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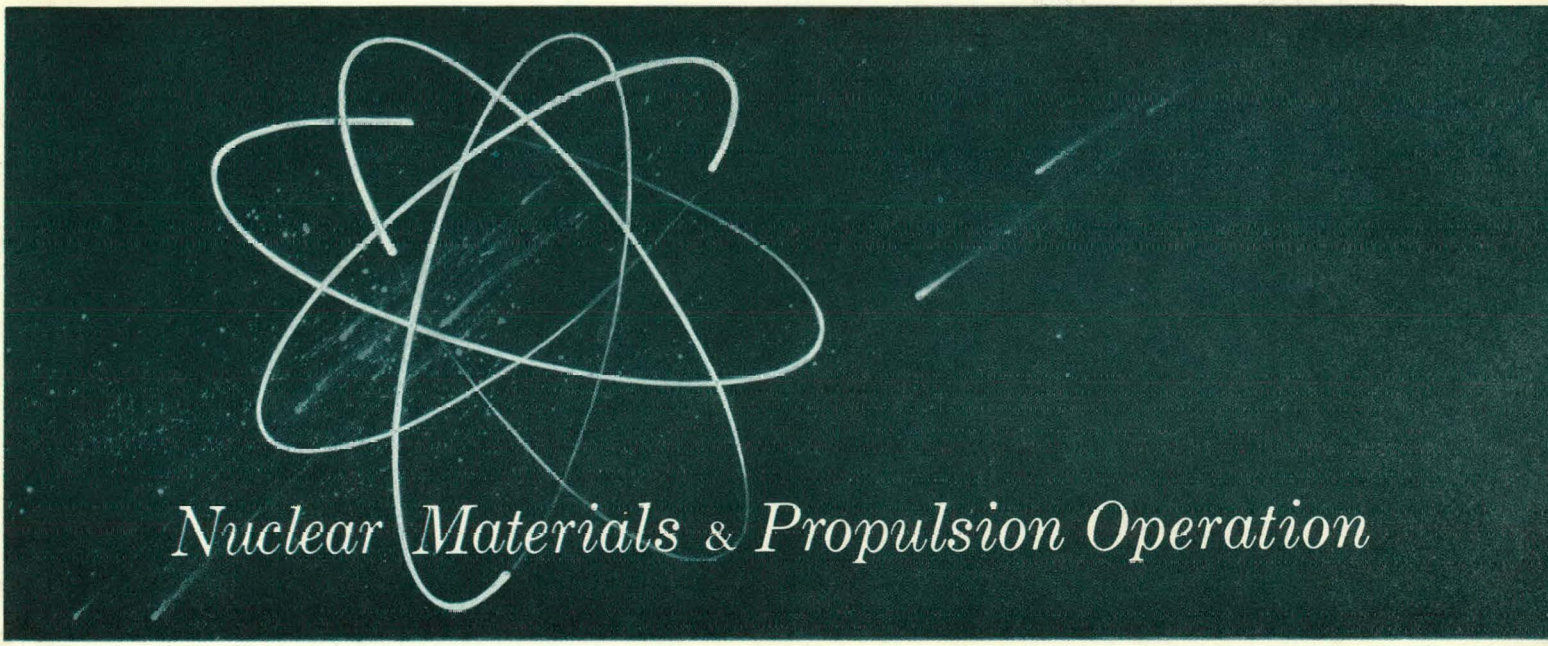

Gamma Ray Production Cross Sections

W. E. Edwards

ADVANCED TECHNOLOGY SERVICES
GENERAL ELECTRIC

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Gamma Ray Production Cross Sections

W. E. Edwards

April 7, 1964

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ABSTRACT

Gamma ray production cross sections are presented in this report as a function of 16 neutron lethargy groups and 11 photon energy groups for 13 elements and isotopes. They were computed by Program GAMMA-P and account for the production of gamma rays by neutron radiative capture, neutron inelastic scattering, neutron induced fissioning, and (n, α) reactions. The production cross sections are available on IBM decimal cards for use with transport theory Program S-X.

CONTENTS

1. INTRODUCTION

Gamma ray production cross sections are presented in this report as a function of 16 neutron lethargy groups and 11 photon energy groups for 13 elements and isotopes. They were computed by Program GAMMA-P[1]* and account for the production of gamma rays by neutron radiative capture, neutron inelastic scattering, neutron induced fissioning, and (n, α) reactions. The production cross sections are available on IBM decimal cards for use with transport theory Program S-X.

Several assumptions are made in Program GAMMA-P to simplify the numerical calculation of production cross sections. First, separation of variables is assumed so that

$$\sigma_{n,\gamma}(\bar{u}_n, \bar{E}\gamma) = \sigma_{n,\gamma}(\bar{u}_n) \cdot S_{n,\gamma}(\bar{u}_n, \bar{E}\gamma),$$

where $\sigma_{n,\gamma}(\bar{u}_n, \bar{E}\gamma)$ is the cross section for the production of gamma rays in gamma energy group $\bar{E}\gamma$ by radiative capture of neutrons in lethargy group $\bar{u}_n$, $\sigma_{n,\gamma}(\bar{u}_n)$ is the cross section for radiative capture of neutrons in lethargy group $\bar{u}_n$, and $S_{n,\gamma}$ is the gamma spectrum resulting from neutron radiative capture. Similar assumptions are made for other production reactions.

Second, the gamma energy spectrum from thermal neutron capture is normalized to the binding energy of the neutron. All unmeasured gamma energy is assumed to be released in the lowest energy group because, in general, gamma rays with low energy have not been measured. The third assumption is that the gamma energy from radiative neutron capture equals the neutron binding energy plus kinetic energy. Corrections for internal conversion are possible; however, they were not considered in this analysis.

*Superscripts refer to reference list at end of the report.

2. DISCUSSION OF PRODUCTION CROSS SECTIONS

The cross sections and spectra used in the computation of these production cross sections are discussed in the same format used by M. J. Ferry.[1] As in her compilation, experimental data supplemented by extrapolation when justified by the available data were used.

In all cases, the gamma spectrum from epithermal neutron capture was assumed to have the same shape as that from thermal neutron capture. All references to gamma spectra from radiative neutron capture are for the capture of thermal neutrons.

No attempt was made to account for all the energy available from inelastic neutron scattering. The upper limit of the gamma energy from inelastic scattering is the kinetic energy of the neutron. However, an appreciable portion of the kinetic energy stays with the scattered neutron. Only experimental data were used for the gamma rays from inelastic scattering. Therefore, these production cross sections underestimate the gamma energy released in inelastic neutron scattering.

Atomic weights needed in binding energy calculations were taken from W. H. Sullivan's "Trilinear Chart of Nuclides."[2] The atomic weights for Mo^{101}, W^{181}, W^{185}, and Re^{185} were computed by equation 8 from reference 1. Percentage abundances of each isotope also were taken from Sullivan. Thermal neutron absorption cross sections were obtained from BNL-325.[3,4]

BERYLLIUM

Radiative Capture

The energies and intensities of discrete gamma rays were taken from a tabulation by Troubetzkoy and Goldstein,[5] and the radiative capture cross section was assumed to vary inversely as the neutron velocity from $\sigma_{n,\gamma} = 0.010$ barns[3] at 0.0253 ev.

Inelastic Scattering

Hall and Bonner[6] reported that there are no detectable gamma rays from inelastic scattering in beryllium.

BORON-10

Radiative Capture

The energies and intensities of discrete gamma rays were taken from Troubetzkoy and Goldstein,[5] and the radiative capture cross section was assumed to vary inversely as the neutron velocity from $\sigma_{n,\gamma} = 0.5$ barns[3] at 0.0253 ev.

Inelastic Scattering

The cross section for the production of 0.717 Mev gamma rays by inelastic scattering measured by Day and Walt[7] for $1.0 \leq E_n \leq 5.5$ Mev was used. It was extrapolated to 70 mb at $E_n = 6$ Mev and assumed constant at 70 mb above 6 Mev.

(n, α) Reaction

It was assumed that each B^{10} (n, α) Li^7 reaction was accompanied by a 0.478 Mev gamma ray,[8] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

CARBON

Radiative Capture

The energies and intensities of discrete gamma rays were taken from Troubetzkoy and Goldstein,[5] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.

Inelastic Scattering

An average $\sigma_{n,\ n'\gamma}$ of 0.27 barn for 3 to 10 Mev neutrons for the production of 4.43 Mev gamma rays was determined from data in BNL - 325. Data are presented there for $4.9 \leq E_n \leq 9.2$ Mev.

OXYGEN

Radiative Capture

The radiative capture cross section of oxygen is less than 0.2 mb at 0.0253 ev,[3] and no reference to measured gamma spectra from neutron radiative capture was found. Therefore, radiative capture was omitted from the gamma production cross sections for oxygen.

Inelastic Scattering

Cross sections for the production of a 6.1 Mev gamma ray and for the production of unseparated 6.9 and 7.1 Mev gamma rays were obtained from BNL - 325. An average energy of 7.0 Mev was assumed for the 6.9 and 7.1 Mev gamma rays.

CHROMIUM

Radiative Capture

The energies and intensities of discrete gamma rays were taken from Troubetsky and Goldstein,[5] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

The cross section for the production of the 1.44 Mev gamma ray by inelastic scattering of neutrons with energies between 1.4 and 2.8 Mev was obtained from BNL - 325. Data from Tralli[10] were used for the energy range 2.8 to 10 Mev.

IRON

Radiative Capture

The energies and intensities of discrete gamma rays were taken from Troubetzkoy and Goldstein,[5] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

The cross section for the production of 0.845 Mev gamma rays by inelastic scattering of neutrons in the energy range 1.4 to 3.0 Mev was obtained from BNL - 325. The cross section was assumed a constant 1.4 barns above 3 Mev. Cross sections for the production of gamma rays with energies 1.26, 1.41, 1.81, 2.1, 2.26, 2.6, 3.0, and 3.3 Mev were obtained directly from or extrapolated from data received from Montague and Paul.[11]

NICKEL

Radiative Capture

The energies and intensities of discrete gamma rays were taken from Troubetzkoy and Goldstein,[5] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

Cross sections for the production of 1.33 and 1.47 Mev gamma rays by inelastic scattering were taken from BNL-325 for neutron energies from threshold to 2.7 Mev. Constant cross sections were extrapolated above 2.7 Mev.

MOLYBDENUM

Radiative Capture

Values of the energy-integrated spectrum of gamma rays from radiative capture were taken from the tabulation of Troubetzkoy and Goldstein,[5] and it was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

Cross sections at $E_n = 3.2$ Mev were obtained from Price, et al.,[12] for the production of 0.73, 1.4, and 2.5 gamma rays by inelastic scattering. These cross sections were extrapolated at constant values above 3.2 Mev.

TANTALUM

Radiative Capture

Data defining the photon spectrum from radiative capture were read at discrete energy points from a curve in the atlas of Groshev, et al.;[13] It was assumed that $\sigma_{n,\gamma}$ equaled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

The cross section for the production of 0.137 Mev gamma rays by inelastic scattering was obtained for $0.3 \leq E_n \leq 1.8$ Mev from BNL-325. The cross section was extrapolated at essentially constant value above 1.8 Mev.

TUNGSTEN

Radiative Capture

Data defining the photon spectrum from the radiative capture were read at discrete energy points from a curve in the atlas of Groshev. It was assumed that $\sigma_{n,\gamma}$ equalled σ_a from the tabulation of Robertson and Benson.[9]

Inelastic Scattering

Spectra calculated by Troubetzkoy[14] for the gamma rays from neutron inelastic scattering in tungsten were used in this analysis. Troubetzkoy's spectra at $E_n = 3$ and 7 Mev were used for W^{183}, and his spectra for W^{184} at the same neutron energies were used for all even isotopes. The spectra for $E_n = 3$ Mev were used for all neutron energies below 7 Mev, and the spectra for $E_n = 7$ Mev were used for all other energies.

The inelastic scattering cross section for $0.1 \leq E \leq 1$ Mev was read from a curve published by Howerton.[15] For neutron energies between 1 and 10 Mev, the inelastic scattering cross section was assumed equal to the non-elastic scattering cross section, and values were read from a curve in Troubetzkoy's report.[14]

RHENIUM

Radiative Capture

Data defining the photon spectrum from radiative capture were read at discrete energy points from a curve in the atlas of Groshev.[13] It was assumed that $\sigma_{n,\gamma}$ equaled σ_a, and σ_a was taken from the tabulation of Robertson and Benson[9] for neutron energies above 61.44 ev. The absorption cross section for neutron energies below 61.44 ev was obtained from a report by Zwick.[15]

Inelastic Scattering

The cross section for the production of 0.135 Mev gamma rays by inelastic scattering were obtained for $0.135 \leq E_n \leq 1.9$ Mev from BNL-325. The cross section was extrapolated at a constant 0.8 barn above 1.9 Mev.

URANIUM-235

Fission

Data compiled by J. G. Carver[17] for prompt-plus-delayed gamma radiation from the fissioning of U^{235} were used to compute the spectrum for an operating time of 15 minutes. The group-averaged U^{235} fission cross sections that were used are listed in the Appendix. Although they have been used extensively in NMPO, they have not been documented.

Radiative Capture

The energy-integrated gamma spectrum from radiative capture was assumed equal to that tabulated by Carver[17] for prompt gamma rays from U^{235} fission. The radiative capture cross section was assumed equal to the absorption cross section tabulated by Robertson and Benson[9] minus the fission cross section.

Inelastic Scattering

No inelastic scattering data were found.

URANIUM-238

Fission

The U^{235} fission gamma spectrum was assumed identical to that used for U^{235}. The group-averaged U^{238} fission cross sections that were used are listed in the Appendix. Again, these data have not been documented.

Radiative Capture

The energies and intensities of discrete gamma rays were taken from the tabulation of Troubetzkoy and Goldstein.[5] The radiative capture cross section was assumed equal to the absorption cross section tabulated by Robertson and Benson[9] minus the fission cross section.

Inelastic Scattering

No inelastic scattering data were found.

3. TABULATION OF GAMMA RAY PRODUCTION CROSS SECTIONS

Cross sections for the production of gamma rays by radiative neutron capture, neutron inelastic scattering, neutron induced fissioning, and (n, α) reactions are tabulated on the following pages for 13 elements and isotopes as a function of ascending photon and neutron energies (descending lethargy).

The 16 neutron energy and lethargy groups are given in Table 1. The 11 photon energy groups are given in Table 2.

TABLE 1

CROSS SECTION ENERGY LATTICE

Group Index	Energy Level	Lethargy Level	Lethargy Interval
1	10.0 Mev	0.0	1.204
2	3.0 Mev	1.204	0.762
3	1.4 Mev	1.996	0.442
4	0.9 Mev	2.408	0.811
5	0.4 Mev	3.219	1.386
6	0.1 Mev	4.605	1.772
7	17.0 Kev	6.377	1.623
8	3.354 Kev	8.0	2.0
9	0.454 Kev	10.0	2.0
10	61.44 ev	12.0	2.0
11	8.315 ev	14.0	1.5
12	1.855 ev	15.5	1.0
13	0.6826 ev	16.5	1.0
14	0.2511 ev	17.5	1.0
15	0.09237 ev	18.5	1.055
16	0.03216 ev	19.555	0.24
	00.0	∞	

TABLE 2

GAMMA PHOTON ENERGY GROUPS

Photon Energy Group	Group Energy Range, Mev
1	0.01 to 0.4
2	0.4 to 0.9
3	0.9 to 1.35
4	1.35 to 1.8
5	1.8 to 2.2
6	2.2 to 2.6
7	2.6 to 3.0
8	3.0 to 4.0
9	4.0 to 5.0
10	5.0 to 7.0
11	7.0 to 10.0

GAMMA PRODUCTION CROSS SECTIONS

BARNS

Sigma ((J,N) J = 11, 1, N = 16, 1))

BERYLLIUM

9	0.	4.5370-02	0.	1.5174-02	0.
9	0.	0.	0.	0.	0.
9	2.0224-04				
9	0.	3.5174-02	0.	1.1764-02	0.
9	0.	0.	0.	0.	0.
9	1.5679-04				
9	0.	2.0901-02	0.	6.9905-03	0.
9	0.	0.	0.	0.	0.
9	9.3166-05				
9	0.	1.2744-02	0.	4.2625-03	0.
9	0.	0.	0.	0.	0.
9	5.6808-05				
9	0.	7.6466-03	0.	2.5575-03	0.
9	0.	0.	0.	0.	0.
9	3.4085-05				
9	0.	4.0782-03	0.	1.3640-03	0.
9	0.	0.	0.	0.	0.
9	1.8179-05				
9	0.	1.5293-03	0.	5.1150-04	0.
9	0.	0.	0.	0.	0.
9	6.8170-06				
9	0.	5.0979-04	0.	1.7050-04	0.
9	0.	0.	0.	0.	0.
9	2.2724-06				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				

BORON 10

```
9    2.3683-01    8.5517-01    2.2128+00    0.           0.
9    0.           0.           0.           0.           1.7000+03
9    1.7731+00
9    1.8444-01    6.6599-01    1.7233+00    0.           0.
9    0.           0.           0.           0.           1.3197+03
9    1.3809+00
9    1.1013-01    3.9766-01    1.0290+00    0.           0.
9    0.           0.           0.           0.           7.7202+02
9    8.2452-01
9    6.6825-02    2.4130-01    6.2437-01    0.           0.
9    0.           0.           0.           0.           4.7843+02
9    5.0031-01
9    4.0523-02    1.4632-01    3.7862-01    0.           0.
9    0.           0.           0.           0.           2.9020+02
9    3.0339-01
9    2.1972-02    7.9339-02    2.0529-01    0.           0.
9    0.           0.           0.           0.           1.5219+02
9    1.6450-01
9    9.3021-03    3.3589-02    8.6913-02    0.           0.
9    0.           0.           0.           0.           7.2264+01
9    6.9644-02
9    3.4322-03    1.2393-02    3.2068-02    0.           0.
9    0.           0.           0.           0.           2.3406+01
9    2.5697-02
9    1.2618-03    4.5563-03    1.1790-02    0.           0.
9    0.           0.           0.           0.           8.7508+00
9    9.4470-03
9    5.0339-04    1.8177-03    4.7034-03    0.           0.
9    0.           0.           0.           0.           3.5354+00
9    3.7689-03
9    2.1732-04    7.8471-04    2.0305-03    0.           0.
9    0.           0.           0.           0.           1.5780+00
9    1.6270-03
9    9.8966-05    3.5736-04    9.2468-04    0.           0.
9    0.           0.           0.           0.           4.9973-01
9    7.4095-04
9    5.7755-05    2.0855-04    5.3963-04    0.           0.
9    0.           0.           0.           0.           2.1269-01
9    4.3241-04
9    4.3691-05    1.5777-04    4.0823-04    0.           0.
9    0.           0.           0.           0.           9.6628-02
9    3.2711-04
9    3.4919-05    1.2609-04    3.2626-04    0.           0.
9    0.           0.           0.           0.           1.5253-01
9    2.6144-04
9    2.6552-05    9.5878-05    2.4809-04    0.           0.
9    0.           0.           0.           0.           9.3927-02
9    1.9879-04
```

CARBON

9	0.	0.	9.6981-03	3.0912-03	0.
9	0.	0.	0.	0.	0.
9	1.3008-03				
9	0.	0.	7.4814-03	2.3846-03	0.
9	0.	0.	0.	0.	0.
9	1.0035-03				
9	0.	0.	4.4334-03	1.4131-03	0.
9	0.	0.	0.	0.	0.
9	5.9465-04				
9	0.	0.	2.7016-03	8.6112-04	0.
9	0.	0.	0.	0.	0.
9	3.6237-04				
9	0.	0.	1.6625-03	5.2992-04	0.
9	0.	0.	0.	0.	0.
9	2.2299-04				
9	0.	0.	1.1084-03	3.5328-04	0.
9	0.	0.	0.	0.	0.
9	1.4866-04				
9	0.	0.	4.8491-04	1.5456-04	0.
9	0.	0.	0.	0.	0.
9	6.5040-05				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
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9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	1.1961+00	0.	0.
9	0.	0.	0.	0.	0.
9	0.				

OXYGEN

9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
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9	0.				
9	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				
9	0.	1.5456+00	0.	0.	0.
9	0.	0.	0.	0.	0.
9	0.				

CHROMIUM

9	7.8855+00	1.5159+00	9.9382-02	3.4671-01	0.
9	1.1934-01	9.6707-02	9.0020-02	0.	5.1671-01
9	8.9118+00				
9	6.1215+00	1.1768+00	7.7150-02	2.6915-01	0.
9	9.2644-02	7.5074-02	6.9882-02	0.	4.0112-01
9	6.9182+00				
9	3.6587+00	7.0335-01	4.6111-02	1.6086-01	0.
9	5.5371-02	4.4870-02	4.1767-02	0.	2.3974-01
9	4.1348+00				
9	2.2190+00	4.2658-01	2.7966-02	9.7563-02	0.
9	3.3582-02	2.7213-02	2.5332-02	0.	1.4540-01
9	2.5078+00				
9	1.3462+00	2.5878-01	1.6966-02	5.9187-02	0.
9	2.0373-02	1.6509-02	1.5367-02	0.	8.8209-02
9	1.5213+00				
9	7.0620-01	1.3576-01	8.9003-03	3.1050-02	0.
9	1.0688-02	8.6608-03	8.0619-03	0.	4.6275-02
9	7.9811-01				
9	3.3520-01	6.4438-02	4.2245-03	1.4738-02	0.
9	5.0729-03	4.1108-03	3.8266-03	0.	2.1964-02
9	3.7882-01				
9	1.8687-01	3.5924-02	2.3552-03	8.2163-03	0.
9	2.8282-03	2.2918-03	2.1333-03	0.	1.2245-02
9	2.1119-01				
9	1.4020-01	2.6952-02	1.7670-03	6.1642-03	0.
9	2.1218-03	1.7194-03	1.6005-03	0.	9.1869-03
9	1.5845-01				
9	3.7561-01	7.2208-02	4.7339-03	1.6515-02	0.
9	5.6846-03	4.6065-03	4.2879-03	0.	2.4613-02
9	4.2450-01				
9	6.3385-02	1.2185-02	7.9884-04	2.7869-03	0.
9	9.5927-04	7.7734-04	7.2359-04	0.	4.1534-03
9	7.1634-02				
9	5.1305-02	9.8628-03	6.4660-04	2.2557-03	0.
9	7.7645-04	6.2920-04	5.8569-04	0.	3.3618-03
9	5.7982-02				
9	5.0470-02	9.7023-03	6.3607-04	2.2190-03	0.
9	7.6381-04	6.1895-04	5.7615-04	0.	3.3071-03
9	5.7038-02				
9	4.8900-02	9.4006-03	6.1629-04	2.1500-03	0.
9	7.4006-04	5.9971-04	5.5824-04	0.	3.2043-03
9	5.5264-02				
9	6.5596-02	1.2610-02	8.2671-04	2.8841-03	0.
9	9.9273-04	8.0445-04	1.6279+00	0.	4.2983-03
9	7.4132-02				
9	1.0055-01	1.9330-02	1.2672-03	4.4209-03	0.
9	1.5217-03	1.2331-03	1.8011+00	0.	6.5887-03
9	1.1364-01				

IRON

9	6.0510+00	1.7232+00	4.6340-01	1.0774+00	3.7131-01
9	0.	1.6033-01	5.3483-01	4.1604-02	4.1770-02
9	6.9753+00				
9	4.6980+00	1.3379+00	3.5979-01	8.3648-01	2.8828-01
9	0.	1.2448-01	4.1524-01	3.2301-02	3.2430-02
9	5.4156+00				
9	2.8062+00	7.9915-01	2.1491-01	4.9966-01	1.7220-01
9	0.	7.4355-02	2.4803-01	1.9294-02	1.9371-02
9	3.2349+00				
9	1.7020+00	4.8469-01	1.3034-01	3.0304-01	1.0444-01
9	0.	4.5097-02	1.5043-01	1.1702-02	1.1749-02
9	1.9620+00				
9	1.0336+00	2.9435-01	7.9157-02	1.8403-01	6.3425-02
9	0.	2.7907-02	9.1357-02	7.1066-03	7.1349-03
9	1.1915+00				
9	5.4313-01	1.5467-01	4.1595-02	9.6706-02	3.3328-02
9	0.	1.4391-02	4.8006-02	3.7343-03	3.7492-03
9	6.2609-01				
9	2.5749-01	7.3328-02	1.9720-02	4.5847-02	1.5800-02
9	0.	6.8226-03	2.2759-02	1.7704-03	1.7775-03
9	2.9682-01				
9	2.7848+00	7.9304-01	2.1327-01	4.9583-01	1.7088-01
9	0.	7.3786-02	2.4614-01	1.9147-02	1.9223-02
9	3.2101+00				
9	3.5142-02	1.0008-02	2.6913-03	6.2571-03	2.1564-03
9	0.	9.3114-04	3.1061-03	2.4162-04	2.4258-04
9	4.0510-02				
9	6.9374-02	1.9756-02	5.3129-03	1.2352-02	4.2570-03
9	0.	1.8382-03	6.1317-03	4.7698-04	4.7889-04
9	7.9971-02				
9	1.3348-01	3.8012-02	1.0222-02	2.3767-02	8.1908-03
9	0.	3.5368-03	1.1798-02	9.1775-04	9.2142-04
9	1.5387-01				
9	5.0336-02	1.4334-02	3.8549-03	8.9624-03	3.0888-03
9	0.	1.3337-03	4.4490-03	3.4609-04	3.4747-04
9	5.8024-02				
9	4.3512-02	1.2391-02	3.3323-03	7.7475-03	2.6701-03
9	0.	1.1529-03	3.8459-03	2.9917-04	3.0037-04
9	5.0159-02				
9	3.9205-02	1.1165-02	3.0025-03	6.9806-03	2.4058-03
9	0.	1.0388-03	3.4652-03	2.6956-04	2.7063-04
9	4.5194-02				
9	5.1180-02	1.4575-02	3.9195-03	9.1126-03	3.1406-03
9	0.	4.1176-02	6.0924-02	7.3432-02	7.7775-01
9	5.8997-02				
9	8.3034-02	2.3646-02	6.3590-03	3.1178-01	1.8510-01
9	5.9900-01	7.4220-01	1.2014-01	2.5257-01	1.1836+00
9	9.5717-02				

NICKEL

```
9    1.7634+01    4.8617+00    2.8519-01    4.0270-01    0.
9    0.           1.7544-01    1.3342-01    8.9760-02    1.6769-01
9    1.1405+01
9    1.3688+01    3.7737+00    2.2137-01    3.1258-01    0.
9    0.           1.3618-01    1.0356-01    6.9673-02    1.3016-01
9    8.8531+00
9    8.1796+00    2.2552+00    1.3229-01    1.8679-01    0.
9    0.           8.1379-02    6.1886-02    4.1636-02    7.7783-02
9    5.2905+00
9    4.9625+00    1.3682+00    8.0258-02    1.1333-01    0.
9    0.           4.9372-02    3.7546-02    2.5260-02    4.7191-02
9    3.2097+00
9    3.0067+00    8.2896-01    4.8627-02    6.8663-02    0.
9    0.           2.9914-02    2.2748-02    1.5305-02    2.8592-02
9    1.9447+00
9    1.5770+00    4.3479-01    2.5505-02    3.6014-02    0.
9    0.           1.5690-02    1.1932-02    8.0274-03    1.4997-02
9    1.0200+00
9    7.4970-01    2.0670-01    1.2125-02    1.7121-02    0.
9    0.           7.4588-03    5.6722-03    3.8161-03    7.1292-03
9    4.8490-01
9    2.7057-01    7.4596-02    4.3758-03    6.1788-03    0.
9    0.           2.6919-03    2.0471-03    1.3772-03    2.5729-03
9    1.7500-01
9    1.2705-01    3.5027-02    2.0547-03    2.9013-03    0.
9    0.           1.2640-03    9.6121-04    6.4669-04    1.2081-03
9    8.2172-02
9    1.4703+00    4.0535-01    2.3778-02    3.3575-02    0.
9    0.           1.4628-02    1.1124-02    7.4839-03    1.3981-02
9    9.5095-01
9    2.8070-01    7.7389-02    4.5397-03    6.4101-03    0.
9    0.           2.7926-03    2.1237-03    1.4288-03    2.6692-03
9    1.8155-01
9    1.1670-01    3.2174-02    1.8873-03    2.6650-03    0.
9    0.           1.1610-03    8.8292-04    5.9401-04    1.1097-03
9    7.5479-02
9    8.5860-02    2.3672-02    1.3886-03    1.9607-03    0.
9    0.           8.5422-04    6.4961-04    4.3705-04    8.1648-04
9    5.5534-02
9    8.0814-02    2.2281-02    1.3070-03    1.8455-03    0.
9    0.           8.0402-04    6.1143-04    4.1136-04    7.6850-04
9    5.2270-02
9    8.6949-02    2.3972-02    1.4062-03    1.9856-03    0.
9    0.           8.6506-04    9.8556-01    3.9944-01    8.2683-04
9    5.6238-02
9    1.2524-01    3.4528-02    2.0254-03    2.8599-03    0.
9    0.           1.2460-03    1.1769+00    5.3264-01    1.1909-03
9    8.1001-02
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MOLYBDENUM

```
9    4.6561-01    3.4588+00    3.1263+00    4.2792+00    0.
9    0.           0.           0.           0.           0.
9    5.1870+00
9    3.6146-01    2.6851+00    2.4269+00    3.3220+00    0.
9    0.           0.           0.           0.           0.
9    4.0267+00
9    2.1600-01    1.6046+00    1.4503+00    1.9852+00    0.
9    0.           0.           0.           0.           0.
9    2.4063+00
9    1.3104-01    9.7342-01    8.7983-01    1.2043+00    0.
9    0.           0.           0.           0.           0.
9    1.4598+00
9    7.9481-02    5.9043-01    5.3366-01    7.3047-01    0.
9    0.           0.           0.           0.           0.
9    8.8543-01
9    3.5271-01    2.6202+00    2.3682+00    3.2416+00    0.
9    0.           0.           0.           0.           0.
9    3.9293+00
9    1.0605+00    7.8783+00    7.1208+00    9.7468+00    0.
9    0.           0.           0.           0.           0.
9    1.1815+01
9    1.1193+00    8.3150+00    7.5155+00    1.0287+01    0.
9    0.           0.           0.           0.           0.
9    1.2470+01
9    4.2008-03    3.1206-02    2.8205-02    3.8607-02    0.
9    0.           0.           0.           0.           0.
9    4.6798-02
9    0.           0.           0.           0.           0.
9    0.           0.           0.           0.           0.
9    0.
9    2.1131-03    1.5697-02    1.4188-02    1.9420-02    0.
9    0.           0.           0.           0.           0.
9    2.3540-02
9    0.           0.           0.           0.           0.
9    0.           0.           0.           0.           0.
9    0.
9    0.           0.           0.           0.           0.
9    0.           0.           0.           0.           0.
9    0.
9    4.3482-03    3.2301-02    2.9195-02    3.9962-02    0.
9    0.           0.           0.           0.           0.
9    4.8440-02
9    0.           0.           0.           0.           0.
9    0.           0.           0.           0.           0.
9    0.
9    0.           0.           0.           0.           0.
9    1.4750-01    0.           4.6200-01    0.           4.8180-01
9    0.
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TANTALUM

9	0.	5.8344+00	1.4169+01	2.3584+01	1.1477+01
9	1.2542+01	1.3021+01	1.3220+01	9.9492+00	8.8548+00
9	1.3633+01				
9	0.	4.8428+00	1.1761+01	1.9576+01	9.5261+00
9	1.0411+01	1.0808+01	1.0973+01	8.2582+00	7.3498+00
9	1.1316+01				
9	0.	2.7458+00	6.6683+00	1.1099+01	5.4012+00
9	5.9026+00	6.1280+00	6.2214+00	4.6823+00	4.1673+00
9	6.4158+00				
9	0.	1.7164+00	4.1684+00	6.9382+00	3.3764+00
9	3.6898+00	3.8307+00	3.8891+00	2.9270+00	2.6050+00
9	4.0106+00				
9	0.	1.6758+00	4.0698+00	6.7740+00	3.2964+00
9	3.6025+00	3.7400+00	3.7970+00	2.8577+00	2.5434+00
9	3.9157+00				
9	0.	9.3737+01	2.2764+02	3.7891+02	1.8439+02
9	2.0151+02	2.0920+02	2.1239+02	1.5985+02	1.4226+02
9	2.1903+02				
9	0.	3.2420+01	7.8733+01	1.3105+02	6.3772+01
9	6.9693+01	7.2354+01	7.3457+01	5.5285+01	4.9203+01
9	7.5752+01				
9	0.	9.8969+00	2.4035+01	4.0005+01	1.9468+01
9	2.1275+01	2.2088+01	2.2424+01	1.6877+01	1.5020+01
9	2.3125+01				
9	0.	2.5958+00	6.3040+00	1.0493+01	5.1061+00
9	5.5802+00	5.7932+00	5.8815+00	4.4265+00	3.9396+00
9	6.0653+00				
9	0.	1.1240+00	2.7296+00	4.5433+00	2.2109+00
9	2.4162+00	2.5084+00	2.5467+00	1.9167+00	1.7058+00
9	2.6262+00				
9	0.	3.5739-01	8.6793-01	1.4446+00	7.0301-01
9	7.6828-01	7.9760-01	8.0977-01	6.0944-01	5.4240-01
9	8.3507-01				
9	0.	9.9475-02	2.4158-01	4.0210-01	1.9568-01
9	2.1384-01	2.2201-01	2.2539-01	1.6963-01	1.5097-01
9	2.3243-01				
9	0.	7.2710-02	1.7658-01	2.9391-01	1.4303-01
9	1.5630-01	1.6227-01	1.6475-01	1.2399-01	1.1035-01
9	2.7264-01				
9	0.	5.7459-02	1.3954-01	2.3226-01	1.1303-01
9	1.2352-01	1.2823-01	1.3019-01	9.7982-02	8.7204-02
9	2.9866-01				
9	0.	4.2204-02	1.0249-01	1.7060-01	8.3018-02
9	9.0726-02	9.4189-02	9.5625-02	7.1969-02	6.4052-02
9	3.4521-01				
9	0.	2.7450-02	6.6663-02	1.1096-01	5.3995-02
9	5.9009-02	6.1261-02	6.2195-02	4.6809-02	4.1660-02
9	3.2444-01				

TUNGSTEN

9	9.7737-01	1.6525+01	1.3229+01	1.8691+01	8.9441+00
9	9.9525+00	9.1644+00	8.9756+00	6.8092+00	1.0525+01
9	3.0395+00				
9	7.9729-01	1.3480+01	1.0791+01	1.5247+01	7.2961+00
9	8.1188+00	7.4758+00	7.3218+00	5.5546+00	8.5858+00
9	2.4794+00				
9	4.6688-01	7.8939+00	6.3193+00	8.9284+00	4.2725+00
9	4.7542+00	4.3777+00	4.2875+00	3.2527+00	5.0277+00
9	1.4519+00				
9	2.8419-01	4.8050+00	3.8465+00	5.4347+00	2.6006+00
9	2.8939+00	2.6647+00	2.6098+00	1.9799+00	3.0603+00
9	8.8377-01				
9	1.7254-01	2.9173+00	2.3354+00	3.2996+00	1.5789+00
9	1.7570+00	1.6178+00	1.5845+00	1.2021+00	1.8581+00
9	5.3657-01				
9	1.2252+00	2.0715+01	1.6583+01	2.3430+01	1.1212+01
9	1.2476+01	1.1488+01	1.1251+01	8.5358+00	1.3194+01
9	3.8101+00				
9	1.1710+00	1.9799+01	1.5849+01	2.2393+01	1.0716+01
9	1.1924+01	1.0980+01	1.0754+01	8.1580+00	1.2610+01
9	3.6415+00				
9	2.9820-01	5.0419+00	4.0361+00	5.7026+00	2.7288+00
9	3.0365+00	2.7961+00	2.7385+00	2.0775+00	3.2112+00
9	9.2734-01				
9	3.5508-02	6.0037-01	4.8061-01	6.7904-01	3.2494-01
9	3.6158-01	3.3294-01	3.2609-01	2.4738-01	3.8238-01
9	1.1042-01				
9	2.7080-02	4.5786-01	3.6653-01	5.1786-01	2.4781-01
9	2.7575-01	2.5391-01	2.4869-01	1.8866-01	2.9162-01
9	8.4214-02				
9	1.1428-02	1.9322-01	1.5468-01	2.1854-01	1.0458-01
9	1.1637-01	1.0715-01	1.0494-01	7.9615-02	1.2306-01
9	3.5538-02				
9	5.7807-03	9.7740-02	7.8243-02	1.1055-01	7.4040-02
9	1.2477-01	1.6967-01	2.4293-01	2.3200-01	1.4790-01
9	7.1527-02				
9	3.8355-03	6.4851-02	5.1914-02	7.3349-02	1.0758-01
9	2.6502-01	4.3184-01	6.8610-01	6.8408-01	3.3494-01
9	1.9553-01				
9	3.0527-03	5.1615-02	4.1319-02	5.8379-02	1.6082-01
9	4.4535-01	7.5440-01	1.2213+00	1.2264+00	5.7121-01
9	3.4609-01				
9	2.2513-03	3.8064-02	3.0471-02	4.3053-02	1.7583-01
9	5.0686-01	8.6895-01	1.4146+00	1.4235+00	6.5312-01
9	4.0021-01				
9	2.0516-03	3.4688-02	6.0197-01	2.1597+00	1.3619+00
9	1.7764+00	2.1329+00	2.6503+00	1.9866+00	7.0171-01
9	4.0731-01				

RHENIUM

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9    0.          2.4593+01   5.5096+01   7.4600+01   3.6773+01
9    4.1066+01   4.3502+01   4.1069+01   3.3616+01   3.0601+01
9    3.1003+02
9    0.          1.4608+01   3.2726+01   4.4311+01   2.1843+01
9    2.4392+01   2.5839+01   2.4394+01   1.9968+01   1.8176+01
9    1.8415+02
9    0.          1.0762+01   2.4110+01   3.2645+01   1.6092+01
9    1.7970+01   1.9036+01   1.7971+01   1.4710+01   1.3391+01
9    1.3567+02
9    0.          2.5913+01   5.8054+01   7.8605+01   3.8747+01
9    4.3270+01   4.5837+01   4.3273+01   3.5421+01   3.2243+01
9    3.2667+02
9    0.          2.7100+02   6.0711+02   8.2204+02   4.0521+02
9    4.5251+02   4.7936+02   4.5255+02   3.7043+02   3.3720+02
9    3.4163+03
9    0.          6.9238+01   1.5511+02   2.1002+02   1.0353+02
9    1.1561+02   1.2247+02   1.1562+02   9.4642+01   8.6151+01
9    8.7283+02
9    0.          8.2138+00   1.8401+01   2.4915+01   1.2282+01
9    1.3715+01   1.4529+01   1.3716+01   1.1227+01   1.0220+01
9    1.0354+02
9    0.          8.1156+00   1.8181+01   2.4618+01   1.2135+01
9    1.3551+01   1.4355+01   1.3553+01   1.1093+01   1.0098+01
9    1.0231+02
9    0.          2.9195+00   6.5406+00   8.8560+00   4.3655+00
9    4.8750+00   5.1643+00   4.8754+00   3.9907+00   3.6327+00
9    3.6804+01
9    0.          1.0822+00   2.4245+00   3.2828+00   1.6182+00
9    1.8071+00   1.9143+00   1.8072+00   1.4793+00   1.3466+00
9    1.3643+01
9    0.          3.8597-01   8.6468-01   1.1708+00   5.7712-01
9    6.4449-01   6.8272-01   6.4454-01   5.2758-01   4.8025-01
9    4.8656+00
9    0.          1.5288-01   3.4250-01   4.6374-01   2.2860-01
9    2.5528-01   2.7042-01   2.5530-01   2.0897-01   1.9023-01
9    1.9610+00
9    0.          5.4831-02   1.2284-01   1.6632-01   8.1987-02
9    9.1557-02   9.6988-02   9.1564-02   7.4949-02   6.8225-02
9    7.7221-01
9    0.          3.8013-02   8.5159-02   1.1531-01   5.6839-02
9    6.3474-02   6.7239-02   6.3478-02   5.1960-02   4.7298-02
9    5.8045-01
9    0.          4.2496-02   9.5202-02   1.2890-01   6.3542-02
9    7.0959-02   7.5169-02   7.0964-02   5.8087-02   5.2876-02
9    6.4371-01
9    0.          2.4667-02   5.5260-02   7.4823-02   3.6883-02
9    4.1188-02   4.3632-02   4.1191-02   3.3717-02   3.0692-02
9    4.1895-01
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URANIUM 235

9	9.0369+00	1.0834+02	2.4921+02	5.8797+02	3.7313+02
9	4.9936+02	6.3980+02	8.7294+02	1.2006+03	1.6005+03
9	7.3891+02				
9	6.8751+00	8.2764+01	1.9087+02	4.5052+02	2.8586+02
9	3.8247+02	4.8998+02	6.6862+02	9.1903+02	1.2245+03
9	5.6480+02				
9	3.7480+00	4.4904+01	1.0324+02	2.4357+02	1.5457+02
9	2.0687+02	2.6506+02	3.6164+02	4.9745+02	6.6319+02
9	3.0622+02				
9	2.1755+00	2.5982+01	5.9617+01	1.4060+02	8.9240+01
9	1.1946+02	1.5307+02	2.0882+02	2.8738+02	3.8328+02
9	1.7710+02				
9	9.4934-01	1.1166+01	2.5367+01	5.9730+01	3.7932+01
9	5.0822+01	6.5154+01	8.8838+01	1.2256+02	1.6376+02
9	7.5937+01				
9	1.1730+00	1.2779+01	2.7506+01	6.4191+01	4.0899+01
9	5.5076+01	7.0794+01	9.6253+01	1.3461+02	1.8170+02
9	8.5870+01				
9	1.3698+00	1.4914+01	3.2088+01	7.4879+01	4.7711+01
9	6.4251+01	8.2590+01	1.1229+02	1.5706+02	2.1201+02
9	1.0021+02				
9	3.8513-01	4.3582+00	9.6438+00	2.2611+01	1.4382+01
9	1.9316+01	2.4795+01	3.3761+01	4.6885+01	6.2954+01
9	2.9465+01				
9	1.6756-01	1.9145+00	4.2649+00	1.0011+01	6.3648+00
9	8.5430+00	1.0962+01	1.4932+01	2.0702+01	2.7762+01
9	1.2963+01				
9	8.2950-02	9.6664-01	2.1825+00	5.1341+00	3.2616+00
9	4.3724+00	5.6071+00	7.6429+00	1.0560+01	1.4127+01
9	6.5648+00				
9	4.7533-02	5.5981-01	1.2729+00	2.9977+00	1.9036+00
9	2.5502+00	3.2693+00	4.4579+00	6.1489+00	8.2145+00
9	3.8079+00				
9	2.5095-02	3.0227-01	6.9738-01	1.6461+00	1.0445+00
9	1.3974+00	1.7902+00	2.4429+00	3.3575+00	4.4733+00
9	2.0630+00				
9	2.0520-02	2.4914-01	5.7767-01	1.3646+00	8.6561-01
9	1.1576+00	1.4826+00	2.0237+00	2.7780+00	3.6978+00
9	1.7023+00				
9	2.0282-02	2.4843-01	5.7919-01	1.3694+00	8.6836-01
9	1.1607+00	1.4862+00	2.0292+00	2.7818+00	3.6991+00
9	1.6996+00				
9	1.9926-02	2.4544-01	5.7420-01	1.3583+00	8.6117-01
9	1.1508+00	1.4732+00	2.0118+00	2.7556+00	3.6620+00
9	1.6805+00				
9	1.9608-02	2.4213-01	5.6733-01	1.3424+00	8.5099-01
9	1.1370+00	1.4555+00	1.9877+00	2.7217+00	3.6159+00
9	1.6584+00				

URANIUM 238

```
9    0.          0.          6.9345-01   3.5304-01   0.
9    0.          0.          0.          0.          7.2852-01
9    9.6816+00
9    0.          0.          5.3921-01   2.7452-01   0.
9    0.          0.          0.          0.          5.6648-01
9    7.5282+00
9    0.          0.          3.1989-01   1.6286-01   0.
9    0.          0.          0.          0.          3.3606-01
9    4.4661+00
9    0.          0.          1.9619-01   9.9884-02   0.
9    0.          0.          0.          0.          2.0612-01
9    2.7392+00
9    0.          0.          1.1942-01   6.0798-02   0.
9    0.          0.          0.          0.          1.2546-01
9    1.6673+00
9    0.          0.          3.7005+01   1.8840+01   0.
9    0.          0.          0.          0.          3.8877+01
9    5.1665+02
9    0.          0.          4.0092+01   2.0411+01   0.
9    0.          0.          0.          0.          4.2120+01
9    5.5975+02
9    0.          0.          3.1279+00   1.5924+00   0.
9    0.          0.          0.          0.          3.2861+00
9    4.3670+01
9    0.          0.          5.7170-01   2.9106-01   0.
9    0.          0.          0.          0.          6.0061-01
9    7.9818+00
9    0.          0.          1.9939-01   1.0151-01   0.
9    0.          0.          0.          0.          2.0948-01
9    2.7838+00
9    0.          0.          1.2922-01   6.5789-02   0.
9    0.          0.          0.          0.          1.3576-01
9    1.8042+00
9    0.          0.          4.7581-02   2.4224-02   0.
9    0.          0.          0.          0.          4.9988-02
9    6.6431-01
9    0.          0.          4.5010-02   2.2915-02   0.
9    0.          0.          0.          0.          4.7287-02
9    6.2842-01
9    6.6000-04   8.3600-03   5.5143-02   6.5117-02   2.9876-02
9    3.9864-02   5.0996-02   6.9696-02   9.5084-02   1.6301-01
9    5.4968-01
9    7.2750-03   9.2150-02   2.3976-01   5.3038-01   3.2931-01
9    4.3941-01   5.6211-01   7.6824-01   1.0481+00   1.4101+00
9    9.2023-01
9    9.2400-03   1.1704-01   2.7843-01   6.6035-01   4.1826-01
9    5.5810-01   7.1394-01   9.7574-01   1.3312+00   1.7636+00
9    8.0450-01
```

APPENDIX: GAMMA-P INPUT LISTING

Input data used in the preparation of these gamma production cross sections are listed on the following pages. The data defining gamma spectra from the various sources could be used in GAMMA-P calculations for other neutron or gamma energy groups.

GAMMA-P INPUT DATA

BERYLLIUM

```
3Z 4.0
4N 16 J 11 I 2 L 0 NOELEM 13 K 1
3D .5 .75
3E 3.41 6.797
3SIGNG .0089 .0069 .0041 .0025 .0015 .0008 .0003 .0001
  0 0 0 0 0 0 0 0
3AMNEUT 1.008986
3AMISO1 9.015060 AMISO2 10.016716
3C1 931.162
3P 1.
3SIGA .01
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 0 0 0 0
```

BORON 10

```
3Z 5.0
4N 16 J 11 I 6 L 1 K 1
3D .8 .3 .1 .18 .06 .008
3E 4.47 4.73 6.74 6.98 8.91 11.43
3SFG 0 .478 0 0 0 0 0 0 0 0 0
3SNNG 420= 0 .717
3SNNG 450= 0 .717
3SIGNG .443 .345 .206 .125 .0758 .0411 .0174 .00642 .00236
  .000941 .000405 .000182 .000103 .000075 .000056 .000034
3FSIG 3556.4 2760.9 1615.1 1000.9 607.11 318.39 151.18 48.9668
  18.3072 7.39614 3.30121 1.04546 .44496 .20215 .26961 .0915
3SIGNN 14= .033 .070
3AMNEUT 1.008986
3AMISO1 10.016119 AMISO2 11.012795
3C1 931.162
3P 1. SIGA 4017.
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 +1 +1 0 0
```

CARBON

```
3Z 6.
4N 16 J 11 I 2 L 1 K 2
3D .3 .7
3E 3.68 4.948
3SNNG 458= 4.43
3SIGNG .0028 .00216 .00128 .00078 .00048 .00032 .00014
  0 0 0 0 0 0 0 0 0
3SIGNN 15= .27
3AMNEUT 1.008986
3AMISO1 12.003816 13.007478
3AMISO2 13.007478 14.007687
3C1 931.162
3P .989 .111 SIGA .0033 .0007
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 +1 0 0 0
```

OXYGEN

```
3Z 8.
4N 16 J 11 I 0 L 2 K 3
3SNNG 459= 6.1
3SNNG 1659= 7.
3SIGNN 15= .196
3SIGNN 55= .05
3AMNEUT 1.008986
3AMISO1 16.000000 17.004537 18.004855
3AMISO2 17.004537 18.004855 19.00959
3C1 931.162
3P .99759 .00037 .00204 SIGA 0 .4 .00021
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL 0 0 +1 0 0 0
```

CHROMIUM

```
3Z 24.
4N 16 J 11 I 26 L 1 K 4
3D .02 .03 .2 .02 .02 .02 .02 .02 .008 .01 .02 .01
 .008 .009 .004 .03 .005 .024 .002 .03 .002 .002
 .06 .05 .14 .05
3E .52 .75 .84 1.75 1.88 2.32 3.02 3.72 4.83 5.26
 5.61 6. 6.12 6.28 6.358 6.644 6.872 7.097 7.21
 7.364 7.54 7.67 7.929 8.499 8.881 9.716
3SNNG 423= 1.44
3SNNG 453= 1.44
3SIGNG 2.572 1.99664 1.19334 .72376 .43907 .23034 .10933
 .06095 .04572 .12238 .02055 .01628 .01525 .01392 .01684 .01875
3SIGNN 14= 1.13 1.25
3AMNEUT 1.008986
3AMISO1 49.96164 51.95699 52.95446 53.95602
3AMISO2 50.96084 52.95746 53.95602 54.95843
3C1 931.162
3P .0431 .8376 .0955 .0238 SIGA 15.9 .76 18.2 .38
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 +1 0 0 0
```

IRON

```
3Z 26.
4N 16 J 11 I 33 L 9 K 4
3D .032 .067 .041 .015 .019 .061 .064 .023 .014 .01
 .029 .021 .021 .029 .039 .014 .011 .02 .007 .02 .01
 .01 .006 .006 .06 .06 .003 .03 .29 .006 .003 .02 .0006
3E .313 .364 .454 1.236 1.53 1.626 1.72 1.802 2.143
 2.672 2.73 2.837 3.146 3.24 3.43 3.552 3.725 3.43
 3.86 4.21 4.44 4.81 4.968 5.51 5.914 6.015 6.369
 7.285 7.639 8.345 8.872 9.298 10.16
3SNNG 421= .845
3SNNG 451= .845
3SNNG 1622= 1.26
3SNNG 1652= 1.26
3SNNG 2823= 1.41
3SNNG 2853= 1.41
3SNNG 4024= 1.81
3SNNG 4054= 1.81
3SNNG 5254= 2.1
3SNNG 6455= 2.26
3SNNG 7655= 2.6
3SNNG 8856= 3.
3SNNG 10057= 3.3
3SIGNG 2.244 1.74224 1.04069 .63118 .38331 .20142 .09549
 1.0327 .01303 .0257 .04921 .01817 .01497 .01272 .015 .01775
3SIGNN 14= .92 1.4
3SIGNN 54= .058 .2
3SIGNN 94= .04 .08
3SIGNN 134= .022 .2
3SIGNN 175= .18
3SIGNN 215= .15
3SIGNN 255= .1
3SIGNN 295= .06
3SIGNN 335= .09
3AMNEUT 1.008986
3AMISO1 53.95664 55.95264 56.95342 57.95147
3AMISO2 54.95565 56.95342 57.95147 58.9536
3C1 931.162
3P .0584 .9168 .0217 .0031 SIGA 2.3 2.7 2.5 2.5
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 +1 0 0 0
```

NICKEL

```
3Z 28.
4N 16 J 11 I 28 L 2 K 5
3D .035 .07 .03 .06 .02 .01 .01 .02 .01 .01 .01 .01 .007
 .013 .006 .03 .004 .013 .01 .02 .09 .006 .004 .04 .06
 .025 .11 .26
3E .28 .33 .436 .467 1.1 1.53 1.74 2.15 3.03 3.17 3.67
 4.05 4.20 5.31 5.7 5.82 5.99 6.1 6.34 6.58 6.839
 7.05 7.22 7.528 7.817 8.119 8.532 8.997
3SNNG 422= 1.33
3SNNG 452= 1.33
3SNNG 1623= 1.47
3SNNG 1653= 1.47
3SIGNG 4.08 3.16695 1.89254 1.14819 .69567 .36488 .17346 .0626
 .02939 .33985 .0646 .02635 .01856 .01656 .01623 .01742
3SIGNN 14= .3 .4
3SIGNN 54= .67 .8
3AMNEUT 1.008986
3AMISO1 57.9538 59.949824 60.9497 61.9476 63.9481
3AMISO2 58.9531 60.9497 61.9476 62.9495 64.9506
3C1 931.162
3P .678 .2623 .0125 .0366 .0115
3SIGA 4.4 2.6 2. 15. 1.52
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 +1 0 0 0
```

MOLYBDENUM

```
3Z 42.
4N 16 J 11 I 0 L 3 K 7
3SNG 7= 1.93 1.41 1.56 .21
3SNNG 451= .73
3SNNG 1653= 1.4
3SNNG 2855= 2.5
3SIGNG 2.2172 1.72124 1.02859 .62399 .37848 1.67959 5.05016
 5.33 .02 0 .01 0 0 .018 0 0
3SIGNN 15= .66
3SIGNN 55= .33
3SIGNN 95= .059
3AMNEUT 1.008986
3AMISO1 91.9352 93.9343 94.9357 95.9349 96.9365
 97.9366 99.9383
3AMISO2 92.9357 94.9357 95.9349 96.9365 97.9366
 98.9400 101.0173
3C1 931.162
3P .1586 .0912 .157 .165 .0945 .2375 .0962
3SIGA .3 0 13.9 1.2 2.2 .4 .5
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL 0 0 +1 0 0 0
```

TANTALUM

```
3Z 73.                                                                          TA
4N 16 J 11 I 31 L 1 NOELEM 3 K 1                                                TA2
3F .1/4 .3/4 .4/4 .82/4 .27/4 .4/4 .43/4 .54/4 .66/4                            FTA1
 .64/4 .63/4 .59/4 .525/4 .38/4 .29/4 .19/4                                     FTA2
 .32/4 .16/4 .17/4 .09/4 .19/4 .08/4 .11/4                                      FTA3
 .05/4 .08/4 .03/4 .07/4 .07/4 .23/4 .075/4 0                                   FTA4
3E .29 .4 .44 .5 .6 .9 1. 1.35 1.8 2.2 2.3 2.6 3. 4.                            ETA1
 4.48 4.58 4.68 4.8 4.88 5. 5.13 5.24 5.27 5.34 5.42 5.56 5.66                  ETA2
 5.7 5.8 6. 6.04                                                                ETA3
3SNNG 360= .137                                                                 SNNGTA13
3SNNG 390= .137                                                                 SNNGTA14
3SNNG 420= .137                                                                 SNNGTA15
3SNNG 450= .137                                                                 SNNGTA16
3SIGNG 18.6135 15.4499 8.7599 5.47596 5.34633 299.05 103.429 31.5732            XNGTA1
 8.2796 3.58136 1.1324 .3076 .21274 .15723 .10296 .04728                        XNGTA2
3SIGNN 12= .75 1.2 1.8 1.9                                                      XNNTA
3AMNEUT 1.008986
3AMISO1 181.0033 AMISO2 182.005                                                 ATA
3C1 931.162
3P 1. SIGA 21.                                                                  PXTATA
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.                              EG
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6                          EN1
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1                                  EN2
  .4 .9 1.4 3. 10.                                                              EN3
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL -1 0 +1 0 +1                                                             TA
```

TUNGSTEN

```
3Z 74.                                                                  W
4N 16 J 11 I 42 L 2 K 5                                                 W
3F .2/4 .4/4 .68/4 .36/4 .8/4 .38/4 .55/4 .32/4                         FW1
 .38/4 .33/4 .39/4 .45/4 .48/4 .53/4 .55/4                              FW2
 .53/4 .43/4 .47/4 .4/4 .59/4 .31/4 .33/4 .28/4                         FW3
 .37/4 .28/4 .48/4 .06/4 .12/4 .3/4 .96/4 .05/4                         FW4
 .01/4 .07/4 .03/4 .3/4 .81/4 .04/4 .05/4                               FW5
 0 0 .08/4 0                                                            FW6
3E .2 .4 .5 .56 .65 .78 .86 .9 1.06 1.17 1.35 1.5 1.8 2.2 2.4           EW1
 2.6 3. 3.1 3.34 3.45 3.6 3.75 4. 4.2 4.36 4.52 4.76 4.9 5.             EW2
 5.15 5.3 5.4 5.7 5.75 6. 6.1 6.2 6.3 6.7 7. 7.3 7.5                    EW3
3SNNG 330= .1014 .2082 .491 .473 .28 .172 .0557                         SNNGW112
3SNNG 360= .1014 .2082 .491 .473 .28 .172 .0557                         SNNGW113
3SNNG 390= .1014 .2082 .491 .473 .28 .172 .0557                         SNNGW114
3SNNG 420= .1014 .2082 .491 .473 .28 .172 .0557                         SNNGW115
3SNNG 450= .1013 .225 .678 .909 .724 .599 .459 .728 .195                SNNGW116
3SNNG 1530= .0516 .0365 .0568 .0694 .0499 .0163 .0047                   SNNGW212
3SNNG 1560= .0516 .0365 .0568 .0694 .0499 .0163 .0047                   SNNGW213
3SNNG 1590= .0516 .0365 .0568 .0694 .0499 .0163 .0047                   SNNGW214
3SNNG 1620= .0516 .0365 .0568 .0694 .0499 .0163 .0047                   SNNGW215
3SNNG 1650= .0535 .0374 .0835 .107 .0921 .0788 .0596 .0907 .0267        SNNGW216
3SIGNG 16.852 13.747 8.05 4.9 2.97498 21.125 20.1901 5.1414 .6121       XNGW1
 .4663 .1956 .0964 .0603 .0447 .0292 .0185                              XNGW2
3SIGNN 11= .35 1.2 2.2 2.57 2.59                                        XNNW1
3SIGNN 51= .35 1.2 2.2 2.57 2.59                                        XNNW2
3AMNEUT 1.008986
3AMISO1 180.0017 182.0039 183.005 184.006 186.010                       AW
3AMISO2 181.0140 183.005 184.006 185.0214 187.012                       AW+1
3C1 931.162
3P .002 .264 .144 .306 .284 SIGA 60. 20. 11. 2. 35.                     PXTAW
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.                      EG
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6                  EN1
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1                          EN2
  .4 .9 1.4 3. 10.                                                      EN3
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL -1 0 +1 0 +1 0                                                   W
```

RHENIUM

```
3Z,75.                                                                  RE
4N 16 J 11 I 27 L 1 K 2                                                 RE
3F .25/4 .68/4 .93/4 .42/4 .47/4 .52/4 .59/4 .62/4                      FRE1
 .6/4 .53/4 .47/4 .38/4 .38/4 .35/4 .23/4                               FRE2
 .35/4 .3/4 .15/4 .17/4 .05/4 .11/4 .09/4                               FRE3
 .22/4 .05/4 .06/4 .05/4 0                                              FRE4
3E .4 .46 .5 .9 1.35 1.6 1.8 2. 2.2 2.6 3. 3.53 3.75                    ERE1
 4. 4.64 4.96 5. 5.12 5.18 5.35 5.46 5.64 5.8 5.9 5.96 6. 6.12          ERE1
3SNNG 330= .135                                                         SNNGRE12
3SNNG 360= .135                                                         SNNGRE13
3SNNG 390= .135                                                         SNNGRE14
3SNNG 420= .135                                                         SNNGRE15
3SNNG 450= .135                                                         SNNGRE16
3SIGNG 66.5 39.5 29.1 70.07 732.78 187.22 22.21 21.9443 7.89335         XNGRE1
 2.924 1.039 .405 .14 .09274 .09568 .04285                              XNGRE2
3SIGNN 11= .25 .6 .75 .8 .8                                             XNNRE
3AMNEUT 1.008986
3AMISO1 185.0209 187.011 AMISO2 186.011 188.016                         ARE
3C1 931.162
3P .3707 .6293 SIGA 104. 66.                                            PXTARE
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.                      EG
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6                  EN1
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1                          EN2
  .4 .9 1.4 3. 10.                                                      EN3
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL -1 0 +1 0 +1                                                     RE
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URANIUM 238

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3Z 92.
4N 16 J 11 I 10 L 0 K 1
3D .09 .1 .08 .06 .02 .08 .08 .02 .02 .07
3E .54 .552 .577 .589 .611 .628 .637 3.576 3.662 4.062
3SFG 1.306 2.863 2.161 1.584 1.159 .906 .679 1.072 .452 .19 .015
3SIGNG 2.4388 1.89636 1.12501 .69 .41999 130.145 141. 11. 2.01
 .7 .45 .16 .14 .1 .05 0
3FSIG 13= .044 .485 .616
3AMNEUT 1.008986
3AMISO1 238.12522 AMISO2 239.12916
3C1 931.162
3P 1. SIGA 2.71
3BNDGAM .01 .4 .9 1.35 1.8 2.2 2.6 3. 4. 5. 7. 10.
3BNDNEU 0 3.216/-8 9.237/-8 2.511/-7 6.826/-7 1.855/-6
  8.315/-6 6.144/-5 4.54/-4 3.355/-3 1.7/-2 .1
  .4 .9 1.4 3. 10.
3RME .510984
3C 2.997923/10
3TK 2.5/-8
4KL 0
-KTROL +1 0 0 +1 0 0
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