International Atomic Energy Agency

INDC(NDS)-118/NE

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

Third Coordinated Research Meeting on the Measurement and Evaluation of Transactinium Isotope Nuclear Data

Vienna, 12-13 June 1980

SUMMARY REPORT

Prepared by A. Lorenz
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International Atomic Energy Agency

October 1980

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

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80 - 5462

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SUMMARY REPORT

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Abstract

Proceedings of the third meeting of the participants in the IAEA Coordinated Research Programme to measure and evaluate required nuclear decay data of transactinium isotopes, convened by the IAEA Nuclear Data Section on 12-13 June 1980, at IAEA Headquarters in Vienna.

The meeting participants reviewed the data requirements, updated and extended the recommended list of half-lives, and began a review of the status of alpha and gamma radiation spectra emitted in the decay of transactinium isotopes.

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I. SUMMARY OF THE MEETING

Introduction

The third meeting of the participants in the IAEA Coordinated Research Programme (CRP) on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data was convened by the IAEA Nuclear Data Section on 12-13 June 1980, at IAEA Headquarters, Vienna. The meeting was chaired by A. Lorenz, IAEA Nuclear Data Section.

The participants in this meeting are listed in Appendix 1.

Main Objectives

The principal objectives of this meeting were to review the status of measurements performed by the participants in this programme, to review and extend the list of proposed half-lives, and to continue the review of the status and accuracy of gamma-ray and alpha emission spectra for the transactinium isotopes.

The Adopted Agenda is given in Appendix 2.

Conclusions and Results of the Meeting

The meeting reviewed the existing and planned programmes for the measurement and evaluation of transactinium isotope nuclear decay data of each participating research group. In particular, the meeting

- reviewed the decay data requirements defined at the second IAEA meeting on transactinium isotope nuclear data (Cadarache, May 1979), and identified the data for which the accuracy requirements had not yet been met;
- updated and extended the list of proposed transactinium isotope half-lives published in INDC(NDS)-108/N (September 1979), and decided to release the new version of this list;
- continued the detailed review of the status and accuracies of the alpha and gamma radiation spectra ($E\alpha/I\alpha$ and $E\gamma/I\gamma$) emitted in the decay of transactinium isotopes.

Specific Actions which resulted from this meeting are listed in Appendix 3.

The participants of this CRP agreed on the date of their next meeting: it was proposed to be on 17-18 September 1981 in Vienna, directly preceding the scheduled meeting of the International Nuclear Data Committee.

II. MEETING PROGRAMME

A. Progress Reports

1. H. Umezawa (Japan/JAERI)

   Report: "Measurement of Nuclear Decay Data of ^{242}Cm". Progress Report to IAEA on the Research Agreement No. 2170/R1/CF. H. Umezawa. Included in this report as Appendix 4.

2. C.W. Reich (US/INEL)

   Report: "Report on the participation of U.S. Laboratories in the work of the IAEA Coordinated Research Programme on the Measurement of Transactinium Isotope Nuclear Decay Data". C.W. Reich. Included in this report as Appendix 5.

3. A.J. Fudge (UK/AERE Harwell)

   Report: "Report to the Coordinated Research Programme on Transactinium Isotope Nuclear Decay Data Committee". A.J. Fudge. Included in this report as Appendix 6.

4. A.L. Nichols (UK/AEE Winfrith)

   Report: "Heavy Element Decay Data: Progress Report for the IAEA Coordinated Research Programme on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data". A.L. Nichols. Included in this report as Appendix 7.

5. R. Vaninbroukx (CBNM/Geel)

   Report: "Status Report. J.R.C.-C.B.N.M. Participation in the IAEA Coordinated Research Programme on the Measurement and Evaluation of Transactinium Nuclear Decay Data". R. Vaninbroukx. Included in this report as Appendix 8.

6. G. Malet (LMRI/Saclay)

   Report: "Etude du spectre de l'^{241}Am. Mesure des energies et des intensites absolues des raies γ". L. Imbert, J. Morel. Available as Technical Note LMRI/79/61, from LMRI, Saclay.

   Report: "Etude du spectre du ^{239}Pu. Mesure des energies et des intensites absolues des raies γ". M. Despres, J. Morel, G. Malet. Available as Technical Note LMRI/79/63, from LMRI, Saclay.

7. V.M. Kulakov (USSR/Kurchatov Institute)

   Report: "Half-lives of ^{249}Bk, ^{249}Cf and ^{253}Es. Working Paper to the Third Research Coordination Meeting on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data". V.G. Polynkhov, G.A. Timofeev, B.I. Levakov, A.A. Elesin. Included in this report as Appendix 9.

In addition to the Progress Reports presented to the meeting, participants submitted the following reports which were used as background documents for discussions during the meeting:

1) "Some Observations on the Status of Nuclear Decay Data of Actinides" by R. Vaninbroukx. This report summarizes the status of the work done so far by this Coordinated Research Programme, and was presented at the Second Technical Meetings on the Nuclear Transmutation of Actinides, at Ispra, Italy, April 21-24, 1980. This report, CBNM/RN/11/80, can be obtained from the author.

2) "Needs and Problems in Alpha Particle Spectrometry", compiled by G. Bortels. This report summarizes the results of a questionnaire sent to forty-two laboratories in order to identify the needs and problems in α-spectrometry; the study was requested to be performed by the "α, β and γ-Ray Spectrometry Working Group" of the International Committee for Radionuclide Metrology (ICRM).

3) Two reports, presented by V.M. Kulakov, put forward a proposed explanation for differences in the results of the ^{241}Pu half-life measurements caused by the possible contributory effect of atomic electrons emitted from the $7S_{1/2}$ shell on beta decay. The extent of this contribution which depends on the chemical state of the β-decaying isotope is believed to have a significant effect on the measured β-decay half-life. The two reports on this topic:

   - "Comment of the Half-life of ^{241}Pu", by V.N. Tikhonov, F.E. Chukreev, and

   - "Beta-decay of Tritium in combined states and its effect on the accuracy of calorimetric measurements", by V.N. Tikhonov and F.E. Chukreev (released as a Kurchatov Institute preprint IAE-3102)

   will be translated and issued as INDC(CCP)-151/GE report.

4) The AERE-R 9631 report on "The non-existence of an Isomeric State in ^{241}Pu". This report has the following abstract:

   The existence of an isomeric state in ^{241}Pu has been suggested as an explanation for the large spread in measured values of the ^{241}Pu half-life. This possibility is considered by examining the decay data and the level scheme of ^{241}Pu. The decay data are found to be completely consistent with a single level decay and the lack of observation of any states which do not fit into the scheme of adopted bands can be taken as strong evidence against the existence of an isomeric state.

B. Review of Decay Data Requirements

The group reviewed the decay-data status and their required accuracies which had been compiled by the "Working Group on the Status and Needs for Nuclear Decay Data of Transactinium Isotopes" at the

second IAEA TND meeting at Cadarache, May 1979 (INDC(NDS)-106) in light of the measurements which had been performed since then. The results of this review are presented in Table I. The list of nuclides for which the accuracies of any of their decay data quantities had not been achieved as of May 1980, is given in Table II.

In considering the future measurement of transactinium isotope decay data by the individual members of this CRP, the participants agreed that the isotopes of uranium and plutonium should receive the highest priority.

C. Review of the recommended list of Half-lives

The group reviewed the "Proposed Recommended List of Transactinium Isotope Decay Data. Part I. Half-lives (September 1979 Edition)", published in INDC(NDS)-108/N, in the light of new measurements which have been completed since the May 1979 meeting, and decided to enlarge the initial 1979 half-lives list to include the "Heavy Element Decay Data Table" presented in Table I of the Summary Report of the May 1979 CRP meeting (INDC(NDS)-105) and an additional list of heavy element decay data taken from the UK Heavy Element Decay Data File compiled at the AEE Winfrith laboratory. The 1980 Edition of the "Proposed Recommended List of Transactinium Isotope Decay Data. Part I. Half-lives", which will incorporate the above indicated changes and additions, will be released in the Fall of 1980.

In reviewing the measurements which have been completed since the last meeting, the group made the following changes in the recommended list of half-lives:

1) Th-230 — Adopted the half-life value of $(7.54 \pm .03) \times 10^4$ y measured by Meadows et al. (Phys. Rev. C 22, 750 (1980) to replace the earlier recommended value of $(7.7 \pm 0.3) \times 10^4$ y, yielding an improved accuracy of 0.4 %. In addition to the new measurement by Meadows et al., the U/Th Workshop, held at USGS, Denver, Colorado, 19 August 1978, did not accept the previously adopted value of 7.7×10^4 y on the grounds that studies of world ocean sedimentation require a value of 7.5×10^4 y in order to remain consistent with established geochronological methods.

2) U -232 — Adopted a new half-life value of $(7.0 \pm 0.1) \times 10^1$ y on the basis of a new measurement by Aggarwal et al. at BARC, Trombay (Phys. Rev. C 20 (1979) 1533) of 69.9 ± 0.39 years. The choice of the lower Aggarwal value was supported by the fact that two higher values obtained by $2\pi\alpha$ counting were cancelled since it was shown that $2\pi\alpha$ counting, used for other nuclides (e.g. Pu 239), was shown to yield $T_{1/2}$ values that were too high.

3) Pu-240 — Adopted a new spontaneous fission half-life value of $(1.2 \pm 0.1) \times 10^{11}$ y on the basis of new measurement by Budtz-Jorgensen and Knitter (Proceedings of a Meeting on Nuclear Data of Pu and Am Isotopes for Reactor applications, R.E. Chrien Ed., Brookhaven 1979). The adoption of this value was also supported by a private communication transmitted from Dr. Sowerby (Harwell) at the 1980 Nuclear Transmutation of Actinides Meeting at Ispra, that the previously adopted value was too high.

4) Am-242m — Adopted the new total half-life value of $(1.41 \pm 0.02) \times 10^{2}$ y measured by A.G. Zelenkov et al. (Atomn. Energiya 47 (1979) 404), and the α-decay branching fraction as $(4.5 \pm 0.2) \times 10^{-3}$.

5) Cm-243 — Adopted the (Nuclear Data Sheets 19, No. 1 (1976) 128) half-life value of (28.5 ± 0.2)y.

6) Cm-245 — Adopted the (Nuclear Data Sheets 19, No. 1 (1976) 165) half-life value of $(8.5 \pm 0.1) \times 10^{3}$ y.

7) Es-253 — Adopted a new half-life value of (20.4 ± 0.1)d as a mean between the earlier proposed value of (20.47 ± 0.02)d and a newly measured USSR value of (20.29 ± 0.09)d at a 95 % confidence level (Private Communication at the May 1980 Meeting, see Appendix 9 of Summary Report).

Comment on the Pu-241 half-life

The group has taken note of a number of newly reported values for the half-life of Pu-241. These are almost exclusively lower than the value recommended by this group. The uncertainties claimed for these measurements are sufficiently small to indicate that these are not reconcilable with some of the previous measurements. No adequate reasons can be found for the rejection of any of the values published in the last ten years or for the discrepancies that exist.

This group recommends that no change be made this year to the presently listed value of (14.7 ± 0.4)y for this quantity. When the measurements recently completed and those in progress are published, it is hoped that a value with the required accuracy can be recommended.

D. Review of the Eα/Iα and Eγ/Iγ data

The CRP participants started a detailed review of the status and accuracies of the alpha and gamma radiation spectra, Eα/Iα and Eγ/Iγ, for the set of transactinium isotopes identified at the May 1979 TND Meeting at Cadarache. After the review of these data, the proposed list of these values will be published in an INDC(NDS) report in the same manner as the recommended half-life list.

In reviewing these data, the CRP members decided to use the Table of Isotopes (Seventh Edition), edited by C.M. Lederer and V.S. Shirley, as the primary source of both Eα/Iα and Eγ/Iγ data, replacing them where justified with values resulting from new measurements or adjusting them on the basis of proven values accepted by the user community.

In their consideration of the individual gamma-ray spectra, the CRP Participants made the following recommendation:

"In view of its importance as a standard, it is strongly recommended that the absolute gamma-ray intensity of the 59.5 keV gamma-ray of ^{241}Am be remeasured to an accuracy of at least 0.5 %".

Table I

Review of the Requirements and Status of Transactinium Isotope Decay Data Defined at the Second TND Meeting Cadarache, May 1979

Nuclides	Quantity	Required Accuracy	Achieved Accuracy	Comments
Th-228	$T_{1/2}$	1 %	0.1 %	Accuracy achieved
	$I\gamma$	2 % (a)	-	Accuracy achieved
Th-229	$T_{1/2}$	1 %	2 %	Required accuracy questionable
	$I\gamma$	2 % (a)	-	
Th-230	$T_{1/2}$	1 %	0.4 %	Adoption of 1980 measurement by Meadows et al. satisfies required accuracy: $T_{1/2} = (7.54 \pm .03) \times 10^4$y
Th-233	$T_{1/2}$	1 %	0.5 %	Accuracy achieved
	$I\beta$	2 %	Not assessable	Requirement not satisfied
	$I\gamma$	2 %	10-20 %	Requirement not satisfied
Pa-231	$T_{1/2}$	1 %	0.3 %	Accuracy achieved
	$I\alpha$	2 %	2-5 %	Work in progress
	$I\gamma$	2 %	5-10 %	Work in progress
Pa-233	$T_{1/2}$	0.5 %	0.4 %	Accuracy achieved
	$I\gamma$	0.5 %	1 %	Required accuracy questionable - see footnote (b) -
U -232	$T_{1/2}$	0.5 % (c)	1.4 %	Change in adopted value based on 1979 Aggarwal et al. measurement has not improved achieved accuracy
	$I\alpha$	2 %	1 %	Accuracy achieved
	$I\gamma$	2 %	5-10 %	Work in progress
U -233	$T_{1/2}$	0.5 %	0.13 %	Accuracy achieved (new measurements agree with recommended values)
	$I\alpha$	1 %	1 %	Accuracy achieved
	$I\gamma$	1 %	10 %	Work in progress
U -234	$T_{1/2}$	0.3 %	0.3 %	Accuracy achieved
	$I\alpha$	1 %	4 %	Requirement not satisfied
	$I\gamma$	2 %	10 %	Work in progress

Nuclides	Quantity	Required Accuracy	Achieved Accuracy	Comments
U -235	$T_{1/2}$	0.5 %	0.1 %	Accuracy achieved
	Iα	1 %	5-10 %	Work in progress
	Iγ	1 %	~10 %	Work in progress
U -236	$T_{1/2}$	0.5 %	0.2 %	Accuracy achieved
	Iα	3 %	5-10 %	Requirement not satisfied
	Iγ	1 %	5-10 %	Work in progress
U -238	$T_{1/2}$	0.5 %	0.1 %	Accuracy achieved
	$T_{1/2}$(SF)	2 %	1- 2 %	Accuracy achieved
	Iα	1 %	5-20 %	Requirement not satisfied
	Iγ	1 %	15 %	Work in progress (b)
U -239	$T_{1/2}$	1 %	0.2 %	Accuracy achieved
	Iβ	2 %	(d)	Requirement not satisfied
	Iγ	2 %	10 %	Requirement not satisfied
Np-236	$T_{1/2}$	5 %	10 %	Requirement not satisfied
	Branching fraction	5 %	2 %	Accuracy achieved
Np-236m	$T_{1/2}$	5 %	2 %	Accuracy achieved
	Branching fraction	5 %	2 %	Accuracy achieved
Np-237	$T_{1/2}$	0.5 %	0.5 %	Accuracy achieved
	Iα	1 %	20 %	Work in progress (b)
	Iγ	0.5 %	10 %	Work in progress (b)
Np-238	$T_{1/2}$	1 %	0.1 %	Accuracy achieved
	Iγ	2 %	10 %	Requirement not satisfied
Np-239	$T_{1/2}$	1 %	0.3 %	Accuracy achieved
	Iβ	2 %	(d)	Accuracy achieved
	Iγ	1 %	2 %	(b)
Pu-236	$T_{1/2}$	1 %	0.3 %	Accuracy achieved
	Iα	2 %	2 %	Accuracy achieved
	Iγ	2 %	30 %	Requirement not satisfied
Pu-238	$T_{1/2}$	0.5 %	0.1 %	Accuracy achieved
	SF Branching frac.	1 % (c)	3 %	Requirement not satisfied
	Iα	1 %	0.2 %	Accuracy achieved by new 1980 measurement by Ahmad (ANL)
	Iγ	1 %	2-5 %	Work in progress

Nuclides	Quantity	Required Accuracy	Achieved Accuracy	Comments
Pu-238 cont'd	L-x-rays	2 %	3 %	Requirement not satisfied
Pu-239	$T_{1/2}$	0.5 %	0.1 %	Accuracy achieved
	Iα	1 %	1-2 %	Requirement not satisfied
	Iγ	1 %	2-5 %	Work in progress
	L-x-rays	5 %	3 %	Accuracy achieved
Pu-240	$T_{1/2}$	0.5 %	0.3 %	Accuracy achieved
	SF Branching fraction	2 %	10 %	Change in adopted value based on new 1980 measurement at CBNM has not improved the accuracy
	Iα	1 %	3 %	Improved accuracy due to new measurements (ANL and Kurchatov) does not satisfy the requirement
	Iγ	1 %	2-5 %	Work in progress
	L-x-rays	5 %	3 %	Accuracy achieved
Pu-241	$T_{1/2}(\beta)$	0.5 %	3 %	Work in progress
	$T_{1/2}(\alpha)$	1 %	2 %	Requirement not satisfied
	Iγ	1 %	2-5 %	Requirement not satisfied
Pu-242	$T_{1/2}$	1 %	0.6 %	Accuracy achieved
	SF Branching fraction	1 % (c)	1 %	Accuracy achieved
	Iα	5 %	4-6 %	Accuracy achieved
	Iγ	5 %	10 %	Requirement not satisfied
Am-241	$T_{1/2}$	0.2 %	0.1 %	Accuracy achieved
	Iγ	1 %	2-3 %	Improved accuracy due to new measurement (LMRI) does not satisfy the requirement (b)
	L-x-rays	2 %	3 %	Difficult to achieve better than 3 % accuracy - requirement not satisfied
Am-242	$T_{1/2}$	1 %	0.1 %	Accuracy achieved
	Branching fraction	1 %	1 %	Accuracy achieved
Am-242m	$T_{1/2}$	1 %	1.4 %	Improved accuracy due to new measurement (Kurchatov) does not satisfy the requirement
	Branching fraction	2 %	4.4 %	Change in accuracy of new measurement (Kurchatov) does not satisfy the requirement

Nuclides	Quantity	Required Accuracy	Achieved Accuracy	Comments
Cm-243	$T_{1/2}$	1 %	0.7 %	Accuracy achieved
	Iα	2 %	2-10 %	Requirement not satisfied
	Iγ	1 %	5-10 %	Requirement not satisfied (b)
Cm-244	$T_{1/2}$	1 %	0.1 %	Accuracy achieved
	SF Branching fraction	3 %	0.2 %	Accuracy achieved
	Iγ	1 %	10 %	Requirement not satisfied (b)
	L-x-rays	5 %	3 %	Accuracy achieved
Cm-245	$T_{1/2}$	1 %	1 %	Accuracy achieved
	Iα	2 %	0.5-5 %	Poorly defined decay scheme. Requirements not satisfied
	Iγ	2 %	not assessable	
Cm-246	$T_{1/2}$	1 %	2 %	Requirement not satisfied
	Iα	2 %	1-5 %	Requirements not satisfied
	Iγ	2 %	not assessable	
Cf-252	$T_{1/2}$	0.2 %	0.4 %	Requirement not satisfied
	SF Branching fraction	1 %	0.3 %	Accuracy achieved

Footnotes

(a) Where nuclides have more than one transition associated with its decay the accuracies of the individual transitions differ depending to a large extent on their abundance. Accuracies of the more abundant transitions of some nuclides are claimed to be known to 0.1 % whereas the less abundant transitions for the same nuclide only to 5-10 %. It is suggested that a careful measurement of the gamma spectra of the decay chain, in secular equilibrium, headed by these nuclides would in some cases be more useful.

(b) It may be difficult to achieve required accuracy.

(c) WRENDA request. Accuracy requirement based on the request submitted to World Request List for Nuclear Data (WRENDA 79/80) published in INDC(SEC)-73 (October 1979).

(d) The beta intensities (Iβ) are inferred from the gamma intensities (Iγ) and hence generally have similar precisions.

Table II

List of Nuclides for which the required Accuracy of the data had not been achieved as of May 1980

Nuclide	$T_{1/2}$	Branching fraction	Iα	Iβ	Iγ	L-x-rays	Work in progress
Th-229	$T_{1/2}$	-	-	-	-	-	-
Th-233	-	-	-	Iβ	Iγ	-	-
Pa-231	-	-	* Iα	-	* Iγ	-	Harwell
U -232	$T_{1/2}$	-	-	-	* Iγ	-	Harwell
U -233	-	-	-	-	* Iγ	-	Harwell+INEL
U -234	-	-	Iα	-	* Iγ	-	Harwell
U -235	-	-	* Iα	-	* Iγ	-	Harwell+INEL
U -236	-	-	Iα	-	* Iγ	-	Harwell
U -238	-	-	Iα	-	* Iγ	-	Harwell
U -239	-	-	-	Iβ	Iγ	-	-
Np-236	$T_{1/2}$	-	-	-	-	-	-
Np-237	-	-	* Iα	-	* Iγ	-	Harwell
Np-238	-	-	-	-	Iγ	-	-
Np-239	-	-	-	-	Iγ	-	-
Pu-236	-	-	-	-	Iγ	-	-
Pu-238	-	SF BF	-	-	* Iγ	L-x-ray	LMRI
Pu-239	-	-	Iα	-	* Iγ	-	INEL, LMRI, Harwell
Pu-240	-	SF BF	Iα	-	* Iγ	-	INEL
Pu-241	* $T_{1/2}$	-	-	-	Iγ	-	Many Laboratories
Pu-242	-	-	-	-	Iγ	-	-
Am-241	-	-	-	-	Iγ	L-x-ray	-
Am-242m	$T_{1/2}$	BF	-	-	-	-	-
Am-243	-	-	Iα	-	Iγ	-	-
Cm-242	* $T_{1/2}$	SF BF	-	-	-	-	JAERI+Harwell
Cm-243	-	-	Iα	-	Iγ	-	-
Cm-244	-	-	-	-	Iγ	-	-
Cm-245	-	-	Iα	-	Iγ	-	-
Cm-246	$T_{1/2}$	-	Iα	-	Iγ	-	-
Cf-252	$T_{1/2}$	-	-	-	-	-	-

* Indicates which quantity is currently being measured.

Appendix 1

LIST OF PARTICIPANTS

Participants in the Coordinated Research Programme are indicated by an asterisk.

* Fudge, A.J.	Actinide Analysis Group Chemistry Division Building 220 AERE Harwell, Didcot OX11 ORA U.K.
Kulakov, V.M.	Institut Atomni Energii I.V. Kurchatova 46 Ulitsa Kurchatova Moscow D-182 U.S.S.R.
Lorenz, A. (project officer)	Nuclear Data Section IAEA, Vienna
* Malet, G.	Laboratoire de Metrologie des Rayonnements Ionisants CEN-Saclay B.P. No. 2 F-91190 Gif-sur-Yvette France
Nichols, A.L.	Technology Branch, Bldg. 08/A50 AEE Winfrith Dorchester, Dorset DT11 8DH U.K.
* Reich, C.W.	Idaho National Engineering Laboratory EG & G Idaho, Inc. P.O. Box 1625 Idaho Falls, Idaho 83415 U.S.A.
* Umezawa, H.	Division of Chemistry JAERI Tokai-Mura, Naka-Gun Ibaraki Ken 319-11 Japan
* Vaninbroukx, R.	Central Bureau for Nuclear Measurements Steenweg naar Retie B-2440 Geel Belgium

Appendix 2

Third Meeting of the CRP on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data

Vienna, Austria, 12-13 June 1980

Adopted Agenda

1. Introductory Items
2. Review of Actions from May 1979 meeting
3. Progress report and activities forecast from CRP members
4. Future of the CRP and final report
5. Decay data requirements
6. Relationship of this effort with the international nuclear structure and decay data (NSDD) programme
7. Consideration of the recommended lists of half-lives: changes and additions
8. Review of the proposed Tables of $E\alpha/I\alpha$ and $E\gamma/I\gamma$ data
9. Next meeting

Appendix 3

List of Actions

1. Malet	Send to IAEA/NDS for further distribution to the CRP group the paper by Ottmar on gamma-ray intensities used in interlaboratory comparison
2. Lorenz	Request from US/NNDC for distribution to the CRP group a retrieval from the ENSDF file of the transactinium isotope decay data
3. Reich	Inquire with N. Holden (US/NNDC) or M. Martin (US/NDP) how the mass-chain network plans to incorporate results from horizontal compilations into ENSDF
4. Kulakov	Send to IAEA for further distribution to the CRP group his report on ^{235}U (including the electron capture effect)
5. Vaninbroukx	Send to IAEA for distribution a note on the current status of the partial α-half-life of ^{241}Pu
6. Kulakov and Reich	Initiate a comparison of the recently measured results of the Iα of ^{240}Pu by Ahmad (ANL) and Baranov (Kurchatov Institute)
7. Lorenz	Inquire from the A. Cesana et al group in Milan, the status of their gamma-ray spectral measurements of transactinium isotopes and where and when they plan to publish their results. Distribute this information to the CRP group
8. Reich	Fill gaps in the γ-intensity data from INEL for ^{239}Pu and send the results to IAEA
9. Vaninbroukx	Inform the CRP group, through the IAEA, of the status of the 59.5-keV Iγ value in the ^{241}Am decay
10. All participants	Find out what value their standards laboratories are using as standard for the absolute intensity of the 59.5-keV ^{241}Am line
11. All participants	Communicate to IAEA results of new Iγ measurements which could be compared with existing values

Appendix 4

MEASUREMENT OF NUCLEAR DECAY DATA OF CURIUM-242

Progress Report to IAEA
on the Research Agreement No.2170/R1/CF

May 1980

H. Umezawa

Japan Atomic Energy Research Institute

Introduction

During the period of the Resaerch Agreement No.2170/R1/CF between IAEA and JAERI the decay measurement of alpha activity has been continued on the ^{242}Cm sources which were prepared in the first year of this programme[1]. Half-life of ^{242}Cm was obtained from the measurement results and is discussed in reference with other values reported[2-6].

In addition, quantitativity and efficiency of mica detectors have been examined to measure quantitatively spontaneous fission fragments by using some ^{242}Pu sources electroplated on platinum plates. It was found that the mica detector techniques enable one to determine the rate of spontaneous fissions occurred in such small sources of spontaneous fissioning isotopes within 2% uncertainty(2σ).

Measurement of Alpha Decay Half-life

Five sources of ^{242}Cm were measured with two independent sets of proportional counters which were the same window-less type, having 2π counting geometry. The intensity of alpha activity of each source was 1.56×10^4 cpm at first, so that correction for counter dead-time was negligible. For each source 10-min counting was repeated several times. The measurements were made every week in principle over a period from November 1978 to May 1980. Stability of the counters used was checked by measuring a reference source of ^{238}Pu at all times[1]. Although it was less than the order of 1%, the counting efficiency of those devices changed slightly from time to time. The deviations were corrected with reference to the counting data of the ^{238}Pu source; the correction factors adopted are set forth in Table 1.

Collaborators: S. Okazaki, S. Usuda, S. Ichikawa, T. Suzuki, H. Okashita

Contamination of ^{241}Am in the ^{242}Cm sources was examined by gamma-ray spectrometry with a Ge(Li) detector for low energy photon spectrometer (LEPS). In the same counting geometry, the 59.6-keV gamma-ray activity of the ^{242}Cm source was compared to that of a reference source of ^{241}Am prepared by LMRI. Contribution of the alpha activity of ^{241}Am to that of the ^{242}Cm source was estimated to be (1.4±0.1)cpm in the 2π proportional counters, that is the product of the activity ratio of the 59.6-keV gamma-ray of the ^{242}Cm to the reference ^{241}Am source and the alpha counting rate of the ^{241}Am source. The alpha activity due to ^{241}Am was thus determined to be 0.01% at early stage of the measurements and increased finally up to 0.1% in reference to the total alpha counts obtained from the ^{242}Cm sources. This provided a contant bias in the alpha counting rates measured that was subtracted as well as back-ground counts which were 0.3 to 0.4 cpm.

On the basis of the isotope abundance of americium used to extract curium in the present work, contents of the other americium isotopes in the ^{242}Cm sources were also calculated as shown in Table 2 from the content of ^{241}Am estimated above. The alpha activity due to ^{243}Am should be 1000 times less than that of ^{241}Am and contamination of ^{242m}Am would yield ^{242}Cm less than 0.005 cpm at the final stage of the decay measurements. Those have never affected the results of the alpha decay measurements of ^{242}Cm.

Correction was necessary for the growth of the long-lived alpha-active daughter, ^{238}Pu. For this purpose the half-lives of ^{242}Cm and ^{238}Pu were taken as 162.5 d and 87.71 y, and it was assumed that ^{238}Pu was completely removed by chemical separation made. The activity of ^{238}Pu amounted to less than 5%, even if it was calculated at the end of the measurements, that was confirmed in the alpha-ray spectra. Figures 1 and 2 show some of the spectra. The final results are not critically dependent on the assumptions taken to evaluate the correction terms.

The alpha counting data obtained were analyzed with a computer code FRANTIC-2 [7]. Table 3 shows values of the half-life of ^{242}Cm obtained from the analysis. Result of the present work is compared with other values appeared in literature as shown in Table 4. The present study provided a significantly short value than the other data reported. Possible contamination of some alpha-active nuclides of curium, americium and plutonium in the source of ^{242}Cm should, however, give longer half-life than the real data. In this case no reason could be found to make its apparent half-life short. Besides, a large number of the measurements was performed over a sufficiently long period with respect to the half-life of ^{242}Cm. It might put full confidence in the present results. Typical dacay data are plotted in Fig. 3.

Taking threefold value of the statistical external error given in Table 3, our best value of the half-life of ^{242}Cm is (161.2 ± 0.3) d.

Measurement of Spontaneous Fissions by Mica Detectors

Mica detector techniques were studied to determine spontaneous fission rate on the ^{242}Pu sources electrodeposited on platinum plates. The mica used was muscovite imported from India.

Etching procedures applied are as follows: (1) Immerse a piece of mica foil in concentrated hydrofluoric acid for a constant time, (2) wash it with water, (3) wash it with concentrated nitric acid, (4) wash it completely with water, (5) wash it with ethyl alcohol, and dried. Appropriate etching time was 3-5 h at room temperature, 20-25°C, to obtain easily distinguishable etch pits for fission fragment tracks.

In order to remove back-ground tracks, the mica detector was pre-treated with hydrofluoric acid for 3 days. the pretreatment makes the etch pits of back-ground tracks so large that those may be distingushed from normally etched tracks of fission fragments. In addition, the mica detector was quite insensitive to alpha particles.

Since the rate of spontaneous fission has been fairly well determined for ^{242}Pu [8], an appropriate amount of ^{242}Pu was electrodeposited in the spot of 6-mm diameter on a platinum plate. After measuring the alpha activity with the 2π proportional counter and the alpha spectrum with a silicon surface barrier detector, a mica detector was placed face-to-face contact with the plutonium source and put pressed between a pair of optically flat glass plates of 5-mm thick.

Track density was controlled by adjusting the amount of ^{242}Pu plated and the time to expose to the detector, being changed from about 2000 to 50000 tracks. In order to count all fission tracks, the mica detector etched was placed on a glass plate having fine rectangle mesh lines and sequential photographs were taken in a microscope of x75 and x150 magnifications. Photocopies of 60 to 70 were needed to cover all area exposed to fission fragments from the 6-mm diameter source in the microscope of x75 magnifications.

Results obtained from the presemt experiments are summarized in Table 5. As also shown in Fig. 4 constant detection efficiency was obtained as the tracks did not largely exceed 10^4 per each measurement. The rate of fission occurred during its exposure time could be detected with efficiency $96.3 \pm 2.0 (2\sigma$ value) %. The efficiency decreased rapidly as the number of tracks exceeded 10^4, that would partly ascribed to missing to count unresolved etch pits and to attenuation in the source material layer, too. It seems to be, however, that the mica detector may be applicable to determine quantitatively the rate of spontaneous fissions with 2% precision, provided that the track density be chosen adequately. It was also found that higher detection efficiency could be achieved when the photographs were taken of x150 magnifications. This improvement is due to better resolution of the pits images obtained though fourfold photocopies are required.

Future Work Plan

Fresh sources of ^{242}Cm will be prepared and subjected to the measurement of the ratio of spontaneous fissions to alpha decays.

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Table 1. Correction factors for counting efficieny of alpha counters determined from measurements of a reference source of ^{238}Pu whose half-life was taken as 87.71 y.

Counter A		Counter B	
Period*	Correction factor	Period*	Correction factor
6- 28	0.99436		
29- 64	0.99637		
65-160	0.99882	94-105	0.99813
		106-144	0.99316
161-178	1.00281	145-214	0.99758
179-279	0.99951	215-223	1.00006
		224-228	0.98904
		229-242	0.98488
		243-270	1.00041
280-292	1.00228	271-333	0.99731
293-336	0.99883		
337-342	1.00102	334-362	0.99923
343-356	0.99791		
357-420	1.00278	363-420	1.00421
421-460	1.00147	421-460	1.00063
461-547	1.00291	461-547	1.00296

* Given in days.

Table 2. Purity of the ^{242}Cm sources used.

Nuclide	Alpha activity (cpm)	Relative atomic abundance
^{242}Cm	15600*	1
^{241}Am	1.4	0.09
^{242m}Am	-	0.00014
^{243}Am	0.0015	0.0017

*: Initial value.

Table 3. Results of the half-life measurements of ^{242}Cm.

Source No.	Counter A		Counter B	
	n_A*	Halh-life (d)	n_A*	Half-life (d)
1	91	160.74 ± 0.11	62	161.13 ± 0.17
2	94	160.91 ± 0.10	64	161.34 ± 0.16
3	92	161.70 ± 0.11	63	161.33 ± 0.16
4	92	161.00 ± 0.14	64	161.32 ± 0.16
5	109	161.47 ± 0.08	61	160.88 ± 0.17
Mean		161.16 ± 0.18#		161.20 ± 0.09#
Overall mean ^{242}Cm half-life		161.18 ± 0.10#		

*: Number of measurements made.

#: Statistical external error of mean: $\varepsilon = \sqrt{\frac{\Sigma(x-\bar{x})}{n(n-1)}}$

Table 4. Comparison of ^{242}Cm half-life measurements.

Reference	Half-life* (d)	Number of samples	Period of decay followed (d)	Number of measurements	Method applied
[2]	162.76 ± 0.04	5	262	3	Alpha counting
[3]	162.46 ± 0.14	?	210	14	Alpha counting
[4]	163.2 ± 0.3	2	287	34-35	Calorimetry
[9]	163.0 ± 1.8	1	365	?	Calorimetry
[5]	163.1# ± 0.4	?	1187	?	Alpha counting
[6]	162.5 ± 2	3	130-365	2-4	Alpha counting
This work	161.18 ± 0.10	5	540	61-190	Alpha counting

*: Errors were reduced to 1σ as taken in Ref. [2].

?: Not described.

#: Originally reported to be 164.4 d and recalculated by Diamond et al. in Ref. [2].

Table 5. Measurements of spontaneous fissions of 6-mmϕ ^{242}Pu sources with mica detector.

Run	α-Activity (cpm)	Exposure time (d)	Number of fissions expected	Fission tracks detected in x75 magnification	Detection probability (%)	Fission tracks detected in x150 magnification	Detection probability (%)
A-11	160,114	2.980	6,200	6,063	97.79		
A-12	159,264	6.001	12,419	11,583	93.27		
A-4	167,355	9.771	21,250	18,514	87.13		
A-1	176,739	14.667	33,686	29,059	86.27		
A-13	72,719	11.713	11,068	9,969	90.07		
A-8	72,564	55.779	52,599	37,148	70.63	44,262	84.15
A-6	47,590	65.722	40,645	32,111	79.00		
A-3	13,230	10.708	1,841	1,773	96.31		
A-2	13,710	10.708	1,908	1,841	96.50		
A-21	13,828	34.042	6,117	5,791	94.67		
A-5	13,048	50.960	8,641	8,303	96.09		
A-20	22,754	32.698	9,668	9,299	96.18	9,590	99.19
A-14	47,590	17.708	10,952	10,498	95.85	10,955	100.03

Fig. 1. Alpha-ray spectrum of the ^{242}Cm source No.2 on 15 November 1978.

Fig. 2. Alpha-ray spectrum of the ^{242}Cm source No.2 on 4 June 1980.

Fig. 3. Decay curve of the ^{242}Cm source No.5.

Fig. 4. Detection probability of fissions with mica detectors against number of fissions expected in ^{242}Pu sources.

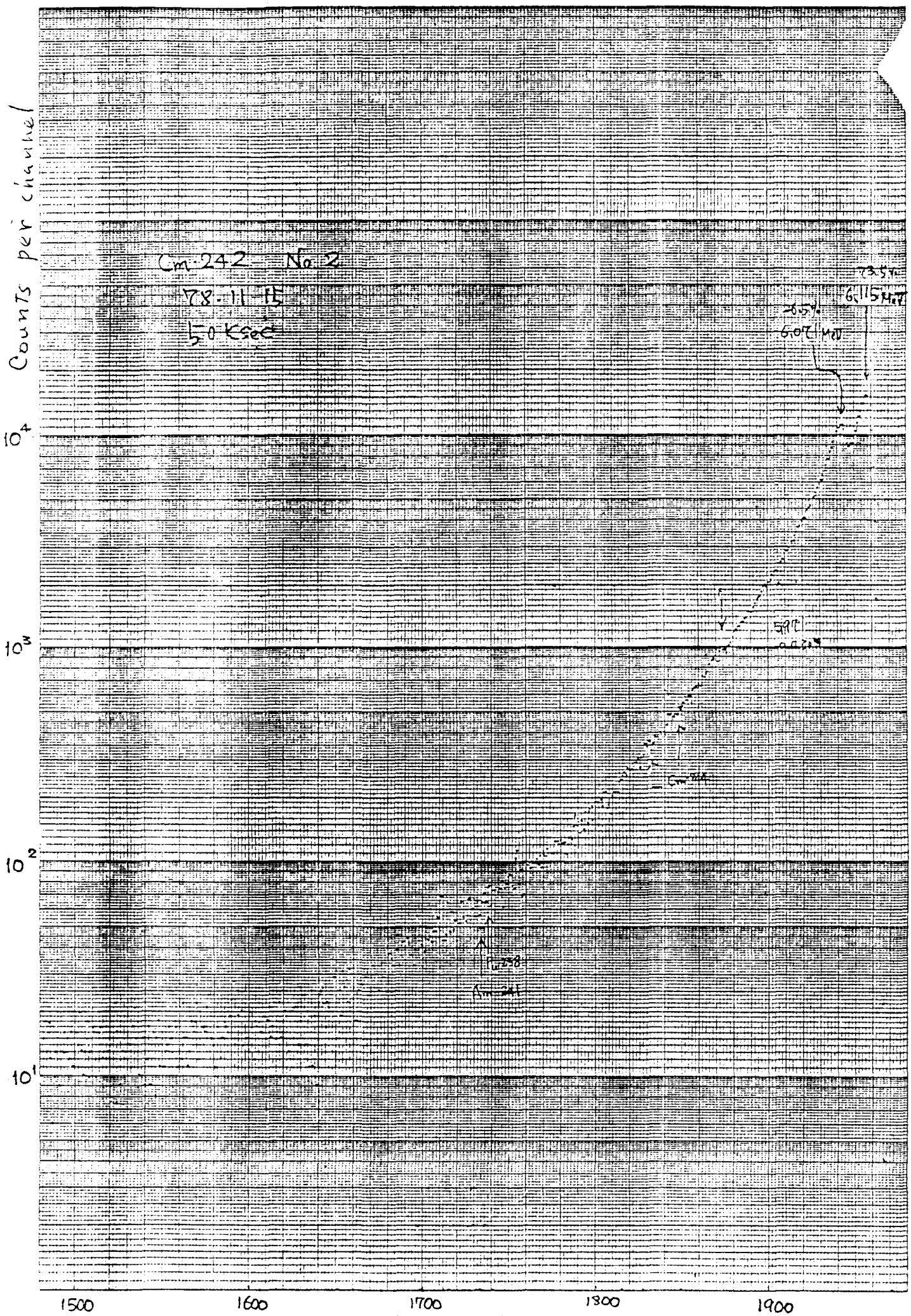

Cm-242 No 2
78-11-15
½ 0 Kscc
73.5%
6.115 MeV
26.5%
6.07 MeV
59.6
Cm-244
Cm-242
Cm-241
Counts per channel
10⁴
10³
10²
10¹
1500
1600
1700
1800
1900
Cannel number

Fig. 1

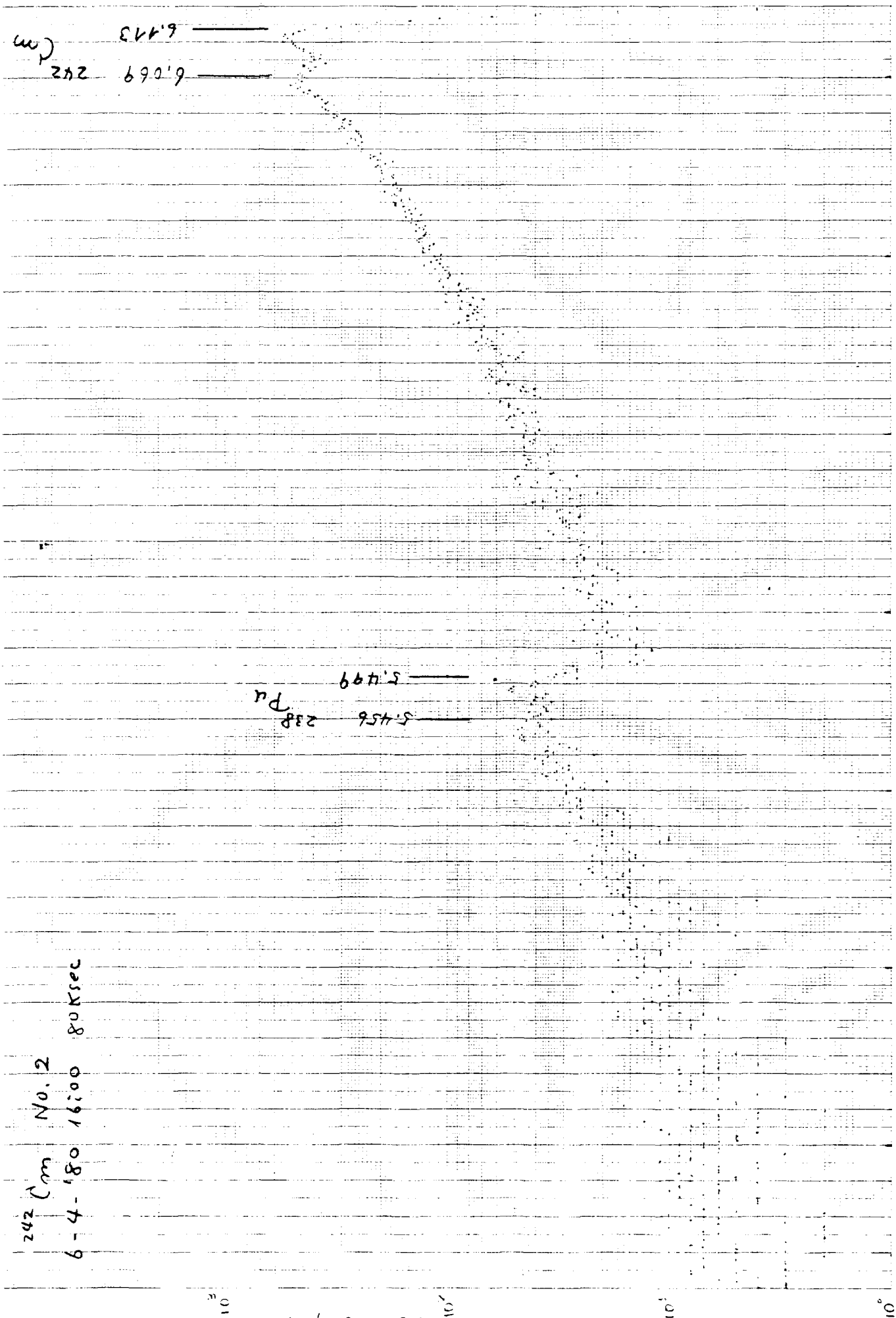

242Cm No. 2
6-4-'80 16:00 80Krsec
Counts per channel
Channel number
6.069 242Cm
6.113
5.456 238Pu
5.499

Fig. 2

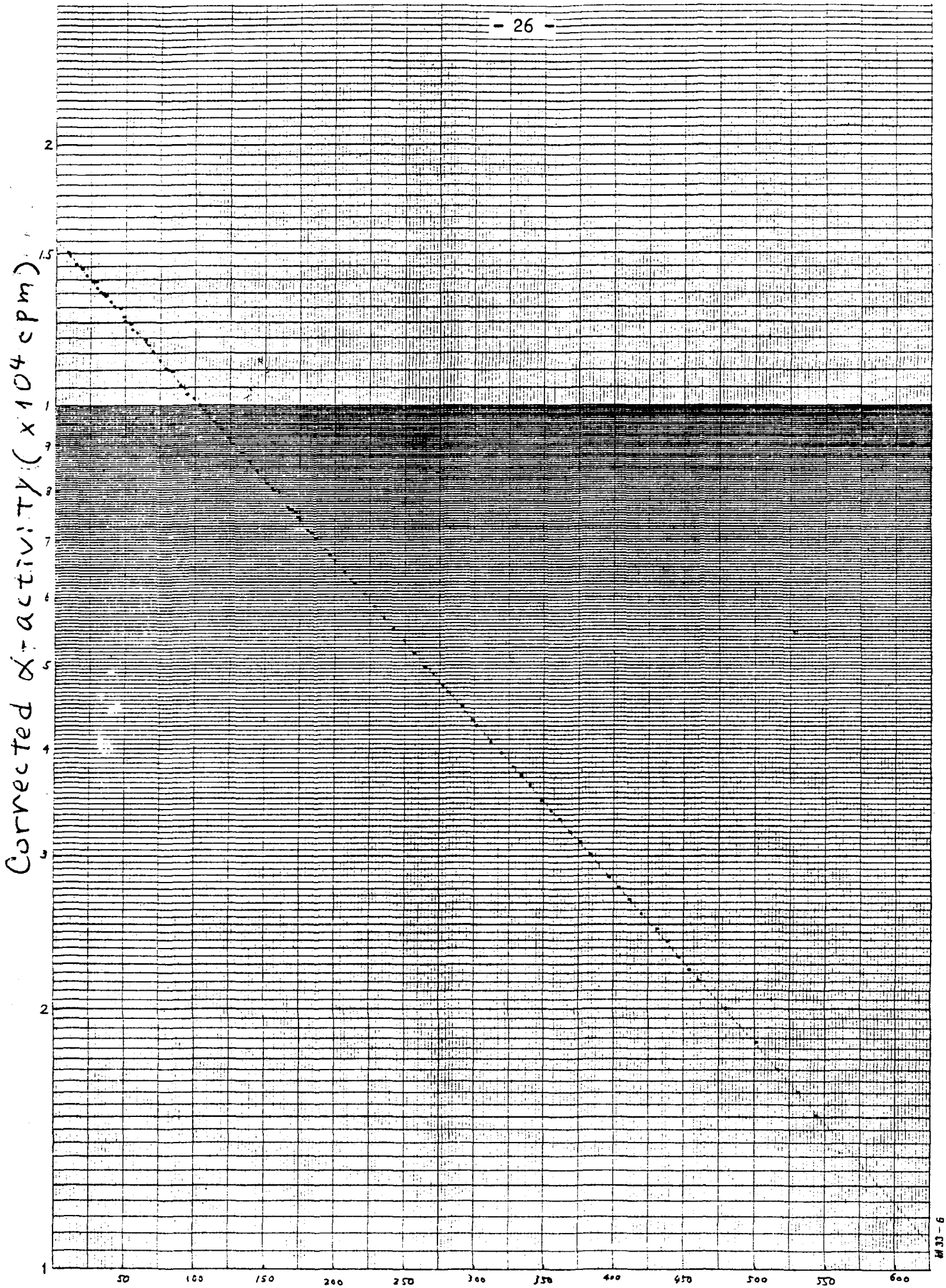
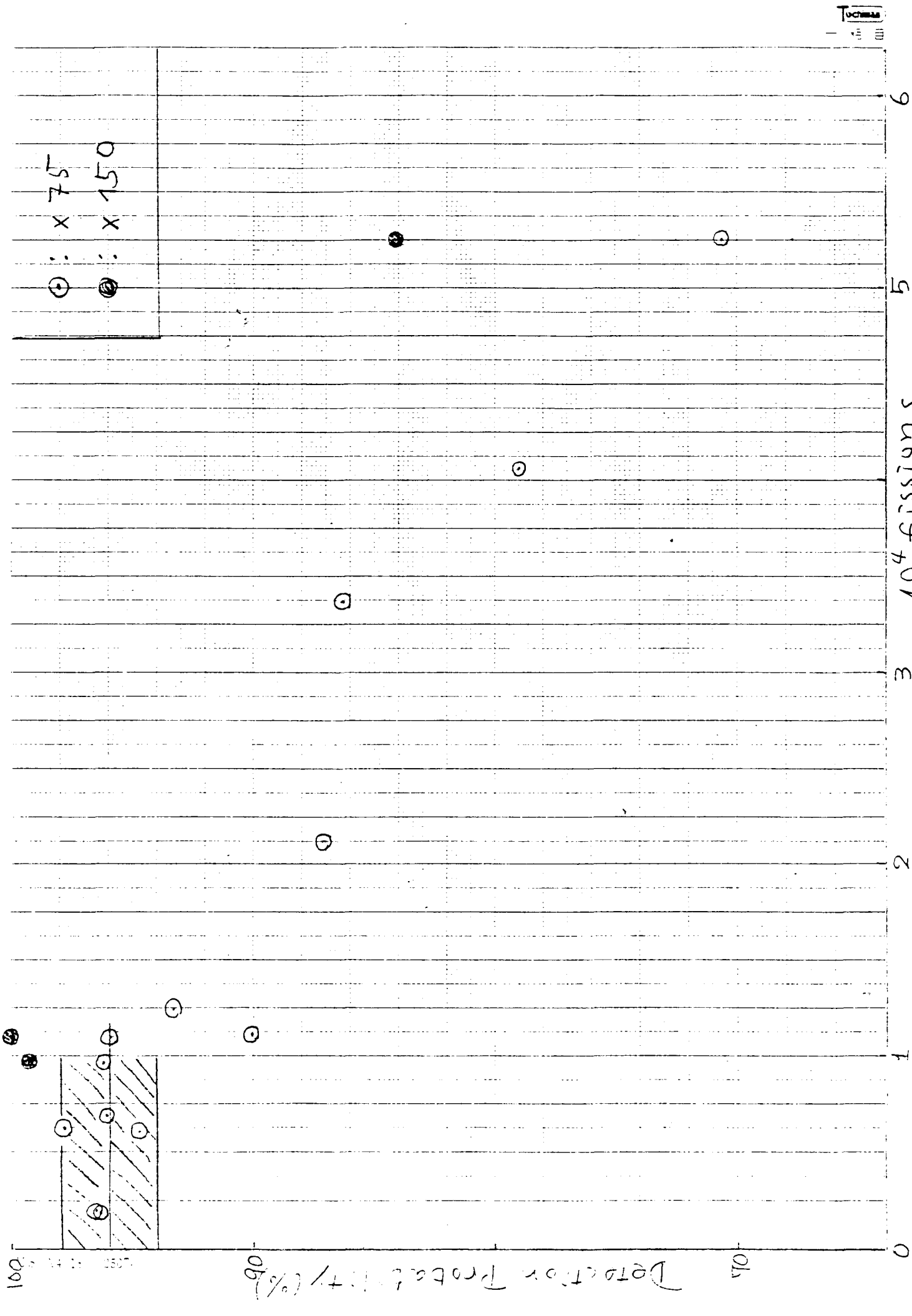

Corrected α-activity (x 10⁴ cpm)
2
1.5
1
9
8
7
6
5
4
3
2
1
50
100
150
200
250
300
350
400
450
500
550
600
Time in days from separation time of ²⁴²Cm
#133-6

Fig. 3


x 75
x 150
0
1
2
3
5
6
10^4 fissions

Appendix 5

Report on the participation of U.S. laboratories in the work of the IAEA Coordinated Research Program on the Measurement of Transactinium Isotope Nuclear Decay Data.

Presented at the Third Meeting of
the Participants in the IAEA CRP

Vienna, June 12-13, 1980

C. W. Reich

Emission Probabilities of Selected γ rays from The Decay of ^{239}Pu and ^{240}Pu; Preliminary Results

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Samples of high purity ^{239}Pu and ^{240}Pu have been used to determine the emission probabilities (absolute intensities) of the stronger γ rays emitted in the decay of these two nuclides. The characteristics of these samples, as quoted by the suppliers, are indicated in Table I. The γ-ray emission probabilities were determined from separate experiments, one of which involved measurement of the α-emission rate per unit of sample mass and the other of which involved determination of the γ-emission rate. To conform with the objectives of the IAEA Coordinated Research Program on the Measurement of Transactinium Isotope Nuclear Decay Data, it is desired that the resultant emission probabilities be determined with accuracies $\leq$1%.

Although the information concerning the content of the original samples indicated that they should be sufficiently pure for the purposes of these investigations, chemical purifications were carried out prior to the beginning of the present measurements. In addition to removing any impurities, this step removed any daughter activities that might have been present. The α-emission-rate measurements were made at the National Bureau of Standards (NBS). The sample preparation for these measurements was carried out as follows. After the chemical purification, a sample was dissolved in an HCl solution. From this solution, known amounts (weighed aliquots) were dispensed onto source holders for γ-ray counting or into vials for shipment to NBS. Dilutions were made as needed to obtain the desired amount of activity in a volume that was large enough to be weighed accurately, but also small enough to be used for a source. The material in the vials was also diluted to the volume desired by NBS. The solution used for γ-ray

counting was dispensed into thin ($\sim$6.7 mg/cm^2) glass-fiber filters in order to contain the liquid while it was drying. These sources were sealed with cellulose tape between layers of KAPTON film in the same configuration as the efficiency-calibration sources (used as described below). The resulting source characteristics are given in Table II. Typical uncertainties in the sample weights are of the order of 0.1%.

The α-calibration was done at NBS by liquid-scintillation counting and by counting with a known geometry counter. The preliminary results are presently quoted with uncertainties of 0.2% for ^{239}Pu and 0.3% for ^{240}Pu. (All uncertainties quoted in this summary are at the 1σ, or 68%, confidence level.)

Two γ-ray detectors were used in these studies. A major fraction of the effort thus far has been to provide highly accurate efficiency calibrations for these detectors. One detector was a 10%, closed-ended coaxial Ge(Li) detector, and the other was a smaller intrinsic Ge planar detector. The coaxial detector has a relatively thick window and is usable only down to $\sim$50 keV, while the planar is useful down to $\sim$15 keV. The sources used for the efficiency calibrations were obtained from the U. S. National Bureau of Standard (NBS), from the Physikalisch-Technische Bundesanstalt (PTB) of the Federal Republic of Germany or, in two cases, from our own 4π β-γ coincidence measurements. The characteristics of these sources are noted in Table III. In our efficiency-calibration measurements, corrections were made for the effects of random and coincidence summing. The γ-ray peak areas were determined by fitting with a Gaussian function, while the spectral background was represented by a step-like function. (The peak areas for the data from one detector were also obtained from a summation method, but this information is not included here.) A preliminary evaluation of the uncertainties associated with the resulting efficiency curves has been made. For the coaxial detector, these uncertainties are 2% from 50 to 100 keV, 1% from 100 to 400 keV and 0.67% from 400 to 1500 keV. Values of comparable precision have been obtained for the planar detector.

For each Pu isotope, three γ sources were counted, although the third ^{240}Pu source was too weak to give statistically useful data. The

results of these measurements are given in Table IV. For the coaxial detector data, the ratio of the γ-emission rates from the various sources are quite consistent with the relative sample weights while those from the planar detector show some ($\sim$1%) inconsistency. These results include corrections (some preliminary) for the finite source size, γ-ray self-absorption in the source, random summing and coincidence summing. The magnitude of these corrections and the uncertainties assigned to them are indicated in Table V.

At present, it is assumed that the measurements made in this study are sufficiently precise for the purposes of the CRP, and we have no plans at present for repeating them. However, some measurements and analyses related to the various corrections need to be carried out. These are of the following nature: (1) the corrections ($\sim$0.6%) for the finite source diameter represent calculated values, and these need to be verified by experimental measurement; (2) the planar detector detects the L x-rays from these samples with a high efficiency. The effects of detecting these radiations have not yet been included in the coincidence-summing corrections; (3) it is currently believed that the inconsistencies in the results from the planar detector are due to the failure of our random-summing correction method to account properly for these same low-energy radiations. The coaxial detector results are not affected by this, since these radiations do not reach the sensitive volume of the detector. An experiment to verify this and to determine the necessary corrections has been initiated; (4) the certified α-emission rates from NBS are not yet available and must be incorporated into the final γ-emission probabilities; (5) an independent check will be made of the ratio of the α-emission rates for ^{238}Pu and ^{240}Pu in the ^{240}Pu sample.

Table I

Sample Characteristics

Sample	Weight (g)	Mass Analysis Isotope	Mass Analysis %	Alpha Analysis[a] %
^{239}Pu	0.050	^{238}Pu	<0.000 12	<0.03
		^{239}Pu	99.998 5	99.995
		^{240}Pu	0.001 26	0.004 7
		^{241}Pu	0.000 09	β^- decay
		^{242}Pu	0.000 14	0.000 009
		^{244}Pu	<0.000 2	<0.000 001
^{240}Pu	0.049	^{238}Pu	0.014	1.0
		^{239}Pu	0.023	-
		^{240}Pu	99.930	99.0
		^{241}Pu	0.003	-
		^{242}Pu	0.029	-
		^{244}Pu	0.001	-
		non-Pu	activities	<0.03

[a]The values for ^{240}Pu were measured by the supplier; those for ^{239}Pu were calculated including only the first member of any decay chain (i.e., for a freshly purified sample).

Table II

Source Characteristics

Sample	Source[c]	Solution mass (mg)	Dilution factors	Total source weight (g)	Total source activity (d/s)
^{239}Pu	γ-1	253.99(14)	-		
	γ-2	146.66(14)	-		
	γ-3	260.98(13)	3.3619(21)[a]		
	v-2	125.13(14)	3.3619(21)[a]	3.3	1.4×10^6
			26.560 (33)[b]		
^{240}Pu	γ-1	312.99(16)	-		
	γ-2	228.70(14)	4.5545(29)[a]		
	γ-3	276.45(14)	4.5545(29)[a]		
			18.837 (13)[b]		
	v-2	420.63(21)	4.5545(29)[a]	3.3	2.3×10^5
			18.837 (13)[a]		
			7.8118(52)[b]		

[a]Dilution occurred before mass determination.

[b]Dilution occurred after mass determination.

[c]The "v" indicates a vial of solution that was shipped to NBS; the other sources are for γ counting.

Table III

Efficiency Calibration Source Characteristics

Isotope	Supplier	$T_{1/2}$(d)	Dis./sec·10^3 at calibration	Age at use (d)	Photon energy (keV)	γ emission probability	Uncertainty in efficiency (%)
^{241}Am	NBS	1.5786(7)x10^5	354.3 (16)	3659	13.9	0.0086	2.6
					17.8	0.132	3.4
					20.8	0.1925	4.3
					26.35	0.0485	4.3
					59.5	0.359	1.2
^{109}Cd	NBS	464(4)	39.4 (4)[a]	581	22.10	22.0 [a]	4.1
					25.02	4.68 [a]	2.9
					88.03	1.000 [a]	1.4
^{57}Co	NBS[b]	272.4(2)	651.4 (21)	581	14.41	0.0909	1.2
					122.06	0.8559	0.49
					136.47	0.1061	1.8
^{139}Ce	NBS[b]	137.1(1)	165.3 (5)	583	33.31		2.4
					38.0		1.16
					165.86	0.7994	0.43
^{113}Sn	NBS	115.2(2)	431 (4)[a]	581	24.14	1.22 [a]	2.1
					27.37	0.267 [a]	2.1
					391.70	1.000 [a]	1.23
^{198}Au	c	2.6956(5)	92.40 (17)	0.2	70.1		1.3
					80.7		1.6
					411.80	0.9552	0.26
^{137}Cs	NBS[b]	10,895(80)	314.0 (17)	168	32.07		2.8
					36.6		1.8
					661.66	0.847	0.64

Table III (continued)

Isotope	Supplier	$T_{1/2}$(d)	Dis./sec·10^3 at calibration	Age at use (d)	Photon energy (keV)	γ emission probability	Uncertainty in efficiency (%)
^{94}Nb	NBS	7.3x10^6	5.153(26)	3623	702.64	0.998	0.54
					871.12	0.999	0.55
^{88}Y	NBS[b]	106.66(5)	240.5 (19)	581	898.04	0.950	1.00
					1836.06	0.9935	0.94
^{60}Co	NBS	1925.2(7)	138.3 (7)	581	1173.24	0.9990	0.49
					1332.50	0.99982	0.49
^{24}Na	c	0.62329(4)	43.16 (8)	0.3	1368.63	0.99993	0.18
					2754.03	0.99873	0.18
^{133}Ba	PTB[d]	3921(17)	6.693(33)	303	81.00[e]	0.374 [e]	2.6
					275.41	0.0710	1.5
					302.86	0.1833	1.3
					356.01	0.623	1.2
					383.86	0.0892	1.3
^{85}Sr	PTB[d]	64.85(5)	40.80 (20)	303	514.01	0.993	0.70
^{54}Mn	PTB[d]	312.3(3)	19.42 (10)	303	834.84	0.9998	0.52
^{65}Zn	PTB[d]	244.0(2)	33.71 (17)	303	1115.55	0.504	0.80
^{182}Ta	PTB	114.41(2)	481 (3)	365	31.74	0.892	2.5
					42.71	0.266	3.3
					58.7	0.280	2.0
					67.7	0.571	2.2
					84.68	0.0263	3.9
					100.11	0.1423	3.0
					113.67	0.0187	3.3
					116.42	0.00445	3.5
					152.43	0.0695	1.5

Table III (continued)

Isotope	Supplier	$T_{1/2}$(d)	Dis./sec·10^3 at calibration	Age at use (d)	Photon energy (keV)	γ emission probability	Uncertainty in efficiency (%)
					156.39	0.0263	2.0
					179.39	0.0309	1.5
					198.35	0.0144	1.5
					222.11	0.0750	1.5
					229.32	0.0364	1.5
					264.08	0.0362	1.8
					1121.30	0.3530	1.17
					1189.05	0.1644	1.18
					1221.41	0.2717	1.18
					1231.02	0.1158	1.24
^{152}Eu	PTB[f]	4857(36)	278.6 (8)	1159	39.9	0.59	2.2
	NBS				121.78	0.2837	1.06
					244.70	0.0751	0.93
					344.28	0.2658	0.84
					411.12	0.02234	0.76
					443.99	0.03121	0.76
					778.92	0.1296	0.73
					867.39	0.0423	1.13
					964.03	0.1462	0.66
					1085.91	0.1016	0.67
					1112.12	0.1356	0.66
					1299.12	0.01626	1.19
					1408.01	0.2085	0.66

[a]Calibration is in terms of the γ-emission rate.

[b]This isotope also occurs in the PTB mixed standard.

[c]Calibration done in our laboratory by 4π β-γ coincidence method.

[d]This isotope is part of PTB mixed standard.

[e]Sum of two γ-ray lines.

[f]Sources from both NBS and PTB were used. The specific values given are for the PTB source.

Table IV

Preliminary γ-ray Emission Probability Data for ^{239}Pu and ^{240}Pu

Isotope	E_γ(keV)	$\gamma/10^5$ decays[a] coaxial detector	$\gamma/10^5$ decays[a] planar detector
^{239}Pu	51.6	26.8 (5)	27.2 (5)
	129.3	6.36 (6)	6.33 (6)
	332.8	0.487(6)	0.490(6)
	375.0	1.537(17)	1.536(14)
	413.7	1.454(11)	1.436(13)
^{240}Pu	45.2	46.1 (?)[b]	42.8 (8)
	104.2	7.18 (7)	7.09 (7)
	160.4	0.407(4)	0.398(5)

[a]Uncertainties in the α emission-rate calibrations are not yet included in these values.

[b]Large uncertainty in efficiency due to absorption in front face of detector

Table V

Corrections for γ-Ray Counting

Effect	Magnitude of correction (%)	Associated uncertianty	Comments
Self-absorption	0.0 - 0.3	negligible	calculated, but range of samples masses provides adequate verification
finite source diameter	0.5 - 0.7	25% of correction	calculated; will be verified by experiment
random summing	<0.1	negligible	measured; but probably in error for low-energy radiation on planar detector
coincidence summing	0.0 - 0.6	negligible	calculated, but needs correction for L x rays which have been neglected
impurities	0.0 for ^{239}Pu 1.0 for ^{240}Pu	negligible for ^{239}Pu 10% of correction for ^{240}Pu	from ORNL isotopic mass assay; will be measured from alpha spectrum

Activities of the Half-Life Evaluation Committee

The two Pu isotopes remaining whose half-lives are to be determined by the members of the Committee are ^{240}Pu and ^{241}Pu. The work on the ^{240}Pu half-life is continuing. At present, about half of the experimenters have completed their work and are waiting on the results of the sample characterizations, which are being done at LASL. All of the chemical-based measurements are completed, and the results have been transmitted to LASL.

It has been decided that, for the ^{241}Pu half-life work, each participating group will separately publish its own results. Three values presently exist. In a manuscript accepted for publication in the International Journal of Applied Radiation and Isotopes, the LASL group reports a value of 14.38 y, with a standard deviation of the mean of 0.013 y and 95% confidence limits of 14.32 to 14.43 y. From Mound Laboratory, the value 14.350 $\pm$ 0.007 y has appeared [Trans. Am. Nucl. Soc. 18, 185 (1974). Note that there is a misprint in the value listed there. The least significant digit should be 0, not, as listed in the reference, 5.] At NBS, two techniques are being used to determine the ^{241}Pu half-life. The first of these involves mass spectrometry, while the second is based on ^{241}Am ingrowth, measured using 4π α-γ coincidence spectrometry. From the first of these techniques, current estimates of the half-life are 14.4 and 14.34 y; and for the latter measurements a value of 14.35 $\pm$ 0.15 y is presently indicated. These NBS results should be regarded as preliminary at the present time.

Helpful discussions with C. Rudy of Mound Laboratory and J. E. Rein of LASL in the preparation of this report on the Half-Life Evaluation Committee are gratefully acknowledged.

MEASUREMENT OF RELATIVE ALPHA INTENSITIES

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The relative intensities of alpha groups in the decay of ^{238}Pu and ^{240}Pu were measured with a 6-mm diam Au-Si surface-barrier detector. Thin isotopically pure sources of ^{238}Pu and ^{240}Pu were prepared by the Argonne electromagnetic isotope separator. Spectra were accumulated at source-to-detector geometries of 0.20% and 0.04%. The low geometries were used in order to reduce distortions in intensities due to summing of the α-particle pulses with the electron and x-ray pulses. The gain of the counting system was held constant with a digital gain stabilizer. Under these conditions a resolution (FWHM) of 13.0 keV was achieved. Peak areas were determined from hand plotted graphs. The relative intensities obtained from the analysis of several spectra are given in Tables I and II. The α_0 intensity measured in the present work is lower (by 1.2% for ^{238}Pu and by 2.7% for ^{240}Pu) than the intensity measured by magnetic spectrometers. At present we do not understand the source of this disagreement.

We plan to measure α intensities for other nuclides recommended by the IAEA committee. We intend to use a computer program for spectral analysis. These measurements will be completed by the end of 1981.

TABLE I. ^{238}Pu α Intensities

Energy (MeV)	Excited State Energy (keV)	Relative Intensity (%)
5.499	0	70.90 ± 0.10
5.457	44	29.0 ± 0.04
5.359	143	0.106 ± 0.003

TABLE II. ^{240}Pu α Intensities

Energy (MeV)	Excited State Energy (keV)	Relative Intensity (%)
5.168	0	72.80 ± 0.10
5.123	45	27.10 ± 0.05
5.014	149	0.090 ± 0.005

Appendix 6

Report to Coordinated Research Programme on
Transactinium Nuclear Decay Data Committee

June 1980.

A.J. Fudge

Summary

Work has continued on the measurement and evaluation of the decay scheme of 237-neptunium. A set of I_γ values for gamma energies greater than 29 KeV have been obtained. These have improved accuracies than previous measurements for these data. Work continues to obtain comparable accuracies for emissions of lower energy. Relative I_γ values have also been obtained for 233-protactinium which has grown in as daughter product nuclide from the α decay of neptunium. Measurement of absolute I_γ values from equilibrium conditions has been complicated by the instability of the protactinium in the solution sources used. Vacuum evaporated sources, have been prepared as a preliminary to I_α measurements. Work has also started on a remeasurement of the half life of Np-237 by specific activity measurement using the stoichiometric compound Cs Np O_2 Cl_4.

Initial measurements have been made on I_γ values for 231-protactinium. A new shielded glove box counting facility has been constructed and extensively calibrated for I_γ measurement work on transactinium nuclides using Ge(Li), Ge(i) and Si(Li) detectors.

Nuclear data obtained from previous measurements of the 238, 239, 240 and 241-plutonium I_γ intensities have been applied to the non-destructive measurement of the mass and isotopic composition of waste and nuclear materials accountancy samples. Comparable work on the isotopes of uranium has been initiated.

Measurements

1. 237-Neptunium

Modifications to the ion exchange separation procedure succeeded in removing all of the 233-Pa daughter activities and produced solutions which could be quantitatively analysed and be used for I_γ measurements. γ-ray measurements were carried out within a few hours of completing the separation and numerous spectra were accumulated in the first four days. The intensities of gamma rays above 29 KeV were obtained from the spectra using the GAMANAL program. These are shown in Table 1 and compared with the evaluated data set of Dr A Nichols which is based almost exclusively on the I_γ values of Skalsey and Connor.

The uncertainties associated with I_γ absolute values are almost identical to the standard deviation (1σ) values for the relative measurements because the mass calibration uncertainties were only ± 0.2%. The other uncertainties are the combined uncertainties for photopeak area and standardisation measurements again at 1σ level.

Measurement of the emissions below 25 KeV using the liquid sources have an unacceptably high uncertainty. Thinly deposited solid sources are now being used to obtain measurements down to 5 KeV.

As the daughter nuclide 233-protactinium is achieving equilibrium growth, measurements of the I_γ values for this nuclide are also being obtained. Initially only relative values have been obtained but these agree very closely with those of Gehrke et al (see Table 2). It might not be possible to obtain absolute values using this technique due to signs of instability of the protactinium in the liquid sources.

Preparation of caesium neptunyl chloride ($Cs_2\ NpO_2\ Cl_2$) in a stoichiometric form has now been achieved as indicated by gravimetry, controlled potential coulometry and α-assay. This compound is now to be used for the I_α and $T_{\frac{1}{2}}$ measurements.

2. 231-Protactinium

Protactinium is being prepared in a purified stoichiometric form by volatilization as fluoride. This will be used in hydrofluoric acid solution for I_γ measurements when available.

Applications

The earlier work on the I_γ measurement for 238, 239, 240 and 241-Pu have now been applied extensively to non-destructive measurements of the mass and isotopic composition of plutonium in waste and accountancy samples. The techniques which cover a range of sophistication have been incorporated into several routine measuring instruments. Comparable work has been requested for uranium and this necessitates a re-examination of I_γ for the isotopes of uranium.

TABLE 1

^{237}Np Gamma Ray Intensities

Gamma Ray Energies in KeV	Relative Intensities Normalised to 86.5 KeV Emission		Absolute Intensities	
	Nichols' Evaluation	This work	Nichols' Evaluation	This work
29.37	110 ± 20	131.04 ±5.83	13.9 ±2.5	15.03 ±0.7
46.53	0.95 ±0.2	0.98 ±0.04	0.12 ±0.02	0.11 ±0.004
57.15	3.53 ±0.2	3.39 ±0.14	0.44 ±0.03	0.39 ±0.02
62.5	0.05 ±0.05	0.05 ±0.02	0.005 ±0.005	0.006 ±0.002
63.9	0.13 ±0.01	0.095 ±0.004	0.016 ±0.001	0.010 ±0.0004
74.7	0.04 ±0.01	0.10 ±0.03		0.011 ±0.003
86.5	100.00	100.00	12.6 ±1.3	11.47 ±0.29
88.04	1.1 ±0.3	1.15 ±0.06	0.14 ±0.04	0.13 ±0.007
94.66	5.04 ±0.35	5.55 ±0.14	0.64 ±0.04	0.63 ±0.01
106.12	0.36 ±0.07	0.46 ±0.014	0.045 ±0.009	0.053 ±0.002
108.6	0.61 ±0.11	0.63 ±0.06	0.077 ±0.014	0.073 ±0.007
115.45	0.021 ±0.006		0.0026 ±0.0007	
117.68	1.47 ±0.1	1.44 ±0.02	0.18 ±0.01	0.16 ±0.003
131.04	0.83 ±0.12	0.73 ±0.055	0.10 ±0.02	0.084 ±0.002
134.23	0.66 ±0.13	0.597 ±0.013	0.08 ±0.02	0.068 ±0.002
140.6	0.15 ±0.04	0.037 ±0.003	0.019 ±0.005	0.0043 ±0.0004
143.21	3.76 ±0.23	3.68 ±0.06	0.47 ±0.03	0.42 ±0.01
151.37	2.03 ±0.13	1.99 ±0.03	0.26 ±0.02	0.230 ±0.004
153.5	0.058 ±0.013	0.040 ±0.007	0.007 ±0.002	0.0046 ±0.0008
155.22	0.79 ±0.06	0.768 ±0.015	0.10 ±0.01	0.088 ±0.002
162.5	0.33 ±0.06	0.290 ±0.010	0.04 ±0.01	0.034 ±0.001
169.17	0.67 ±0.07	0.607 ±0.013	0.08 ±0.01	0.070 ±0.001
170.63	0.133 ±0.020	0.130 ±0.005	0.017 ±0.002	0.015 ±0.001
172.6	0.057 ±0.015			
176.09	0.139 ±0.028	0.124 ±0.005	0.018 ±0.003	0.014 ±0.001
180.8	0.18 ±0.04	0.142 ±0.006	0.023 ±0.005	0.016 ±0.001
186.8	0.026 ±0.026	0.011 ±0.007		0.0013 ±0.0008
191.45	0.23 ±0.032	0.196 ±0.008	0.029 ±0.004	0.023 ±0.001
193.26	0.35 ±0.035	0.397 ±0.007	0.044 ±0.004	0.045 ±0.001
194.7	0.095 ±0.027		0.012 ±0.003	
195.09	1.37 ±0.17	1.57 ±0.02	0.17 ±0.02	0.18 ±0.003
196.84	0.186 ±0.027	0.173 ±0.011	0.023 ±0.003	0.020 ±0.001
200.2	0.029 ±0.011	0.043 ±0.006	0.004 ±0.001	0.0049 ±0.0007
201.7	0.36 ±0.04	0.350 ±0.009	0.045 ±0.005	0.040 ±0.001
202.7	0.039 ±0.015		0.0049 ±0.0019	
209.2	0.157 ±0.016	0.117 ±0.006	0.02 ±0.002	0.014 ±0.001
212.42	1.35 ±0.09	1.28 ±0.02	0.17 ±0.01	0.150 ±0.002
214.09	0.38 ±0.03	0.323 ±0.006	0.048 ±0.004	0.037 ±0.001
222.51	0.014 ±0.014	0.019 ±0.010	0.0018 ±0.0018	0.0022 ±0.00004
230.0	0.093 ±0.023	0.060 ±0.006	0.012 ±0.003	0.0068 ±0.0006
238.0	0.61 ±0.07	0.505 ±0.010	0.077 ±0.009	0.058 ±0.001
248.9	0.039 ±0.017	0.067 ±0.009		0.0077 ±0.0010
257.7	0.053 ±0.028	0.046 ±0.004	0.007 ±0.003	0.0053 ±0.0005
262	0.062 ±0.018	0.053 ±0.005		0.0061 ±0.0006
279.4	0.014 ±0.014			

THESE DATA SHOULD BE TREATED AS PRELIMINARY UNTIL THE FULL DECAY SCHEME HAS BEEN COMPLETED AND EVALUATED.

TABLE 2

^{233}Pa I_γ values relative to 312 KeV emission

Energy KeV	I_γ rel(This work)	I_γ rel(Gehrke et al)
103.84	2.09 ± 0.05	2.25 ± 0.08
248.50	0.169 ± 0.007	0.154 ± 0.006
271.56	0.86 ± 0.03	0.85 ± 0.03
300.13	16.99 ± 0.14	17.14 ± 0.15
311.89	100.00	100.00
340.46	11.60 ± 0.13	11.57 ± 0.10
375.46	1.77 ± 0.03	1.76 ± 0.02
398.50	3.61 ± 0.04	3.60 ± 0.03
415.73	4.49 ± 0.06	4.52 ± 0.04

Appendix 7

Heavy Element Decay Data: Progress Report for the IAEA Co-ordinated Research Programme on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data (May 1980)

A L Nichols
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Abstract

A computer file (UKHEDD-1) of heavy element decay data has been completed in the UK. The ENDF/B-V format has been adopted, and decay scheme data for 125 nuclides have been evaluated for this file.

1 Introduction

The computer based file of heavy element decay data (UKHEDD-1) has been described in detail at previous meetings[1,2]. These data are for use in reactor calculations and the ENDF/B-V format[3] has been adopted. Decay data for 125 specific heavy element nuclides have been evaluated (including 75 actinides), but excluding the spontaneous fission decay data. This work was carried out under the guidance of the UK Chemical Nuclear Data Committee (UKCNDC).

2 The Decay Data

The evaluated data required to produce UKHEDD-1 include:

(i) half life,
(ii) Q-values,
(iii) branching fractions,
(iv) alpha decay data,
(v) beta decay data, including transition type,
and (vi) gamma decay data, including internal conversion coefficient data.

Data uncertainties are included. Table 1 lists the 125 nuclides and their associated material numbers within the completed file.

Table 2 lists selected decay data for the nuclides evaluated in 1979/80. It represents a summary of a few selected decay properties and is only a small fraction of the data evaluated for these nuclides. The half-life, branching fractions, decay mode Q-values and transition probability of the emission directly populating the ground nuclear level of the daughter state are listed. The uncertainties correspond to 1σ confidence levels expressed in terms of the last significant figure(s) for that datum. This tabulation corresponds to an equivalent table to be found in reference 1, which gives similar details for nuclides evaluated prior to May 1979.

3 The UK Chemical Nuclear Data Committee Heavy Element Decay Data File, UKHEDD-1

The data are stored on a standard label 1600 bpi magnetic tape and each record length is a card image (80) with a block size of 8000. Further information concerning this and other UKCNDC data files can be obtained from:

Mr B S J Davies,
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CEGB Berkeley Nuclear Laboratories,
Berkeley,
Gloucestershire,
England.

Acknowledgements

The author would like to thank Mr A Tobias and Mr B S J Davies for their advice during the more difficult stages of this work.

Table 1: UKHEDD-1 File of Heavy Element Decay Data

Nuclide	Material Number	Nuclide	Material Number	Nuclide	Material Number
206-Hg	6500	222-Rn	6542	240m-Np	6584
206-Tl	6501	221-Fr	6543	241-Np	6585
*206m-Tl	6502	223-Fr	6544	236-Pu	6586
207-Tl	6503	223-Ra	6545	237-Pu	6587
*207m-Tl	6504	224-Ra	6546	238-Pu	6588
208-Tl	6505	225-Ra	6547	239-Pu	6589
209-Tl	6506	226-Ra	6548	240-Pu	6590
210-Tl	6507	228-Ra	6549	241-Pu	6591
205-Pb	6508	225-Ac	6550	242-Pu	6592
209-Pb	6509	227-Ac	6551	243-Pu	6593
210-Pb	6510	228-Ac	6552	244-Pu	6594
211-Pb	6511	227-Th	6553	245-Pu	6595
212-Pb	6512	228-Th	6554	246-Pu	6596
214-Pb	6513	229-Th	6555	240-Am	6597
210-Bi	6514	230-Th	6556	241-Am	6598
*210m-Bi	6515	231-Th	6557	242-Am	6599
211-Bi	6516	232-Th	6558	242m-Am	6600
212-Bi	6517	233-Th	6559	243-Am	6601
*212m-Bi	6518	234-Th	6560	244-Am	6602
*212n-Bi	6519	235-Th	6561	244m-Am	6603
213-Bi	6520	231-Pa	6562	245-Am	6604
214-Bi	6521	232-Pa	6563	246-Am	6605
215-Bi	6522	233-Pa	6564	246m-Am	6606
209-Po	6523	234-Pa	6565	241-Cm	6607
210-Po	6524	234m-Pa	6566	242-Cm	6608
211-Po	6525	235-Pa	6567	243-Cm	6609
*211m-Po	6526	232-U	6568	244-Cm	6610
212-Po	6527	233-U	6569	245-Cm	6611
*212m-Po	6528	234-U	6570	246-Cm	6612
213-Po	6529	235-U	6571	247-Cm	6613
214-Po	6530	235m-U	6572	248-Cm	6614
215-Po	6531	236-U	6573	249-Cm	6615
216-Po	6532	237-U	6574	250-Cm	6616
218-Po	6533	238-U	6575	249-Bk	6617
215-At	6534	239-U	6576	250-Bk	6618
217-At	6535	240-U	6577	249-Cf	6619
218-At	6536	236-Np	6578	250-Cf	6620
219-At	6537	236m-Np	6579	251-Cf	6621
217-Rn	6538	237-Np	6580	252-Cf	6622
218-Rn	6539	238-Np	6581	253-Cf	6623
219-Rn	6540	239-Np	6582	253-Es	6624
220-Rn	6541	240-Np	6583		

*These nuclides are not products of actinide decay; they are included for completeness.

Table 2: Selected, Evaluated Heavy Element Decay Data

Nuclide	Decay Mode	Half-life	Branching ratio	Q-value (keV)	Intensity of ground state transition (%)	Comments
206m-Tl	IT	3.8(2)m	1	2643(8)	-	
208-Tl	β^-	3.053(4) m	1	4992(4)	zero	
210-Tl	(β^-n)	1.30(3) m	1	5487(13)	zero	incomplete decay scheme
205-Pb	EC	1.4(1) x 10^7 y	1	60(6)	100	
210-Pb	α β^-	22.2(2) y	$2.2(7)\times10^{-8}$ 1.00	3792(20) 63.0(5)	$2.2(7)\times10^{-6}$ 18(8)	
212-Pb	β^-	10.64(1) h	1	573(4)	11.4(30)	
210-Bi	α β^-	5.013(5)d	$1.3(1)\times10^{-6}$ 1.00	5042.7(18) 1161.5(15)	zero 100	
210m-Bi	α	$3.0(2)\times10^6$y	1	5313(5)	zero	
212-Bi	α $\beta^-(\alpha)$	60.60(5) m	0.359(1) 0.641(1)	6207.4(1) 2246(4)	9.6(1) 55(5)	
212m-Bi	α $\beta^-(\alpha)$	25(1) m	0.93(4) 0.07(4)	6460(20) 1370(20)	53(2) -	
212n-Bi	β^-	9(1) m	1	2000(200)	100	decay to 212m-Po
213-Bi	α β^-	45.59(6) m	0.0216(13) 0.9784(13)	5982(5) 1421(10)	2.0(1) 72(4)	
214-Bi	α β^-	19.9(4) m	0.00021(1) 0.99979(1)	5617.1(31) 3270(12)	0.0082(5) 16.1(9)	
209-Po	α EC	102(5) y	0.9974(1) 0.0026(1)	4978(3) 1895(7)	19.9(10) zero	
210-Po	α	138.376(2) d	1	5407.5(1)	100	
212-Po	α	$3.00(5)\times10^{-7}$ s	1	8953.5(1)	100	
212m-Po	α	45.1(6) s	1.000(15)	11885(20)	97.0(2)	
213-Po	α	$4.2(8)\times10^{-6}$ s	1	8536(3)	99.997(1)	
217-At	α β^-	$3.23(4)\times10^{-2}$ s	0.99988(4) 0.00012(4)	7199.7(2) 733(11)	99.9(1) 0.012(4)	
217-Rn	α	$5.4(5)\times10^{-4}$ s	1	7884(4)	99.9(1)	
221-Fr	α	4.9(2) m	1	6458.0(15)	83.4(8)	
223-Fr	α β^-	21.8(4) m	0.00006(1) 0.99994(1)	5440(80) 1147.6(28)	0.006(1) zero	
225-Ra	β^-	14.8(2) d	1	362(12)	33(6)	
225-Ac	α	10.0(1) d	1	5935.4(15)	50.7(15)	incomplete decay scheme
227-Ac	α β^-	21.773(3) y	0.0138(1) 0.9862(1)	5041(4) 43.7(20)	0.65(3) 54(5)	incomplete decay scheme
227-Th	α	18.718(10) d	1	6146.64(20)	24.5(30)	
229-Th	α	7340(160) y	1	5168.6(12)	0.01(1)	incomplete decay scheme
233-Th	β^-	22.3(2) m	1	1245(2)	30(5)	
234-Pa	β^-	6.70(5) h	1	2207(5)	zero	
234m-Pa	β^- IT	1.17(1) m	0.9987(2) 0.0013(2)	2282(6) 75(1)	98.22(7) 0.13(2)	

References

1 A L Nichols, M F James in INDC(NDS)-105/N, Editor: A Lorenz.

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3 R Kinsey, C Dunford, BNL-NCS-22865/R, 1977 and summarised in Trans Am Nucl Soc 26, 480, 1977.
A Tobias, CEGB Report RD/B/N4423, 1978.

Appendix 8

STATUS REPORT

J.R.C. - C.B.N.M. Participation in the I.A.E.A. Coordinated Research Programme on the Measurement and Evaluation of Transactinium Nuclear Decay Data

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INTRODUCTION

A small group of about 5 people is part time active in the field of the determination of decay data of actinides. About 1.5 man-year of real effort was devoted to it in the period May 79 - May 80.

MEASUREMENTS

Decay Parameters of ^{224}Ra and ^{228}Th

For the Uranium Series Intercomparison Project (USIP) for dating groundwaters by measurements of uranium and thorium isotope disequilibria, the relative α emission probability of the 5.45 MeV α transition to the excited level of 241 keV in the ^{224}Ra decay is of relevance. The emission probability of about 5% is only known with an accuracy of 10%. The 5.45 MeV α line is located under the 5.42 MeV main peak of ^{228}Th, the spike used by most of the laboratories of the USIP. The emission probability to the 241 keV level can be measured by α-particle spectrometry or by determining the γ-emission probability for the 241 keV photons and calculating then the α-emission probability by taking into acccount the internal conversion coefficient. Both methods were applied. The nuclide ^{224}Ra belongs to the ^{232}U decay chain. If the ^{232}U is separated, ^{224}Ra and the subsequent daughters will be nearly in equilibrium with the parent nuclide ^{228}Th after a period of 10 - 15 year.
For our experiments we used a ^{228}Th material which is more than 13 year old. The γ-emission probability, $P_\gamma(241)$, of the 241.0 keV photons from the ^{224}Ra decay was determined using a calibrated Ge-detector. A typical resolution of the detector is 580 eV FWHM at 122 keV. For the measurements sealed sources of ^{228}Th were used. The disintegration rates of these

sources were determined from measurements with a calibrated Ge(Li) detector, mainly via the 583 keV photons from the decay of ^{208}Tl, belonging to the ^{228}Th decay chain. $P_\gamma(241)$ was also determined relative to the rather well known emission probability $P_\gamma(239)$[1,2] of the 238.6 keV γ from the ^{212}Pb decay, also belonging to the ^{228}Th decay chain. A typical γ-ray spectrum of ^{224}Ra - ^{212}Pb in the region around 240 keV is shown in Fig. 1.

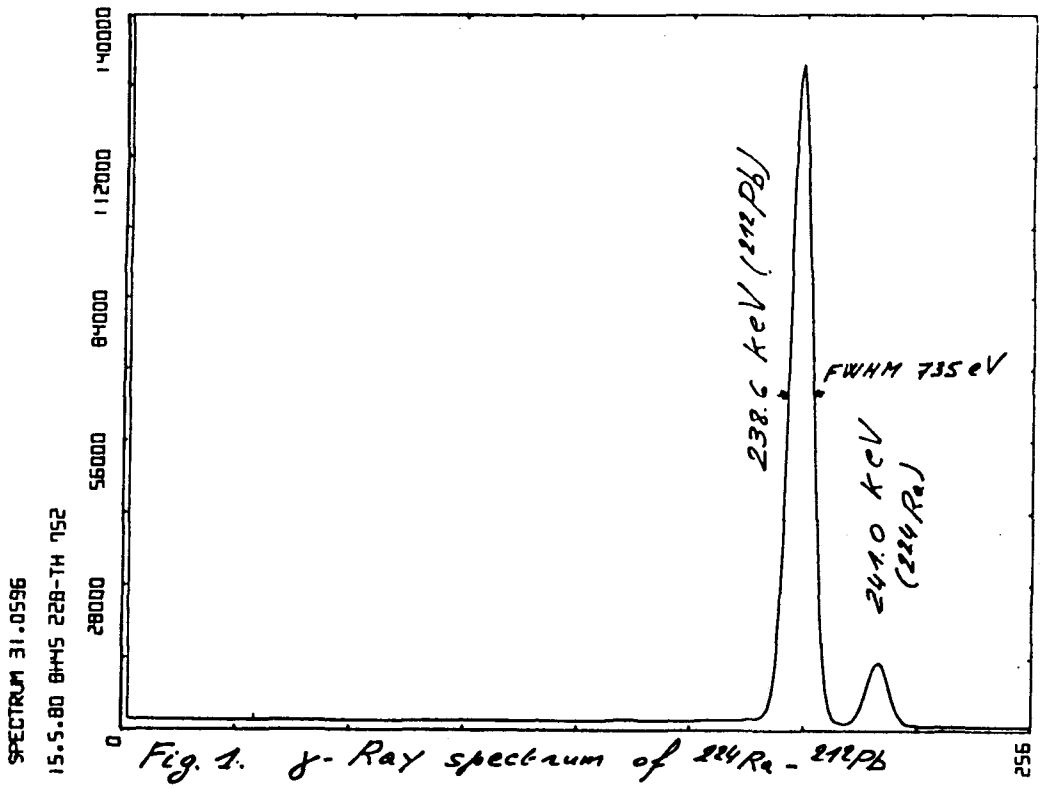

Fig. 1. γ-Ray spectrum of ^{224}Ra - ^{212}Pb

The emission probability $P_\gamma(239)$ from the ^{212}Pb decay was also redetermined. For the relative determinations of P_γ 241.0 vs. P_γ 238.6 a correction of about 2% for the difference in detection efficiency had to be applied. A correction for overlapping of both peaks was experimentally determined using the 244 keV γ-line of ^{152}Eu. The peak areas were calculated with the programme RETEOH which is an adapted version of CUTIPIE [3]. For the calculation of the α-emission probability $P_\alpha(241)$ of ^{224}Ra to the 241 keV level the total conversion coefficient for the 241 keV γ-transition was obtained by interpolation of the values tabulated by ROSEL et al. [4]: $\alpha_T = 0.2816 \pm 0.0004$.

The preliminary results of the measurements are:

$$P_\gamma(239) = 0.440 \pm 0.014$$

$$P_\gamma(241) = 0.0425 \pm 0.0020$$

$$P\alpha(241) = 0.054 \pm 0.003$$

The still rather high uncertainties are mainly due to possible escape of small amounts of the ^{220}Rn from the source, perturbing the equilibrium between ^{224}Ra and the ^{220}Rn daughters. Further experiments will solve this problem.

The ^{224}Ra sources for the α spectrometric measurements have been produced by collecting recoil atoms from the decay of a ^{228}Th source onto a stainless steel tray. Source strenghts of 60-120 s^{-1} in the ^{224}Ra peaks were obtained in this way. Measurements were carried out using two new 100 mm^2 premium grade surface barrier detectors. A solid angle of about 5% has been used. Spectra have been obtained both with and without using an absorber foil. This absorber prevents recoils from the source to reach the detector surface, hence, satellite peaks due to decaying atoms in the detector are eliminated. A resolution of 12 keV was obtained without absorber and 18.8 keV when a 40 $\mu g/cm^2$ Vyns absorber is used. A typical spectrum is shown in Fig. 2.

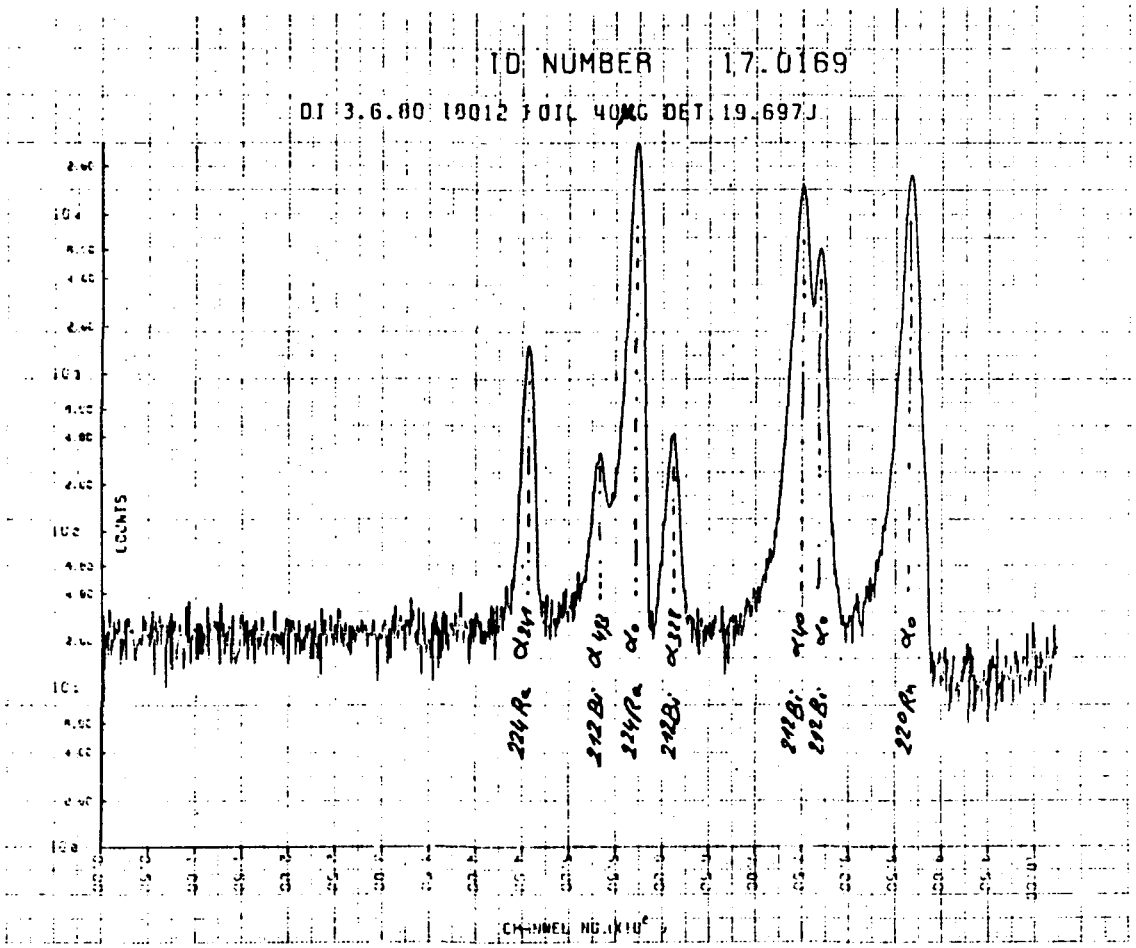

Fig. 2. α-Particle spectrum of ^{224}Ra and daughters

The main ^{224}Ra a peak of 5685 keV has been corrected for the contribution by the minor ^{212}Bi peak of 5607 keV, which is quite well resolved in the spectrum. This correction is about 1%. No background corrections were necessary. The preliminary value for the a-transition probability to the 241 keV level (E_a = 5449 keV), obtained from the measured ratio of the two ^{224}Ra peaks, is:

$$P_a(241) = 0.051 \pm 0.001$$

Some further measurements have to be performed in order to clarify the difference between the results obtained by γ-ray and a-particle spectrometry.

Spontaneous Fission Half-Life of ^{240}Pu

The values available in the literature for the spontaneous fission half-life of ^{240}Pu range from 1.20 x 10^{11}y and 1.45x10^{11}y. Many of these results do not agree with each other within the quoted uncertainties. Therefore, in the frame

of a measurement of the neutron induced fission cross section of ^{240}Pu, the spontaneous fission half-life was evaluated from a fragment spectrum of the spontaneous fission of ^{240}Pu (5). The result is $T_{1/2}(SF) - {}^{240}Pu = (1.15 \pm 0.03)10^{11}$y.

This figure is definitely lower than the value of $(1.31 \pm 0.05)10^{11}$y recommended in INDC(NDS)-108/N (1979).

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Appendix 9

HALF-LIVES OF ^{249}Bk, ^{249}Cf and ^{253}Es

(Working paper to the Third Research Coordination Meeting on the Measurement and Evaluation of Transactinium Isotope Nuclear Decay Data, Vienna, June 1980)

V.G. Polyukhov, G.A. Timofeev, B.I. Levakov and A.A. Elesin (Institute of Nuclear Reactors, Dimitrovgrad, USSR) have performed new measurements of half-lives of ^{249}Bk, ^{249}Cf and ^{253}Es)

BERKELIUM-249

30 targets have been prepared of the two ^{249}Bk samples, aged ~1 and ~3 years and measured for 600 and 410 days, respectively. The results were treated by the least square method. The mean weighted half-life of ^{249}Bk was found to be 239 ± 4 days at 95 % confidence level.

The value of $(1.476 \pm 0.043).10^{-5}$ for α/β branching ratio was obtained at 95 % confidence level.

CALIFORNIUM-249

The half-life of ^{249}Cf determined by the growth of ^{249}Cf in radiochemically pure ^{249}Bk samples has coincided with the value obtained earlier by the isotope dilution method with respect to the partial half-life of ^{252}Cf ($T_{1/2\alpha} = 2.731 \pm 0.007$ y) with accuracy of 0.8 %.

The simultaneous treatment of the new data and the results of the previous work (the Soviet journal "Radiochimiya", v. 19, No. 4, p. 460, 1977) gave the mean weighted value for $T_{1/2\alpha}$ (^{249}Cf) 363 ± 5 years at 95 % confidence level.

EINSTEINIUM-253

The half-life of ^{253}Es was measured by radiometric techniques. The measurement of 20 targets during ~6 $T_{1/2}$ have the mean weighted value of 20.29 ± 0.09 days at 95 % confidence level.

The papers are to be published in the Soviet journal "Radioch miya".