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Institut für Radiochemie INDC (GER) – 12/U+W

Geschäftsführung – Technisch-wissenschaftliche Koordination und Planung

Survey of the Nuclear Data Needs in Activation Analysis

H. Münzel, W. Michaelis

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Survey of the Nuclear Data Needs in Activation Analysis

von

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Umfrage über die in der Aktivierungsanalyse benötigten Kerndaten

Zusammenfassung

Es wurde eine Umfrage durchgeführt, deren Ziel es war, für das Gebiet der Aktivierungsanalyse

a) einen Überblick über Art und Genauigkeit der benötigten Kerndaten zu erhalten, und

b) zu überprüfen, ob die derzeit verfügbaren Kompilationen die Wünsche der Benutzer in befriedigender Weise erfüllen.

Die Ergebnisse der Umfrage werden dargestellt und diskutiert. Außerdem enthält der Anhang eine umfangreiche Liste der Kerndaten-Kompilationen.

Abstract

The goals of the inquiry, the results of which are described in this report, were the following:

a) to yield a survey about the kind and the accuracy of nuclear data needed in activation analysis, and

b) to provide information about the usefulness of the available compilations and if they cover the needs of the users.

In the appendix a reference list for 87 compilations is given.

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Survey of the Nuclear Data Needs in Activation Analysis

H. Münzel and W. Michaelis

In 1972 a meeting of an International Working Group (IWGNSRD) was initiated by the IAEA to discuss problems connected with the compilation, evaluation and dissemination of nuclear structure and reaction data.A result of the discussion was that at present it is very difficult to decide, if the data needs in the different fields of application are covered by the available compilations or if major gaps exist. This unfortunate situation is mainly due to the missing feedback from the users of the data. Therefore at the meeting it was decided, that actions should be initiated to improve the cooperation between compilers and users.
It was proposed, to prepare a survey about the data needs in activation analysis. The results of this survey are summarized below.

In 1972 altogether 151 copies of the questionnaire given in the appendix were sent out to scientists all over the world. The distribution and the number of answers received are given in table 1. In addition, 101 copies of a slightly modified questionnaire were sent to german scientists.

The first question one encounters in such a survey is, to whom a questionnaire should be sent. In our case the selection was greatly aided by the list of the participants of the Paris Conferences on Activation Analysis in October 1972. The adresses of the german scientists were obtained from a list provided by Professor Lux, München.

As shown in the table about 30 %, i.e. 74, questionnaires were sent back to us. The distribution of the answers shows a wide scatter over many countries, but unfortunately no answers were received from Russia. Also some groups, which are well known for their work done in activation analysis, did not respond to the questionnaire. But, nevertheless, we still think that the results of this survey are representative for the data needs in activation analysis.

If not stated otherwise the numbers given in the following summary correspond to the frequency of a specified answer in the filled in questionnaires.

I) Fields of applications

The following distribution was found:

a) Live sciences (biology, medicine, pharmacy) 22
b) Geosciences (geology, mineralogy, oceanography, cosmochemistry) 15
c) Analytical investigations of very pure metalls, surface layers, ... 13
d) Industry (mining, burn up determinations, production and applications of radionuclides) 10
e) Basic research in chemistry (nuclear chemistry, extraction systems, ...) 6
f) Environmental studies 3

This list shows that many different fields are covered. The applications mentioned in 10 questionnaires show that the use of the data has at least some commercial aspects. Judging from the institutions mentioned in the given addresses this number is presumably even higher. In 7 cases the data are applied to

isotope production.

Besides the general field quite often additional information is given about the actual application of the data. In most cases the data are used for

a) identification of radionuclides,
b) evaluation of limits of detection,
c) estimation of interferences by matrix materials as well as impurities (activation analysis), and
d) calculation of the yield (isotope production).

II) Data requested

In this section the general aspects of the data needs will be discussed before we will go into datails.

In the questionnaire we asked not only for the type of data needed but also for the necessary accuracy. In addition it was possible to specify if the data were needed for light, medium or heavy nuclides. In more than 90 % of the cases where figures or crosses are given for a certain type of data, entries are made in all three columns, i.e. the specified type is needed for all kinds of nuclides (see also below). Therefore, the summary of the data needs given in table 2 is not subdivided in respect of the kind of nuclides.

As can be seen from table 2 in many questionnaires no values for the accuracy are given. But it can safely be assumed that the distributions of the requested accuracies obtained from the remaining questionnaires may be fairly representative because they show a sharp maximum in each case. According to table 2 the sufficient accuracy of the cross sections is in general about 5 %.

Only for the reactions with thermal and reactor neutrons higher accuracies are requested in many cases. According to some questionnaires this higher accuracy is necessary for the absolute activation analyses. For half lives and energies of the radiation practically the highest accuracy possible is necessary, whereas the requests in respect to the intensities are not so stringent.

In many cases a limit is given for the requested half-lives. In general, the interest decreases considerably for half-lives below 1 second and above 1 year. The upper limits given for the energy of charged projectiles ranges from 5 to 100 MeV with an average of about 40 MeV.

In the questionnaire it was also asked for more detailed informations about the data needed in the near future. Only in 58 cases figures were given in the corresponding columns. According to 42 questionnaires the data are needed for all the nuclides produced in reactions with

a) thermal or reactor neutrons (30),
b) fast neutrons (15),
c) charged projectiles (15), and
d) γ-rays (7).

Sometimes it was stated, that for instance due to the variety of analytical problems encountered, a more detailed specification was not possible. The data requested for these nuclides correspond very closely to the general specification summarized in table 2.

In table 3 the detailed requests are shown. Besides the data mentioned here also neutron capture γ-rays as well as the specific energy loss of charged particles were requested twice.

III) Accessibility of the data and their influence on activation analysis

The question, if it was difficult to obtain the specified data was answered with yes (31), some (8) and no (7). The accuracy is mentioned as the main reason for the difficulties encountered. In two cases it was complained that one has to look up too many compilations to obtain the necessary data. The difficulties mentioned are: search for decay data (3), cross sections for reactions with reactor neutrons (1), 14 MeV neutrons (3) and charged projectiles (5).

According to 35 questionnaires the work is affected strongly by an inadequate knowledge of the requested data. The following reasons were given for this influence of the data:

a) accuracy (21),
b) limitation of the applicability of activation analysis (7), for instance the absolute methods,
c) the necessary data have to be measured (9) which of course is a time consuming task,
d) difficulties encountered in the identification of radionuclides (2), or in the preparation of a complete computerized data file (1).

IV) Compilations used

The results of the survey are summarized in table 4 which also gives some specific comments stated in the questionnaires. The list of the compilations is given in the appendix.

V) General comments about the compilations

The general comments given about the available compilations can be summarized as follows:

a) out of date (10),
b) insufficient accuracy (8),
c) too many compilations for the same type of data available (6) which differ in the data given,
d) incomplete (6), for instance in respect to energy and intensity of γ-rays,
e) not easy to handle (4), for instance due to presentation used (1),
f) no recommended values are given (3).

According to the questionnaires the following compilations are missing:

a) special handbook for activation analysis (11),
b) cross sections for reactions with charged projectiles (9),
c) cross sections for reactor neutrons (7),
d) catalogue of X-ray spectra taken with a 5 mm Ge(Li)-detector (1),
e) fission yields (1),
f) international file of decay data (1).

This list shows that the situation in respect of decay data seems to be rather satisfactory. Therefore it is not surprising that in 11 cases an overall content with the situation was stated, i.e. that all necessary data were available from the compilations.

VI) Priority

The proposals made about the priorities in the future work can be summarized as follows:

1. New or updated compilations are needed for

a) activation analysis (handbook) (12); two times a CINDA-like representation was requested,

b) cross sections for reactions with charged projectiles (10),

c) decay data (9), especially of short-lived nuclides (2),

d) cross sections for reactions with neutrons (3),

e) Ge(Li)-spectra catalogue for γ-rays (2) and X-rays (1).

The compilations should be prepared in such a way that they are easy to handle (4) and that they can be updated more frequently (6), for instance by issueing annually revisions (1). For this purpose, the compilations should consist of replaceable sheets (2), like the former Nuclear Data Sheets.

2. Evaluations are requested

a) for decay data (22), as well as cross sections for thermal or reactor neutrons (15) and charged projectiles (14),

b) for the calculation of recommended data (8).

VII) Conclusions

1) There is a vital interest of activation analysists in compilations containing a variety of different types of nuclear data.

2) Due to the application of the activation analysis to many different problems, which quite often have to be solved in a rather short time, a detailed request list for the data needed can in general not be given.

3) The following topics are not sufficiently covered by available compilations:

   a) Handbook for activation analysis
   b) Cross sections for charged particle induced reactions
   c) Cross sections for reactions with reactor neutrons

4) In the future the work should concentrate on the preparation of few comprehensive compilations, which should be updated more frequently. The compilations should give data for the decay of radionuclides, cross sections for neutron and charged particle induced reactions, and also for capture γ-rays, X-rays and fission yields.

5) In general data with higher accuracy or even recommended values are requested.

Table 1: Distribution of the questionnaires

Country	sent out	received	Country	sent out	received
Austria (+ IAEA)	3	2	Israel	2	1
Australia	1	1	Italy (+Ispra)	15	7
Belgium	8	4	Japan	3	2
Brasil	1	-	Jugoslavia	2	-
Canada	5	2	Norway	2	1
Czechoslovakia	2	-	Poland	3	3
Denmark	2	2	South Africa	2	2
Egypt	1	-	Spain	3	-
England	12	3	Sweden	5	2
Finland	1	1	Switzerland	3	-
France	20	5	Turkey	1	-
Germany (DDR)	2	-	UDSSR	4	-
Greece	2	-	USA	33	6
Holland	7	5		151	50
Hungaria	5	1	Germany (BRD)	101	24
India	1	-	Total	252	74

Table 2: Summary of the general data needs

Type of data		Accuracy requested (in %) <0.1	< 1	< 2	< 5	<10	not stated	Total
Cross sections for reactions with the following projectiles								
thermal or reactor neutrons		-	14	3	16	3	27	63
energetic neutrons (mainly 14 MeV)			6	2	14	2	16	40
charged particles (p, d, ^{3}He, ^{4}He)			6	1	14	4	13	38
γ-rays, Bremsstrahlung		-	1	1	4	1	8	15
Decay data								
Half-lives		7	19	2	3	2	27	60
Energy of	α	-	6	1	1	-	11	19
	β_{max}	-	10	-	2	1	16	29
	γ	28*	3	-	-	1	26	58
	e^-	-	6	-	-	-	9	15
Intensity for	α^r	-	5	1	-	-	4	10
	α^a	-	5	2	-	-	6	13
(r: relative)	β^r	-	5	1	2	-	9	17
(a: absolut)	β^a	-	5	3	2	-	11	21
	γ^r	1	13	3	3	-	20	40
	γ^a	-	12	6	4	-	21	43
Branching ratios		1	9	2	4	1	16	33

*) The accuracy for the γ-energies is in 14 cases not given in % but in keV

Table 3: Data requests for specified nuclides or groups of nuclides

Nuclides	Type and accuracy of data (accuracy in %; if not stated +)					
	Cross sections			Decay data		
	n_{therm} +n_{react}	n_{14}	charged p. projectiles	$T_{1/2}$	E	I
$^{16}O, ^{18}O, ^{14}N, ^{15}N, ^{28}Si$			1			
B,C,N,O,F,Na,Al, Si,S,Cl			5			
^{64}Cu, ^{76}As				+	γ+	
$^{72}Se, ^{121}Sb, ^{122}Te$ (α,xn)			1			
^{81}Br (n,p)	0,1 mb					
As,Se,Ga,Ge			5			
^{87}Rb, ^{238}U (spont.fission)				1		
$^{104}Rh, ^{109m}Ag, ^{192}Ir, ^{194}Ir, ^{199}Au$				5	γ 2	
^{109}Ag	5					
^{133}Ba				1		γ(abs)1
$^{140}Ba, ^{148}Pm$				1	γ 0.1	γ(abs)1
Light elements*)			5 5	2	α2;ß2;γ2 γ 0,1 keV	α2;ß2;γ2 ß2;γ2
Rare earth elements	5					
Fission products	fission yields			+	γ+;ß**	γ+

additional data: *) yield of X-ray emission induced by charged particles

**) average ß-energy, accuracy 1 %

Table 4: Survey of the compilations used

Frequency	Number of compilation (s. appendix)				
	decay data	Cross sections: neutrons	Cross sections: charged part. γ-rays	Handbooks for act.anal.	others
51	1				
38	2				
23	3				
20	4				
19	5				
18	6				
13	7,8,9				
12	10,11				
11					
10	12,13		1		
9	14,15	1	2		
8	16	2,3			
7	17,18		3	1	1
5					2
4	19,20,21		4		
3	22	4	5	2	3
2	23,23,25,26,27	5,6,7		3	4,5,6,7
1	28,29,30,31,32 33,34,35,36,37 38,39,40,41,42	8,9,10, 11,12	6,7,8	4,5,6,7	8.9.10.11 12
0	43,44	13	9		13,14

Special comments (DD: Decay data compilations)
(N : Neutron cross sections compilations)

compilation Nr.	comments	compilation Nr.	comments
DD1;DD1;N4	should be updated	DD15;DD17	old
DD10	good	DD15;DD17	inaccurate
DD11;DD29;DD35	very useful	DD19	presentation good

QUESTIONNAIRE Appendix 1

1. NAME:
2. Institution and Address
3. Which type of nuclear data do you need in your work?

   a) General survey (please state, if possible, the accuracy of the data required instead of only crossing the entries)

Type		light	medium nuclides	heavy
Cross sections for projectiles:	γ n p Charged particles with A $\geq$ 1			
(state also energy range)				
Half Lives				
Energy of Radiation:	α β_{max} γ e^-(conv)			
Intensity of Radiation (r.:relative; a: absolute)	α β γ			
Branching ratios				

   b) detailed information:

   Would you please specify the nuclear data you use at the moment or which you will need in the near future in more detail:

Nuclide	Type of data	Accuracy requested	used for

Did you have difficulties in obtaining the above-mentioned data?

4. Is your work strongly affected by an inadequate knowledge of the specified nuclear data? If yes, please state in which way.

5. In which field do you mainly apply the needed nuclear data? (for instance: Determination of isotopes in biological samples by activation analysis.)

6. Which of the existing compilations do you use to obtain the data? Please indicate the compilations and comment in detail on their usefulness for your purpose. You may refer to a list of compilations, which, together with a short description of their content, is given in an annex to this questionnaire. Please, indicate any other compilation or source of information, which you use and which is not contained in this list.

7. Do you have some general comments to make about the available compilations, for instance in respect to their usefulness in your case?

8. Is there a lack of special compilations? If yes, please state your opinion about the type of data that should be compiled and how these data are best presented.

9. What has, in your opinion, the highest priority, if more manpower could be made available for the compilation and evaluation of nuclear data? Please state, if other nuclear data should be compiled or if more effort should be made with respect to accuracy of the data in the evaluations etc.

Please return the questionnaire together with additional comments to

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Appendix 2

List of compilations (references as cited in the questionnaires)

I. Decay data

Number		Frequency
1	C.M. Lederer, J.M. Hollander, I. Perlman: Table of Isotopes; Wiley, New York 1967	51
2	W. Seelmann-Eggebert, G. Pfennig, H. Münzel: Nuklidkarte; Gersbach, München, 1968	38
3	R.L. Heath: Scintillation Spectrometry Gamma Ray Catalog; IDO-16880	23
4	Nuclear Data Group: Recent References; Nuclear Data B	20
5	C. Meixner: Table of Gamma Rays for Activation Analysis; Thiemig, München (1970); Jül-811-RX (1971)	19
6	M.A. Wakat: Catalogue of γ-Rays emitted by Radionuclides; Nuclear Data A8, 445 (1971)	18
7	F. Adams, R. Dams: Different Compilations of γ-Energies; Radioanal. Chem. 3, 99 (1969), 3, 271 (1969), 7, 127 (1971); Radiochim. Acta 10, 1 (1968)	13
8	M. Cuypers, I. Cuypers: Gamma-Ray Spectra and Sensitivities for 14 MeV-Neutron Activation Analysis; J. Radioanal. Chem. 1, 243 (1968)	13
9	I.M.H. Pagden, G.J. Pearson, J.M. Bewers: An isotope catalogue for instrumental activation analysis, J. Radioanal. Chem. 8, 127 (1971), 8, 373 (1971), 9, 101 (1971)	13
10	N.E. Holden: Chart of Nuclides; GE-KAPL	12
11	D.J. Horen et al.: Evaluations of the Nuclear Data Group; Nuclear Data B	12

Number		Frequency
12	F. Ajzenberg-Selove, T. Lauritsen: Energy Levels of Light Nuclei ($5 \leq A \leq 20$); Nucl. Phys. 78, 1 (1966), A114, 1 (1968), A152, 1 (1970), A166, 1 (1971), A190, 1 (1972)	10
13	C.E. Crouthamel, F. Adams, R. Dams: Applied γ-Ray Spectrometry; Pergamon Press 1970	10
14	P.M. Endt, C. van der Leun: Energy Levels of Nuclei ($11 \leq Z \leq 21$); Nucl. Phys. A105, 1 (1967)	9
15	B.S. Dzhelepov, L.K. Peker: Decay Schemes of Radioactive Nuclei $A < 100$; Izdatel'stvo "Nauka", Moscow 1966	9
16	R.H. Filby: Washington State University Publication WSUNRC-97 (2) 1970	8
17	W. Kunz, J. Schintlmeister: Nuclear tables; Pergamon Press 1963	7
18	Vogg: Catalogue of γ-Ray Spectra from Neutron Activation Analysis with 14 MeV Neutrons; Thiemig Verlag München	7
19	M.J. Martin, P.H. Blichert-Toft: Radioactive Atoms, Auger-Electron, α-, ß-, γ-, and X-Ray Data. Nuclear Data A8, 1, 1970	4
20	J.H. Hamilton et al.: Experimental Values of Internal-Conversion Coefficients of Nuclear Transitions; Nucl. Data A1, 521 (1966)	4
21	L.A. Sliv, I.M. Band in Volume 2 of Siegbahn: Table of Internal Conversion Coefficients. Alpha-Beta- and Gamma-Ray Spectroscopy. North-Holland, Amsterdam (1965)	4
22	G.J. Pearson, J.M. Bewers: Compilation of γ-Ray-Interferences, Chemical Oceanography Div. Dartmourth, Nova Scotia (1971)	3

Number		Frequency
23	M. de Bruin, P.J.M. Korthoven: γ-rays and branching ratios; IRI-Report 133-71-06, Nucl. Data Section, Vienna	2
24	H. William, H. Sullivan (ORNL): Trilinear Chart of Nuclides	2
25	M. de Bruin, P.J.M. Korthoven: Low-energy gamma rays from isotopes produced by (n,γ)-reactions J. Radioanal. Chem. 10, 125 (1972)	2
26	Girardi et al.: Catalogue of γ-ray Spectra; Euratom Report 1898 e	2
27	R.C. Hawkings, W.J. Edwards and E.M. McLeod: Tables of γ-Rays from the decay of Radionuclides; AECL 1225	2
28	R.S. Hager, E.C. Seltzer: Internal Conversion Tables; Nuclear Data A4, 1 (1968), A6, 1 (1969)	1
29	F. Dyer (ORNL): γ-ray compilation	1
30	R.A. Creig, R.E.J. Porritt, S.J. Bone: Tables of γ-Rays from (n,γ) produced Nuclides; AAEC/TM 585 1971	1
31	R.L. Heath: Table of Isotopes; in Handbook of Chemistry in Physics, 1970-71	1
32	D.E. Greg ed.: Handbook, American Institute of Physics	1
33	O. Tannila, J. Kantele: Table of Radioactive Species ($T_{1/2} \geq$ 1ms); Research Report 2/1969 and 3/1969, Jyväskylä, Finnland	1

Number		Frequency
34	D.N. Slater: Gamma-rays of Radionuclides in Order of Increasing Energy; Butterworth, London 1962	1
35	Janni: AFWL-TR-65-150	1
36	Wapstra: Tables of internal conversion coefficients;	1
37	Yen Wang: Handbook of Radioactive Nuclides; The Chemical Rubber Co. 1969	1
38	A. Rakow: Tabellen zur Identifizierung unbekannter Gammaspektren; Thiemig Taschenbücher Nr. 2	1
39	D. Nachtigall: Table of specific γ-ray constants; K.Thiemig Verlag, München	1
40	S. Kinsman (Hrsg.): Radiological Health Handbook; PB 121 784 R, United States Department of Health, Education and Welfare	1
41	N.C. Rasmussen et al: Thermal neutron capture γ-rays spectra of the elements (Z=1-83); Air Force Cambridge Research Laboratories, AFCRL-69-007, 1969	1
42	R. Gunnink et al.: γ-Ray Energies and Intensities; UCID-15439 (1969)	1
43	I.P. Selinov: Izotopy, parts I-III; Izdatel'stvo "Nauka", Moscow 1970	0
44	Balalaye et al.: Properties of Nuclei with A=174; Inst. of Nucl. Phys., Acad. of Sciences Moscow, USSR, 1969	0

II. Neutron cross sections

Number		Frequency
1	Sigma Center, Brookhaven National Laboratory: Neutron Cross Sections; BNL 325	9
2	CINDA (72): IAEA, Vienna 1972	8
3	F. Baumgärtner: Tabellen zur Neutronenaktivierung; Kerntechnik 3, 356 (1961)	8
4	J.C. Roy, J.J. Hawton: Table of estimated cross sections for (n,p)-, (n,α)- and (n,2n) Reactions in a fission neutron spectrum; CRC-1003, ONTARIO, 1960	3
5	J.B. Marion, J.L. Fowler: Several articles in Fast Neutron Physics, part, II (1963)	2
6	H. Neuert, H. Pollehn: Tables of cross sections of Nuclear Reactions ...; Euratom Report EUR 122 e, Hamburg 1963	2
7	M. Drake: A compilation of Resonance Integrals; Nucleonics 1966	2
8	S.C. Mathur et al.: Compilation of Neutron Reaction and Total Cross Sections at 14 MeV; Texas Nuclear Corporation Report, Austin 1964	1
9	R.J. Howerton: Tabulated Neutron Cross Sections; University of California, Livermore 1959	1
10	M.P. Yule, H.R. Lukens jr., V.P. Guinn: Utilization of Reactor Fast Neutrons for Activation Analysis; GA-5978, Dez. 1964	1
11	R. van der Linden, F. De Corte, P. van den Winkel, J. Hoste: A Compilation of infinite Delution Resonance Integrals; J. Radioanal. Chem. 11, 133 (1972)	1

Number		Frequency
12	E. Steinnes: Resonance activation integrals of some nuclides of interest in neutron activation analysis; J. inorg. nucl. chem. 34, 2699 (1972)	1
13	4 centres: files of the four cooperating neutron cross section centres - National Neutron Cross Section Center, Brookhaven, USA; Centre de Compilation des Données Neutroniques, Saclay, France; Centr po Jadernym Dannym, Obninsk, USSR; Nuclear Data Section, Vienna, Austria	0

III. Charged particle cross sections

Number		Frequency
1	F.K. McGowan et al.: Compilations of the Charged-Particle Cross Section Data Centre; Nuclear Data A1, 203 (1966), A2, 1 (1966), A3, 123 (1967); Reference lists: Nuclear Data A6, 353 (1969), A7, 1 (1969), A8, 199 (1970), A9, 469 (1971), A11,1 (1972)	10
2	C. Maples, G.W. Goth, J. Ceruy: Nuclear Reaction Q-values; Nuclear Data A2, 429 (1967)	9
3	J. Lange, H. Münzel: Cross Sections for Charged Particle induced Reactions; KFK-767 (1968)	7
4	E.G. Fuller et al.: Photonuclear Data Center, NBS: Photonuclear Data Index; NBS Special Publication 322, 1971	4
5	E. Strom, H.I. Israel: Photon Cross Sections from 1 keV to 100 MeV for Elements Z=1 to Z=100 Nuclear Data A7, 565, 1970	3
6	N.N. Krasnov (Obninsk): Charged particle data; Chem. Zvesti 21, 611 (1967)	1
7	N. Jarmie, J.D. Seagrave: Charged particle cross sections LA-2014 (1957)	1
8	Sapristi: Charged particle reactions; C.I.D. Euratom	1
9	I. Slaus, G. Paic: Several tables; in Solid State Physics, Nucl. Physics and Particle Phys. Benjamin, N.Y. 1968	0

IV. Handbook for Activation Analysis

Number		Frequency
1	A.I. Aliev et al.: Handbook of Nuclear Data for Neutron Activation Analysis; Sprarochnik 1969, Engl. transl. Israel Progr. for Scient. Transl. Ltd. Jerusalem 1970	7
2	R.C. Koch: Activation Analysis Handbook; Academic Press, New York 1960	3
3	I.A. Moslov, V.A. Luknitskii; Neutron Activation Analysis Handbook, Izdatel'stvo Nauka Leningradskoe Otdelenie, 1971	2
4	J. Perolijon: L'analyse par activation; Masson & Cie, Editeurs, Paris 1967	1
5	The Radiochemical Manual, Second edition 1966	1
6	W. Schulze: Neutronenaktivierung als analytisches Hilfsmittel; F. Enke Verlag, 1962	1
7	W. Schulze: Activation Analysis; Some Basic principles; in Advances in Activation Analysis I	1

V. Miscellaneous

Number		Frequency
1	G.A. Bartholomew et al., (AECL) and L.V. Groshev et al.: Compendium of Thermal-Neutron-Capture γ-Ray Measurements; Nucl. Data A3, 367, 1967; A5, 1, 1968; A5, 243, 1969	7
2	A.H. Wapstra, N.B. Gove: The 1971 Atomic Mass Evaluation; Nuclear Data, A9, 265, 1971	5
3	J. Lindskog et al.: Table of life-time measurements of excited nuclear states; in Siegbahn: Alpha- Beta- and Gamma-Ray Spectroscopy, Volume 2, North-Holland, Amsterdam (1965)	3
4	G.H. Fuller, V.W. Cohen: Nuclear Spins and Moments. Nuclear Data A5, 433, 1969	2
5	P. del Marmol: Delayed-Neutron precursors Nuclear Data A6, 141, 1969	2
6	I. Lindgren: Table of Nuclear Spins and Moments; in Siegbahn: Alpha- Beta- and Gamma-Ray Spectroscopy, Volume 2, North-Holland, Amsterdam (1965)	2
7	C.F. Williamson, J.-P. Boujot, J. Picard: Tables of range and stopping power of chemical elements for charged particles of energy 0,05 to 500 MeV; CEA-R 3042	2
8	K.E.G. Löbner, M. Vetter, V. Hönig: Nuclear Intrinsic Quadrupole Moments and Deformation Parameters; Nuclear Data, A7, 495, 1970	1
9	W. Whaling: Compilation of stopping power data; in Encyclopedia of Physics; Springer Verlag	1
10	M.E. Meek, B.F. Rider: Compilation of fission products yields; NEDO 12154 (1972)	1

Number		Frequency
11	S. Katcoff: Fission product yields from neutron induced fission; Nucleonics 18, 201 (1960)	1
12	H. Graewe: Tabelle der stabilen und Radionuklide; Dümmlerbuch 4132, Bonn	1
13	B.J. Allen, J.R. Bird, M.J. Kenny: Compilation of keV Neutron Capture Gamma Rays (A=40-70) AAEC/E 200, 1969	0
14	H.R. Collard, L.R.B. Elton, R. Hofstadter: Nuclear Radii, Landolt-Börnstein, New Series, I., Vol. 2, Springer-Verlag, Berlin 1967	0