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INTERNATIONAL NUCLEAR DATA COMMITTEE

TRANSACTINIUM ISOTOPE NUCLEAR DATA - 1984

Summary Report of the Third Advisory Group Meeting on
Transactinium Isotope Nuclear Data
organized by the International Atomic Energy Agency
held at the Gustaf Werner Institute,
University of Uppsala, Sweden,
21-25 May 1984

Edited by A. Lorenz
Nuclear Data Section
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ABSTRACT

The Third Advisory Group Meeting on Transactinium Isotope Nuclear Data was convened by the IAEA Nuclear Data Section at the Gustaf Werner Institute, Uppsala, University, in Sweden from 21-25 May 1984. The meeting was attended by 32 participants and 5 observers from 15 Member States and 2 international organizations.

The main objectives of this meeting were to assess the transactinium nuclear data (TND) requirements for nuclear fission reactors, their fuel cycles and other applications with emphasis on new trends in nuclear technology, and to review the status of the required TND in the light of new measurements, calculations and evaluations.

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MEETING SUMMARY

A. Introduction

The third Advisory Group Meeting on Transactinium Isotope Nuclear Data (TND) was convened by the IAEA Nuclear Data Section as a sequel to the first two IAEA Advisory Group Meetings on Transactinium Isotope Nuclear Data, held at the Kernforschungszentrum Karlsruhe, Fed. Rep. of Germany, in November 1975 and in Cadarache, France in May 1979. This meeting was held at the Gustaf Werner Institute of the University of Uppsala, in Uppsala, Sweden, from 21-25 May 1984. The meeting was attended by 32 participants and 5 observers from 15 Member States and 2 international organizations. The list of participants is given in Appendix A.

B. Objectives

Transactinium isotopes comprise all isotopes heavier than actinium (i.e., Z larger than 89). They play important roles in the nuclear fuel cycles of both thermal and fast reactors, and have found increasing areas of applications in science and industry. The quantitative appraisal of the role and applications of these isotopes can only be done with an adequate knowledge of their nuclear characteristics, that is their nuclear data.

The participants of the first meeting recognized that transactinium isotopes had become more and more important in nuclear technology, and that the knowledge of nuclear data required to evaluate the effects of transactinium isotopes in nuclear technology was not satisfactory. Recommendations of the 1975 meeting led to the formation of two IAEA-sponsored coordinated research programmes: one on the intercomparison of evaluations of transactinium isotope neutron nuclear data, the other on the measurement and evaluation of transactinium isotope decay data.

Since the time of the first meeting, a considerable amount of effort has gone into TND measurements and evaluations aiming specifically to satisfy data requirements which were identified at the first two TND meetings.

The primary objective of this third TND meeting was to review the developments which have taken place in the TND field since then, and to identify those data which are still discrepant or which do not satisfy the required accuracies.

C. Meeting proceedings and achievements

During the first two days of the meeting, eight review papers and seventeen contributed papers were presented. The titles and authors are listed in Appendix B. During the following two days, three working groups reviewed the data status and drafted specific conclusions and recommendations in the form of Working Group Reports which are included in this report. The review papers and contributed papers have been published separately in a IAEA-TECDOC-Report.

In addition to specific and technical recommendations included in the Working Group Reports, the participants in this Advisory Group made the following recommendations:

1. Recommendation on the TND Newsletter:

The continued publications of the TND Newsletter edited by Dr. S. Raman of the Oak Ridge National Laboratory was considered by the majority of those attending this Advisory Group Meeting to be of great benefit. It has enabled many laboratories to gain information of work in progress on measurements and evaluations long before it was likely to be published in the literature. This has permitted collaboration and comparisons of data at an earlier stage. The need for all establishments to ensure that their contributions were made was again stressed to ensure the continued success of the venture. The meeting thanked Dr. Raman and the Oak Ridge National Laboratory for their efforts and strongly recommended that the TND Newsletter be continued.

2. Recommendation on non-English TND literature:

The presentation of experimental data from the People's Republic of China at the present meeting was particularly appreciated by the participants. However, most of the original data reports were published in Chinese which prevented considerably earlier dissemination of this information. A systematic translation and distribution by IAEA of the most relevant Chinese publications is highly desirable. Experimental data of Chinese origin should also be included in the EXFOR nuclear data files. The translation of selected USSR reports in Russian should also continue.

3. Recommendation in support of the Agency's CRP on TND validation:

The meeting considered and supports the programme of the Agency's coordinated research project on the Validation and Benchmark Testing of Actinide Nuclear Data. In view of the large number of recent evaluations available, it is essential to validate and test the evaluated data files, to assess and document the encountered discrepancies and to work towards further improvements of the data.

4. Recommendation for a request list for TND decay data:

The Working Group on the Status and Needs for Nuclear Decay Data of Transactinium Nuclides believed that a regular assessment of decay data requirements is important. This implies some form of recognised procedure to record and maintain an international request list. Whilst this function has been undertaken by the IAEA Advisory Group Meetings and the Coordinated Research Programme on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data (CRP on decay data), this activity will no longer occur when the CRP concludes its work in November 1984. It is recommended that the IAEA Nuclear Data Section devise an appropriate means of maintaining an international request list of decay data.

5. Recommendation for continued coordination of TND decay data measurements and evaluation:

Without the mechanism which has been provided by the CRP on decay data, the expertise in decay-data measurement and evaluation represented in this group is likely to become dispersed and much less efficient. In order to maintain international cooperation without this CRP, it is recommended that ways be explored that will permit continuing international coordination of transactinium decay-data measurements and evaluations. One possible mechanism through which this could be accomplished could be the establishment of an international working group, which would meet periodically under the auspices of the IAEA.

6. Recommendation to establish international gamma-ray calibration measurement standards:

Reference standards are important for the calibration of the detectors used to measure gamma-ray emission probabilities, and it is essential that a common data base be adopted for these reference nuclides. It is recommended that an evaluation be carried out by experienced evaluators to create a data base of the form given in INDC(NDS)-145 for the most commonly used radionuclides and gamma-ray transitions. The participants in the Working Group on the Status and Needs for Nuclear Decay Data of Transactinium Nuclides believe that a suitable mechanism for accomplishing this exists within the framework of the International Committee for Radionuclide Metrology (ICRM).

7. Future TND Meetings

With regard to future meetings on TND, most participants felt that more was to be gained from smaller meetings on specific TND discrepancies. Another meeting of the size and scope convened at Karlsruhe (1975), Cadarache (1979) and Uppsala (1984) was not recommended.

WORKING GROUP ON STATUS OF EXPERIMENTAL DATA

H. Condé
H.H. Knitter (Secretary)
Zhang Huanqiao
S. Daroczy
B. Trostell
P. Andersson
F. Communeau
J. Fréhaut (Chairman)

I. INTRODUCTION

The working group has considered the status of the experimental data base in particular as presented at this meeting. Since the field of transactinium neutron data measurements is very wide, a total coverage could not be made. If any specific reviews and recommendations are wanted, then the field for future meetings of this type should be narrowed.

II. GENERAL RECOMMENDATIONS

1. New complementary or alternative techniques should be developed in order to improve the accuracy of measurements and/or identify systematic errors in existing experiments. This is particularly needed for accurate measurements on standards and for capture cross section measurements.

2. In data reduction and error estimations, the correlations, when present, must be considered. IAEA should distribute papers on the application of error correlations in the neutron data field (e.g., those by D.L. Smith ...) to make experimentators sensitive to this problem.

3. Theoretical calculations are used in domains and/or for nuclei where cross section measurements are not possible. Experimental data are needed to support these calculations. Entry data, which are not only cross sections, are also necessary (e.g., level schemes ...). It is felt that all the needs have not yet been clearly and fully expressed. Theoretical calculations can also be useful in improving experimental data accuracy (e.g., gamma-multiplicity calculations are important to determine capture detector response).

4. Indirect experimental information and non-neutron induced data should be more thoroughly investigated as possible sources of data entries for theoretical calculations. The derivation of first and second chance fission probabilities from prompt fission gamma-ray and prompt nu-bar measurements or the use of charged-particle-induced fission to derive fission probabilities have been mentioned as examples.

5. Rare samples for which data are requested should be made available to more laboratories. The interlaboratory comparison work on ^{235}U samples undertaken by ANL is acknowledged. Further intercomparisons of this type are encouraged.

III. SPECIFIC RECOMMENDATIONS

Many measurements of the different cross section types on a large number of transactinium isotopes have been published since the last TND meeting at Cadarache and have considerably enlarged the experimental data base (total, scattering, fission, capture ...). However, much remains to be done to fill in the existing gaps and improve the data base in order to satisfy the existing requests.

Fission cross sections

- It was generally agreed that the conclusions made in the review paper of Dr. Frehaut for fission cross sections are well formulated and can be accepted.

- Low energy neutron perturbations in cross section measurements at higher energies should be checked using a threshold cross section isotope. $^{238}U(n,f)$ is recommended as a secondary standard.

- The H(n,p) cross section accuracy should be improved. The 0.9 % accuracy was regarded to be insufficient to meet the requested accuracy in the measurement of the standard ^{235}U fission cross section.

Prompt nu-bar Measurements

The latest measurements of prompt nu-bar for the ^{252}Cf standard reveal that discrepancies still exist, and the effort in that domain should be maintained.

In relative measurements, fission neutron representations of the type described by Madland and Nix should be used as entries for corrections.

Discrepancies for prompt nu-bar measurements on ^{232}Th and ^{237}Np have been reported. Possible explanations are given in the Review Paper by Dr. Frehaut at this meeting.

Capture Cross Sections

This is a field where many requests still remain to be satisfied. Therefore development and application of new experimental techniques is strongly encouraged in order to achieve better accuracy in capture cross section measurements.

A discrepancy between the measured capture resonance integral of Am^{243} and the corresponding value inferred from the evaluated capture cross section was identified. To resolve this discrepancy, a direct capture cross section measurement is recommended.

(n,2n) Cross Sections

The new results for the $^{237}Np(n,2n)$ cross section below 10 MeV presented at this meeting probably fulfill the request. However confirmation measurements would be desirable near threshold and between 10 and 14 MeV.

The branching ratio to the ground state has been measured at 14 MeV. Theoretical calculations agree with the measured value and predict a very weak energy dependence from near threshold up to 20 MeV.

The existing $^{238}U(n,2n)^{237}U$ data fulfilled the requirements.

WORKING GROUP ON STATUS OF EVALUATED DATA FILES

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F. Højerup
S. Igarasi
N. Janeva
V.A. Konshin (Subgroup on the Fast Energy Region)
H. Küsters (Chairman)
H.D. Lemmel (Secretary)
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A. Santamarina
J. Salvy
A. Trkov

I. INTRODUCTION

The Working Group on the status of evaluated data files prepared a status report identifying recent improvements by measurements and evaluations and identifying remaining discrepancies which require further investigations in order to satisfy the accuracy requirements for reactor design and fuel cycle analysis or to improve data prediction by calculations based on nuclear theory.

The Working Group concentrated its discussions on the actinide isotopes in the following sequence

- actinides of major importance for reactor design and fuel cycle:

  Th-232, U-233, U-235
  U-236, U-238, Np-236
  Np-237, Pu-238, Pu-239
  Pu-240, Pu-241, Pu-242
  Am-241, Am-243, Cm-244

- other actinides of low importance

II. GENERAL RECOMMENDATION

It is recommended to perform at first tests for neutron reactions in a simple and energetically well defined environment (thermal neutrons and neutrons in a 1/E-flux densiry, see also No. 14 of the working group 2 summary). It is mandatory to assess carefully existing experiments. When results from integral experiments are missing as e.g. for those actinides of low importance in reactor design and fuel cycle analyses, new experiments are encouraged, whenever possible with highly pure target materials. Tests on more complicated integral experiments as in fast zero power reactors or tests by post-irradiation analyses, both experimental and theoretical techniques require high sophistication and should be considered in the research project only then, if experience of participating members exist so that reliable results can be expected.

III. SUMMARY OF SOME RECENT ACHIEVEMENTS IN DATA IMPROVEMENTS

Many new evaluations were performed based on new measurements and improved theory, partly co-ordinated by the IAEA [compare paper by H.D. Lemmel, this meeting]. Part of these new data have already been successfully tested on integral experiments [see for instance the review paper of H. Küsters, this meeting]. The most important improvements of the nuclear data are listed as follows (this summary does not claim to be complete):

1. The accuracy requirements for σ_f(Th-232) were met.
   [Compare paper by S. Ganesan et al.]

2. A simultaneous evaluation of σ_T, σ_f, σ_c for U-235 was performed in the thermal and resonance region.
   [Konshin, data to be released]

3. Discrepancies in the U-238 neutron-width above 1keV were resolved due to a NEANDC task force which presented two reports by Derrien and by Olsen.
   [reported in the discussions]

4. Information on the energy dependence of the Np-236 branching ratio was improved.
   [see paper by N.V. Kornilov et al.]

5. Data for σ_f(Np-237) in the thermal and resonance region were improved.
   [reported in the discussions; see H. Derrien, INDC(FR)-42 with revision of Weston's experimental value]

6. Data for Np-237(n,2n) were significantly improved.
   [see paper by N.V. Kornilov et al.]
   [compare also report "Nuclear Data Discrepancies" by OECD, Paris 1984, p.42]

7. A new evaluation for Pu-238 is available.
   [i.e. Derrien's evaluation in INDL/A by which earlier evaluations can probably be regarded as superseded]

8. The 2200 m/s value for σ_f(Pu-239) and its curve shape in the thermal energy range can be regarded as final, [see paper by H. Derrien and P. Long] after the fission cross-section was increased dur to the revised Pu-239 half life.

[compare paper by C.W. Reich and R. Vaninbroukx on the actinide decay data work co-ordinated by IAEA]

9. A multilevel Reich-Moore evaluation for Pu-239 in the resonance region was performed.
[see paper by H. Derrien and P. Long]

10. The evaluation of the Am-241 cross-sections (i.e. three recent evaluations in INDL/A is in agreement with the result of new measurements of

- σ_c(Am-241), 10-150keV, by Wisshak et al.,
- σ_f(Am-241), in the subthreshold range, by Hage et al.,
- σ_T(Am-241), above 300keV, by Phillips et al.

[see review paper by H. Küsters]

11. The evaluation of the Am-243 cross-sections (i.e. three recent evaluations in INDL/A) is in agreement with the result of new measurements by Wisshak et al. of

- σ_c(Am-243), 10-90keV and
- σ_f(Am-243), in the subthreshold range.

[see review paper by H. Küsters]

12. Data for σ_c(Cm-244) were significantly improved.
[see review paper by H. Küsters]

13. Data for secondary neutron yields and neutron-spectra from (α,n) reactions on oxygen and other materials were significantly improved.
[experiment by Jacobs and Liskien as reviewed in the paper by V. Benzi]

IV. REMAINING DATA DISCREPANCIES

1. U-235 capture: Experimental data have discrepancies by a factor of 2 in the range 10-100keV. Recent data up to 1MeV differ by 15%. The same discrepancies exists in three new evaluations (India, Romania, Japan).

   → New experiments are recommended.

2.a. U-233 capture, fast region: There are only few experimental data which are discrepant by a factor of 2, particularly in the energy range above 2MeV.

   → New experiments are recommended.

2.b. U-233 fission, fast region: Experimental and evaluated data agree within 10%, but above 1MeV there exist too few data.

→ If U-233 is to be loaded into the core of a fast reactor, new experiments with improved accuracy are recommended.

3.a. U-235 resonance region: There are discrepancies of about 20% in α values between earlier data by Gwin (ORNL) and recent data by Muradjan (USSR). Data by Corvi (Geel, see 1982 Antwerp Conf.) are in between. See NEANDC Discrepancy File pages 50-52.

An Adler-Adler analysis of capture and total cross-sections together with ORNL polarization data of Keyworth and Moore has been performed by Konshin. (The results will be made available through IAEA). The analysis is not yet quite satisfactory, probably because of old σ_T data.

→ New accurate σ_T measurements are recommended.

3.b. U-235 thermal: Discrepancies existed for capture and alpha in the thermal region in curve shapes and absolute values. New evaluations of the 2200 m/s values are available by NNDC (1983) and Axton (1983, continuing). New curve shapes are not yet available. The new 2200 m/s values by NNDC resp. Axton (1983) are not yet included in an evaluated file. Evaluations for ENDF/B-6 (Moore) and for JENDL-3 are in progress and must be awaited in order to see whether the thermal capture discrepancies will be resolved. (Konshin's new evaluation bypassed this question by adopting ENDF/B-5 standards).

3.c. U-235 fast region: New σ_f measurements have accuracies of 3% in the range 1keV-15MeV except for the region 200-400keV (5%). Recent evaluations agree with these data.

For capture recent evaluations agree within 5%.

→ Evaluations may have to be updated with the new σ_c data by Muradjan (1983).

→ The accuracy requirements are not yet fulfilled for σ_c but new experiments can be recommended only with new experimental techniques.

4.a. U-236 capture, first resonance: New evaluations (JENDL-2, ENDL-82) show discrepancies near the first resonance so that the values of the resonance integral are discrepant.

→ A critical assessment of the evaluations is recommended.

4.b. U-236 capture, fast region: There are two discrepant groups of experimental data.

→ A critical analysis of the experiments (and perhaps a new experiment) are needed.

5. U-238 capture, keV region: Improvements of the data are required; it is recommended:

- → to determine more accurate average resonance parameters in the unresolved region,

- → to evaluate recent transmission function experiments in order to extend the resolved region up to 10keV, at least for large resonances (work in progress by Olsen at ORNL),

- → to remeasure and evaluate σ_{inel} for the first level.

6. (n,2n) cross-sections: New theoretical models have been developed and new experimental data (USSR) are available. Nevertheless further improvements are desirable.

   - → Evaluation methods require further development. The new USSR experiments must be considered in the evaluations.

   - → For the testing of nuclear models new measurements of (n,2n) and (n,3n) cross-sections from threshold up to 15MeV are requested, particularly for Pu-239 (because of its large fission competition).

   - → For Np-237 new experiments above 10MeV are recommended.

7.a. Np-237 subthreshold fission:

   - → The subthreshold fission cross-section below 10keV requires re-evaluation (for dosimetry of pressure vessel embrittlement).

7.b. Np-237(n,2n): Compare above under item 8. Furthermore,

   - → the energy dependence of the Np-237(n,2n)Np-236 isomeric branching ratio requires further investigation.

7.c. Np-237 capture, thermal: It should be noted that the only experimental data in the thermal and resolved energy range are σ_A data by Weston (around 1975) which were significantly adjusted in 1981 to be in agreement with the total cross-section measured at Saclay.

   - → Only evaluations based on the new higher value should be used (i.e. Derrien's evaluation or Weston's new evaluation, whereas JENDL-2 is based on the old superseded ENDF/B-5 value).

8.a. Pu-239 resonance region: There are several discrepancies which are difficult to analyse.

   There is a discrepancy between the total cross-section measured at Dubna and the earlier Saclay data. This discrepancy introduces an uncertainty of 2 barns in the potential scattering.

   There are inconsistencies over the broad resonances when the fission data are compared with the total data.

The neutron widths obtained at Dubna are 10 to 20% smaller than the old values from Saclay.

→ At least a new precision measurement of the transmission of a thick sample at a suitable energy point between resonances and at a point in the range of the broad resonances is recommended to resolve the discrepancies.

8.b. Pu-239 alpha, keV region: Experimental and evaluated data achieve 7% accuracy up to 30keV and 12-15% up to 1MeV.

→ For improvement of the accuracy new experiments will be useful only after developing new experimental techniques.

8.c. Pu-239 σ_f, fast region: Experimental data agree within 3-4%; evaluations agree within 5%. For obtaining better accuracies it is recommended

→ to develop new experimental techniques.

9.a. Pu-240, eV region: The scattering cross-section in the low eV region is based on only one measurement by Lounsbury, which obtained an unusually low value. It is essential to validate this value for the purpose of a realiable resonance analysis. The parameters of the 1eV resonance were recently determined by Chrien with high accuracy. Konshin found in his evaluation, that the combination of Lounsbury's scattering cross-section, Chrien's parameters for the first resonance, and the data of the higher resonances are inconsistent within 3-5% and cannot be reproduced in a consistent resonance analysis.

→ A re-investigation of the cross-sections in the neighbourhood of the first resonance is recommended.

9.b. Pu-240, subthreshold fission:

→ For the purpose of validating nuclear theory, the Pu-240 subthreshold fission cross-section requires further investigation.

9.c. Pu-240 capture, MeV range:

→ A critical assessment of the discrepancies encountered in evaluations is requested.

10.a. Pu-241 capture: In the fast energy region the Pu-241 capture data are based on only one experiment by Weston (1978).

→ New measurements are recommended.

10.b. Pu-241 fission:

→ In the fast region new measurements are recommended to obtain an accuracy of 3% for the ratio σ_f(Pu-241/σ_f(U-235).

10.c. Pu-241 resolved resonance: A simultaneous multilevel analysis of the total, fission and capture data, as requested at the IAEA Meeting on U and Pu resonance parameters, Vienna 1981, may still show discrepancies. Work is in progress at Minsk.

11.a. Am-241, Am-242m, Am-243 resonance integrals: There are unresolved discrepancies in the resonance integrals for capture and fission. The experimental values of the resonance integrals may be affected by impurities of other isotopes.

In the case of Am-243 capture the experiments agree (2200-2300 b) but all evaluations produce values between 1820 and 1850 b. [See NEANDC Discrepancy File 1983, p.72] This suggests that there is a systematic misinterpretation in either the experiments or the evaluations. No definite conclusion about this discrepancy could be reached in post-irradiation experiments.

→ Re-investigation of the resonance-integrals for capture (especially Am-243) and fission is recommended.

11.b. Am-243 capture: Evaluations above 200keV are discrepant due to lack of experimental data.

→ Evaluations (e.g. JENDL-2) must be re-assessed in view of new experimental data by Wisshak. An additional experiment at 1 or 1.5MeV would be suitable for resolving the discrepancies.

12. Additional statements on data of lower importance.

12.a. For Pu-242 no problem was reported. Differences in evaluations of σ_c may have to be assessed because of its importance for Cm production.

12.b. For Pu-238 the capture data are based on a single bomb shot experiment which may have an uncertainty of 30%. This uncertainty should be reduced. However, the build-up of Pu-238 appears to be more important than the Pu-238 cross-sections.

13. Reich-Moore parameters: For the isotopes of major importance evaluators consider Reich-Moore parameters as the best way of analysing and reproducing the cross-sections in the resonance region.

→ The methods of reprocessing Reich-Moore parameters (e.g. conversion to Adler-Adler parameters by the POLLA code) must be validated, and the evaluators must be informed about status and progress of computer codes.

14. Neutron data for actinides of low importance in fuel cycle analysis (e.g. higher curium isotopes). Existing evaluations are widely discrepant because too few or no experimental data exist.

Recommendations:

→ Measurements at one or two energies will be helpful to normalize the evaluations.

→ Careful measurements of thermal cross-sections and of resonance-integrals are encouraged.

→ For the improvement of theoretical models, experimental determination of average resonance parameters and level structure is requested.

→ It can be expected that nuclear systematics will improve the accuracy of σ_f in the range 0.6-20 MeV; investigations are encouraged.

REPORT OF THE WORKING GROUP ON THE STATUS AND NEEDS FOR NUCLEAR DECAY DATA OF TRANSACTINIUM NUCLIDES

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1. INTRODUCTION

This Working Group considered decay-data requirements for a wide range of applications. The primary objectives of the group were to re-define the requirements and to review the current status of the relevant transactinium-nuclide decay data. The results are given in Table I, which brings together specific features of Review Papers 7 and 8 given at the Third IAEA Advisory Group Meeting, Uppsala. This table is a detailed list of the various data requests, but may not cover all requirements for the many applications considered. These requests have been identified through a continuing process of discussions between data users and measurers. Communications between these two groups have been beneficial and important to the success of the Coordinated Research Programme (CRP). Such discussions between users and measurers must continue.

2. ACHIEVEMENTS OF THE CRP

The IAEA Coordinated Research Programme (CRP) on Transactinium-Nuclide Decay Data has been in existence since April 1978. This CRP will have accomplished many of its original aims by the end of 1984, and these achievements are summarized below.

Assessments have been made of the accuracy requirements defined by the decay-data users at the First and Second Advisory Group Meetings. These requests can be grouped into three categories:

(i) those satisfied by the available data,

(ii) those not satisfied by the existing data and considered to be achieveable with present experimental capabilities,

(iii) those not satisfied by the existing data, but beyond the measuring capabilities of present techniques.

The status of the existing data has been continually re-assessed in the light of the requirements, including up-dating of this status as new measurements became available.

Existing measurement facilities have been identified and work coordinated in order to acquire and evaluate the desired data. The current status of the data has been presented under three categories:

(i) data evaluated from measurements performed by, or in close contact with, members of the CRP and compared with measured and evaluated results from elsewhere,

(ii) data evaluated from new or existing data which have been obtained by other measurers and evaluators,

(iii) data of lower priority taken from various sources with little or no evaluation by members of the CRP and included for completeness.

A number of laboratories have been stimulated into developing the expertise necessary to carry out measurements to the required accuracies. It was found necessary to establish an agreed set of standard calibration data in order to provide a consistent and accurate basis for the measurement of gamma-ray emission probabilities. This objective has been accomplished as detailed in INDC(NDS)-145. Furthermore, through their familiarity with and access to several national decay-data files, CRP participants have been able to unify the transactinium-nuclide data from these sources and prepare a list of evaluated decay data that reflects the current status (for example, INDC(NDS)-149).

The IAEA CRP has been an effective means of achieving the goals outlined above. Measurements and evaluations undertaken under the auspices of the CRP have resulted in a substantial improvement in the quality of the transactinium nuclide decay data.

3. OUTSTANDING REQUIREMENTS

Although the situation has been improved considerably since the First and Second Advisory Group Meetings, several of the identified decay-data needs remain unsatisfied. Table I includes new requests and confirmatory data identified in Review Paper 7 presented at this meeting. Clear statements are made in the comments column of this Table identifying those requests which remain unsatisfied. In addition, the comments column contains statements questioning the high accuracies of some of the requests and identifies those that will be difficult to achieve.

TABLE I

TRANSACTINIUM ISOTOPE DECAY DATA: Requirements, Status and CRP Activities

The laboratories which are contributing to the IAEA Coordinated Research Programme for the Measurement and Evaluation of Transactinium Isotope Decay Data are referred to by their abbreviations: AEEW - UK Atomic Energy Establishment at Winfrith, AERE - UK Atomic Energy Research Establishment at Harwell, CBNM - CEC Central Bureau for Nuclear Measurements at Geel, Belgium, INEL - Idaho Nuclear National Engineering Laboratory, Idaho Falls, USA, JAERI - Japan Atomic Energy Research Institute, LMRI - French CEA Laboratoire de Metrologie des Rayonnements Ionisants, Saclay, France.

(a) Uncertainties for alpha, gamma and x-ray emission probabilities: the required and achieved accuracies apply to the major transitions only. The stated uncertainties are intended to correspond to 1σ confidence levels.

(b) The listed requirements represent those for the more prominent transitions from all the members of the decay chain of these nuclides.

(c) The beta-emission probabilities are inferred from the gamma-emission probabilities.

(d) P_x refers to L-x-ray emission probabilities.

(e) The label "+" refers to measurements or evaluations performed by laboratories that are not contributing directly to the IAEA Coordination Research Programme; the detailed origin of these data can be found in Table 2 of Review Paper 8 by C.W. Reich and R. Vaninbroukx in these proceedings.

		Accuracy (%)[a]			CRP Activities (e)		
Nuclide	Data Type	Required	Achieved	Needs	Measurements	Evaluations	Comments
Pb-214	$T_{1/2}$	not defined	unknown	Environmental studies (radon daughters)	-	-	Half-life values require confirmation as only one measurement reported without quoted accuracy.
Po-218	$T_{1/2}$	not defined	unknown		-	-	Requirements not satisfied
Th-228	$T_{1/2}$	1	0.1	Decay chain calculations (includes daughters)	-	-	
	P_γ	2(b)	1-2		CBNM, INEL	CBNM, LMRI	
Th-229	$T_{1/2}$	1	2	Mass determination in U-233 chain	-	-	CRP participants believe that the achieved accuracy of the half-life is adequate
	P_γ	2(b)	2		INEL, +	INEL	
Th-230	$T_{1/2}$	1	0.4	Marine dating	+	+	
Th-231 (U-235 daughter)	P_γ	not requested			AERE, CBNM, INEL	CBNM	
Th-232	$T_{1/2}$	not requested		Includes daughters	-	+	
	P_γ	not requested			+	-	
Th-233	$T_{1/2}$	1	0.5	Thorium cycle - decay heat	-	-	P_β and P_γ requirements are not satisfied.
	P_β	2	unknown		-	-	
	P_γ	2	20		AERE	-	AERE measurement of P_γ planned for 1985
Pa-231	$T_{1/2}$	1	0.3	Non-destructive assay	-	-	
	P_α	2	2-5		-	-	
	P_γ	2	1-10		AERE	AEEW	
Pa-233	$T_{1/2}$	1	0.4	Decay heat and mass determination	-	-	
	P_β	2	unknown		-	-	Requirement for P_β is not satisfied
	P_γ	2	1		AERE, CBNM, INEL	INEL	

Nuclide	Data Type	Accuracy (%)[a] Required	Accuracy (%)[a] Achieved	Needs	CRP Activities (e) Measurements	CRP Activities (e) Evaluations	Comments
U-232	$T_{1/2}$	1	1.4	Shielding calculations (includes daughters)	AERE,+	+	$T_{1/2}$ requires confirmation. AERE measurement is planned for 1985
	P_α	2	1		-	-	
	P_γ	2	1-2		AERE,CBNM, INEL,+	CBNM	
U-233	$T_{1/2}$	0.5	0.1		+	+	
	$T_{1/2}$(SF)	not requested		Thorium fuel cycle	+	-	
	P_α	2	1	and environmental	+	-	
	P_γ	2	1	studies	AERE,INEL	INEL	AERE measurement planned
	P_X(d)	5	unknown		-	-	for 1985. P_X requirement not satisfied
U-234	$T_{1/2}$	0.3	0.2		+	+	
	$T_{1/2}$(SF)	not requested		Mass determination	+	-	
	P_α	1	0.2	and non-destructive	CBNM	AEEW	
	P_γ	2	1-2	assay	CBNM,JAERI	AEEW	
U-235	$T_{1/2}$	0.5	0.1		-	+	
	$T_{1/2}$(SF)	not requested		Mass determination	+	-	The required accuracy of
	P_α	3	5-10	and non-destructive	-	-	3 % for P_α is unlikely
	P_γ	1	1	assay	AERE,CBNM, INEL,+	CBNM	to be achieved
U-236	$T_{1/2}$	1	0.2		-	+	
	$T_{1/2}$(SF)	not requested		Mass determination	+	-	
	P_α	3	5-10	and non-destructive	-	-	P_α and P_γ require-
	P_γ	3	5-10	assay	-	-	ments are not satisfied
U-237	P_γ	not requested			AERE,INEL	LMRI	AERE measurement of P_γ in progress
U-238	$T_{1/2}$	1	0.1	Mass determination	-	+	$T_{1/2}$(SF) accuracy not
	$T_{1/2}$(SF)	2	5	and non-destructive	+	+	achieved. Required
	P_α	3	5-20	assay; $T_{1/2}$(SF) for			accuracies for P_α,
	P_γ	3	15	geochronology; P_X	AERE,+	-	P_γ and P_X are un-
	P_X(d)	3	unknown	for environmental studies.			likely to be achieved. AERE measurement of P_γ planned for 1985
U-239	$T_{1/2}$	1	0.2		-	-	
	P_β	2	10-40	Decay heat	+	AEEW	P_β and P_γ require-
	P_γ	2	2-10		+	AEEW	ments are not satisfied
Np-235	P_X(d)	2	unknown	Environmental studies	-	-	P_X requirement not satisfied
Np-236	$T_{1/2}$	5	10		+	-	$T_{1/2}$, P_β and P_γ
	Branching Ratio	5	2	U-232 production	-	-	requirements not satisfied
	P_β	2	unknown		-	-	
	P_γ	2	unknown		-	-	
Np-236m	$T_{1/2}$	5	2		-	-	
	Branching Ratio	5	2	U-232 production	-	-	

Nuclide	Data Type	Accuracy (%)[a] Required	Achieved	Needs	CRP Activities (e) Measurement	Evaluation	Comments
Np-237	$T_{1/2}$	0.5	0.5		AERE/CBNM	-	Confirmatory measurement of $T_{1/2}$ is definitely required. New $T_{1/2}$ results are expected from AERE and CBNM in 1985. P_α, P_γ and P_x requirements are not satisfied. Measurement of P_α is planned by CBNM in 1985
	P_α	1	20	Environmental studies and mass determination	CBNM	-	
	P_γ	1	2-10		AERE,CBNM,+	INEL	
	P_x(d)	2	unknown				
Np-238	$T_{1/2}$	2	0.1	Activation analysis of Np-237 and Am-242m determination	-	-	
	P_γ	2	10		-	-	P_γ requirement is not satisfied
Np-239	$T_{1/2}$	1	0.3	Decay heat and detector calibration standard	-	-	
	P_β	2	(c)		-	-	
	P_γ	1	1		CBNM,+	CBNM	
Pu-236	$T_{1/2}$	1	0.3		-	-	P_α and P_γ requirements are not satisfied (results of recent AERE measurement to be communicated by A. Fudge).
	P_α	2	unknown	U-232 production	-	-	
	P_γ	3	unknown		-	-	
Pu-237	$T_{1/2}$	not requested			+	CBNM	
	P_x(d)	2	unknown	Environmental studies	-	-	P_x requirement is not satisfied
Pu-238	$T_{1/2}$	0.5	0.1		+	LMRI	
	$T_{1/2}$(SF)	2	3	Mass determination and non-destructive assay P_x for detector calibration	-	-	$T_{1/2}$(SF) requirement is not satisfied. LMRI measurement of P_γ planned for 1985
	P_α	1	0.1-0.2		CBNM,+	LMRI	
	P_γ	1	1		CBNM,INEL, LMRI	LMRI	
	P_x(d)	2	2-3		-	-	
Pu-239	$T_{1/2}$	0.5	0.1		AERE,CBNM,+	JAERI	
	P_α	1	0.3-2	Mass determination, non-destructive assay and environmental studies	+	JAERI	
	P_γ	1	1		INEL,LMRI,+	JAERI	
	P_x(d)	3	3		-	-	
Pu-240	$T_{1/2}$	0.5	0.1		+	CBNM/LMRI	
	$T_{1/2}$(SF)	2	4	Mass determination, non-destructive assay and environmental studies; $T_{1/2}$(SF)for waste management	CBNM	-	$T_{1/2}$(SF) requirement is not satisfied LMRI measurement planned for 1985
	P_α	1	0.1		+	LMRI	
	P_γ	1	1		INEL,LMRI	LMRI	
	P_x(d)	3	3		-	-	
Pu-241	$T_{1/2}$	0.5	1	Mass determination and non-destructive assay	AERE,CBNM,+	CBNM	$T_{1/2}$ requirement is not satisfied (measurements in progress)
	$T_{1/2}(\alpha)$	1	1		CBNM	CBNM	
	P_γ	1	1		INEL,+	LMRI	
Pu-242	$T_{1/2}$	1	0.5	Mass determination, non-destructive assay and environmental studies	+	-	
	$T_{1/2}$(SF)	5	1		-	-	
	P_α	5	4-6		-	-	
	P_γ	5	20		CBNM	-	P_γ and P_x requirements are not satisfied. P_γ measurement in progress at CBNM
	P_x(d)	3	unknown		-	-	

Nuclide	Data Type	Accuracy (%)[a] Required	Achieved	Needs	CRP Activities (e) Measurements	Evaluations	Comments
Pu-244	$T_{1/2}$	not requested			–	+	
Am-241	$T_{1/2}$	0.2	0.1	Non-destructive assay	–	–	
	P_α	not requested		and low energy gamma	+		
	P_γ	0.5–1	0.2–10	emission standard.	CBNM,LMR1	CBNM	CBNM measurement of P_γ
	P_x(d)	2	3	0.5 % accuracy request-	–	–	in progress. P_x
				ed for 59.5 keV gamma			requirement not satisfied
				emission probability			
Am-242	$T_{1/2}$	1	0.1	Cm-244 production and	–	–	
	Branching Ratio	1	1	Am mass determination	–	–	
Am-242m	$T_{1/2}$	1	1	Cm-244 production and	+	–	$T_{1/2}$ requires confir-
	Branching ratio	1	3	Am mass determination	–	–	matory measurement.
							P_x branching ratio
	P_x(d)	3	unknown		–	–	requirement not satisfied
Am-243	$T_{1/2}$	1	0.5	Mass determination,	+	–	
	P_α	1	unknown	long-term storage and	–	–	P_α, P_γ and P_x
	P_γ	1	2	environmental studies	CBNM,+	CBNM	requirements are not
	P_x(d)	2	unknown		–	–	satisfied
Cm-242	$T_{1/2}$	0.2	0.2		AERE,JAERI,+	JAERI	
	$T_{1/2}$(SF)	5	4	Non-destructive	JAERI,+	JAERI	JAERI measurement of
	P_γ	5	25	assay	–	–	$T_{1/2}$(SF) in progress.
							P_γ requirement is not
							satisfied.
Cm-243	$T_{1/2}$	1	1		–	–	
	P_α	5	2–10	Non-destructive assay	–	–	
	P_γ	5	3	and environmental	–	–	
	P_x(d)	5	unknown	studies	–	–	P_x requirement is not
							satisfied
Cm-244	$T_{1/2}$	1	1		–	–	
	$T_{1/2}$(SF)	3	0.2		–	–	
	P_α	3	2	Non-destructive assay	–	LMRI	
	P_γ	3	10	and environmental	–	–	P_γ requirement is not
	P_x(d)	3	3	studies		--	satisfied
Cm-245	$T_{1/2}$	1	1	Long-term storage and	+	–	
	P_α	5	5	environmental studies	–	–	
	P_γ	5	unknown		–	–	P_γ and P_x require-
	P_x(d)	5	unknown		–	–	ments are not satisfied
Cm-246	$T_{1/2}$	1	2	Long-term storage and	–	–	$T_{1/2}$, P_α, P_γ and
	P_α	3	5	environmental studies	–	–	P_x requirements are not
	P_γ	3	unknown		–	–	satisfied
	P_x(d)	3	unknown		–	–	
Cm-247	$T_{1/2}$	not requested			+	–	

Nuclide	Data Type	Accuracy (%)[a] Required	Achieved	Needs	CRP Activities (e) Measurements	Evaluations	Comments
Cm-248	$T_{1/2}$	2	1	Long-term storage and	-	-	
	P_α	3	unknown	environmental studies	-	-	P_α, P_γ and
	P_γ	3	unknown		-	-	P_x requirements are
	P_x(d)	3	unknown		-	-	not satisfied
Bk-249	$T_{1/2}$	not requested			+	-	
Cf-249	$T_{1/2}$	not requested			+	-	
Cf-250	$T_{1/2}$	0.2	1	Impurity in Cf-252	-	-	$T_{1/2}$ and $T_{1/2}$(SF)
	$T_{1/2}$(SF)	2	4	neutron standard	-	-	requirements are not satisfied
Cf-252	$T_{1/2}$	0.2	0.3	Neutron standard	LMRI	INEL	$T_{1/2}$ requirement is not
	$T_{1/2}$(SF)	1	0.5		-	-	satisfied; discrepancies exist among measured half-lives
Es-253	$T_{1/2}$	not requested			+	-	

Third IAEA Advisory Group Meeting on

Transactinium Isotope Nuclear Data

Uppsala University, Sweden, 21-25 May, 1984

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Appendix B

Papers Presented at the Third IAEA

Advisory Group Meeting on Transactinium Isotope

REVIEW PAPERS

R1 Testing of Evaluated Transactinium Isotope Neutron Data and Remaining Data Requirements. H. Küsters.

R2 Requirements and Status of Transactinium Isotope Nuclear Reaction Data. S. Igarasi and T. Nakagawa.

R3 Progress in Transactinium Isotope Neutron Data Measurements. J. Frehaut.

R4 Progress in Theoretical Calculation of Transactinium Isotope Nuclear Data. J. Salvy.

R5 Progress in Transactinium Isotope Neutron Data Evaluation. V. Konshin.

R6 The IAEA Nuclear Data Library for Actinides (INDL/A) and the Related Coordinated Research Programmes. H.D. Lemmel.

R7 Current Requirements for Heavy Element and Actinide Nuclear Decay Data. A.L. Nichols.

R8 Current Status of Nuclear Decay Data and Report on the IAEA Coordinated Research Programme on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data. C.W. Reich and R. Vaninbroukx.

CONTRIBUTED PAPERS

C1 Nuclear Data Needs for Requirements for Passive Neutron Assay. R. Arlt.

C2 The Measurement of $^{237}Np(n,2n)^{236}Np$(22.5 h) Reaction Cross Sections in the Neutron Energy Range 7. to 10. MeV. N.V. Kornilov, et al.

C3 ^{232}U Fission Cross Sections by Fast Neutrons. B.I. Fursov, B.F. Samylin and G.N. Smirenkin.

C4 The ^{236}U and ^{238}U to ^{235}U Fission Cross Sections Ratios in the Neutron Energy Range 5. to 11. MeV. A.A. Goverdevsky, et al.

C5 Status of Neutron Radiative Capture Data for ^{236}U and ^{237}Np. V.A. Tolstikov and V.N. Manokhin.

C6 On Uncertainties and Fluctuations of Averaged Neutron Cross Sections in Unresolved Resonance Energy Region for ^{235}U, ^{238}U and ^{239}Pu. A.A. Van'kov, A.I. Blokhin, V.N. Manokhin and I.V. Kravchenko.

C7 Activities of Transactinium Isotope Nuclear Data at the Chinese Nuclear Data Centre (CNDC). Zhang Huanqiao.

C8 Absolute Measurements of ^{235}U and ^{239}Pu Fission Cross Section Induced by 14.7 MeV Neutrons. Li Jingwen, et al.

C9 The Swedish Nuclear Data Committee Compilation of Experimental and Evaluated Data. H. Condé.

C10 Nuclear Data for ^{235}U, ^{238}U and ^{239}Pu in the Unresolved Resonance Region. N. Janeva.

C11 The (α,n) Neutron Yield and Energy Spectrum in Oxide Nuclear Fuels. V. Benzi.

C12 Total Gamma Ray Spectra and Isomeric Ratio Calculations in Thermal and Fast Neutron Capture for U-238, Pu-240 and Am-241. G. Reffo.

C13 Intercomparison of Different Evaluations in Various Formats for the Same Materials. A. Trkov, M. Budnar and A. Perdan.

C14 A Programme of Evaluation, Processing and Testing of Nuclear Data for Th-232. S. Ganesan, M.M. Ramanadhan, V. Gopolakrishnan and R.S. Keshavamurthy.

C15 Status of Pu-239 Cross Section Evaluation in the Resonance Region. H. Derrien, P. Long.

C16 Complete Evaluations of Neutron Nuclear Data for Cm Isotopes. G. Maino, E. Menapace and M. Vaccari.

C17 Investigation of Nuclear Characteristics of Transactinide Nuclei in the USSR. V. Vukolov.