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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

REQUEST LIST OF NUCLEAR DATA FOR SAFEGUARDS DEVELOPMENT PURPOSES AS SUBMITTED TO THE INTERNATIONAL ATOMIC ENERGY AGENCY BY MEMBER STATES

Compiled and Edited

by

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1. Background

The results of a preliminary survey performed in mid-1970 by the Nuclear Data Section (NDS) on the role of nuclear data in the development of non-destructive and destructive safeguards techniques, were summarized in the draft report INDC(NDS)-21/G and presented to the third meeting of the International Nuclear Data Committee (INDC). The Committee, after examining the results of this initial survey, considered that appropriate steps should be taken in Member States submitting request lists for nuclear data needed for safeguards development so that such requests are examined and filtered by both the national safeguards authorities and the national nuclear data authorities, to ensure that requests are fully justified and officially approved. The official nature of the finally established international request list, which would be guaranteed by such procedures, is an essential prerequisite for providing the necessary motivation required to fulfill those data needs. Towards these ends, appropriate procedures have now been established in certain Member States, and in the case of the U.S.A. these procedures were outlined in the report INDC(USA)-33/G. In accordance with those procedures the Agency has received officially screened and sanctioned requests from the U.S.A., U.S.S.R. and the Federal Republic of Germany.

2. Present Status

The list of nuclear data needs from these three Member States has been merged on the basis of increasing atomic number and are given in Annex IV of this report. The names and addresses of the requestors are listed in Annex I, whilst the priority criteria which were used in assigning priorities to each request are reproduced in Annex II. These priority criteria were used by all of the requestors in the 3 Member States in question and were originally developed by the group at Los Alamos (U.S.A.). The Los Alamos criteria were however modified by an Ad-Hoc Sub-Committee on Safeguards of the USAEC's Nuclear Cross Section Advisory Committee (NCSAC). This Sub-Committee was established after the USAEC's Office of Safeguards and Materials Management (OSMM) responded to a request from the USAEC's Division of Research concerning participation in the nuclear data aspects of safeguards technical development. These modified criteria (Annex II) were subsequently adopted by the INDC at its fourth meeting (July 1971) and have therefore formed the basis for priority assignments in the current request list (Annex IV).

The format of the request list conforms to that used in INDC(NDS)-21/G and the description of the various items in the list is given in Annex III.

3. Summary of the Content of the Request List

The list contains some 23 priority I, 76 priority II and 25 priority III requests for nuclear data needed for the development of active and passive non-destructive assay techniques.

In addition, the half-lives of Zr-95, Ru-106, Cs-134, Cs-137, Ba-140 and Ce-144 and the thermal neutron capture cross sections of Zr-95, Ru-106, Cs-133, Cs-134, Cs-137 and Ba-140 are needed. The fission yield per fission event, resulting from thermal neutron fission of U-235 and Pu-239, of Cs-137, Cs-133, Ru-106, Zr-95, Ba-140 and Ce-144 are also required to within a maximum total uncertainty of 1 %.

4. Conclusions

At the fourth meeting of the INDC (Bombay, 12-16 July 1971), the Committee recommended "that the Agency take the necessary steps to produce as soon as practicable an official list of nuclear data requests for safeguards development purposes". The request list given in Annex IV is therefore being submitted to the Committee for its approval prior to the Secretariat initiating action to have the list of data needs distributed with the scientific and safeguards communities as recommended by the INDC.

The Nuclear Data Section has solicited the views of the Department of Safeguards and Inspection (DSI) on the structure and content of Annexes II-IV of this report and the response of the DSI is given in Annex V. In particular, the DSI commented that regarding the question of terminology it would be better to use the term "nuclear material" rather than "special nuclear material" in the priority criteria (Annex II) since the former is defined internationally whilst the latter is essentially defined by, and used in, the U.S.A. Turning to more substantive matters, the DSI noted that, though it was somewhat apprehensive about too wide a circulation, at an early stage, of the finally approved request list, they had no objection to the distribution of the final list to the parties listed below. However, in such an eventuality it should be made clear that the list has been drawn-up from requests originating in a few Member States and that the DSI is not, at the present time, sponsoring a world-wide circulation of nuclear data needs for safeguards. This the DSI considers important so as to avoid the impression that the DSI are urgently in need of, for their present purposes, the nuclear data requested in the list. Bearing these limitations in mind, it is proposed to have the finally approved list distributed as an INDC document to the following groups:-

1. The requestors themselves, their institutes and the national nuclear data and safeguards authorities in their countries.
2. Other safeguards development groups in Member States and other relevant international organizations.
3. Experimental nuclear physicists and their respective funding agencies, in a position to perform the required measurements.
4. Evaluators (both of neutron and non-neutron data) of experimental nuclear data.

Since some of the specialists in groups 3 and 4 above are unlikely to have much notion of the various technical aspects of safeguarding nuclear material, the DSI has agreed to prepare a short introduction to the final approved request list outlining the role of non-destructive measurements in the accounting function of a safeguards system. This summary will highlight a few selected applications of non-destructive techniques at specific fuel cycle points and discuss some of the developmental problems.

Turning to the priority criteria given in Annex II, the DSI observed that these criteria continue to present it with some problems. Since for the time being nuclear data measurements as such have been given a rather low priority in its (DSI) overall development programme, it is somewhat difficult for them (DSI), at the present time, to consider the criteria for assigning priorities to the needed data. This situation may change in the future, when they (the DSI) may be able to form a clearer picture about the needs for better nuclear data to improve existing non-destructive assay or to develop new techniques for safeguards.

One highly relevant point which the DSI recalled was that in most cases of applying safeguards one only makes relative measurements in the field and the accuracy of nuclear data does not matter - unlike the case of reactor core design calculations where one is seeking to calculate absolutely. A standard is available for comparison with the sample under interrogation or an item is chosen as a standard. These factors therefore indicate that one is more concerned with the reproducibility and precision of ones instrument, stability of electronics or background counts, etc. rather than with the accuracy of cross sections, yields or half-lives.

The Committee now has before it an officially screened and sanctioned list of requests from 3 Member States and this, along with the views of the DSI, should enable the committee to pass its judgement on the content of the request list, the distribution category of the finally approved list and such other matters as it may consider to be of relevance.

Acknowledgements

The Nuclear Data Section wishes to express its gratitude to the staff of the Division of Development in the Department of Safeguards and Inspection for their valuable comments during the preparation of this report.

A. Bremsstrahlung and Photon Induced Active Techniques

Lists of nuclear data needs have been formulated by Bramblett (U.S.A.), Markov (U.S.S.R.) and Fröhner (F.R.G.). Bramblett's needs relate to the total neutron yield produced by bremsstrahlung for fertile and fissile nuclear materials as well as for certain non-nuclear materials. In addition, the delayed neutron yield and fission product delayed γ-ray yields produced by bremsstrahlung from fertile and fissile materials are also required. Markov's needs concern the fission product yield, fission cross section and total neutron yield, as functions of the incident γ-ray energy, for Pu-238, Pu-241 and Am-241; whilst Fröhner's requests deal with the photo-neutron (γ,n) spectra, for neutron energies between 0-100 eV, for U-235, U-238 and Pu-239. One of the principal characteristics of these requests is that in most cases the data simply do not exist and hence an extensive measurement programme is implied.

B. Neutron Induced Active Techniques

Data on delayed neutron yields resulting from high energy (Mev) incident neutrons are needed by Weisbin and Walton (U.S.A.), Markov (U.S.S.R.) and Stegemann (F.R.G.). Delayed neutron emission probabilities for Rb-92, 93 and 94 and the half-lives of the delayed neutron precursors Rb-92, 93, 94, I-139 and Br-88 resulting from U-235 thermal fission have been requested by Maksyutenko (U.S.S.R.). Weitkamp's (F.R.G.) requests are for data on the thermal and 2 Kev neutron capture γ-ray spectra of fissile and fertile materials. In addition, delayed fission γ-ray spectra and yields as a function of delay time for Mev neutron fission and thermal neutron fission have been requested by Kouts (U.S.A.) and Weitkamp (F.R.G.) respectively. Weitkamp being concerned with delay time intervals of less than 1 second, whilst for Kouts delay times from 10 μ sec. up to 1 hour are of interest.

C. Burn-up Calculations

Neutron cross section data (fission and capture) for Np-237, Pu-238, Pu-241 and Am-241 have been requested by Fischer (F.R.G.) for burn-up calculations.

D. Calorimetry

Decay heat data for Pu-240 and Pu-241 are needed by Schneider (F.R.G.) for calorimetric Pu determinations. In the case of Pu-241 an order-of-magnitude improvement is requested in the total % uncertainty of the specific decay heat (milliwatts/gramme) which is at present only known from direct measurements to about $\pm$ 5 %.

E. Passive Assay Techniques

Skvortsov and Miller (U.S.S.R.) have formulated a series of data requests for the assay of spent fuel elements by the analysis of γ spectra from fission products. Amongst their data requests are the yields of γ-quanta per β-decay event of Zr-95, Ru-106, Cs-134, Cs-137, La-140 and Ce-144.

Annex I

Names and Address of Requestors: -

Dr. R. Bramblett,	Gulf Energy and Environmental Systems Inc., P.O.Box 608, San Diego California 92112, U.S.A. (formerly Gulf Radiation and Technology Inc.)
Dr. E.A. Fischer,	Institut für Angewandte Reaktortechnik, Gesellschaft für Kernforschung mbH, 75 Karlsruhe, Postfach 3640, Fed.Rep. of Germany.
Dr. F. Fröhner,	Institut für Angewandte Kernphysik, Gesellschaft für Kernforschung mbH, 75 Karlsruhe, Postfach 3640, Fed. Rep. of Germany. Present address: O.E.C.D. Neutron Data Compilation Centre, B.P.No. 9, 91 Gif-sur-Yvette, France.
Dr. H. Kouts,	Brookhaven National Laboratory, Upton, New York 11973, U.S.A.
Dr. B.P. Maksyutenko,	Institute for Physics and Energetics, Obninsk, Kaluga Region, U.S.S.R.
Dr. V.K. Markov,	Institute for Geo- and Analytical Chemistry, Moscow, U.S.S.R.
Dr. O.A. Miller,	I.V. Kurchatov Institute of Atomic Energy, Moscow, U.S.S.R.
Dr. V. Schneider,	ALKEM-Alpha-Chemie and Metallurgie GmbH, 7501 Leopoldshafen, Fed.Rep. of Germany.
Dr. S.A. Skvortsov,	I.V. Kurchatov Institute of Atomic Energy, Moscow, U.S.S.R.
Dr. D. Stegemann,	Lehrstuhl und Institut für Kerntechnik, Technische Universität Hannover, Elbestrasse 38A, 3 Hannover, Fed.Rep. of Germany.
Dr. R.B. Walton,	Los Alamos Scientific Laboratory, P.O.Box 1663, Los Alamos, New Mexico 87544, U.S.A.
Dr. C. Weisbin,	Los Alamos Scientific Laboratory, P.O.Box 1663, Los Alamos, New Mexico 87544, U.S.A.
Dr. C. Weitkamp,	Institut für Angewandte Kernphysik, Gesellschaft für Kernforschung mbH, 75 Karlsruhe, Postfach 3640, Fed.Rep. of Germany.

Annex II.

Priority Criteria Used in Assigning Priorities to Nuclear Data Requests for Safeguards Purposes.

First Priority - (I)

First priority shall be given to those requests for nuclear data that

(1) are necessary for the refinement of an existing technique in order to bring its accuracy to within acceptable limits for safeguards purposes, or

(2) are essential for the development of a new and promising technique for the nondestructive assay and control of Special Nuclear Material in amounts that are significant to the safeguards system.

Second Priority - (II)

Second priority shall be given to those requests for nuclear data that

(1) are essential for the use or interpretation of an existing or proposed technique for nondestructive assay and that are now obtained either by extrapolation or by an empirical method but for which experimental confirmation is desirable, or

(2) are necessary for the development of a technique for nondestructive assay that may reasonably be expected to be useful for safeguards purposes.

Third Priority - (III)

Third priority shall be given to those requests for nuclear data that

(1) may be needed for the nondestructive assay of materials not now included in the safeguards system but that are likely to be in the future, or

(2) are necessary for the assessment or elimination of minor sources of error in the assay of Special Nuclear Material, or

(3) are needed for the exploration of new techniques for nondestructive assay for future applications, or

(4) may be needed for the development of new techniques for nondestructive assay for which the required technology does not now exist but which may reasonably be expected to in the future.

Annex III.

Description of the Headings in the Request List.

The sequence and meaning of the entries in the list given in Annex IV are as follows: -

1.) Request Number (Req.No.). References only certain U.S.A. requests which also occur in the U.S.A. request list for neutron data measurements needed for reactor development.

2.) Target. The atomic number-chemical symbol-mass number are indicated for the target nucleus (for active assay) or the nucleus of interest (for passive assay).

3.) Reaction Type (Quantity and Variable). The Reaction Type is expressed in terms of the physical Quantity needed (e.g. half-life, fission yield etc.) and, if necessary, the Variable (e.g. fission product γ-ray spectra as a function of delay time).

4.) Priority. The priority (I, II or III) assigned to the needed data is indicated in this field. The priority criteria used by all requestors are given in Annex II.

5.) Incident Energy. The minimum and maximum energies of the incident particle are indicated in this field. Unless otherwise stated, neutrons are the incident particles. Incident electrons and photons are denoted by the symbols E_e and E_γ respectively.

6.) Accuracy Required. The accuracy to which the requested nuclear data is needed is indicated in this column. Generally, the accuracy needed for the development and testing of techniques and instruments may be quite different from that required for the final application. The accuracies have not been broken down by the requestors into the random and systematic components - instead they have indicated the total % accuracy required for the needed nuclear data; this has been taken as a quadratic sum of the two components.

7.) Laboratory/Organization (Lab./Org.). The abbreviated name of the requesting laboratory, with the organization in parenthesis, is given in this field. The Member State is indicated directly below, also in parenthesis.

8.) Requestor, Comments, Status, Justification. The requestors name is first stated. This is followed by relevant Comments in which further specifications about the request are indicated, such as, special experimental conditions in performing the measurements needed to satisfy the request. This is followed by statements regarding the Status of needed data. Under Status, either remarks on existing or forthcoming measurement or evaluation work are given, or a statement made whether no nuclear data exist at all for the reaction in question. Following the Status remarks comes the Justification for the request, such as whether the data are needed for burn-up calculations, passive γ-ray scanning of spent fuel elements, active photonuclear assay etc.

9.) Year. The year in which the request was originated is indicated in this last column.

Annex IV.

International Request List of Nuclear Data Needed for the Development of Safeguards Techniques.

REQUEST LIST FOR NUCLEAR DATA FOR THE DEVELOPMENT OF SAFEGUARDS TECHNIQUES

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	1-D-2	$(x\gamma,n)$		I	E_e = Threshold − 10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	7
		Comments: Total neutron yield produced by bremsstrahlung required. Absolute 4π yield per electron is required. Emergent neutron flat-energy response. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons.							
		Status: No useful data and calculations insufficient.							
		Justification: Standard for non-destructive photonuclear assay.							
	3-Li-6	$(x\gamma,n)$		III	E_e = Threshold − 10 Mev ΔE_e = 1 %	20 %	GRT(OSMM) (USA)	Bramblett	7
		Comments: Total neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.							
		Status: No useful data.							
		Justification: Background effect on non-destructive photonuclear assay.							
25	4-Be-9	$(n,p)Li^{9}\xrightarrow{\beta^-}Be^{9*}\hookrightarrow n$		II	14 Mev	10 %	LASL (USA)	Weisbin and Walton	70
		Comments: Delayed neutron yield required.							
		Status: Preliminary measurements at LASL; measurement of Alburger Phys. Rev., 132, 328 (1963) at 16 Mev.							
		Justification: Background in delayed neutron assays.							

Req.No.	Target	Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	4-Be-9	$(n,p)Li \xrightarrow{\beta^-} Be^{9*} \hookrightarrow n'$	$P(E_{n'})$	II	14-16 Mev	10 %	GEOHI (USSR)	Markov	71

Comments: Delayed neutron yield required.

Status: Alburger, Phys.Rev., 132, 328 (1963)

Justification: Allowance for background in delayed-neutron counting.

	4-Be-9	$(x\gamma,n)$		II	E_e=Threshold-10Mev ΔE_e= 1%	20 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Total neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: No useful data.

Justification: Background effect on non-destructive photonuclear assay.

	6-C-13	$(x\gamma,n)$		II	E_e=Threshold-10Mev ΔE_e = 1%	20 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Total neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: No useful data.

Justification: Background effect on non-destructive photonuclear assay.

	8-O-17	$(x\gamma,n)$		II	E_e = Threshold-10 Mev ΔE_e = 1 %	20 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Total neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: No useful data.

Justification: Background effect on non-destructive photonuclear assay.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Yea
	40-Zr-95	Yield of γ-quanta per β- decay event		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: N.G. Gusev, "Protection against γ-radiation from fission products," (Manual) Moscow, Atomizdat (1968).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe Vol. 1, p.521 (1970).
S.Hiller, Kerntechnik, 12, No. 11, 485 (1970)
Nir-El, Israel Atomic Energy Comm. (Repts)No. 1168, 70-71 (1968)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	40-Zr-95	Half-Life		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: N.G. Gusev, "Protection against γ-radiation from fission products," (Manual) Moscow, Atomizdat (1968).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe Vol. 1, p.521 (1970).

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	40-Zr-95	$\sigma(n,\gamma)$		III	Thermal; 0.06 eV	5 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Determination to within 5 % required.

Status: Data unknown.

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

Req.No.	Target	Reaction Type / Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requester, Comments, etc.	Year
	44-Ru-106	Yield of γ-quanta per β-decay event		II	_____	3 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 3% required.

Status: O.A. Miller et.al., Soviet Atomic Energy, 27,281 (1969)
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol.1, p. 521 (1970).

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	44-Ru-106	Half-Life		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: O.A. Miller et.al., Soviet Atomic Energy, 27, 281 (1969)
N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p.521 (1970).

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	44-Ru-106	$\sigma(n,\gamma)$		III	Thermal; 0.06 eV	10 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 10 % is required.

Status: M. Goldberg et.al., Neutron Cross Sections, BNL-325, S.E. V.II B, Suppl.No.2 (1966)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor.Comments.etc.	Year
55-Cs-133		$\sigma(n,\gamma)$		II	Thermal; 0.06 eV	3 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 3 % is required.

Status: M. Goldberg et.al., Neutron Cross Sections, BNL-325,S.E. V. II B, Suppl. No. 2 (1966)
Analytic Chem., 37 , 351 (1965)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

55-Cs-134		$\sigma(n,\gamma)$		II	Thermal; 0.06 eV	3 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 3 % is required.

Status: M. Goldberg et.al., Neutron Cross Sections, BNL-325,S.E.V. II B, Suppl. No. 2 (1966)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

55-Cs-134		Half-Life		I	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: O.A. Miller et.al. Soviet Atomic Energy, 27, 281 (1969)
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol.1, p.521 (1970)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

55-Cs-134		Yield of γ-quanta per β-decay event		I	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p.521 (1970)
Nucl.Sci, and Engin., 22, 416(1965)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	55-Cs-137	Yield of γ-quanta per β-decay event		I	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: Analytic Chem., 37. 351(1965)
S. Miller, Kerntechnik, 12, No. 11, 485(1970)
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe. Vol. 1, p.521(1970)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	55-Cs-137	Half-Life		I	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: V.A. Greshilov et.al., "Products of prompt fission of U-235, U-238 and Pu-239 from 0 to 1 hour", (Manual), Moscow, Atomizdat (1969).
J. of Inorganic Nucl.Chem., 27, 121 (1965)
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p.521 (1970)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	55-Cs-137	$\sigma(n,\gamma)$		II	Thermal: 0.06 eV	10 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 10 % is required.

Status: M.Goldberg et.al., Neutron Cross Sections, BNL-325, S.B.V.11 B, Suppl.No.2 (1966)

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

	56-Ba-140	Half-Life		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Different values are quoted in the literature. Determination to within 1 % is required.

Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968).

Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	56-Ba-140	$\sigma(n,\gamma)$		III	Thermal; 0.06 eV	5 %	IAE (USSR)	Skvortsov and Miller	70
		Comments: Determination to within 5 % required.							
		Status: Data unknown.							
		Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.							
	57-La-140	Yield of γ-quanta per β-decay event		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70
		Comments: Different values are quoted in the literature. Determination to within 1 % is required.							
		Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968)							
		Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.							
	58-Ce-144	Half-Life		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70
		Comments: Different values are quoted in the literature. Determination to within 1 % is required.							
		Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968) V.A. Greshilov et.al., "Products of prompt fission of U-235, U-238 and Pu-239 from 0 to 1 hour", (Manual), Moscow, Atomizdat (1969).							
		Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.							
	58-Ce-144	Yield of γ-quanta per β-decay event		II	_____	1 %	IAE (USSR)	Skvortsov and Miller	70
		Comments: Different values are quoted in the literature. Determination to within 1 % is required.							
		Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968). S.Hiller, Kerntechnik, 12, No. 11, 485 (1970)							
		Justification: For assay of U and Pu in fuel elements from fission product γ-radiation.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requester, Comments, etc.	Year
	90-Th-232	$(x\gamma,n)$		II	E_e=Threshold-10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70

Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: Gozani et.al., Trans.American Nucl.Soc., 13, 707 (1970) - Relative data.
Katz et.al., Canadian J. of Physics, 35, 470 (1957).

Justification: To allow non-destructive photonuclear assay of Th mixtures.

	90-Th-232	Delayed-N-Y	N(t)	I	E_e=Threshold-10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: Gozani et al. Trans.American Nucl.Soc., 13, 707 (1970)-Relative data.
Katz et.al., Canadian J. of Physics, 35, 470 (1957).

Justification: To allow non-destructive photonuclear assay of Th mixtures.

	90-Th-232	Fission Product γ-Y(1 msec-1 hour)	$P(E_\gamma,t)$	III	E_e = 10 Mev ΔE_e = 5 %	10 %	GRT (OSMM) (USA)	Bramblett	70

Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ = 0.5 - 5.0 Mev with ΔE_γ= 3 Kev.

Status: Rundquist, Trans. American Nucl.Soc., 13, 746 (1970) - Preliminary data.

Justification: For non-destructive photonuclear assay of Th mixtures.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
90	-Th-232	$\sigma(n,f)$		I	1-15 Mev	5%	IKT(TUH) (FRG)	Stegemann	70

Comments: Fission cross section required to within 5%.

Status: Ben-David, IAEA-107, 57 (1968) review up to 14 Mev.
Bak et al., INDC(NDS)-36/G (1971) and J. of the Korean Nuclear Society, 3, 77 (1971).

Justification: Standard for non-destructive assay of spherical fuel elements.

90-Th-232	$\bar{\nu}$	Prompt	I	1-15 Mev	3%	IKT(TUH) (FRG)	Stegemann	70

Comments: Average number of prompt neutrons per neutron induced fission required.

Status: Davey, Nucl. Sci. and Engin, 44, 345(1971) evaluation up to 15 Mev.
Manero et al., INDC(NDS)-34/G (1972) evaluation to be published in Atomic Energy Review (1972)

Justification: Standard for non-destructive assay of spherical fuel elements.

90-Th-232	Delayed-N-Y	$P(E_n,)$	I	1-15 Mev	5%	IKT(TUH) (FRG)	Stegemann	70

Comments: Delayed neutron fraction, β_i, required.

Status: Krick et al, NCSAC-31, 156 (1970). Preliminary results up to 15 Mev.

Justification: Standard for non-destructive assay of spherical fuel elements.

Rq.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
348	90-Th-232	Delayed -γ-γ	$P(E_\gamma, T^{1/2})$	II	2 and 14 Mev	35 %	BNL(OSMM) (USA)	Kouts	69
		Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and 10 μsec $\leq T_{1/2} \leq$ 1 hour. Absolute γ-ray yields to a factor of 2 also useful.							
		Status: R.Chrien, (BNL unpublished) has some data for U-235 and Pu-239. N.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p.637 (1969); presented some data for U.							
		Justification: Background effects in assay of U-233 - Th-232.							
	92-U-233	$(x\gamma,n)$		I	E_e = Threshold-10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: Neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.							
		Status: Katz et.al., Canadian J. of Physics, 35, 470 (1957).							
		Justification: To allow non-destructive photonuclear assay of U-233.							
	92-U-233	Delayed-N-Y	N(t)	I	E_e = Threshold-10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.							
		Status: No data.							
		Justification: To allow non-destructive photonuclear assay of this SNM.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Year
	92-U-233	Fission Product γ-γ(1 msec- 1 hour)	$P(E_\gamma, t)$	II	E_e = 10 Mev ΔE_e = 5 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ = 0.5 - 5.0 Mev with ΔE_γ = 3 Kev.							
		Status: No data.							
		Justification: For non-destructive photonuclear assay of this SNM.							
364	92-U-233	Delayed-γ-γ	$P(E_\gamma, T\frac{1}{2})$	I	2 and 14 Mev	35 %	BNL(OSMM) (USA)	Kouts	69
		Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and 10 μsec $\lesssim T\frac{1}{2} \lesssim$ 1 hour. Absolute γ-ray yields to a factor of 2 also useful.							
		Status: R. Chrien, (BNL unpublished) has some data for U-235 and Pu-239. N.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p.537 (1969); presented some data for U.							
		Justification: Assay of U-233 fuels.							
	92-U-234	(xγ,n)		II	E_e = Threshold - 10 Mev ΔE_e = 1 %	30 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 (xγ.n) yield or may be absolute.							
		Status: No data.							
		Justification: Effect on non-destructive photonuclear assay of U-233 and U-235.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Acouracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-234	Delayed-N-Y	N(t)	III	E_e=Threshold-10 Mev ΔE_e = 1 %	30 %	ORT(OSMM)	Bramblett (USA)	70

Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 ($x\gamma$,n) yield or may be absolute.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of U-233 and U-235.

	92-U-234	Fission Product γ-γ(1 msec-1 hour)	$P(E_\gamma,t)$	III	E_e = 10 Mev ΔE_e = 5 %	30 %	ORT(OSMM) (USA)	Bramblett	70

Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ= 0.5 - 5.0 Mev with ΔE_γ= 3 Kev.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of U-233 and U-235.

	92-U-235	Fission Product γ-ray spectra and yields.	$P(E_\gamma)$	II	Thermal	$\pm$ 15 % Absolute yield.	LASL (USA)	Weisbin and Walton	70

Comments: Fission product γ-ray spectra for γ-ray energies, E_γ = 0.25 - 5 Mev, and yields (photons/fission - Mev - sec) from 1 msec - 12 hours resulting from thermal neutron fission required. Ge(Li) resolution at 1.2 Mev should be 2.5 Kev and absolute yields to $\pm$ 15 % accuracy.

Status: Walton and Sund, Phys. Rev., 178, 1894 (1969)
Fisher and Engle, Phys. Rev., 134, B796 (1964)
F.C. Maienschein et.al., *1958 Geneva Conference on Peaceful uses of Atomic Energy*, Vol. 15, 366 (1958).
Better resolution desired. Associate γ-rays with fission products if possible.

Justification: Non-destructive assay of U-235.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-235	σ(n,f)		I	Thermal-15 Mev	3%	IKT(TUH) (FRG)	Stegemann	70

Comments: Fission cross section required to within 3 %.

Status: Sowerby et al., AERE-M-2497 (1972) simultaneous evaluation from 100 eV - 20 Mev.
WARD-4210 T4-1 (1972) recent evaluation for ENDF/B-III library.
Steen, WARD-TM-691 (1969) evaluation from thermal up to 14 Mev.
Boroughs et al., GA-8854 (1968) evaluation from 0.01 - 10 Mev.

Justification: Standard for non-destructive assay of fuel elements.

	92-U-235	$\bar{\nu}$	Prompt	I	Thermal-15 Mev	3%	IKT(TUH) (FRG)	Stegemann	70

Comments: Average number of prompt neutrons per neutron induced fission required.

Status: Davey, Nucl. Sci. and Engin., 44, 345 (1971) evaluation up to 15 Mev.
Manero et al., INDC(NDS)-34/G (1972) and to be published in Atomic Energy Review (1972) evaluation up to 15 Mev.
Mather et al. AWRE-O-55/71 (1971) evaluation up to 15 Mev.
Boroughs et al., GA-8854(1968) evaluation up to 15 Mev.
Colvin, 1969 IAEA Symposium on Physics and Chemistry of Fission, p. 930 (1969) evaluation up to 14 Mev.

Justification: Standard for non-destructive assay of fuel elements.

	92-U-235	Delayed-N-Y	$P(E_n)$	I	Thermal-15 Mev	5 %	IKT(TUH) (FRG)	Stegemann	70

Comments: Delayed neutron fraction, β_i, required.

Status: Amiel, 1969 IAEA Symposium on Physics and Chemistry of Fission, p. 569 (1969); review from thermal-15 Mev.
Krick et al., WASH-1155, 156(1970) preliminary results
Manero et al., INDC(NDS)-34/G (1972) and to be published in Atomic Energy Review (1972).

Justification: Standard for non-destructive assay of fuel elements.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-235	Delayed-N-Y	$\bar{\nu}_D$	II	5 - 14 Mev	5 %	LASL (USA)	Weisbin and Walton	71

Comments: Delayed neutron yield required. Data desired for extrapolation to 15 Mev.

Status: Hunter, LA-3527; evaluation to 2.5 Mev.
Masters et.al., American Nucl.Soc., 11, 179; measurements at 3 and 14 Mev.
Krick and Evans, Preliminary data (LASL), 0.1 - 6.7 Mev.

Justification: Calculations of moderating assemblies for U-235 assays.

	92-U-235	Delayed-N	Precursor Half-Lives	III	Thermal	5 %	FEI (USSR)	Maksyutenko	71

Comments: The half-lives of Rb-92, Rb-93 and Rb-94, I-139 and Br-88 are anomalous. The half-lives of these delayed neutron precursors, resulting from thermal neutron fission, should be measured more accurately - to 5 %.

Status: S. Amiel, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p. 569 (1969).

Justification: For interpretation of delayed-neutron data.

	92-U-235	Delayed-N	Emission probabilities	III	Thermal	5 %	FEI (USSR)	Maksyutenko	71

Comments: The delayed neutron emission probabilities for Rb-92, Rb-93 and Rb-94 are in contradiction with data from nuclear systematics. More accurate (5 %) determinations are needed for these isotopes resulting from thermal neutron fission.

Status: S. Amiel, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p. 569 (1969).
The emission probabilities quoted by different authors vary by factors of 1.5-2.0

Justification: For the interpretation of delayed neutron data.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Yr
	92-U-235	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	III	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	

Comments: Delayed fission γ-ray spectra as a function of delay time required. Particularly interesting for intervals $<$ 1 sec. Accuracy refers to γ-ray intensities. Errors of - 50 % to + 100 % for $T_{1/2}$ acceptable.

Status: No data.

Justification: For non-destructive assay of fissionable material by γ-spectroscopy of short lived fission products.

392	92-U-235	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	I	2 and 14 Mev	35 %	BNL(OSLM) (USA)	Kouts	

Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and 10 μ sec $\lesssim T_{1/2} \lesssim$ 1 hour. Absolute γ-ray yields to a factor of 2 also useful.

Status: R. Chrien, (BNL unpublished) has some data for U-235 and Pu-239.
N.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p.637 (1969); presented some data for U.

Justification: Assay of U-235 fuels.

	92-U-235	(n, γ)	$P(E_\gamma)$	I	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	7(

Comments: Capture γ-ray spectra required.

Status: Experimental determination of $P(E_\gamma)$ for high energy γ's ($E_\gamma > 2$ Mev) resulting from thermal neutrons nearly completed at Karlsruhe to an accuracy of -50% to + 100% or better. Final report to be published in 1972.
Preliminary data published at 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 2, p.113 (1970) and at 1971 Ispra meeting on Non-Destructive Measurement and Identification Techniques in Nuclear Safeguards and at 1972 Berlin meeting of Deutsche Physikalische Gesellschaft.

Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.

Req.No.	Target	Reaction Type / Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requester, Comments, etc.	Year
	92-U-235	Fission Yield of 55-Cs-133		I	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 55-Cs-133 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: O.A. Miller et.al., Soviet Atomic Energy, 27, 281 (1968)

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	92-U-235	Fission Yield of 44-Ru-106		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fision event of 44-Ru-106 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: S. Hiller, Kerntechnik, 12, No. 11, 485 (1970)
I.P. Grechushkina, "Tables showing the composition of prompt fission products from U-235, U-238 and Pu-239 fission", Moscow, Atomizdat (1964).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	92-U-235	Fission Yield of 40-Zr-95		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fision event of 40-Zr-95 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: O.A.Miller et.al., Soviet Atomic Energy, 27,281 (1969)
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p.521 (1970)
S.Hiller, Kerntechnik, 12, No.11, 485 (1970).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	92-U-235	Fission Yield of 55-Cs-137		I	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 55-Cs-137 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: O.A.Miller et.al., Soviet Atomic Energy, 27, 281 (1969).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques. Karlsruhe, Vol.1 p.521 (1970).
S.Hiller, Kerntechnik, 12, No. 11, 485 (1970).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

Req.No.	Target	Reaction Type / Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-235	Fission Yield of 56-Ba-140		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 56-Ba-140 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968).
V.A. Greshilov et.al., "Products of prompt fission of U-235, U-238 and Pu-239 from 0 to 1 hour". (Manual). Moscow, Atomizdat (1969). J. of Inorganic Nucl.Chem., 27, 121 (1965)

Justification: For assay of U and Pu in spent fuel elements by the fission products γ-rays.

	92-U-235	Fission Yield of 58-Ce-144		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 58-Ce-144 resulting from thermal fission of U-235 required to within 1 % accuracy. Different values are quoted in the literature.

Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968).
S. Hiller, Kerntechnik, 12, No. 11, 485 (1970).

Justification: For assay of U and Pu in spent fuel elements by the fission product -rays.

	92-U-235	(γ,n)Spectra		III	E_γ = 5-8 Mev	10 %	IAK (GFR) (FRG)	Frönner	70

Comments: Photoneutron spectra with resolved resonances and neutron energies between 0-100 eV required. Accuracies refer to shape and absolute values to within 20% accuracy would be helpful. Photon energy resolution should be better than 100 Kev.

Status: No active work known.

Justification: Needed for the exploration of new techniques for non-destructive assay whose potential usefulness is unknown.

Reg.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-235	$(x\gamma,n)$		II	E_e = Threshold - 10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70

Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: Gozani et.al., Trans.American Nucl.Soc., 13, 707 (1970) - Relative data.
Bowman et.al., Phys.Rev., 133, B676 (1964) - (γ,n) data above 7 Mev.

Justification: For non-destructive photonuclear assay of this SNM.

	92-U-235	Delayed-N-Y	N(t)	II	E_e=Threshold -10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.

Status: Gozani et.al., Trans. American Nucl.Soc., 13, 707 (1970)- Relative data.

Justification: For non-destructive photonuclear assay of U-235.

	92-U-235	Fission Product γ-γ(1 msec- 1 hour)	$P(E_\gamma,t)$	II	E_e = 10 Mev ΔE_e = 5 %	10 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ = 0.5-5.0 Mev with ΔE_γ = 3 Kev.

Status: Rundquist, Trans.American Nucl.Soc., 13, 746 (1970)-Preliminary data.

Justification: For non-destructive photonuclear assay of this SNM.

	92-U-236	Fission Neutron Spectrum		II	One energy above fission threshold	10 %	LASL (USA)	Weisbin and Walton	70

Status: Parker, AWRE-O-30/64 (1964); evaluation.

Justification: Background corrections in U-235 spent fuel assay.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Reference, Comments, etc.	Date
	92-U-236	Delayed-N-γ	$\bar{\nu}_D$	I	3 and 14 Mev	10 %	LASL (USA)	Weinstein and Walton	7[illegible]

Status: No experimental work to date. Data have been obtained empirically.

Justification: Background correction in U-235 spent fuel assay.

	92-U-236	(γ,n)		II	E_e=Threshold - 10 Mev ΔE_e = 1%	30 %	GRT(OSMM) (USA)	Bramblett	7[illegible]

Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 (γ,n) yield to may be absolute.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of U-235.

	92-U-236	Delayed-N-γ	N(t)	III	E_e=Threshold - 10 Mev ΔE_e = 1 %	30 %	GRT(OSMM) (USA)	Bramblett	7[illegible]

Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 (γ,n) yield or may be absolute.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of U-235.

	92-U-236	Fission Product γ-γ (1 msec-1 hour)	$P(E_\gamma,t)$	III	E_e= 10 Mev ΔE_e= 5 %	30 %	GRT(OSMM)	Bramblett	7[illegible]

Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ = 0.5-5.0 Mev with ΔE_γ = 3 Kev.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of U-235.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Year
	92-U-238	$\bar{\nu}$	Prompt	II	1-15 Mev	5 %	IKT(TUH) (FRG)	Stegemann	70

Comments: Average number of prompt neutrons per neutron induced fission required.

Status: Davey, Nucl.Sci. and Engin., 44, 345 (1971) evaluation up to 15 Mev.
Manero et al., INDC(NDS)-34/G (1972) evaluation up to 15 Mev; to be published in Atomic Energy Review (1972).
Mather et al., AWRE-O-44/71 (1971) evaluation up to 15 Mev.

Justification: Standard for non-destructive assay of fuel elements.

	92-U-238	Delayed-N-Y	$P(E_n)$	II	1-15 Mev	5 %	IKT(TUH) (FRG)	Stegemann	70

Comments: Delayed neutron fraction, β_i, required.

Status: Maksyutenko et al., Soviet J. of Nucl. Physics, 7, No. 2, 189 (1968) experiments up to 21 Mev.
Krick et al., NCSAC-31, 156 (1970)

Justification: Standard for non-destructive assay of fuel elements.

92-U-238	σ(n,f)		II	1 - 15 Mev	5%	IKT(TUH) (FRG)	Stegemann	70

Comments: Fission cross section required to within 5%.

Status: Bak et al., INDC(NDS)-36/G (1971) and J. of the Korean Nuclear Society, 3. 77(1971) evaluation up to 20 Mev.
Silbert et al., BNL-50298, 112(1971).
Sowerby et al., AERE-M-2497 (1972), simultaneous evaluation up to 20 Mev.

Justification: Standard for non-destructive assay of fuel elements.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
417	92-U-238	Delayed -γ-γ	P(E_γ, $T_{1/2}$)	II	2 and 14 Mev	35 %	BNL(OSMM) (USA)	Kouts	69

Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and 10μsec $\lesssim T_{1/2} \lesssim$ 1 hour Absolute γ-ray yields to a factor of 2 also useful.

Status: R. Chrien, (BNL Unpublished) has some data for U-235 and Pu-239. N.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p.637 (1969); presented some data for U.

Justification: Assay of U fuels.

	92-U-238	(γ,n)Spectra		III	E_γ= 3-8 Mev	10 %	IAK(GfK) (USA)	Fröhner	70

Comments: Photoneutron spectra with resolved resonances and neutron energies between 0-100 eV required. Accuracies refer to shape and absolute values to within 20 % accuracy would be helpful. Photon energy resolution should be better than 100 Kev.

Status: No active work known.

Justification: Needed for the exploration of new techniques for non-destructive assay whose potential usefulness is unknown.

	92-U-238	($\gamma\gamma$,n)		II	E_e=Threshold-10 Mev ΔE_e = 1%	10 %	GRT(OSMM) (USA)	Bramblett	?

Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 ($\gamma\gamma$,n) yield or may be absolute.

Status: Gozani et.al., Trans. American Nucl.Soc., 13, 707 (1970) - Relative data. Katz et. al., Canadian J. of Physics, 35, 470 (1957).

Justification: For non-destructive photonuclear assay of U.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	92-U-238	Delayed-N-Y	N(t)	II	E_e=Threshold-10 Mev ΔE_e= 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 (γ,n) yield or may be absolute.							
		Status: Gozani et.al., Trans. American Nucl.Soc., 13,707 (1970) - Relative data.							
		Justification: For non-destructive photonuclear assay of U.							
	92-U-238	Fission Product γ-γ (1msec-1 hour)	$P(E_\gamma,t)$	II	E_e= 10 Mev ΔE_e= 5 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ= 0.5-5.0 Mev with ΔE_γ= 3 Kev.							
		Status: Rundquist, Trans. American Nucl. Soc., 13, 746 (1970)- Preliminary data.							
		Justification: For non-destructive photonuclear assay of U.							
412	92-U-238	Delayed-N-Y	$\bar{\nu}_D$	II	5-14 Mev	5 %	LASL (USA)	Weisbin and Walton	70
		Comments: Delayed neutron yield required. Data desired for extrapolation to 15 Kev.							
		Status: Hunter, LA-3527; evaluation to 2.5 Mev. Masters et.al., American Nucl. Soc., 11, 179; measurements at 3 and 14 Mev. Krick and Evans, Preliminary data (LASL), 0.1 - 6.7 Mev.							
		Justification: Calculations of moderating assemblies for background effects on assays of U-235.							
	92-U-238	(n,γ)	$P(E_\gamma)$	II	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	70
		Comments: Capture γ-ray spectra required.							
		Status: No useful data for thermal or 2 keV incident neutrons known.							
		Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requester, Comments, etc
	93-Np-237	$\sigma(n,\gamma)$		II	0.001 eV-1 Kev	3-10 %	IAR(GfK) (FRG)	Fischer

Comments: Accuracy of 3 % from thermal - 10 eV needed. Accuracy of 5 % Γ_n and accuracy 10 % Γ_γ from thermal - 1 Kev.

Status: Paya, (Saclay) has $\sigma(n,f)$, $\sigma(n,total)$ and resonance parameters up to 2 Kev.
Gavrilov, Atomic Energy, 28, 362 (1970) up to 10 Kev.
Simons et.al., BNWL-1312 (1970); Evaluation up to 20 Mev.
Brown et.al., Nuclear Physics, A156, 609 (1970) data up to 2.2 Kev and from 100 Kev - 2.8 Mev.
Hoffman; WASH-1136 preliminary data from 25 eV - 100 Kev.

Justification: For burn-up calculations.

	93-Np-237	$\sigma(n,f)$		II	1 Kev - 5 Mev	10 %	IAR (GfK) (FRG)	Fischer

Comments: Fission cross section required.

Status: Paya, (Saclay) has $\sigma(n,f)$, $\sigma(n,total)$ and resonance parameters up to 2 Kev.
Gavrilov, Atomic Energy, 28, 362 (1970) up to 10 Kev.
Simons et.al., BNWL-1312 (1970); Evaluation up to 20 Mev.
Brown et.al., Nuclear Physics, A156, 609 (1970) data up to 2.2 Kev and from 100 Kev - 2.8 Mev.

Justification: For burn-up calculations.

	93-Np-237	$\sigma(n,\gamma)$		II	1 Kev-5 Mev	10 %	IAR(GfK) (FRG)	Fischer

Comments: Capture cross section required to within 10 %.

Status: Nagle et al., Third Conf. on Neutron Cross Sections and Technology, Knoxville (U.S.A.), 259 (1971)
Smith et al., IN-1182 (1969) evaluation up to 15 Mev.

Justification: For burn-up calculations.

Req.No.	Target	Reaction Type Quantity Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Year
	94-Pu-238	σ(n,f)	II	1 - 10 Mev	10 %	IAR(GfK) (FRG)	Fischer	70

Comments: Fission cross section required.

Status: Silbert, LA-4108 (1969) and LA-4674 (1971) - Data up to 3 Mev.
Drake, LA-4420 (1970) - Data up to 2.6 Mev.

Justification: For burn-up calculations.

	94-Pu-238	σ(n,γ)	II	Thermal-10 Mev	10 %	IAR (GfK) (FRG)	Fischer	70

Comments: Carture cross section required.

Status: Silbert et.al., NCSAC-31 (1970). Preliminary data from 10 - 100 Kev.
Young, Nuclear Sci. and Engin., 30, 365; resonance parameters to 190 eV.
Silbert et.al., WASH-1124 (1968); 30 eV - 1 Mev preliminary.
Dunford et.al., NAA-SR-12271 (1967); evaluation from thermal to 10 Mev.
Hinkelmann, KFK-1186 (1970); evaluation from thermal-10 Mev

Justification: For burn-up calculations.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Year
	94-Pu-238	(n,γ)	$P(E_\gamma)$	II	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	70

Comments: Capture γ-ray spectra required.

Status: No useful data for thermal or 2 keV incident neutrons.

Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.

	94-Pu-238	Fission Yield and $\sigma(\gamma, f)$		II	E_γ = Threshold - 10Mev	10%	GEOHI (USSR)	Markov	71

Comments: The energy dependence (as a function of incident γ energy) of the fission fragment yield (and fission cross section) resulting from γ-induced fission is required to within 10 %.

Status: Data unknown.

Justification: For photonuclear assay of Pu.

	94-Pu-238	(γ,n)		II	E = Threshold-10 Mev	10%	GEOHI (USSR)	Markov	71

Comments: The energy dependence (as a function of incident γ-energy) of the neutron yield resulting from γ irradiation is required to within 10 %.

Status: Data unknown.

Justification: For photonuclear assay of Pu.

	94-Pu-239	Delayed-N-Y	$\bar{\nu}_D$	II	3 - 14 Mev	10 %	LASL (USA)	Weisbin and Walton	70

Comments: Delayed neutron yield required. Data desired for extrapolation to 15 Mev.

Status: Masters et.al., American Nucl.Soc., 11, 179; measurements at 3 and 14 Mev.
Maksyntenko, ICD-1,266; measurement at 3.8 and 15 Mev.
Petrzak, Atomic Energy, 11, 539.
Krick and Evans, Preliminary data (LASL), 0.1 - 6.7 Mev.

Justification: Calculations of moderating assemblies for Pu-239 assays.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments,etc	Year
	94-Pu-239	(n, γ) Spectra and Yields	P(E_γ) $E_\gamma > 1.2$ Mev	III	Thermal-100 eV	See Comments	LASL (USA)	Weisbin and Walton	70

Comments: Capture γ-ray spectra and yields of γ-rays per capture required to ≈ 20 % accuracy, for γ-rays of energy > 1.2 Mev. Ge(Li) resolution at 1.2 Mev should be 2.5 Kev.

Status: Jurney, LASL (1970) Progress report-see also BNL-50276,152 (1970). Recent data for thermal neutrons; γ-ray spectra from 3 - 6 Mev.

Justification: Development of new Pu-239 assay technique.

	94-Pu-239	(n, γ)	P(E_γ)	II	Thermal; 2 Kev	25 %	IAK (GfK)	Weitkamp	70

Comments: Capture γ-ray spectra required.

Status: Experimental determination of P(E_γ) for high energy γ's (E_γ 2 Mev) resulting from thermal and 2 Kev (scandium filtered beam) neutrons nearly completed at Karlsruhe to an accuracy of -50% to + 100% or better. Final report to be published in 1972.Preliminary data published at 1970 IAEA Symposium on Safeguards Techniques,Karlsruhe, Vol.2, p.113 (1970) and at 1971 Ispra meeting on Non-Destructive Measurement and Identification Techniques in Nuclear Safeguards and at 1972 Berlin meeting of Deutsche Physikalische Gesellschaft.Also preliminary data of Jurney,BNL-50276, 152 (1970).

Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.

448	94-Pu-239	Fission Product γ-ray spectra and yields	P(E_γ)	II	Thermal	± 15 % Absolute Yield	LASL (USA)	Weisbin and Walton	71

Comments: Fission product γ-ray spectra for γ-ray energies, E_γ = 0.25-5 Mev, and yields (photons/fission-Mev-sec) from 1msec - 12 hours resulting from thermal neutron fission required. Ge(Li) resolution at 1.2 Mev should be 2.5 Kev and absolute yields to ± 15% accuracy.

Status: Walton and Sund, Phys. Rev., 178, 1894 (1969)
Fisher and Engle, Phys. Rev., 134, B797 (1964)
F.C. Maienschein, 1958 Geneva Conference on Peaceful Uses of Atomic Energy, Vol. 15, 366 (1958).
Better resolution desired. Associate γ-rays with fission products if possible.

Justification: Non-destructive assay of Pu-239.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Year
448	94-Pu-239	Delayed $-\gamma-\gamma$	$P(E_\gamma, T_{1/2})$	I	2 and 14 Mev	35 %	BNL(OSMW) (USA)	Kouts	7

Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and $10\,\mu\text{sec} \lesssim T_{1/2} \lesssim 1$ hour. Absolute γ-ray yields to a factor of 2 also useful.

Status: R. Chrien, (BNL Unpublished) has some data for U-235 and Pu-239. N.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p.637 (1969); presented some data for U.

Justification: Assay of Pu- fuels.

	94-Pu-239	Fission Yield of 55-Cs-137		I	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 55-Cs-137 resulting from thermal fission of Pu-239 required to within 1 % accuracy. Different values are quoted in the literature.

Status: O.A. Miller et.al., Soviet Atomic Energy, 27, 281 (1969).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p.521 (1970)
S.Hiller, Kerntechnik, 12, No. 11, 485 (1970)

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	94-Pu-239	Fission Yield of 55-Cs-133		I	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 55-Cs-133 resulting from thermal fission of Pu-239 required to within 1% accuracy. Different values are quoted in the literature.

Status: O.A. Miller et.al., Soviet Atomic Energy, 27, 281 (1969).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-239	Fission Yield of 44-Ru-106		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 44 Ru-106 resulting from thermal fission of Pu-239 required to within 1 % accuracy. Different values are quoted in the literature.

Status: S.Hiller, Kerntechnik, 12, No. 11 , 485 (1970)
I.P. Grechushkina, "Tables showing the composition of prompt fission products from U-235, U-238 and Pu-239 fission", Moscow, Atomizdat (1964).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	94-Pu-239	Fission Yield of 40-Zr-95		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	70

Comments: Fission product yield per fission event of 40-Zr-95 resulting from thermal fission of Pu-239 required to within 1% accuracy. Different values are quoted in the literature.

Status: O.A.Miller et.al., Soviet Atomic Energy, 27, 281 (1969).
R.S. Forsyth et.al., 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 1, p. 521 (1970).
S. Hiller, Kerntechnik, 12, No. 11, 485 (1970).

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	94-Pu-239	Fission Yield of 56-Ba-140		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	

Comments: Fission product yield per fission event of 56-Ba-140 resulting from thermal fission of Pu-239 required to within 1 % accuracy. Different values are quoted in the literature.

Status: N.G. Gusev, "Protection against γ-radiation from fission products," (Manual) Moscow, Atomizdat (1968).
V.A. Greshilov et.al., "Products of prompt fission of U-235, U-238 and Pu-239 from 0 to 1 hour", (Manual), Moscow, Atomizdat (1969).
J. of Inorganic Nucl.Chem., 27, 121 (1965)

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc	Yr
	94-Pu-239	Fission Yield of 58-Ce-144		II	Thermal	1 %	IAE (USSR)	Skvortsov and Miller	

Comments: Fission product yield per fission event of 58-Ca-144 resulting from thermal fission of Pu-239 required to within 1 % accuracy. Different values are quoted in the literature.

Status: N.G. Gusev, "Protection against γ-radiation from fission products", (Manual) Moscow, Atomizdat (1968).
S. Hiller, Kerntechnik, 12, No. 11, 485 (1970)

Justification: For assay of U and Pu in spent fuel elements by the fission product γ-rays.

	94-Pu-239	(γ,n) Spectra		III	E_γ = 5-8 Mev	10 %	IAK(GfK) (FRG)	Pröhner	

Comments: Photoneutron spectra with resolved resonances and neutron energies between 0-100 eV required. Accuracies refer to shape and absolute values to within 20 % accuracy would be helpful. Photon energy resolution should be better than 100 Kev.

Status: No active work known.

Justification: Needed for the exploration of new techniques for non-destructive assay whose potential usefulness is unknown.

	94-Pu-239	$(\alpha\gamma,n)$		II	E_e=Threshold-10 Mev ΔE_e = 1 %	10 %	GRP(OSMM) (USA)	Bramblett	0

Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(\alpha\gamma,n)$ yield or may be absolute.

Status: Gozani et.al., Trans. American Nucl. Soc., 13. 707 (1970) - Relative data.

Justification: For non-destructive photonuclear assay of Pu-239.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-239	Delayed-N-Y	N(t)	II	E_e = Threshold - 10 Mev ΔE_e = 1 %	10 %	GRT(OSMX) (USA)	Bramblett	70
		Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 ($x\gamma$,n) yield or may be absolute.							
		Status: Gozani et.al., Trans. American Nucl. Soc., 13, 707 (1970) - Relative data.							
		Justification: For non-destructive photonuclear assay of Pu-239.							
	94-Pu-239	Fission Product γ-Y(1msec-1 hour)	$F(E\gamma,t)$	II	E_e = 10 Mev ΔE_e = 5 %	10 %	GRT(OSMX) (USA)	Bramblett	70
		Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, $E\gamma$ = 0.5-5.0 Mev with ΔE_γ = 3 Kev.							
		Status: Rundquist, Trans.American Nucl. Soc., 13, 746 (1970) - Preliminary data.							
		Justification: For non-destructive photonuclear assay of Pu-239.							
	94-Pu-239	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	III	Thermal;2 Kev	25 %	IAK(OfK) (FRG)	Weitkamp	70
		Comments: Delayed fission γ-ray spectra as a function of delay time required. Particularly interesting for intervals $\leq$1 sec. Accuracy refers to γ-ray intensities. Errors of -50 % to + 100 % for $T_{1/2}$ acceptable.							
		Status: No data.							
		Justification: For non-destructive assay of fissionable material by γ-spectroscopy of short lived fission products.							
457	94-Pu-240	Delayed-N-Y	$\bar{\nu}_D$	II	0.75-14 Mev	20 %	LASL (USA)	Weisbin and Walton	70
		Comments: Delayed neutron yield required. Data desired for extrapolation to 15 Mev.							
		Status: Hunter, LA-3528 (1968); evaluation up to 2.5 Mev. Diven, 1961 IAEA Symposium on Physics of Fast and Intermediate Reactors, Vienna, Vol. 1, p. 149 (1961). Data at 6.3 Mev.							
		Justification: Calculations of moderating assemblies for Pu assays of spent fuel.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-240	Decay Heat		II	_____	0.2 %	AERE (PRG)	Schneider	70
		Comments: Specific decay heat, in e.g. Watts/gramme required. Percentage of heat carried-off by long-range particles (x-rays, γ-rays) would be useful.							
		Status: Uncertainty determined by half-life - most recent measurement by Dokuchaev, Atomnaya Energ., 6, 74 (1959) - $T_{1/2}$ = 6620 ± 50 years. This yields, with Q_α = 5255.3 ± 0.7 keV, the decay heat of 7.008 ± 0.76 % milliWatts/ gramme.							
		Justification: For calorimetric Pu determination.							
462	94-Pu-240	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	II	2 and 14 Mev	35 %	BNL(OSMM) (USA)	Nouts	69
		Comments: Accuracy requested refers to relative intensities of delayed γ-rays from neutron induced fission for $E_\gamma > 2$ Mev and 10μsec $\lesssim T_{1/2} \lesssim$ 1 hour. Absolute γ-ray yields to a factor of 2 also useful.							
		Status: H. Chrien, (BNL Unpublished) has some data for U-235 and Pu-239. F.R. Large and R.J. Bullock, 1969 IAEA Symposium on Physics and Chemistry of Fission, Vienna, p. 637 (1969)); presented some data for U.							
		Justification: Assay of Pu fuels.							
	94-Pu-240	$(x\gamma,n)$		II	E_e=Threshold-10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett	70
		Comments: 4π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.							
		Status: No data.							
		Justification: Effect on non-destructive photonuclear assay of Pu-239.							
	94-Pu-240	Delayed-N-Y for $t <$ 100 sec	N(t)	II	E_e =Threshold- 10 Mev ΔE_e = 1 %	10 %	GRT(OSMM) (USA)	Bramblett.	70
		Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(x\gamma,n)$ yield or may be absolute.							
		Status: No data							
		Justification: Effect on non-destructive photonuclear assay of Pu-239.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-240	Fission Product γ-γ (1msec-SF background)	$P(E\gamma,T)$	II	E_e = 10 Mev ΔE_e = 5 %	10 %	GRT(OSMM) (USA)	Bramblett	7
		Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, $E\gamma$ = 0.5 - 5.0 Mev with $\Delta E\gamma$ = 3 Kev.							
		Status: No data.							
		Justification: Effect on non-destructive photonuclear assay of Pu-239.							
	94-Pu-240	(n, γ)	$P(E\gamma)$	II	Thermal; 2 Kev	25 %	IAK (GfK) (FRG)	Weitkamp	7
		Comments: Capture γ-ray spectra required.							
		Status: No useful data for thermal or 2 keV neutrons.							
		Justifcation: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.							
471	94-Pu-241	Delayed-N-Y	$\bar{\nu}_D$	III	Thermal - 14 Mev	10 %	LASL (USA)	Weisbin and Walton	7
		Comments: Delayed neutron yield required. Data needed for extrapolation to 15 Mev.							
		Status: Only work at thermal energy. See Keepin Nucleonics, 20, 8, 150 (1962).							
		Justification: Calculations of moderating assemblies for Pu assays.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	%Accuracy	Lab/Org.	Requestor, Comments, etc	Year
	94-Pu-241	$\sigma(n,\gamma)$		II	Thermal - 30 Kev	3 %	IAR(GfK) (FRG)	Fischer	70
		Comments: Capture cross section or alpha (α) required. Accuracy to 3 % in eta (η).							
		Status: Yiftah, IA-1152 (1967); evaluation 0.1 eV - 15 Kev. This evaluation being revised. Smith, WASH-1136, 70 (1969): evaluating for ENDF/B library.							
		Justification: For burn-up calculations.							
	94-Pu-241	Alpha	$\frac{\sigma(n,\gamma)}{\sigma(n,f)}$	II	1 Kev - 2 Mev	20 %	IAR(GfK) (FRG)	Fischer	70
		Comments: Alpha ($\sigma(n,\gamma)/\sigma(n,f)$) needed but capture cross section would be equally useful.							
		Status: Davey, 1970 IAEA Conference on Nuclear Data for Reactors, Helsinki, Vol. 2, p. 119 (1970); review paper 100 Kev - 10 Mev.							
		Justification: For burn-up calculations.							
	94-Pu-241	Decay Heat		II	_____	0.5 %	ALKEM (FRG)	Schneider	70
		Comments: Specific decay heat, in e.g. Watts/gramme required. Percentage of heat carried-off by long-range particles (X-rays, γ-rays) would be useful).							
		Status: Uncertainty mainly determined by average β-energy therefore direct calorimetric measurement of decay heat made by Oetting, Phys.Rev., 168, 1388-result was 3.62 $\pm$ 5.0 % milliwatts/gramme.							
		Justification: For calorimetric Pu determination.							
	94-Pu-241	Fission Yield and $\sigma(\gamma,f)$		II	E_γ = Threshold-10 Mev	10 %	CBOHI (USSR)	Markov	71
		Comments: The energy dependence (as a function of incident γ energy) of the fission fragment yield (and fission cross section) resulting from γ-induced fission is required to within 10 %.							
		Status: Data unknown.							
		Justification: For photonuclear assay of Pu.							

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-241	(γ,n)		II	E_γ= Threshold-10 Mev	10 %	GEOHI (USSR)	Markov	71

Comments: The energy dependence of the neutron yield is required to within 10 % for γ-irradiation by γ-rays of different energies.

Status: Data unknown.

Justification: For photonuclear assay of Pu.

	94-Pu-241	Fission Yield of Ce, Cs, Zr and Ru, isotopes		III	Thermal	5 %	IAE (USSR)	Skvortsov and Miller	70

Comments: The fission fragment yield of Ce, Cs, Zr and Ru fission products for fission by thermal neutrons is required to within 5 %.

Status: Data unknown.

Justification: For assay of U and Pu in fuel elements by means of the fission product γ-radiation.

	94-Pu-241	Delayed-γ-γ	$P(E_\gamma, T_{1/2})$	III	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	71

Comments: Delayed fission γ-ray spectra as a function of delay time required. Particularly interesting for intervals < 1 sec. Accuracy refers to γ-ray intensities. Errors of - 50 % + 100 % for $T_{1/2}$ acceptable.

Status: No data.

Justification: For non-destructive assay of fissionable material by γ-spectroscopy of short-lived fission products.

	94-Pu-241	$(\gamma\gamma,n)$		III	E_e= Threshold-10 Mev ΔE_e = 1 %	30 %	GRT(OSUM) (USA)	Bramblett	7[illegible]

Comments: 4 π neutron yield (including fission) produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 $(\gamma\gamma,n)$ yield or may be absolute.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of Pu.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Yr
	94-Pu-241	Delayed-N-Y	N(t)	III	E_e = Threshold - 10 Mev ΔE_e = 1 %	30 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Delayed neutron yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Neutron yield may be relative to D-2 (γ,n) yield or may be absolute.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of Pu.

	94-Pu-241	Fission Product γ-y(1msec-1 hour)	$P(E_\gamma,t)$	III	E_e = 10 Mev ΔE_e = 5 %	30 %	GRT(OSMM) (USA)	Bramblett	70

Comments: Absolute fission product delayed γ-ray yield produced by bremsstrahlung required. Bremsstrahlung converter (preferably Ta) of sufficient thickness to stop electrons. Emergent γ-ray energies, E_γ = 0.5-5.0 Mev with ΔE_γ = 3 Kev.

Status: No data.

Justification: Effect on non-destructive photonuclear assay of Pu.

	94-Pu-241	σ(n,f)		II	Thermal-10 Mev	3-10 %	IAR(GfK) (FRG)	Fischer	3

Comments: Fission cross section required. Accuracy to 3 % from thermal to 10 eV; and to 10 % from 10 eV to 30 Kev; and to 5-10 % from 30 Kev to 10 Mev. Ratio to U-235 or Pu-239 fission cross sections would be useful.

Status: James, AERE-R-6676 (1971): evaluation from thermal to 20 eV; see also AERE-M-2157 (Rev.) evaluation to 20 Kev.
Käppeler, 1970 IAEA Conference on Nuclear Data for Reactors, Helsinki, Vol. 2, p.77 (1970). Ratio to σ(n,f) U-235.
Blons et.al. 1970 IAEA Conference on Nuclear Data for Reactors, Helsinki, Vol. 1, p.469 (1970). Data from 1 eV to 3 Kev.
Smith et.al. , IN-1407, 57 (1970); evaluation for ENDF/B library.

Justification: For burn-up calculations.

Reg.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
	94-Pu-241	(n, γ)	$P(E_\gamma)$	II	Thermal; 2 Kev	25%	IAK(GfK) (FRG)	Weitkamp	70

Comments: Capture γ-ray spectra required.

Status: Experimental determination of $P(E_\gamma)$ for high energy γ's ($E_\gamma > 2$ Mev) resulting from thermal neutrons nearly completed at Karlsruhe to an accuracy of -50 % to + 100 % or better. Final report to be published in 1972.
Preliminary data published at 1970 IAEA Symposium on Safeguards Techniques, Karlsruhe, Vol. 2, p. 113 (1970) and at 1971 Ispra meeting on Non-Destructive Measurement and Identification Techniques in Nuclear Safeguards and at 1972 Berlin meeting of Deutsche Physikalische Gesellschaft.

Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.

	94-Pu-242	(n,γ)	$P(E_\gamma)$	III	Thermal; 2 Kev	25 %	IAK(GfK) (FRG)	Weitkamp	70

Comments: Capture γ-ray spectra required.

Status: No useful data for thermal and 2 Kev neutrons.

Justification: For non-destructive assay of nuclear material by neutron capture γ-ray spectrometry.

473	94-Pu-242	Delayed-N-γ	$\bar{\nu}_D$	III	3 and 14 Mev	20 %	LASL (USA)	Weisbin and Walton	70

Comments: Delayed neutron yield required.

Status: No data.

Justification: Calculations of moderating assemblies for Pu-assays.

	95-Am-241	σ(n,f)		II	20 Kev - 10 Mev	10 %	IAR(GfK) (FRG)	Fischer	70

Comments: Fission cross section required to 10 % accuracy.

Status: Seeger et.al., Nucl.Phys., A96, p. 605; 20 eV to 1 Mev data.
Hirkelmann, KFK-1166 (1970); evaluation to 10 Mev.
Drivak et.al., INDC(CCP) - 9/U, p.6 (1970); from 8 Kev to 3.3 Mev.
Fomushkin, INDC (CCP) - 7/U, p. 28 (1970); from 440 Kev to 3.6 Mev.

Justification: For burn-up calculations.

Req.No.	Target	Reaction Type Quantity	Variable	Priority	Incident Energy	% Accuracy	Lab/Org.	Requestor, Comments, etc.	Year
95-Am-241		$\sigma(n,\gamma)$		II	Thermal - 10 Mev	see Comments	IAR(GfK) (FRG)	Fischer	70

Comments: Capture cross section required to accuracy of 10 % from thermal to 1 Kev; accuracy of 50 % from $\approx$ 100 eV to 300 Kev and accuracy of 20 - 30 % from $\approx$ 100 Kev to 10 Mev.

Status: Dovbenko et.al., INDC(CCP) - 9/U, p.7 (1970); Thermal value.
Hinkelmann, KFK-1186 (1970); evaluation.
Jungclaussen, Izv. Akad. Nauk SSSR, 33, 695 (1969)
Flerov et.al., Nucl. Phys., A102, 443 (1967).

Justification: For burn-up calculations.

95-Am-241		Fission Yield and $\sigma(\gamma,f)$		II	E_γ = Threshold-10 Mev	10 %	GEOHI (USSR)	Markov	71

Comments: The energy dependence (as a function of incident γ energy) of the fission fragment yield (and fission cross section) resulting from γ-induced fission is required to within 10 %.

Status: L. Katz et.al., 1958 Geneva Conference on Peaceful Uses of Atomic Energy, Vol. 15, p. 188 (1958).
Yu.P. Gangrsky et.al., Soviet Journal of Nucl. Physics, 11, 54 (1970)

Justification: For photonuclear assay of Pu.

95-Am-241		(γ,n)		II	E_γ = Threshold-10 Mev	10 %	GEOHI (USSR)	Markov	71

Comments: The energy dependence of the neutron yield is required to within 10 % for γ-irradiation by γ-rays of different energies.

Status: Data unknown.

Justification: For photonuclear assay of Pu.

Annex 1

INTERNATIONAL ATOMIC ENERGY AGENCY

INTEROFFICE MEMORANDUM

TO: Mr. J. J. Schmidt
Mr. T. Iyer
Nuclear Data Section
Division of Research and Laboratories

DATE 31 May 1972

OUR REF.:

Through: Mr. E. López-Menchero
Director
Division of Development

YOUR REF.:

From: Mr. A. J. Waligura
Mr. S. Sanatani
Methods & Techniques Section
Division of Development

SUBJECT: International Request List of Nuclear Data Needed for Safeguards Development Purposes

We have received your latest list, comprising about 124 requests from the USA, USSR and the Federal Republic of Germany. The memorandum accompanying the list and the entries under the item 'Justification' helped us to form a clearer picture as to why certain nuclear data are requested by the scientists concerned.

Our response to the points raised by you could be briefly formulated as follows:

A. The priority criteria continue to present us with some problems. For the time being nuclear data measurements as such have been given a rather low priority in our overall development programme; it is, therefore, rather difficult for us, at the present time, to consider the criteria for priorities of data needed. The situation might change in the future, when we might be able to form a clearer idea about the needs of better nuclear data to improve existing techniques of non-destructive assay or to develop new techniques for safeguards.

B. The list seems to have been prepared in the format usual for such lists; we do not have any comments. Brevity, essential for such lists, might sometimes cause doubts, especially in the minds of novices; but one might always ask the requestor or approach a more knowledgeable person for clarification if required.

C. We are a little apprehensive of too wide a circulation at an early stage. Apart from this thought we see no objection to distribution of the request list to the parties listed by you, provided it is made clear that the list has been prepared from requests from a few Member States and that the IAEA or DSI is not at the present time sponsoring a world wide circulation of data needs for safeguards. We should be very careful not to give an impression that DSI or the Division of Development for their present purposes are urgently in need of the data requested in the list.

D. Various review articles on non-destructive techniques for safeguards have been written. We do not mind preparing another short summary highlighting a few selected applications and discussing some of the developmental problems, if you wish.

E. We agree it might be better to use the term 'nuclear materials' rather than the expression 'special nuclear material' (SNM).

F. A thought which has now and then crossed our minds but which need not be discussed in the list you plan to circulate is the following:

In most cases of safeguards application you only make relative measurements in the field and the accuracy of nuclear data does not matter. A standard is available for comparison or an item is chosen as a standard. You are more concerned with the reproducibility and precision of your instrument, stability of electronics or background counts, etc. rather than with the accuracy of cross sections, yields or half lives.

cc: Mr. Rometsch
Mr. Finkelstein
Mr. Ferronsky
Mr. López-Menchero
Mr. Waligura
Mr. Hough
Mr. Sanatani
DSI