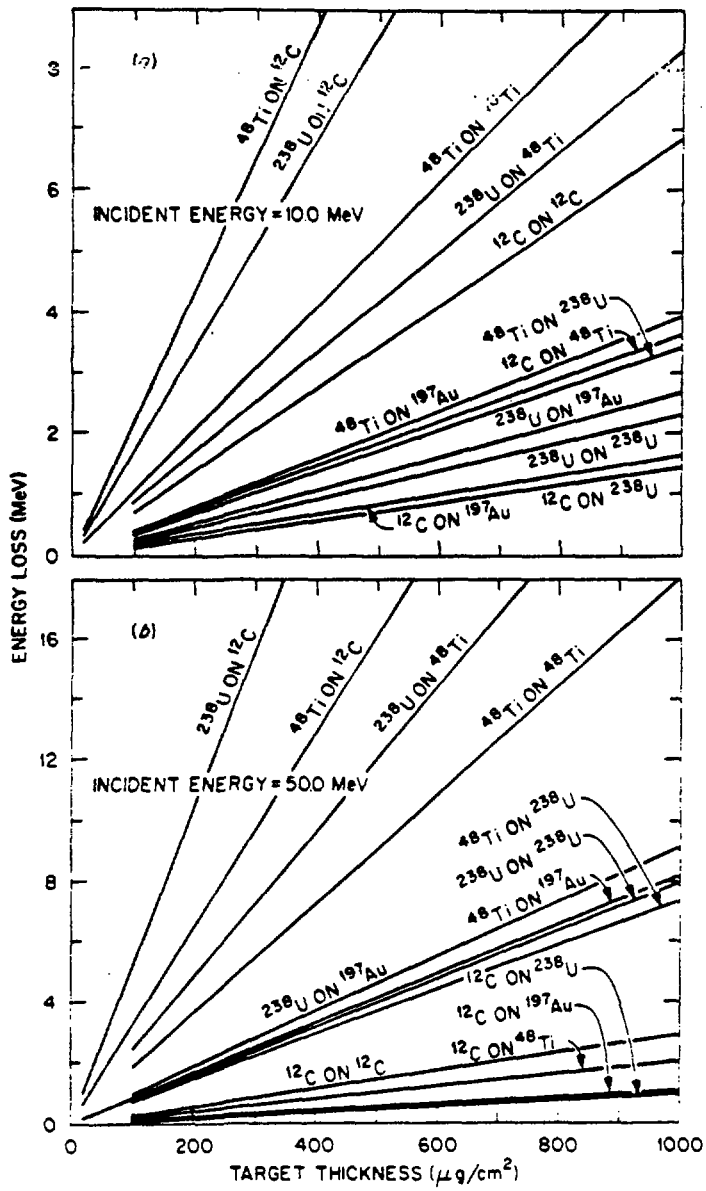


Fig. 1. Energy loss of ^{12}C, ^{48}Ti, and ^{238}U ions in ^{12}C, ^{48}Ti, ^{197}Au, and ^{238}U targets for projectile energies of (a) 10 MeV and (b) 50 MeV.

3. Impurity Problems with an (n,γ) Experiment Involving Magnesium Isotopes[2]

Attempts were made to investigate excited states in ^{25}Mg using the $^{24}Mg(n,\gamma)^{25}Mg$ reaction. Magnesium isotopes have a low cross section for neutron capture. Impurities of boron, gadolinium, and cadmium which have large capture cross sections cause serious problems at the ppm level. Attempts at removing the impurities added another impurity (Cl) which also caused problems. Spectra for the $^{24}Mg(n,\gamma)^{25}Mg$ reaction are shown in figs. 2 and 3. Specific impurities and the neutron capture cross sections are shown. It should be noted that although sulfur has a fairly low cross section compared to the other impurities, it is easily detected which is indicative of a large amount of sulfur being present.

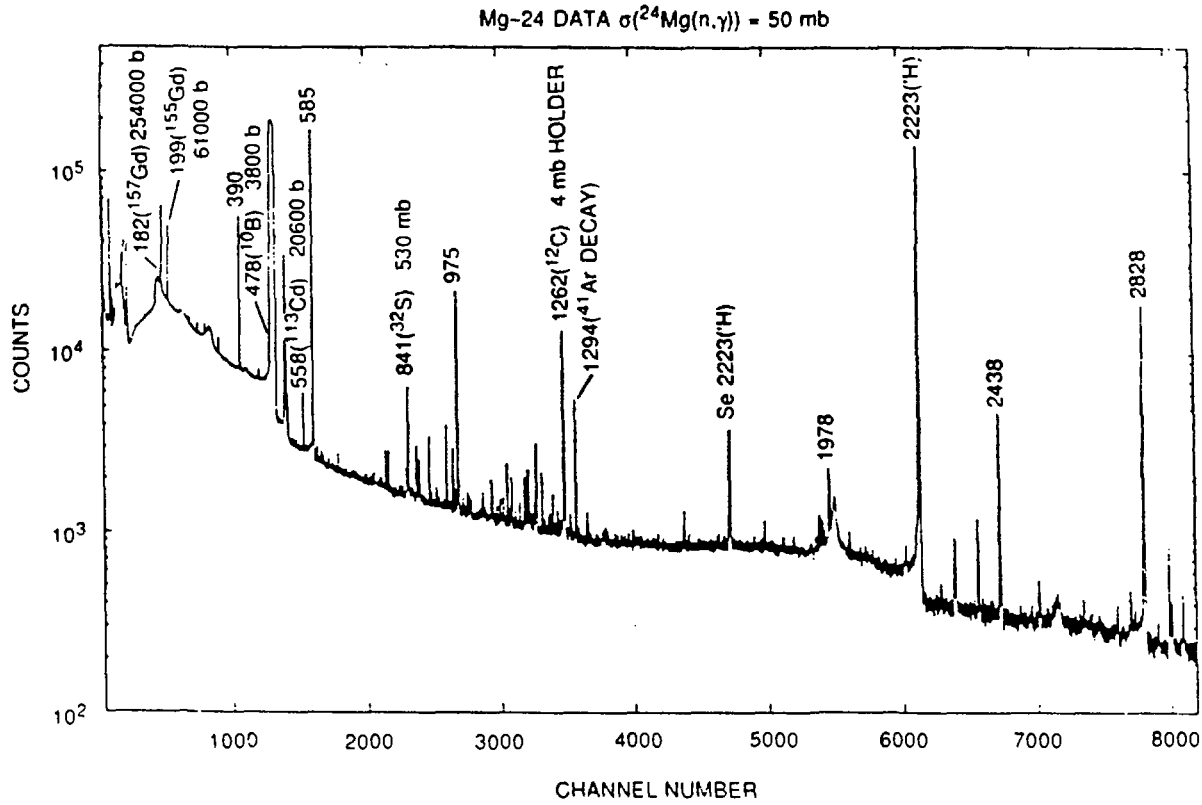


Fig. 2. Mg-25 spectral data obtained from $^{24}Mg(n,\gamma)^{25}Mg$ reaction.

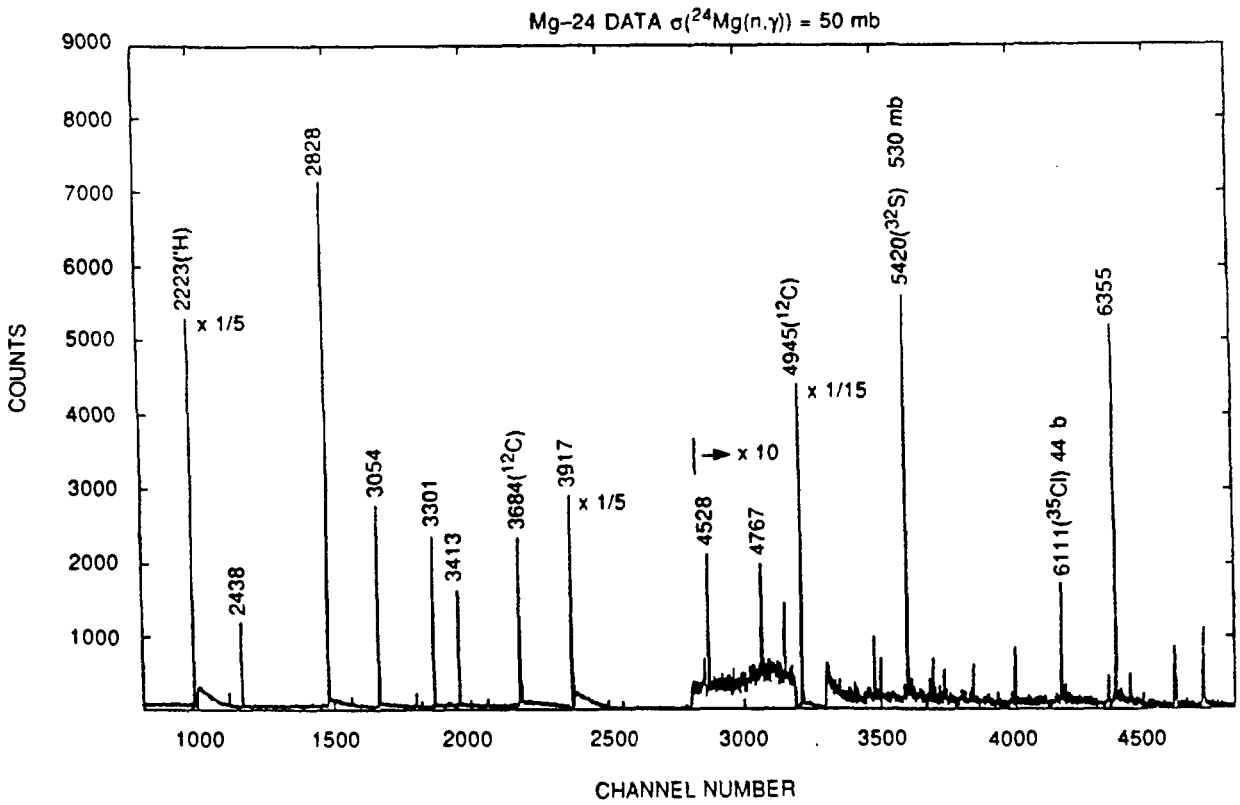
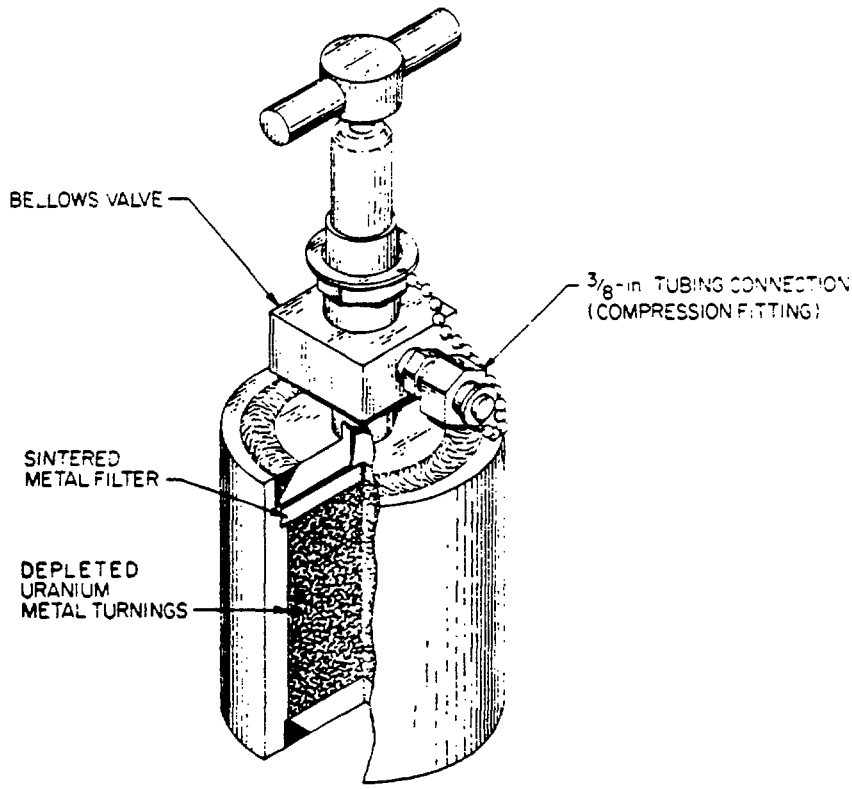


Fig. 3. Mg-25 spectral data obtained from $^{24}Mg(n,\gamma)^{25}Mg$ reaction.

4. Contamination of Tritium with ^3He

Tritium in the form of T_2 is provided by the Oak Ridge National Laboratory (ORNL) Isotopes Program for a wide range of research, development, and production applications. Major commercial applications include tritium lights, electronic tubes, and products using a tritium-based luminous compound such as in clocks and compasses. Gaseous tritium is provided to ORNL by the Savannah River Laboratory (SRL) where the tritium is produced by irradiating aluminum lithium targets in a heavy water reactor (HWR). The tritium received from SRL is sorbed on uranium traps in an ORNL tritium facility and subsequently used for filling specific orders. The amount of tritium processed in this facility each year is approximately 2 MCi (74 PBq).

Tritium processing for the ORNL Sales Program involves a chemical purification process for tritium gas received from SRL. As the tritium decays, the concentration of the ^3He daughter in the storage containers increases to the point that it is difficult to process by the customers. For the most part, the ORNL purification process involves removal of the ^3He. Recently, a customer who uses the tritium to produce tritium lights had observed that the light output was not as expected. Further analysis



TRITIUM SHIPPING CONTAINER
MODEL DG-1

Fig. 4. Uranium-tritium trap shipping container.

revealed that the ^3He levels in the tritium supplied by ORNL were much higher than what would be expected from decay since the purification at ORNL.

Although not completely confirmed, the additional ^3He could have come from the uranium tritium traps (fig. 4) which are used for shipping tritium. The traps are evacuated prior to loading with tritium; however, it is believed that ^3He could be interstitially trapped in the uranium and would not be removed unless the trap is heated while it is being evacuated.

REFERENCES

1.P. E. Hodgson, "Nuclear Heavy Ion Reactions," Oxford University Press (1978) p. 2.

2.S. Raman, Oak Ridge National Laboratory, Personal Communication, August 1988.

REMARKS ON TRITIUM APPLICATIONS AND HANDLING AT OAK RIDGE NATIONAL LABORATORY

E. H. Kobisk, Retired

With the advent of fusion energy, tritium control would seem to be an imperative issue. On a world basis it is estimated that the inventory of tritium will increase by as much as 100 MCi from 70-140 MCi currently in the environment. Concerns over handling of wastes from fission reactors should transfer to fusion devices albeit the waste products from the latter power sources will be of much shorter half-life.

Therefore, research and development efforts must continue to attain effective and safe methods of treating tritium-containing effluents. Being a hydrogen isotope, tritium is a chemically reactive species and easily converted to water on almost any surface in the presence of oxygen. The biological hazard to humans is 10,000 times greater when tritium is in the form of water rather than in elemental form because of the rapid absorption into body tissue through skin contact or inhalation.

At Oak Ridge National Laboratory tritium handling procedures have evolved through pragmatic experience and dedicated effort to minimize personnel exposure on the "as low as reasonably achievable" (ALARA) principle. Generally two procedures (or combinations of these) have been used to limit exposure to tritium. Where only small releases of elemental tritium are anticipated (less than 50 Ci), a high velocity air sweep over processing equipment is used with subsequent exhaust of the effluent gases to the atmosphere. This technique has been found practical and effective. No deleterious environmental consequences of this procedure have been observed over a twenty-year history. Where direct handling of tritium-contaminated equipment is required, protective clothing and fresh air masks are provided for the personnel.

A second approach is the "total containment" concept wherein all tritium handling is confined to enclosures using materials known to have very low permeability to hydrogen. In this case, effluent gases are vented to catalytic converters in which elemental tritium is oxidized to water and subsequently removed by sorption on solids to be later disposed of as solid waste.

Depending upon the application, both of these procedures (or a combination) have proved effective in limiting personnel and environmental exposures. Development efforts in West Germany, Japan, the United States and other countries have resulted in finding new containment materials, low porosity surface coatings and improved elastomers which limit tritium releases from containment facilities -- and the efforts continue.

In the Isotopes Program at Oak Ridge National Laboratory, the principal uses of tritium in significant quantities are the preparation of metal hydride targets for 14.5 Mev neutron production, packaging of tritium for shipment to other laboratories and commercial firms, preparation of radioluminescent light sources, and the helium-doping of metallurgical test specimens for embrittlement studies (most samples being used for fusion reactor

first-wall materials evaluation). In these programs, several megacuries of tritium are handled annually with no significant health hazard to operating personnel or environmental insult.

From our experience it appears that future consumption of tritium in these and other programs (including medical applications) will increase significantly. An excellent example of such projected increase is the relatively new development of radioluminescent light sources (RL) for use in remote geographic regions where electric power is limited or is nonexistent. Our development of these tritium-containing phosphor lights will be commercially exploited through technology transfer. Because of the half-life limitation of tritium in these sealed RL light sources, Oak Ridge National Laboratory is now developing a safe tritium recovery process for "spent" sources. Such development should impact the much greater needs for separation, purification and storage of tritium associated with fusion reactors.

CHAIRMEN'S REMARKS

Chairman and Co-chairman both appreciated the organization of the IAEA Advisory Group Meeting (AGM) in conjunction with the INTDS Conference. In this way, frequent and open discussions between target/sample users and producers were made possible, also with producers not attending the AGM.

Such discussions between users and producers were felt very useful in several respects:

- the users had the occasion to clearly explain some of their problems and to look for possible solutions together with the producers

- the producers got a better understanding of some aspects of the sample/target, which they believed to be trivial but which turned out to have a great impact on the nuclear data measurements

- a series of possible sources of error in nuclear data, originating from erroneous or insufficient sample assay, were identified.

Summarizing, our impression of both the meetings is very positive, although a combination of two meetings puts a heavy load on the chairmen during the meeting.

C. Wagemans (Chairman)

S.M. Qaim (Co-chairman)

S U M M A R Y

In this summary, the various contributions and comments are grouped together according to the topics discussed, irrespective of the session of the INTDS Conference or of the Advisory Group Meeting in which they were presented.

These topics are:

1. Neutron producing targets
2. Targets for charged particle work
3. Samples for nuclear data measurements
4. Standard foils
5. List of suppliers of targets and samples
6. Training Courses

1. NEUTRON PRODUCING TARGETS

Neutrons are produced via several nuclear processes. The properties of neutron sources and the resulting spectra are generally known (cf. IAEA Advisory Group Meeting, Leningrad 1986, IAEA-TECDOC-410). During the present meeting several newer aspects were discussed.

Böttger gave an overview of nuclear reactions, viz. T(d,n), D(d,n), T(p,n), ^{7}Li(p,n), ^{45}Sc(p,n) and ^{65}Cu(p,n), used for the production of monoenergetic neutrons over a broad neutron energy range extending from 1 keV to 20 MeV. Investigation of a fresh Ti(T) target (2.4mg/cm^2 Ti) revealed a very high fraction of deuterium present in the Ti-layer (~15% relative to T), which is not acceptable for precise measurements in 19 MeV neutron field produced by the T(d,n) reaction. The C and O contamination of the target observed could not be fully reproduced by a blank target measurement. The net spectrum contains a fluence contribution of about 6% from these impurities under the experimental conditions used. In the case of a Ti(D) target, at E_n = 5 MeV the background from C could be well reproduced by the blank target. A used target clearly showed self target build-up within the backing (fluence contribution ~2%). This target should not be used for higher energy neutron fields. In the case of T(p,n) reaction (E_n = 2.5 and 1.2 MeV)

using a Ti(T) target, the background contribution stems predominantly from neutron scattering at the target assembly due to the angular distribution of the production reaction. The enlargement of the backing thickness cannot fully reveal the scattering background. Monte Carlo simulation should be performed to verify this effect. In the case of $^{7}Li(p,n)$ reaction, reproducible results were obtained using a LiF target. The $^{45}Sc(p,n)$ and $^{65}Cu(p,n)$ reactions make use of resonances near the thresholds resulting in neutron energies between 1 and 28 keV. Only thin targets must be used and the energy of protons should be well defined.

There was some discussion on the handling of tritium since it is used in several neutron producing targets. Kobisk reported on extensive experience available at Oak Ridge on the production and safe handling of mega-curies of tritium. Generally two procedures have been used to limit exposure to tritium. Where only small releases of elemental tritium are anticipated ($\leq$ 50 Ci), a high velocity air sweep over processing equipment is used with subsequent exhaust of the effluent gases to the atmosphere. Where direct handling of tritium-contaminated equipment is required, protective clothing and fresh air masks are provided for the personnel. A second approach is the "total containment" concept wherein all tritium handling is confined to enclosures using materials known to have very low permeability to hydrogen. In this case, effluent gases are vented to catalytic converters in which elemental tritium is oxidized to water and subsequently removed by sorption on solids to be later disposed off as solid waste.

Since the T(d,n) reaction is used in many laboratories to produce 14 MeV and higher energy neutrons which find applications in cross section measurements and radiation damage studies for fusion reactor technology, tritium targets were considered in detail. Seeliger discussed some of the changes in tritium target parameters during irradiations. Formation of oxygen and carbon layers on the surface, sputtering of Ti(T) layer by incident ions, thermal decomposition of hydrides and replacement of tritium by deuterons are some of the important reasons. The changes in target parameters have strong repercussions on measurements of excitation functions of high threshold reactions. Presence of strong low energy components in the neutron spectra also interfere in double differential neutron emission cross section measurements. It was emphasized that in cross section work the source neutron spectrum should always be

characterized and the changes in target characteristics as a function of time be followed. The target producers are asked to provide detailed descriptions of target surface conditions. The importance of multilayer targets was discussed and further development work relevant to the optimization of tritium targets was urged.

Sumita reviewed different types of tritium targets used in high intensity neutron sources. Due to the high power density, in most of the cases the solid Ti(T) target is cooled by high speed water flow and is rotated. Furthermore, a beam analyzing magnet and a tritium collection unit in the outgas system are used as accessories. Some of the distortions in neutronic characteristics originating from tritium target specifications were reported. The increase in anisotropy was found to be significant. The mean neutron energy at the primary position decreases due to the finite size effect of the deuterium beam spot on the large-sized tritium target. The question of uncontrolled tritium release was also considered. This may occur through one or all of the processes given below: (a) gas emission (b) HTO release (c) spread of Ti(T) flakes or powder. The uncontrolled release may occur while changing a target or handling contaminated parts.

The question of tritium contamination was discussed in some detail during the meeting. Due to relatively short biological half-life, T_2 and HTO do not constitute great health hazards. The powder or flake form, however, is strongly dangerous. There was a general feeling that some laboratories do not take enough precautionary measures in handling tritium targets. This Advisory Group therefore gives certain recommendations on this topic which are listed elsewhere in this report.

Winkler pointed out that in the case of a solid Ti(T) target, contrary to the general belief, there is considerable energy spread also in the neutrons emitted at angles between 90 and 100°. This is due to small angle scattering of the incident deuterons, especially for low incident energies (150 - 250 keV) commonly used at neutron generators (cf. INDC(AUS)-011/LI). The shift in energy can be verified by observing the spectra of charged particles produced in neutron induced reactions in a Si detector, or by using a pair of monitor reactions with very different thresholds. The effects of uncertainties in the thickness and uniformity of the neutron producing target layer were considered, and some of the corrections needed due to scattering, attenuation and production of secondary neutrons were discussed.

Wasson reported that the condition of the target has strong influence on the emitted neutron spectrum. The energy distribution of neutrons from a lithium target using the ^{7}Li(p,n) reaction changes with time as the chemical composition of lithium is changed during irradiation with the proton beam. Similarly the angular distribution of 14 MeV neutrons produced in the T(d,n) reaction showed changes due to changes in tritium concentration in the Ti(T) target.

Shorin presented results on T(p,n) neutron spectrum calculations for Sc(T) targets used in neutron capture measurements by the activation method over the energy range of 0.3 to 1.2 MeV. The calculations and the model under consideration take into account the geometry effects (in the case of "bad" geometry) and tritium depth profile variation (derived from neutron yield functions measured above (p,n)-reaction thresholds) during the irradiation. These effects on capture cross sections amounted to 2 to 7%. The model can be extended to different (p,n) reactions or to different cross sections.

2. TARGETS FOR CHARGED PARTICLE WORK

While traversing through matter, charged particles (p, d, ^{3}He, ^{4}He or heavy ions) lose energy rapidly. For nuclear studies, therefore, thin and homogenous targets are needed. Since a great variety of elements and isotopes are investigated, a large number of target preparation techniques have been used.

Qaim reviewed the preparation of targets for excitation function measurements relevant to the production of some medically important radioisotopes at a cyclotron. In case of solids the "stacked-foil" technique is commonly used and for gases the "stacked-cell" method. Thin solid samples are obtained by electrodeposition, vacuum deposition etc. on thin low activation metal backings. Since in recent years investigations have concentrated primarily on highly enriched isotopes, the sample preparation technique used has to be very efficient. The mass of the target material is determined using several independent techniques. In general weighing and neutron activation analysis (subsequent to the desired measurement) are applied. An error in the mass of the target material results in an error not only in the cross section but also in the energy scale since in the technique used the

energies are calculated using energy degradation formulae. In the "stacked-cell" technique for gases, especially isotopically enriched gases, cryogenic handling is common. The windows of the cell have to be thin to allow the beam to reach the gas. The cell dimensions are chosen such that the whole beam is contained. The mass of the target gas is determined via measurement of pressure.

Bokemeyer discussed the importance of target parameters in heavy ion positron and quasi-atomic spectroscopy. Four aspects were given detailed consideration: (a) Suppression of principal background via suppression of nuclear k-hole production as well as through subtraction of nuclear e^+ production. For a thin ^{208}Pb target the former condition was fulfilled using a ^{136}Xe beam and the latter via a ^{208}Pb beam; (b) Enhancement of the basic physical effect. Irradiation of a target consisting of the heaviest available target material on a low Z backing (e.g. ^{248}Cm on Ti) with the heaviest available beam (^{238}U) was exemplified; (c) Systematic variation of basic parameters. Through a variation in Z of targets it was concluded that spontaneous e^+ emission is insignificant. Using deformed and spherical nuclei it was postulated that individual nuclear origins could be excluded; (d) Effects of target thickness. In general thin targets covering only the most optimum energy region of the excitation function should be used. The effects of target distortion and target constitution were discussed.

Gono described some targets used in heavy ion experiments. Be was chosen as a production target ($46mg/cm^2$) to investigate the unstable nucleus ^{13}B. The yield of ^{13}B was found to be limited by the detector size and not by the target thickness. A thin ^{92}Mo target was used to study high energy γ-rays from the fusion reaction products. The energy spread of the complete fusion products depended on the thickness of the target. The difference in the energy spreads affected the energy spectra of the fusion products.

In determining the appropriate target design and composition, one of the major considerations in charged particle induced experiments is the attenuation of background. In the case of heavy ions low Z-contaminants are particularly bad since they generate structured signals. High Z-materials produce a smooth background that is easy to subtract. In work with high energy electrons, on the other hand, as pointed out by Dionisio, low Z elements are preferred. Adair discussed the question of

impurities in a few targets used in heavy ion work. Gono described the effect of target impurities on some atomic physics experiments performed using heavy ion beams. Cheng addressed this problem in nuclear spectroscopy work using 25 MeV protons. The target impurities (e.g. H, C, O in a Ni target) were found to be concentrated in the surface region of the target, suggesting that they originated during the target preparation via electroplating.

In contrast to the relatively thin targets used in charged particle induced nuclear reactions and spectroscopic studies, thick targets are needed in radioisotope production work. Qaim outlined some of the important considerations in target development for medical radioisotope production at a cyclotron and reviewed the routinely used target systems in several laboratories. Some of the recent developments in targetry involve enhanced use of enriched isotopes as target materials and construction of small-sized gas and water targets suitable for use at low-energy cyclotrons. Experimental thick target yields in high current irradiations are appreciably lower than the values calculated from the excitation functions, presumably due to radiation damage (solid target), local boiling (water target) and density reduction along the beam direction (gas target). The demands on the quality of the product (high radionuclidic and chemical purity, well defined radiochemical form, high specific activity etc.) can only be met if properly constructed targets are used.

3. SAMPLES FOR NUCLEAR DATA MEASUREMENTS

Wagemans discussed various general aspects of the influence of sample characteristics on nuclear data measurements. He especially demonstrated the necessity of alternative methods to determine accurately sample thicknesses and masses.

Wasson described a method to determine the uniformity of the areal density of uranium deposits using Rutherford backscattering spectrometry combined with a scan of the natural α-particle decay of the uranium. Moreover, the stoichiometry of the deposit was investigated with X-ray scattering.

Wiltshire reported on the re-determination of the ^{239}Pu half-life by measuring the specific activity of $CsPuCl_6$. Critical to this

experiment was the careful assay of the stoichiometry and isotopic and chemical purity.

Vacuum evaporated samples of ^{236}Pu, ^{252}Cf and ^{227}Ac for absolute measurements of E_α required the maximum activity compatible with the minimum thickness. The problems of availability, daughter growth and handling hazards were highlighted.

The presence of low levels of Pu in U-targets intended for ^{236}Pu and ^{237}Pu production was reported. Finally, ^{241}Am and ^{243}Am oxide samples for capture cross-section measurements were described.

Adair gave two examples of problems caused by impurities in samples. In the first example he demonstrated that for heavy-ion experiments low-Z impurities in the target should be avoided. In the second example impurity problems hindering $^{24}Mg(n,\gamma)$ spectroscopy were discussed.

Liskien discussed problems related to the H(n,n)H standard; difficulties in the assay of hydrogen in foils were reported. At present it is not clear whether the needed absolute accuracy of 0.3% can be met.

Winkler gave a detailed discussion of the impact of sample properties on the results of energy dependent cross-section measurements, in particular on activation measurements with fast neutrons. These influences were discussed in the frame of the basic requirements for obtaining accurate cross-section data (e.g. number of nuclei, "standards", fluence monitors, energy scale, corrections, optimization of irradiation conditions, reliable measurement of the relevant activity of the exposed samples, uncertainty statements).

Cheng Xiaowu discussed the influence of sample impurities on the accuracy of reaction cross-section measurements. Especially the inelastic scattering of protons on Ni-isotopes was dealt with.

Dionisio reported on the influence of sample properties on nuclear spectroscopy experiments. Typical examples encountered in in-beam electron and γ-ray spectroscopy measurements were discussed.

Soloviev presented large area surface barrier detectors and detectors with special shapes used for the assay of α-active layers.

Drapchinsky described the most important characteristics which actual fission foils should have, as well as various methods to verify these characteristics. Special attention was given to the requirements for the sample backing, the verification of the characteristics of the basic material and the determination of the uniformity of the areal density and 2π-fragment detection efficiency.

Mizumoto discussed the impact of water absorption in samples on neutron cross-section measurements. Neutrons are slowed-down by multiple scattering in the water, resulting in erroneous cross-section data. A corresponding Monte-Carlo correction procedure was presented.

Pauwels reported on the dramatic influence of the ^{239}Pu ingrowth on $^{243}Am(n_{th},f)$ cross-section measurements, resulting in fission cross-section values up to three times too large. A method to limit this effect was presented.

Qaim discussed the prominent role of sample preparation in the study of fast neutron induced low-yield reactions like (n,t) and (n,^{3}He). Many erroneous results were reported in the literature up to 1971 due to isotopic and non-isotopic impurities. These problems have been overcome by using extremely pure basic materials combined with a thorough sample assay using various techniques. The low yield products in the irradiated materials were chemically separated and transformed into suitable samples for radioactivity measurements.

Wagemans and Dionisio mentioned similar problems occurring in μbarn (n_{th},f) cross-section measurements and in thermal neutron induced γ- and electron-spectroscopy measurements, respectively.

Pauwels finally stated that a hydrogen standard established with an accuracy <0.3% might constitute a wishful thinking. Neither hydrogen foils presently available nor their absolute assay actually suit the physicists' needs. Moreover, an intercomparison of H-determinations performed in various laboratories showed discrepant results.

4. STANDARD FOILS

The necessity of a thorough assay of standard fission foils was discussed by Drapchinsky, Wasson, and Winkler. In particular, the need to determine for each sample the areal density distribution and its roughness using various techniques, was stressed.

The exchange of standard foils between different laboratories was found to be very useful in order to get a realistic appreciation of the actual accuracy with which the ^{235}U reference fission cross-section is known. In this context, Drapchinsky reported on the status of a recent standard foil exchange programme between laboratories in the USSR and the USA which was coordinated through the IAEA. The total masses were determined by means of alpha-particle decay measurements and thermal neutron induced fission measurements. However, the areal density variation was not measured.

Okamoto and Seeliger mentioned that the problem of storage of standard fission foils was discussed during previous INDC Meetings, and it was concluded that the best place for storage is the institute where the foils were produced, since the manufacturer is in the best position to verify the status of the foils before re-using them. Such valuable foils should only be sent to laboratories having sufficient experience in manipulating them.

Finally, the AGM supports the idea of a set of standard fission foils under the aegis of the IAEA and raises the problem of the budget to be made available for this purpose by the IAEA.

5. LIST OF SUPPLIERS OF TARGETS AND SAMPLES

Representatives of four target/sample producing laboratories:

S. Soloviev (Radium Institute, Leningrad, USSR)

H. Adair (ORNL, Oak Ridge, USA)

J. Pauwels (CBNM, Geel, Belgium)

R. Wiltshire (AERE, Harwell, UK)

gave short presentations of the targets/samples which they are currently producing and selling.

More detailed information including that furnished subsequently by some other suppliers is given in the Appendices.

6. TRAINING COURSES

The possibility of organizing training courses in sample preparation techniques, especially for scientists from developing countries, was discussed.

Four possibilities were presented:

- Seeliger mentioned that a training course on techniques of utilization of neutron generators will be organized at Dresden in cooperation with the IAEA-NDS from November 28 to December 9, 1988. An essential part of this course is the use and handling of tritium targets.
- Maier presented a model for cooperation with developing countries. An aspirant target-maker from country X should come for 4 weeks to his laboratory in München for training. Two months later, a staff member of the Target Laboratory at München would go to country X for 3 weeks. In this way a transfer of practical experience is realized. The funding is done in equal parts by the two institutions concerned.
- Maier also presented the results of a discussion on this topic during the INTDS Business Meeting. The INTDS Board will soon set up a proposal following the Target Laboratory München model to organize training courses on special topics such as stripper foils, reduction of metal oxides, actinide target preparation etc. Participants wishing to be trained can submit their personal data and educational background as well as the topic(s) to be covered to the INTDS Board. For candidates from developing countries, this could be done via the IAEA-NDS. The INTDS Board will handle the requests and try to find a suitable laboratory for placement of the candidate. The possibility to organize theoretical courses will be investigated.
- Drapchinsky reported that the V.G. Khlopin Radium Institute is willing to organize training courses in sample preparation techniques in 1990. An official proposal has been sent to the IAEA recently. A number of lessons and practical exercises on the preparation and characterization of samples will be included in the programme.

Although the basic idea was to organize courses for potential target/sample makers from developing countries, it was mentioned explicitly that also participants from other countries would be welcome.

CONCLUSIONS AND RECOMMENDATIONS

1. Several measures are recommended referring to tritium targets:

   - The international radiological protection regulations must be strictly observed while handling tritium targets: storage should be done in an inert atmosphere; manipulations should be done in a hood or glove box having a strong air sweep; protective clothing and gas masks must be carried.

   - The characteristics of tritium targets used to produce neutrons for basic nuclear data measurements must be well defined. For targets producing neutrons for applied purposes (activation analysis, radiation damage studies, etc.) it is not so critical.

   - Whenever possible, the characteristics of a tritium target should be investigated at a primary neutron energy of 19 MeV. Use of a blank target very close to the primary target is strongly suggested. The target parameters should be checked via simulation through Monte Carlo calculations.

   - More fundamental research should be done to optimize tritium targets (lesser tritium content, higher neutron flux, longer life).

   - In double differential neutron emission cross section measurements at 14 MeV the neutron flux must be known to a high precision. It is recommended that the INDC and the relevant CRP consider this point in more detail.

2. Targets for medical radioisotope production must take into account the demanded radionuclidic and chemical purity, radiochemical form and specific activity of the product.

3. The enormous impact of sample characteristics on a large variety of nuclear data measurements was vividly demonstrated by various specialists. Several examples of erroneous results were reported.

Although a "universal ideal sample" does not exist since the requirements strongly vary with the type of experiment, a few aspects deserving special attention can be highlighted:

- In order to achieve an accurate determination of the sample mass, the use of at least two different mass-assaying methods is recommended.

- For samples to be used for high resolution spectroscopy experiments, the layer thickness and its variance should be checked, especially when it has been determined via selective methods.

- Special attention should be given to all kinds of impurities present or growing-in in the sample or appearing after the sample production (e.g. oxidation, hygroscopy etc.).

- In the final accuracy statement, the sample contribution should be clearly identifiable.

4. Especially for the standard fission foils, a thorough assay of the areal density distribution and its roughness using various techniques was found to be necessary. Also the interlaboratory exchange of fission foils was strongly endorsed since this is an excellent tool to obtain a realistic estimation of the present accuracy of the $^{235}U(n,f)$ reference cross-section. The problem of the budget to be made available by the IAEA for this purpose was risen. It was also concluded that the best place for storage of the standards foils is the laboratory where the foils were produced. This laboratory should check the status of the foils before they are re-used.

5. Four prominent sample/target producing laboratories gave short presentations of their present capabilities. They in principle agree to sell samples/targets to developing countries, depending possibly on export licences. It was felt that the IAEA/NDS could play a mediating and advising role in this respect.

6. Two laboratories, T.U. Dresden and Khlopin Radium Institute, Leningrad, have concrete plans to organize training courses in target/sample handling and preparation techniques. Also the INTDS

Board will set up a proposal to organize such courses. All the three initiatives are strongly endorsed by the Advisory Group, recognizing the mediating task of the IAEA/NDS in this respect. The Advisory Group also recommends strict adherence to the safety aspects of preparing, handling and storing of targets and samples.

Finally, the organization of an Advisory Group Meeting in conjunction with the INTDS Conference was found to be very useful, since it strongly facilitated contacts and discussions between target/sample users and producers. Possibilities of further contacts with the INTDS in this area should be considered.

S. Soloviev
Khlopin Radium Institute
Leningrad, USSR

I In the Khlopin Radium Institute targets containing fissile nuclides from U up to Cf are prepared, including those:

- with active layer areal density up to 10 mg/cm^2 (U), 3 mg/cm^2 (Th), 1 mg/cm^2 (Np, Pu)
- on the backings support from Al_2O_3
- with low number of nuclei (up to 10^{13})
- with inhomogeneity of active layer of about ~1%

II Following semiconductor detectors with non-planar shape are produced:

- $2\pi\alpha$ (for calibration purposes low activity target with a diameter up to 24mm)
- Cylindrical (outer diameter 5 mm)
- Canal (diameter of canal 5-8 mm)

III Semiconductor detectors with fissile layer on the sensitive surface.

The conditions of target and detector production should be agreed with the Institute management.

Appendix 2

H.L. Adair
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831, USA

The Oak Ridge National Laboratory Isotope Distribution Program (IOP) provides isotope research materials for research, development, and production applications. Most of the isotopes of elements in the periodic chart are available on an international basis, from this program. The general list of materials and services are detailed below:

1. radioisotopes,
2. enriched stable isotopes,
3. special nuclear materials, and
4. unique isotope products and services.

In addition to the above, routine fabrication processes are available to prepare both stable and radioisotope samples to meet the most stringent requirements.

Specific details on isotopic materials and services available through the IOP can be obtained by writing to the following address:

Oak Ridge National Laboratory
Isotope Distribution Program
P.O. Box 2008
Building 3037
Oak Ridge, Tennessee 37831
Phone 615-574-6984

Supply of Samples and Targets By CBNM, Geel, Belgium

J. Pauwels

Samples and targets for nuclear measurements have been supplied by CBNM for more than 25 years. They are generally supplied upon request according to specifications to be agreed upon between the customer and the laboratory.

They include:

- thin layers of several actinides and other materials of nuclear interest prepared by vacuum deposition, electrospraying, spraypainting, etc. Most targets can be supplied on very thin substrate foils, especially on 20 to 40 $\mu g/cm^2$ polyimide foils.

  Under optimal conditions the number of nuclide atoms can be determined with accuracies below 1%.

- bulk samples of metals or oxides prepared from fine materials and/or enriched isotopes.

- alloy samples in different forms and shapes prepared by quantitative alloying using e.g. high-frequency levitation melting. These include dosimetry alloys (e.g. AlCo, AlU, VNp,...), metallic spikes for isotope dilution mass spectrometry (e.g. U-Pu alloys), etc.

- reference materials for the non-destructive analysis of the isotope composition of uranium or for reactor neutron dosimetry ($^{238}UO_2$, $^{237}NpO_2$, Ni, Cu, Fe, Al, Nb, AlCo).

Finally, more than 1000, mainly actinide deposits are available from stock. A regularly updated computer list of these can be obtained upon request.

Appendix 4

The supply of stable and active isotopes and targets from the Harwell Laboratory

R.A.P. Wiltshire

A wide range of active and stable isotopes from ^{6}Li through to ^{252}Cf are currently available from the Harwell laboratory.

Nuclides can be supplied as solids, liquids and targets manufactured to customers specifications.

^{57}Fe and ^{119}Sn for use as Mössbauer absorbers are held in stock.

An extensive range of carbon foils for use as beam stripper foils and target backings can be manufactured.

Radioactive sources of single or multiple nuclides can be prepared and calibrated to high accuracy. ^{252}Cf fabricated for use as fission fragment sources are held in stock.

Tracer solutions of ^{227}Ac through to ^{252}Cf for environmental and dio-equilibrium studies are available from stock.

Enquiries are invited for variable energy cyclotron (VEC) or reactor produced nuclides.

A UK export licence is required for some isotopes and information on the end use and user may be required.

Enquiries should be addressed to:

Actinide Chemistry and Analysis Group
Chemistry Division
Harwell Laboratory
Oxfordshire OX11 ORA, England
Telex 83135, Telephone (0235) 24141 ext. 4212

MICROMATTER Co.
P.O. Box 123
123 Madrona Lane
Deer Harbor, WA 98243, U.S.A.
Phone: (206)376-4007

Joanne M. Heagney

MICROMATTER offers the experimenter a wide range of foil and target fabrication capabilities. Our capabilities include pressing, rolling, and vacuum evaporation of both natural and isotopically enriched materials. We also perform some reductions of isotopic materials used in these samples. We prefer to mount foils on customer provided frames and ship ready for use in our returnable vacuum shipping container, except for thicker gauge foils which may be shipped self-supporting. (For detailed information request our Foil Products and Accelerator Target Service Information). We also offer carbon foils on glass slides in the thickness range from 3 to 50 $\mu gm/cm^2$. (Request Carbon Foil Information). For X-ray fluorescence we offer 63 elements as thin, single-element calibration standards on a wide variety of backing and mounts. (Request X-ray Fluorescence Standards Information.)

IAEA Advisory Group Meeting on
THE INFLUENCE OF TARGET AND SAMPLE PROPERTIES ON NUCLEAR DATA MEASUREMENTS

in co-operation with the
International Nuclear Target Development Society (INTDS)

Darmstadt, Federal Republic of Germany
5-9 September, 1988

LIST OF PARTICIPANTS

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	H. Liskien Central Bureau of Nuclear Measurements Steenweg naar Retie B-2440 Geel
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INTDS & IAEA-INDC Conference
"Heavy-Ion Targets and Related Phenomena"

GSI Darmstadt, 5-9 September 1988

PROGRAMME

Monday, Sep. 5, 1988

14:00 IAEA Advisory Group Meeting

16:00 INTDS Directory Board Meeting

Tuesday, Sep. 6, 1988

9:15 H.A. Folger (GSI), Brief Welcome and Technical Announcements
H.L. Adair (ORNL, USA), Introductory Remarks
K. Okamoto (IAEA, Vienna), A Brief Comment to the Work of IAEA-INDC

SESSION 6.1 Target Problematics and Applications — Chairperson H. Liskien

- P. Kienle
  A Special Scientific Welcome Address to the Conference
- C. Wagemans
  On the Necessity of Alternative Methods to Determine Sample Thicknesses and Masses
- J.S. Dionisio et al.
  The Influence of Target Properties on Nuclear Spectroscopy Measurements
- W. Kraft-Weyrather et al.
  The Preparation of Biological Targets for Low Energy Heavy-Ion Experiments

SESSION 6.2 Heavy-Ion Target Users' Comments — Chairperson P. Maier-Komor

- G. Münzenberg et al.
  On-Line Measurements of Target Properties in Experiments for the Investigation of Heavy Elements
- Y. Gono and M. Ishihara
  Target for Heavy-Ion Physics
- H. Bokemeyer
  On the Importance of Target Parameters in Heavy-Ion Positron Spectroscopy

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The underlined are invited persons to the IAEA Advisory Group Meeting.

SESSION 6.3 Fissioning Targets — Chairperson K. Okamoto

- L.V. Drapchinsky and A. Filatenkov
  Fission Foil Characteristics

- G. Hermann
  A Historical Target: Ammonium-diuranate

SESSION 6.4 Cross-Section Measurements — Chairperson H.-J. Maier

- Cheng Xiaowu
  The Influence of Target Impurities on the Accuracy of Reaction Cross Section Measurements

- S.L. Loshaev, S.M. Soliviev et al.
  Semi-conductor Detectors for the Calibration of the Targets from Fissible Radionuclides

- G. Winkler
  On the Influence of Sample and Target Properties on the Results of Energy-Dependent Cross Section Measurements

- M. Mizumoto and M. Sugimoto
  The Influence of Water Absorption in a Sample for Neutron Cross Section Measurements

SESSION 6.5 Tritium Processing — Chairperson J. Pauwels

- E.H. Kobisk et al.
  Tritium-Processing Operations at the Oak Ridge National Laboratory with Emphasis on Safe-Handling Practices

SESSION 6.5 Tritium Target Problematics

- D. Seeliger
  Problems of Tritium Targets

- K. Sumita
  Tritium Solid Targets for Intense D-T Neutron Production and It Related Problems

- S.V. Tikhonov and V.S. Shorin
  On the Fast Neutron Spectra Shape in the Nuclear Constant Measurement Experiments with an Electrostatic Accelerator

- R. Böttger et al.
- Problems Associated with the Production of Mononenergetic Neutrons

Wednesday, Sep. 7, 1988

SESSION 7.1 Stripper Foils — Chairperson J. Gursky

- W.S. Aaron et al.
  Development and Preparation of Thin, Supported Targets, and Stripper Foils

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The underlined are invited persons to the IAEA Advisory Group Meeting.

- G. Dollinger and P. Maier-Komor
  Stripper Foil Requirements for Optimum Ion Transmission at the Munich MP-Tandem

- Xu Guoji
  A Simple Preparation Method for Carbon Stripper Foils

- Isao Sugai et al.
  Hybrid-Type Long-Lived Carbon Stripper Foils

- Barry L. Barthel and Thomas A. Archuleta
  Pinhole Plate Diagnostic for Neutral Particle Beam Accelerator

- P. Maier-Komor
  Large Area Polyimide Foils for Heavy Ion Gas Detector Systems

SESSSION 7.2 Electro Depositions — Chairperson J.A. Heagney

- N. Trautmann and H. Folger
  Preparation of Actinide Targets by Electrodeposition

- H. Mast, R. Eykens, J. Pauwels and C. Wagemans
  Am-243 Targets for Nuclear Fission Experiments: Requirements and Realisation

- A. Cecchi and P. Sona
  Self-Supporting Ruthenlum Targets Produced by Electroplating

SESSION 7.3 Various Target Preparations — Chairperson P. Dmytrenko

- W.R. Lozowsky
  Three Diverse Target Preparations: $^{14}C(12mg/cm^2)$, $^{71}Ga^{24}Mg$ ($12mg/cm^2$ ^{71}Ga, $3mg/cm^2$ ^{24}Mg), $^{66,67}Zn$ ($1.8-14.9mg/cm^2$)

- G.E. Thomas
  New Techniques for Producing Thin Boron Films

- J.C. Gursky, H. Baier, and F.F. Flick
  Precision Nuclear Targets for Drell-Yan Cross-Section Measurements at 800 GeV

- P. Maier-Komor
  Ferromagnetic Gadolinium Foils for Transient Fields Experiments

SESSION 7.4 Activity Reports of Target Laboratories — Chairperson J. Tracy

- R. Pengo
  Developments at the LNL Target Laboratory

- R. Golser
  Experiments in the Preparation of Thin Layers for Accelerator Measurements

- N. Ueta
  Activity Report of the Target Laboratory of the Pelletron Accelerator Sao Paulo

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The underlined are invited persons to the IAEA Advisory Group Meeting.

- J.P. Geene and G.E. Thomas
  Recent Developments in the Target Facilities at Argonne National Laboratory

SESSION 7.5 Oxide Reductions; Plunger Target — Chairperson L. Sapir

- H.-J. Maier
  Preparation of Ductile Zr from ZrO_2

- H.-J. Maier
  Preparation of Elemental Si from SIO_2

- A.J. Michielsen and P. Decowski
  Silicon Targets

- K.O. Zell and A. Dewald
  Removal of Points from Plunger Targets by Electric Discharges

- INTDS Business Meeting

- IAEA Advisory Group Meeting (parallel meeting)

Thursday, Sep. 8, 1988

SESSION 8.1 Characterizing Targets and Damages — Chairperson G. Sletten

- O.A. Wasson
  Use of Rutherford Backscattering to Determine Uranium Deposit Uniformity

- K.E. Stlebing et al.
  Influence of Heavy-Ion Irradiation on the Structure of Targets of Nuclear Studies

- P. Lorenzen, H. Rothard, K. Kronenberger, J. Kemmier, M. Burkhard, K.O. Greeneveld
  Target Characterization by Fast Ion Impact

- G. Dollinger and P. Maier-Komor
  Heavy-Ion Irradiation Damage in Carbon Stripper Foils

- C. Ingelbrecht, F. Petermans, J. Pauwels
  A Study of the Homogeneity of Aluminium-Cobalt Alloys for Neutron Dosimetry

- D. Kraft et al.
  An Experimental Setup for the Fast Determination of Composition, Microstructure, Homogeneity and Content of Impurities in Targets

- Th. Osipowicz and K.P. Lieb
  Erosion of Solid Krypton Targets under Proton Bombardment, Measured with PIXE

The underlined is invited person to the IAEA Advisory Group Meeting.

SESSION 8.2 Rolling and Milling of Targets — Chairperson R. Leonard

- R. Blanc, O. De Gabrielli, J. Menet, J.P. Richaud
  A New Ionic Erosion Method for Self-Supporting Target Making

- G. Manente and R. Pengo
  Preparation of Thin Rolled Cadmium and Tin Films on to Lead Sandwich

Friday, Sep. 9, 1988

SESSION 9.1 Isotopes Separations — Chairperson E. Kobisk

- J.G. Tracy
  Isotope Separation Program - Present and Future

- A.G. Kudziev
  Present Status and Prospects of Stable Isotope - Production and Application in the USSR

- W.L. Roberts
  Gas Centrifugation of Research Isotopes

- A.J. Szady
  Enrichment of Chromium Isotopes by Gas Centrifugation

- H. Geissel et al.
  Phase-Space Pecularities of Ions Penetrating Through Ion-Optical Systems and Matter

- K. Brand et al.
  Production of Isotopically Enriched U-Targets by Ion Implantation

SESSION 9.2 Medical Isotope Production — Chairperson M. Mizumoto

- S.M. Qaim
  Target Development for Medical Radiositope Production

- R.M. Lambrecht et al.
  Target Preparation and Recovery of Isotopically Eneriched Isotopes Utilized for Medical Radionuclide Production

SESSION 9.3 Electron-, Gas-, & Plasma-Targets — Chairperson G.E. Thomas

- A. Müller
  Targets Consisting of Free Charged Particles

- J. Jacoby
  Heavy-Ion Targets for Intense Beam Experiments for Beam-Plasma Interaction Research

- A. Gruber et al.
  Internal Gas Jet Target for the ESR at GSI

- D. Darquennes (speaker) et al.
  Target Development for RIB

The underlined is invited person to the IAEA Advisory Group Meeting.

SESSION 9.4 Various Target Preparations — Chairperson S. Aaron

- P. Maier-Komor
  Nonmetallic Target for Heavy-Ion Experiments

- H.-J. Maier et al.
  Special Techniques of Nuclear Target Preparation

- J.P. Greene and G.E. Thomas
  Isotopic Tellurium Targets for Heavy-Ion Nuclear Physics Produced by Vapor Deposition

- H. Folger et al.
  Fabrication of Carbon-Sandwiched Uranium Layers for the Use on Rotating Target Wheels in High-Energy Heavy-Ion Bombardments

- J.O. Stoner, Jr. (no oral presentation)
  Production of Large Screen-Mounted Aluminum Neutralizer Foils

- J.O. Stoner, Jr. (no oral presentation)
  Properties of Evaporated Target Foils Studied by Computer Simulation of Ballistic Aggregation

14:00 Parallel Session of The IAEA Advisory Group Meeting

16:00 Session of Concluding Remarks

ABSTRACTS OF PRESENTATIONS BY INVITED SPEAKERS TO THE CONFERENCE

ON THE NECESSITY OF ALTERNATIVE METHODS TO DETERMINE SAMPLE THICKNESSES AND MASSES

Cyriel Wagemans
SCK/CEN, B-2400 Mol, Belgium
and
Nuclear Physics Lab., State University,
B-9000 Gent, Belgium

Abstract

The great impact of an inaccurate determination of the sample mass or the layer thickness on nuclear data measurements is discussed. This is illustrated by selected realistic examples.

A short survey of the advantages and disadvantages of various methods to determine the mass or the thickness of a layer is given, especially with respect to their consequences on the accuracy of nuclear data measurements.

THE INFLUENCE OF TARGET PROPERTIES ON NUCLEAR SPECTROSCOPY MEASUREMENTS

J.S. Dionisio, Ch. Vieu, CSNSM (IN2P3) Orsay, FRANCE
J.M. Lagrange, M. Pautrat, IPN Orsay, FRANCE
J. Vanhorenbeeck, ULB, Bruxelles, BELGIQUE
A. Passoja, University of Joensuu, FINLAND

A B S T R A C T

A broad review of different kinds of in-beam nuclear spectroscopy measurements particularly influenced by the target properties is outlined. To illustrate such an influence a few typical examples of in-beam electron and gamma-ray spectroscopy measurements, performed at the Orsay MP Tandem accelerator, are reported. In particular several applications of the recoil ion catcher method in the study of short lived nuclear isomers (with half-lives between ten and a few hundred nanoseconds) are briefly described. This method is operated mostly with

a pulsed heavy ion beam, bombarding a thin self supported target but avoiding to hit the catcher foil. Moreover, the time of flight filtering properties of this experimental device is improved by a fast detection of compound nucleus deexcitation (performed with an array of several BaF_2 crystals). This kind of measurements shows clearly the importance of the target qualities as well as the need of good focusing properties and time structure for the accelerated particle beam. Finally, the required characteristics of the targets and recoil ion stopper foils needed for these measurements (and similar ones performed with the recoil ion shadow method) are analyzed in detail for a few typical experimental arrangements.

The Target for Heavy Ion Physics

Y. Gono and M. Ishihara

The Institute of Physical and Chemical Research (RIKEN)
Wako-shi, Saitama, 351 - 01, Japan

ABSTRACT:
We are engaged in researches on nuclear and atomic physics using heavy ion accelerators such as Linac, Tandem Van de Graaff, separate-sector cyclotron. Beam energies covered range from a few MeV/u to 100 MeV/u. The requirements for target properties widely vary with the individual research chosen and the type of beam used. Typical problems are concerned with thickness uniformity, heat tolerance, target preparation of non-metallic elements, density of gaseous target and so on. In this report we illustrate several specific examples of such problems encountered in current experiments.

On the Importance of Target Parameters in Heavy Ion Positron Spectroscopy

H. Bokemeyer

Gesellschaft für Schwerionenforschung

D-6100 Darmstadt, Federal Republic of Germany

Abstract

Details of the target constitution may represent important ingredients to the feasibility of heavy ion experiments. The central role of such target characteristics will be examplified using experiments on positron spectroscopy and related fields pursued with heavy ion beams of the GSI UNILAC-machine in Darmstadt. The scope includes the influence of the target compounds on both the basic physics and the background, the use of radioactive targets, the influence on ionic charge distributions, and the use of the stopping behaviour of the heavy ions for the measurement of the beam energy and life-time discrimination by means of kinematic shifts. Targets bombarded by heavy ion beams suffer considerable deterioration. Thus the use of special techniques became important for the on- and off-line control of critical target parameters and will be introduced here.

FISSION FOIL CHARACTERISTICS

L.V. Drapchinsky
Radium Institute
Leningrad, U S S R

A B S T R A C T

From the users' point of view the most important characteristics of fission samples are consindered taking into account their influence on the final results of nuclear data measurements.

THE INFLUENCE OF TARGET IMPURITIES ON THE ACCURACY OF REACTION CROSS SECTION MEASUREMENTS

Cheng Xiaowu
Shanghai Institute of Nuclear Research, Academia Sinica, Shanghai, China

A B S T R A C T

Inelastic scattering of protons on Ni isotopes has been measured at 25 MeV incident energy. Special attention has been paid to the low energy part of the energy spectra to study the isotopic effect on preequilibrium emission. H, C, and O contaminations on targets have been analyzed by backscattering and nuclear reaction, both before and after the experiment. Methods used to minimize the contamination and to deduct its contribution to the energy spectra will be described. The influence of target impurities on the accuracy of reaction cross sections will be discussed.

SEMICONDUCTOR DETECTORS FOR THE CALIBRATION OF THE TARGETS FROM FISSIBLE RADIONUCLIDES

S.L. Loshaev, S.M. Soloviev, et al.
Radium Institute
Leningrad, U S S R

A B S T R A C T

The description of the set of semiconductor detectors with a large area and complicated shapes used in the Radium Institute for the calibration of alpha activities of targets from fissile radioculides including low radioactive targets and targets with complex configurations will be presented.

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, Boltzmanngasse 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.

THE INFLUENCE OF WATER ABSORPTION IN A SAMPLE FOR NEUTRON CROSS SECTION MEASUREMENTS.

Motoharu Mizumoto and Madayoshi Sugimoto
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken, Japan

A B S T R A C T

Sample-related corrections for average neutron cross section measurements are often complicated in the keV region due to the resonance structure. In particular, corrections for neutron multiple-scattering and self-shielding for chemical compound samples of rare earth materials should be carefully made, because they are highly hygroscopic. A Monte-Carlo method has been developed by taking into account the effects caused by neutron slowing down into the resonance region due to the scattering from hydrogen and oxygen atoms. The validity of calculated results for corrections has been investigated by comparing experimental data of oxide samples with those of metallic samples. The calculation method and related problems will be discussed in detail.

TRITIUM-PROCESSING OPERATIONS AT THE OAK RIDGE NATIONAL LABORATORY WITH EMPHASIS ON SAFE-HANDLING PRACTICES*

E. H. Kobisk**, D. W. Ramey, W. S. Aaron,
J. A. Tompkins, K. W. Haff, and H. L. Adair

Oak Ridge National Laboratory

ABSTRACT

Tritium, a radioactive isotope of hydrogen, is used in many applications, including neutron production from the (d,t) reaction, radioluminescent lighting, helium doping of materials, and radiography. The Isotopes Section of the Oak Ridge National Laboratory (ORNL) has been involved in providing tritium gas and various tritium-containing materials to the international research, development, and production communities for more than 28 years. Many programs at ORNL and other facilities have benefited from the expertise developed within the Isotopes Section for preparing tritium-containing materials such as titanium or erbium tritide for use in neutron production through the development of radioluminescent lighting or through the use of tritium to implant ^{3}He in tensile specimens. A major consideration in all the operations is to minimize personnel exposure to tritium and to keep this exposure to a level that is as low as reasonably achievable (ALARA). Present and future tritium-processing operations are described.

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*Research sponsored by the Division of Basic Energy Sciences and Division of Nuclear Sciences, U.S. Department of Energy, under contract DE-AC05-84OR21400 with the Martin Marietta Energy Systems, Inc.

**Retired

PROBLEMS OF TRITIUM TARGETS

D. Seeliger
Technische Universität Dresden
DDR-8027 Dresden
German Democratic Republic

Abstract

Solid state tritum targets are widely used for 14 MeV neutron production of DT-neutron generators. Usually they are produced by evaporation of a Titanium and Zirconicum layer on a thin copper backing, with a subsequent absorption of tritium gas in it. The literature of solid state tritium targets during irradiation with ion beam is limited by the heating of the target connected with a higher diffusion rate of Tritium out of the titanium layer, the formation of thin carbon layers at the surface and also ion sputtering processes. It depends also on the composition of ion beam striking the targets (admixture of molecular a.o. components). The use of tritium targets implies the necessity of radiation protection measures due to the radio activity of tritium. The present status of this aspects is discussed in the paper presented including some recommendations concerning the most efficient use of solid state tritium targets.

TRITIUM SOLID TARGETS FOR INTENSE D-T NEUTRON PRODUCTION AND ITS RELATED PROBLEMS

Kenji Sumita

Faculty of Engineering. Osaka University.
Yamada-Oka 2-1. Suita Osaka. Japan

ABSTRACT

This review paper is divided into three parts.

Firstly, to attain an intense neutron production rate, the construction of a design with a higher tritium-containing surface and an effective cooling system like a rotating target device are discussed. The maximum attainable intensity based on tritium solid targets shall be estimated regarding plannings for future D-T sources.

Secondly, on the way to carry out some experiments, an absolute intensity calibration and an angular dependent neutron energy spectrum of the neutron source are essential parameters to analyse the results of the experiments. Sometimes the space dependent neutron spectrum is required as well as the space dependet neutron

flux near the targets and irradiation samples. The measurement methods and their examples are reviewed for tritium solid targets.

The third part is devoted to discuss the protection to tritium contamination problems due to unavoidable release of tritium gas from targets. Performance and effectiveness of tritium collection systems for intense D-T neutron sources shall be discussed on some examples. Tritium contamination incidents due to the faulted film powder of target surface are also reported in some real incident cases.

ON THE FAST NEUTRON SPECTRA SHAPE IN THE NUCLEAR CONSTANT MEASUREMENT EXPERIMENTS WITH AN ELECTROSTATIC ACCELERATOR

S.V. Tikhonov and V.S. Shorin
Physical Power Institute,
Obninsk, U S S R

A B S T R A C T

The approach to calculate the spectra of neutrons being produced in (p,n) reac tions on the Van de Graaf accelerators has been considered. The model takes into account the actual layout of the solid tritium target and the irradiated sample as well as the target composition. The main spectrum parameters - the everage energy E and the variants D - have been calculated for the real experiment.

"Problems Associated with the Production of Monoenergetic Neutrons"

R. Böttger, S. Guldbakke, H. Klein, H. Schölermann,
H. Schuhmacher, H. Strzelczyk
Physikalisch-Technische Bundesanstalt
Bundesallee 100
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Neutron producing reactions (1 keV < E_n < 19 MeV) have been investigated with respect to the neutron background production with the time-of-flight method employing pulsed proton or deuteron beams from the Van-de-Graaff accelerator. The largest fraction of

background for the reaction $^{3}H(d,n)^{4}He$ results from a high impurity of deuterium in some solid Ti-T targets, whereas other background components can nearly fully be taken into account by a blank target measurement. Self target build-up was observed for an old Ti-D target, while for the $^{3}H(p,n)^{3}He$ reaction neutron scattering at the target construction, which could only partially be determined by backing thickness variation, was found to be a significant effect. The problems with LiF and metallic Li as target material for the $^{7}Li(p,n)^{7}Be$ reaction are discussed. In order to meet the desired resonance in the $^{45}Sc(p,n)^{45}Ti$ reaction, the energy of the protons has to be precisely determined by the time-of-flight method.

^{243}Am TARGETS FOR NUCLEAR FISSION EXPERIMENTS : REQUIREMENTS AND REALISATION

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ABSTRACT

Target characteristics required to carry out reliable thermal neutron induced fission studies on ^{243}Am are discussed. Especially the problems caused by the ingrowth of ^{239}Pu in the material are examined, and purification of the ^{243}Am base material is studied. The purification was carried out by anion exchange on Dowex-1 in HNO_3 medium, followed by cation exchange on Dowex-50 to eliminate iron introduced in the first purification step, and precipitation by NH_4OH to eliminate sodium. The material was then transformed into americium acetate and two targets were prepared by electrospraying. The targets were used for the study of the reaction characteristics and for the determination of the thermal neutron induced fission cross section.

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USE OF RUTHERFORD BACKSCATTERING TO DETERMINE URANIUM DEPOSIT UNIFORMITY

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ABSTRACT

A Rutherford Backscattering (RBS) facility has been established at the 3-MV positive-ion accelerator at the National Bureau of Standards. This facility has been used to study the areal density distribution of uranium deposits used in neutron cross section measurements. A versatile scattering chamber with numerous ports, five-axis goniometer, target ladder, and solid state detector is in operation. Beams of 1 MeV He^+ ions and 5 MeV He^{++} ions are available.

The variation in areal density of a 75 cm diameter UO_2 deposit was measured using a 1 MeV He^+ beam. The results are in excellent agreement with those obtained from alpha-particle activity measurements. However, the RBS measurements provide better definition of the uniformity near the edge of the deposits. Our experience in the use of these two methods to characterize the areal densities of deposits for cross section measurements will be presented.

Target Development for Medical Radioisotope Production at a Cyclotron

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With the increasing use of cyclotron produced short-lived neutron deficient radioisotopes in nuclear medicine, the demand for newer and more efficient production routes is increasing. For optimization of a production method, especially for minimization of impurities, a knowledge of reaction cross-section data is necessary. The large scale production, on the other hand, involves development of target systems capable of withstanding high currents and giving high practical yields. In this paper a short review of target development relevant to both nuclear data measurements and large scale production of radioisotopes will be given.

In cross-section measurements stacks of thin targets are commonly used and irradiations are done at low currents (~ 100 nA) with well-focussed beams. In case of metals thin foils may be commercially available. For non-metals, liquids or

gases, however, preparation of thin and uniform samples may involve considerable effort, especially if the target material is isotopically enriched and rather expensive. Techniques like sublimation, vacuum evaporation, electrodeposition etc. have been applied. In case of gases thin walled cylinders in a series are used. Some of the methods used in recent years in cross-section measurements on target elements Cl, As, Se, Te, Kr, Xe etc. will be outlined.

For large scale production of a radioisotope, a relatively thick target covering the optimum part of the excitation function is used. Due to the use of high beam currents (up to 100 μA) the power density effective at a target is rather high (up to a few KW/cm^2). Not every possible nuclear process is therefore suitable for production purposes. Development of appropriate target materials therefore constitutes one of the major efforts in cyclotron production of radioisotopes. An efficient cooling of the target and of the foil separating the cyclotron vacuum from the target is crucial. Irradiations of materials in all the three forms, viz. solid, liquid and gaseous, have been done. The practical yield of the radioisotope is invariably smaller than the theoretical yield calculated from the excitation function. A few examples of recently developed high current target systems for the production of some commonly used radioisotopes will be given and the reasons of low yields discussed.