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ATLAS OF PHOTONEUTRON CROSS SECTIONS OBTAINED WITH MONOENERGETIC PHOTONS
(Bicentennial Edition)

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The data included in this supplement replace earlier preliminary results presented in the Bicentennial Edition of the *Atlas of Photoneutron Cross Sections* (UCRL-78482, 1976). The nuclei included are ^{13}C , ^{18}O , ^{55}Mn , ^{59}Co , $^{186,188,189,190,192}\text{Os}$, ^{232}Th , and $^{235,236,238}\text{U}$, all from measurements performed at Lawrence Livermore Laboratory. Please note that when these data are cited, reference should be made to the original publication as well (all of these will appear in *Phys. Rev. C* within the next several months).

An updated, edited, and expanded digital data library of the cross sections included in the Atlas is in preparation and should be available within a short time. This library will include, in addition to the cross sections listed in the Table, the neutron yield cross sections $\sigma(\gamma, Xn) = \sigma[(\gamma, n) + 2(\gamma, 2n) + 3(\gamma, 3n) + \bar{\nu}(\gamma, F)]$. Running sums (as a function of photon energy) of all the integrated cross sections and their moments will be available as well.

Thanks are due to S. S. Dietrich for considerable help in the preparation of the Atlas.

EXPLANATION OF THE TABLE

$E_{\gamma\max}$ The upper-energy limit of the data.

$\sigma_{\text{int}}(\gamma, \text{tot})$ The integrated total photoneutron cross section

$$\sigma_{\text{int}}(\gamma, \text{tot}) = \int_{E_{\text{thr}}(\gamma, n)}^{E_{\gamma\max}} \sigma(\gamma, \text{tot}) dE_{\gamma}$$

where $E_{\text{thr}}(\gamma, n)$ is the photoneutron threshold energy, $\sigma(\gamma, \text{tot}) = \sigma[(\gamma, 1n) + (\gamma, 2n) + (\gamma, 3n)]$, $\sigma(\gamma, 1n) = \sigma[(\gamma, n) + (\gamma, pn)]$, and $\sigma(\gamma, 2n) = \sigma[(\gamma, 2n) + (\gamma, p2n)]$.

For the actinide nuclei, the photofission cross section $\sigma(\gamma, F)$ is substituted for $\sigma(\gamma, 3n)$, where $\sigma(\gamma, F)$ is the sum of the first- and second-chance photofission cross sections $\sigma(\gamma, f)$ and $\sigma(\gamma, nf)$, respectively, and the lower limit of integration is 5 MeV.

$\sigma_{\text{int}}(\gamma, 1n)$ The integrated single photoneutron cross section

$$\sigma_{\text{int}}(\gamma, 1n) = \int_{E_{\text{thr}}(\gamma, n)}^{E_{\gamma\max}} \sigma(\gamma, 1n) dE_{\gamma}$$

$\sigma_{\text{int}}(\gamma, 2n)$ The integrated double photoneutron cross section

$$\sigma_{\text{int}}(\gamma, 2n) = \int_{E_{\text{thr}}(\gamma, 2n)}^{E_{\gamma\max}} \sigma(\gamma, 2n) dE_{\gamma}$$

where $E_{\text{thr}}(\gamma, 2n)$ is the threshold energy for the photoejection of two neutrons.

$\sigma_{int}(\gamma, 3n)$

The integrated triple photoneutron cross section

$$\sigma_{int}(\gamma, 3n) = \int_{E_{thr}(\gamma, 3n)}^{E_{\gamma max}} \sigma(\gamma, 3n) dE_{\gamma}$$

where $E_{thr}(\gamma, 3n)$ is the threshold energy for the photoejection of three neutrons. For ^{18}O ,

$\sigma_{int}(\gamma, p)$ appears in this column, and for the actinide nuclei

$$\sigma_{int}(\gamma, F) = \int_{5 \text{ MeV}}^{E_{\gamma max}} \sigma(\gamma, F) dE_{\gamma} .$$

σ_{-1}

The first moment of the integrated total photoneutron cross section

$$\sigma_{-1} = \int_{E_{thr}(\gamma, n)}^{E_{\gamma max}} [\sigma(\gamma, tot)/E_{\gamma}] dE_{\gamma} .$$

σ_{-2}

The second moment of the integrated total photoneutron cross section

$$\sigma_{-2} = \int_{E_{thr}(\gamma, n)}^{E_{\gamma max}} [\sigma(\gamma, tot)/E_{\gamma}^2] dE_{\gamma} .$$

Fitting
Interval

The photon energy interval over which the Lorentz-curve fits to the data were made.

$E_{mi}, \sigma_{mi}, \Gamma_i$

The parameters of the Lorentz curves fitted to the data within the fitting interval given in the preceding column. The Lorentz curves are of the form

$$\sigma(E_{\gamma}) = \sum_i \sigma_{mi} / \{1 + [(E_{\gamma}^2 - E_{mi}^2)/E_{\gamma i}^2]\} .$$

For spherical nuclei, $i = 1$; for deformed nuclei $i = 1, 2$. Here "spherical" merely indicates that a one-component Lorentz curve gives a better fit to the data than a two-component one, and "deformed" indicates the opposite. The fitting procedure used is the standard best-least-squares method, wherein the squares of the residuals are weighted with the inverse squares of the statistical uncertainties.

Reference	The data references follow the Table.
Figure Number	The figure number in this supplement.
Old Figure Number	The number of the figure in UCRL-78482 (1976) that is replaced.

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EXPLANATION OF THE GRAPHS

The graphs presented are listed in the Table with relevant figure numbers.

The following designations are used on the graphs:

(a) Total photoneutron cross section

$$\sigma(\gamma, \text{tot}) = \sigma[(\gamma, 1n) + (\gamma, 2n) + (\gamma, 3n)] .$$

(b) Single photoneutron cross section

$$\sigma(\gamma, 1n) = \sigma[(\gamma, n) + (\gamma, pn)] .$$

(c) Double photoneutron cross section

$$\sigma(\gamma, 2n) = \sigma[(\gamma, 2n) + (\gamma, p2n)] .$$

(d) Triple photoneutron cross section $\sigma(\gamma, 3n)$. For

180 , part (d) is $\sigma(\gamma, p)$, and for the actinide

nuclei it is $\sigma(\gamma, f)$.

Threshold Energies Indicated on the graphs by arrows; values are taken

from A. H. Wapstra and K. Bos, Atomic Data and
Nuclear Data Tables 19, 215 (1977).

The solid curves, drawn on the graphs of the total photoneutron cross sections for the medium and heavy nuclei, are Lorentz curves fitted to the giant-resonance data, whose parameters are given in the Table.

Giant-Resonance Properties from Monoenergetic-Photon Measurements

Lorentz Parameters

Nucleus	$E_{\gamma \text{ max}}$ (MeV)	$\sigma_{\text{int}}(\gamma, \text{tot})$ (MeV-mb)	$\sigma_{\text{int}}(\gamma, n)$ (MeV-mb)	$\sigma_{\text{int}}(\gamma, 2n)$ (MeV-mb)	$\sigma_{\text{int}}(\gamma, 3n)$ (MeV-mb)	σ_{-1} (mb)	σ_{-2} (mb-MeV ⁻¹)	Fitting Interval (MeV)	E_{m1} (MeV)	σ_{m1} (mb)	Γ_1 (MeV)	E_{m2} (MeV)	σ_{m2} (mb)	Γ_2 (MeV)	Reference	Figure Number	Old Figure Number
¹³ C	41.8	126.1	121.3	4.7		5.72	0.306								79Ju	1	11
¹⁸ O	41.8	198.3	121.5	76.7	44.4 ^a	9.08	0.483								79Wo	2	16
⁵⁵ Mn	36.5	733	567	163	3	35.4	1.93	14-21	16.82	51.4	4.33	20.09	45.2	4.09	79Al	3	38
⁵⁹ Co	36.5	807	653	150	4	40.1	2.14	14-21	16.43	28.3	2.73	18.66	58.4	7.38	79Al	4	40
¹⁸⁶ Os	19.7	2500	2040	460		179	13.2	10.8-18.8	13.03	308	3.13	15.26	302	3.38	79Be	5	139
¹⁸⁸ Os	30.4	3620	2620	880	120	239	16.7	10.8-18.8	12.81	260	2.76	14.88	390	4.19	79Be	6	140
¹⁸⁹ Os	29.9	3340	2130	1000	210	228	16.7	10.8-18.8	12.68	268	2.71	14.68	395	3.62	79Be	7	141
¹⁹⁰ Os	30.4	3230	2010	1080	140	220	15.8	10.8-18.8	12.68	206	2.60	14.40	401	4.16	79Be	8	142
¹⁹² Os	29.9	3310	1920	1200	190	224	16.0	10.8-18.8	12.68	206	2.49	14.35	389	4.41	79Be	9	143
²³² Th	18.3	3480	1660	1450	370 ^b	276	22.8	9-18	11.03	302	2.71	13.87	449	4.77	79Ca	10	157
²³⁵ U	18.3	3500	1140	200	2160 ^b	278	23.1	9-18	10.90	328	2.30	13.96	459	4.75	79Ca	11	158
²³⁶ U	18.3	3160	1260	450	1450 ^b	252	21.0	9-18	10.92	271	2.55	13.78	415	4.88	79Ca	12	159
²³⁸ U	18.3	3580	1360	1130	1090 ^b	286	24.0	9-18	10.77	311	2.37	13.80	459	5.13	79Ca	13	163

^a $\sigma_{\text{int}}(\gamma, p)$

^b $\sigma_{\text{int}}(\gamma, f)$

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Photon Energy (MeV)

Fig. 13