XA9026789

IAEA-NDS- 115

Rev. 0

INTERNATIONAL ATOMIC ENERGY AGENCY

NUCLEAR DATA SERVICES

DOCUMENTATION SERIES OF THE IAEA NUCLEAR DATA SECTION

PROMPT GAMMA-RAYS FROM THERMAL-NEUTRON CAPTURE

M.A. Lone, R.A. Leavitt, D.A. Harrison
Chalk River, Canada

Abstract: This document describes format and contents of a nuclear data library on magnetic tape which lists prompt gamma rays from thermal-neutron capture evaluated by M.A. Lone et al. The magnetic tape is available, costfree, from the IAEA Nuclear Data Section.

(H.D. Lemmel, ed.)
April 1989

Prompt gamma-rays from thermal-neutron capture

M.A. Lone, R.A. Leavitt, D.A. Harrison
Chalk River, Canada

The contents of this data file is fully described in "Atomic Data and Nuclear Data Tables" ADNDT vol. 26 (1981) of which the introduction is attached.

The data file is an EBCDIC tabulation not requiring any software. The file is given in two sorts. File 1 is sorted by gamma-ray energy. File 2 is sorted by element first (Z-number) and then by gamma-ray energy. These files include some more lines than have been included in the publication in ADNDT.

File 1 contains the following data columns:

1. the gamma-ray energy, ranging from 23. keV up to 10829. keV

2. the gamma-ray intensity in terms of gamma-rays emitted per 100 neutron radiative captures

3. the element which is irradiated with thermal neutrons, ranging from Z=1 to 83

4. the thermal neutron-capture cross-section in barns (cross-section at E_n = 0.0253 eV) taken from BNL-325, 3rd ed., vol. 1 (June 1973)

5.- 8. energy and intensity of the two major gamma-rays of the same element.

File 2 contains for each element its thermal-neutron capture cross-section and a list of its gamma-ray energies, the uncertainty, and the intensity (defined as above).

The size of the library: File 1 = 13029 records, File 2 = 10781 records. The record length is 80.

The authors pointed out a typographical error: The intensity of the 3028 keV line of Ge is 0.39% instead of 39% which was given in ADNDT. This was corrected in the tape at the IAEA Nuclear Data Section.

(H.D. Lemmel, ed.)

Sample of File 1

GAMMA ENERGY KEV	GAMMA INTENS. N/100	***ELEMENT*** Z	SMBY.	CROSS SEC. BARN	*****TWO MAJOR LINES***** ENERGY KEV	INTENS. N/100	ENERGY KEV	IN N
23.0	.75	65	TB	2.6E+01	75.1	10.80	63.8	8
26.6	18.00	25	MN	1.3E+01	7243.8	12.13	7057.8	11
27.2	1.69	53	I	6.2E+00	133.6	8.43	442.9	4
28.5	.17	57	LA	9.1E+00	1596.2	15.36	218.2	10
29.8	.20	25	MN	1.3E+01	26.6	18.00	7243.8	12
30.0	2.30	57	LA	9.1E+00	1596.2	15.36	218.2	10
31.4	.78	43	TC	1.9E+01	172.2	48.79	299.5	11
32.7	.37	65	TB	2.6E+01	75.1	10.80	63.8	8
33.1	.90	65	TB	2.6E+01	75.1	10.80	63.8	8
34.7	.29	57	LA	9.1E+00	1596.2	15.36	218.2	10
39.5	.63	43	TC	1.9E+01	172.2	48.79	299.5	11
40.3	.52	65	TB	2.6E+01	75.1	10.80	63.8	8
41.9	4.80	65	TB	2.6E+01	75.1	10.80	63.8	8
42.8	.34	53	I	6.2E+00	133.6	8.43	442.9	4
43.3	.39	43	TC	1.9E+01	172.2	48.79	299.5	11
43.6	.79	43	TC	1.9E+01	172.2	48.79	299.5	11
45.9	.18	57	LA	9.1E+00	1596.2	15.36	218.2	10
46.1	.19	43	TC	1.9E+01	172.2	48.79	299.5	11
51.2	3.00	65	TB	2.6E+01	75.1	10.80	63.8	8
52.5	1.14	53	I	6.2E+00	133.6	8.43	442.9	4
54.0	2.14	65	TB	2.6E+01	75.1	10.80	63.8	8
54.9	2.30	57	LA	9.1E+00	1596.2	15.36	218.2	10
56.2	.17	57	LA	9.1E+00	1596.2	15.36	218.2	10
58.2	1.85	53	I	6.2E+00	133.6	8.43	442.9	4
59.7	3.50	65	TB	2.6E+01	75.1	10.80	63.8	8
60.0	8.48	55	CS	2.9E+01	116.4	15.15	176.4	10
61.1	.18	55	CS	2.9E+01	116.4	15.15	176.4	10
61.2	.15	55	CS	2.9E+01	116.4	15.15	176.4	10
62.9	2.22	43	TC	1.9E+01	172.2	48.79	299.5	11
63.2	4.00	57	LA	9.1E+00	1596.2	15.36	218.2	10
63.8	8.70	65	TB	2.6E+01	75.1	10.80	41.9	4
63.9	1.00	43	TC	1.9E+01	172.2	48.79	299.5	11
64.6	1.40	65	TB	2.6E+01	75.1	10.80	63.8	8
67.1	.59	53	I	6.2E+00	133.6	8.43	442.9	4
67.3	1.20	55	CS	2.9E+01	116.4	15.15	176.4	10
69.2	.24	57	LA	9.1E+00	1596.2	15.36	218.2	10
71.6	.22	43	TC	1.9E+01	172.2	48.79	299.5	11
73.6	.22	55	CS	2.9E+01	116.4	15.15	176.4	10
74.1	2.24	55	CS	2.9E+01	116.4	15.15	176.4	10
75.1	10.80	65	TB	2.6E+01	63.8	8.70	41.9	4

Sample of File 2

Z = 1 ELEMENT : H
CROSS SECTION = 3.3200E-01
1 GAMMA LINE(S).

ENERGY	ERROR	INTENSITY
2223.30	2.0000	100.00

Z = 3 ELEMENT : LI
CROSS SECTION = 3.6300E-02
6 GAMMA LINE(S).

ENERGY	ERROR	INTENSITY
477.60	2.0000	2.59
980.70	2.0000	9.83
1052.70	2.0000	4.91
2032.50	2.0000	89.33
6771.00	2.0000	1.07
7246.70	2.0000	4.02

Z = 4 ELEMENT : BE
CROSS SECTION = 9.2000E-03
11 GAMMA LINE(S).

ENERGY	ERROR	INTENSITY
219.30	0.2000	0.05
547.41	0.1500	0.16
631.83	0.1500	0.24
853.53	0.0030	25.96
2590.15	0.0125	23.28
2811.80	0.3000	0.13
2896.40	0.3000	0.15
3367.61	0.0594	33.71
3443.51	0.0891	11.59
5956.73	0.2054	1.75
6809.41	0.0880	63.75

Z = 5 ELEMENT : B
CROSS SECTION = 1.0300E-01
4 GAMMA LINE(S).

ENERGY	ERROR	INTENSITY
4443.00	2.0000	75.96
4710.20	2.0000	34.18
6759.30	2.0000	39.50
7005.10	2.0000	47.85

Z = 6 ELEMENT : C
CROSS SECTION = 3.3700E-03
3 GAMMA LINE(S).

ENERGY	ERROR	INTENSITY
1261.74	0.0624	29.53
3683.93	0.0038	32.10
4945.33	0.0103	67.64

ATOMIC DATA AND NUCLEAR DATA TABLES 26, 511–559 (1981)

PROMPT GAMMA RAYS FROM THERMAL-NEUTRON CAPTURE

M. A. LONE, R. A. LEAVITT,* and D. A. HARRISON†

Atomic Energy of Canadas Limited
Chalk River Nuclear Laboratories
Chalk River, Ontario KOJ 1JO, Canada

A catalog of γ-rays emitted following thermal-neutron capture in natural elements is presented. In Table I, γ-rays are arranged in order of increasing energy. Each line contains the γ-ray energy, intensity, element identification, thermal-neutron radiative-capture cross section, and the energies and intensities of two of the more abundant γ-rays associated with that element. In Table II, γ-rays are arranged by element and γ-ray energy; energy uncertainty and γ-ray intensity are given. The catalog is designed for use in high-resolution analytical prompt γ-ray spectroscopy.

* Summer student from Queen's University, Kingston, Ontario, Canada

† Summer student from Toronto University, Toronto, Ontario, Canada

0092-640X/81/060511-49$02.00/0

CONTENTS

INTRODUCTION

This catalog of the prompt γ-rays from thermal-neutron capture in natural elements is designed primarily as a convenient tool for analytical prompt γ-ray spectroscopy. The employment of this technique which complements neutron-activation analysis is growing rapidly.[1] Other potential uses will be the identification of background γ-rays and of chemical trace impurities in target materials used for (n, γ) studies.[2]

Previous compilations[3-5] provided information on γ-rays from thermal-neutron capture in individual isotopes and natural elements and covered data published prior to 1969. Since then more data with higher resolution have become available which supersede earlier results. The present catalog based on the data published between 1968 and March 1980 updates the information on natural elements in the previous compilations.

The catalog is divided into two sections. In Table I, γ-rays are listed in order of increasing energy. Only γ-rays with intensity greater than 1% are included. Each entry consists of γ-ray energy, intensity, element identification, thermal-neutron radiative-capture cross section, and two of the more abundant γ-rays from the element. In Table II, γ-rays are listed by element. This table includes references, thermal-neutron radiative-capture cross sections, γ-ray energies, energy uncertainties, and intensities.

References

1. E. T. Jurney, in *Neutron Capture Gamma-Ray Spectroscopy*, edited by R. E. Chrien and W. R. Kane (Plenum, New York 1979), p. 461
2. M. A. Lone and G. A. Bartholomew, in *Neutron Capture Gamma-Ray Spectroscopy*, edited by R. E. Chrien and W. R. Kane (Plenum, New York, 1979), p. 675
3. G. A. Bartholomew et al., "Compendium of Thermal-Neutron-Capture Gamma-Ray Measurements," Part I, Nuclear Data A 3, 367 (1967); Part II, Nuclear Data A 5 (1968), 1; Part III, Nuclear Data A 5, 243 (1969)
4. N. C. Rasmussen, Y. Hukai, T. Inouye, and V. J. Orpan, "Thermal Neutron Capture Gamma-Ray Spectra of the Elements," Massachusetts Institute of Technology Rept. MITNE-85 (1969); also AFCRL-69-0071
5. J. N. Hamawi and N. C. Rasmussen, Massachusetts Institute of Technology Rept. MITNE-105 (1969)
6. CINDA-A. *An Index to the Literature on Microscopic Neutron Data* (Int. At. Energy Ag., Vienna, 1979), Vols. 1, 2
7. CINDA 79. Supplement to CINDA-A (Int. At. Energy Ag., Vienna, 1979)
8. S. F. Mughabghab and D. I. Garber, "Neutron Cross Sections," Vol. 1, "Resonance Parameters," National Neutron Cross Section Center, Brookhaven National Laboratory Rept. BNL-325, 3rd ed. (1973)
9. W. W. Bowman and K. W. MacMurdo, ATOMIC DATA AND NUCLEAR DATA TABLES, 13, 90 (1974)

POLICIES

LITERATURE COVERAGE The data were obtained from a survey of the literature published between 1968 and March 1980. The references for this survey were selected primarily from the International Atomic Energy Agency reports CINDA-A[6] and CINDA-79[7] and Nuclear Data Sheets (recent references). Thermal-neutron capture cross sections are taken from BNL-325.[8]

DATA SELECTED For analytical prompt γ-ray spectroscopy a single Ge(Li) or a Ge(Li)–NaI spectrometer is used. Consequently, data for this catalog are taken from measurements made with such spectrometers. Thus the extremely high-resolution, mostly low-energy data, collected with bent crystal spectrometers, are not included. In Table I, γ-rays with intensity greater than or equal to 1% are included. Table II contains γ-rays with intensity greater than 0.05%. References to the literature containing data on weaker γ-rays are identified in Table II.

GAMMA-RAYS INCLUDED Listed are only prompt γ-rays from thermal-neutron capture in all elements with $Z = 1$ through $Z = 83$ (except $_{61}$Pm) and in $^{232}_{90}$Th and $^{239}_{94}$Pu. Gamma-rays from the decay of the residual nucleus are not included. These were compiled earlier by Bowman and MacMurdo[9]

GAMMA-RAY ENERGY The energy of each γ-ray is a weighted average of the energies reported by various authors computed from the relation

$$E = \sum (\delta E_i)^{-2} E_i / \sum (\delta E_i)^{-2}$$

ENERGY ERROR The uncertainty in the mean γ-ray energy is found from

$$\Delta E = [\sum (E_i - E)^2 (\delta E_i)^{-2} / (N - 1) \sum (\delta E_i)^{-2}]^{1/2}$$

GAMMA-RAY INTENSITY The γ-ray intensities adopted are unweighted averages. If the original article reported only relative intensities, the absolute intensities were computed by normalizing to the absolute intensities reported by others. The intensities are given in terms of γ-rays emitted per 100 neutron radiative captures.

ELEMENT IDENTIFICATION The atomic number Z and the chemical symbol of the element are given in both tables. In some instances the presence of trace chemical impurities in target materials may have led to wrong assignments of γ-rays especially in the case of elements with low neutron capture cross sections. The listing of capture cross sections and TWO MAJOR LINES in Table I helps in identifying such erroneous assignments.

CROSS SECTION Thermal-neutron capture γ-ray production cross sections are taken from BNL-325[8]

ESCAPE PEAKS Energies of γ-ray peaks which result from single and double escape of annihilation photons from the detector are not included

REFERENCES Reference keys are given in the style 68Jo. A complete reference list follows the Tables

EXPLANATION OF TABLES

TABLE I. γ-Rays Ordered by Energy

TABLE II. γ-Rays Ordered by Element and Energy

Z = 1–83 (except for $_{61}$Pm), 90, and 94

E	Gamma-ray energy as observed in the spectrometer
I	Gamma-ray intensity per 100 neutron radiative captures
Z	Atomic number
SY	Chemical symbol
SIG	Thermal neutron γ-ray production cross section for the element
TWO MAJOR LINES	Two of the more abundant γ-rays associated with the element