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ENDF/B Neutron Cross-section Data for Natural Helium (ENDF-125)

by

E. M. Pennington

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Reactor Physics Division

October 1968

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ABSTRACT

This report describes the compilation of neutron cross-section data for natural helium. The elastic scattering cross section, $\bar{\mu}_L$, ξ, γ, and elastic scattering Legendre coefficients are included for ^{4}He. Since ^{3}He has a natural abundance of merely 0.00013%, only its (n,p) cross section, which is large at low energies, is considered. A listing of the data in the ENDF/B format is presented, as are graphs of much of the data.

I. INTRODUCTION

Since natural helium is a possible coolant for fast breeder reactors, the present helium cross-section data were compiled. The data will be distributed with ENDF/B identification number MAT = 1088.

The composition of natural helium is 99.99987% ^{4}He and 0.00013% ^{3}He. Because of the low abundance of ^{3}He, only its (n,p) cross section, which is large at low energies, need be considered. Elastic scattering is the only possible reaction for neutrons incident on ^{4}He at energies below 15 MeV. Thus the elastic scattering cross section and values of $\bar{\mu}_L$, ξ, and γ are included in the compilation, as well as elastic scattering Legendre coefficients. Here $\bar{\mu}_L$ is the average cosine of the angle of elastic scattering in the laboratory system, ξ is the average logarithmic energy decrement in an elastic collision, and γ, the Greuling-Goertzel parameter, is the average of the square of the logarithmic energy decrement divided by twice the average logarithmic energy decrement. Parameters for a free-gas thermal scattering law are also included.

II. DATA SOURCES AND CALCULATIONAL METHODS

The elastic scattering cross section and Legendre expansion coefficients were calculated from s-, p-, and d-wave phase shifts using a FORTRAN program written for the purpose. Appendix A presents the equations involved in this program. The phase shifts were read from smooth curves based on Table I of Ref. 1. At energies below the 300-keV lower limit of this table, each of the two p-wave phase shifts was obtained by using a functional form based on the low-energy limit for a single p-wave resonance, with parameters determined from fitting the low-energy phase shifts of the table. Appendix B presents the equations connected with the low-energy phase shifts, and the parameters obtained by the fitting procedure. The s-wave phase shift below 300 keV was calculated using hard-sphere scattering and a nuclear radius of a = 2.4 F. This yields a thermal scattering cross section of $4\pi a^2$ = 0.7238 barn, in agreement with the experimental value[2] of 0.73 ± 0.05 barn. The low-energy s-wave phase shifts of Ref. 1 are consistent with a nuclear radius of about 2.48 F and so would yield a somewhat high thermal cross section.

Table I lists the phase shifts used in the calculations at energies above 10 keV.

TABLE I. Helium Phase Shifts Used in Calculations of Elastic Scattering Cross Sections and Legendre Expansion Coefficients

E_{lab}, MeV	δ_0^+	δ_1^+	δ_1^-	δ_2^+	δ_2^-
0.02	3.08203	0.00092	0.00022		
0.03	3.06865	0.00171	0.00040		
0.05	3.04742	0.00373	0.00086		
0.07	3.03017	0.00629	0.00143		
0.10	3.00842	0.0110	0.00246		
0.15	2.97849	0.0212	0.00457		
0.20	2.95326	0.0343	0.00711		
0.25	2.93103	0.0504	0.0100		
0.30	2.9025	0.0698	0.0133		
0.35	2.8833	0.0930	0.0170		
0.40	2.8658	0.1204	0.0209		
0.45	2.8466	0.1536	0.0252		
0.50	2.8292	0.1920	0.0299		
0.55	2.8152	0.2356	0.0348		
0.60	2.8047	0.2845	0.0401		
0.65	2.7908	0.3421	0.0454		
0.70	2.7786	0.4067	0.0524		
0.75	2.7646	0.4800	0.0576		
0.80	2.7524	0.5725	0.0646		
0.85	2.7402	0.6615	0.0698		
0.90	2.7297	0.7662	0.0768		
0.95	2.7175	0.8779	0.0838		
1.00	2.7070	0.9983	0.0908		
1.05	2.6965	1.1170	0.0977		
1.10	2.6861	1.2235	0.1065		
1.13	2.6791	1.2881	0.1100		
1.15	2.6756	1.3299	0.1134		
1.17	2.6721	1.3701	0.1169		
1.20	2.6669	1.4312	0.1222		
1.25	2.6564	1.5202	0.1292		
1.30	2.6477	1.5970	0.1379		
1.35	2.6389	1.6668	0.1466		
1.40	2.6302	1.7296	0.1553		
1.45	2.6215	1.7802	0.1641		
1.5	2.6128	1.8239	0.1745		
1.6	2.5953	1.9059	0.1937		
1.7	2.5796	1.9652	0.2129		
1.8	2.5639	2.0106	0.2321		
1.9	2.5482	2.0438	0.2531		
2.0	2.5342	2.0752	0.2758	0.0012	0.0009
2.1	2.5203	2.0961	0.2967	0.0012	0.0009
2.2	2.5063	2.1153	0.3194	0.0014	0.0010
2.3	2.4923	2.1293	0.3403	0.0016	0.0012
2.4	2.4784	2.1398	0.3630	0.0017	0.0012
2.5	2.4644	2.1468	0.3857	0.0019	0.0014
2.6	2.4522	2.1537	0.4084	0.0021	0.0016
2.7	2.4400	2.1590	0.4328	0.0024	0.0017
2.8	2.4278	2.1642	0.4555	0.0026	0.0019
2.9	2.4155	2.1660	0.4782	0.0030	0.0021
3.0	2.4051	2.1677	0.5009	0.0031	0.0023
3.2	2.3806	2.1712	0.5428	0.0037	0.0026
3.4	2.3579	2.1729	0.5847	0.0042	0.0031
3.6	2.3370	2.1694	0.6248	0.0049	0.0035
3.8	2.3178	2.1625	0.6667	0.0054	0.0038
4.0	2.2986	2.1537	0.7086	0.0061	0.0044
4.2	2.2794	2.1468	0.7435	0.0070	0.0049
4.4	2.2602	2.1398	0.7767	0.0077	0.0054
4.6	2.2427	2.1328	0.8081	0.0084	0.0059
4.8	2.2253	2.1258	0.8360	0.0093	0.0065
5.0	2.2078	2.1171	0.8622	0.0101	0.0070
5.2	2.1904	2.1084	0.8849	0.0110	0.0075
5.4	2.1747	2.0996	0.9058	0.0120	0.0082
5.6	2.1590	2.0892	0.9250	0.0131	0.0087
5.8	2.1450	2.0804	0.9442	0.0141	0.0094
6.0	2.1293	2.0717	0.9617	0.0152	0.0103
6.2	2.1153	2.0630	0.9774	0.0162	0.0108
6.4	2.1014	2.0543	0.9896	0.0175	0.0115
6.6	2.0857	2.0438	1.0001	0.0185	0.0124
6.8	2.0717	2.0351	1.0105	0.0197	0.0133
7.0	2.0577	2.0263	1.0210	0.0209	0.0140
7.2	2.0455	2.0176	1.0280	0.0222	0.0145
7.4	2.0316	2.0089	1.0350	0.0236	0.0152
7.6	2.0193	2.0001	1.0420	0.0248	0.0159
7.8	2.0054	1.9914	1.0472	0.0262	0.0166
8.0	1.9932	1.9827	1.0507	0.0279	0.0175
8.2	1.9809	1.9740	1.0559	0.0297	0.0183
8.4	1.9705	1.9652	1.0594	0.0314	0.0190
8.6	1.9583	1.9565	1.0612	0.0332	0.0197
8.8	1.9478	1.9478	1.0629	0.0349	0.0206
9.0	1.9356	1.9391	1.0647	0.0367	0.0215
9.2	1.9234	1.9321	1.0647	0.0384	0.0223
9.4	1.9129	1.9234	1.0647	0.0401	0.0234
9.6	1.9007	1.9146	1.0647	0.0419	0.0243
9.8	1.8902	1.9059	1.0629	0.0436	0.0253
10.0	1.8780	1.8972	1.0629	0.0454	0.0262
10.5	1.8535	1.8780	1.0612	0.0506	0.0288
11.0	1.8291	1.8570	1.0577	0.0541	0.0314
11.5	1.8047	1.8378	1.0507	0.0593	0.0340
12.0	1.7802	1.8169	1.0402	0.0646	0.0367
12.5	1.7593	1.7994	1.0297	0.0698	0.0384
13.0	1.7383	1.7820	1.0193	0.0750	0.0419
13.5	1.7174	1.7628	1.0071	0.0803	0.0436
14.0	1.6965	1.7453	0.9966	0.0855	0.0454
14.5	1.6755	1.7279	0.9861	0.0908	0.0471
15.0	1.6546	1.7104	0.9756	0.0960	0.0489

Values of $\bar{\mu}_L$, ξ, and γ were calculated from the Legendre coefficients using a FORTRAN program, MUXIGA. This program is based on the equations derived in Refs. 3-5. These equations are summarized in Appendix C.

An elastic scattering Legendre-coefficient transformation matrix from the center-of-mass system to the laboratory system was computed using CHAD.[6] A minor revision was made in the CHAD code to avoid elements of the matrix being set equal to zero if they were larger than elements closer to the diagonal.

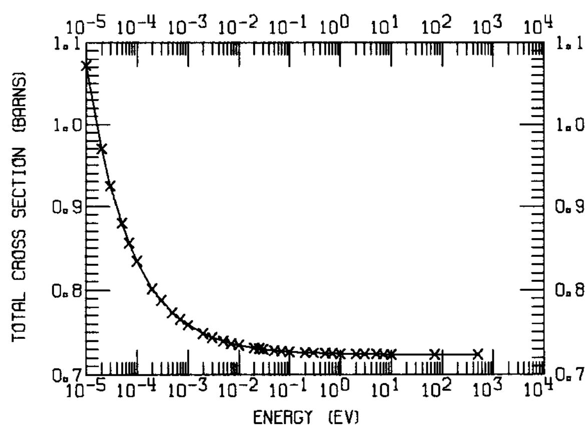
The (n,p) cross section for ^{3}He is that recommended in the ^{3}He evaluation by J. Als-Nielsen.[7] Extension from 10 to 15 MeV was made using linear extrapolation on a log σ versus log E scale.

The total cross section is the sum of the elastic scattering and (n,p) cross sections.

The free-gas thermal scattering law involves a value of 0.7238 barn for the free-atom scattering cross section.

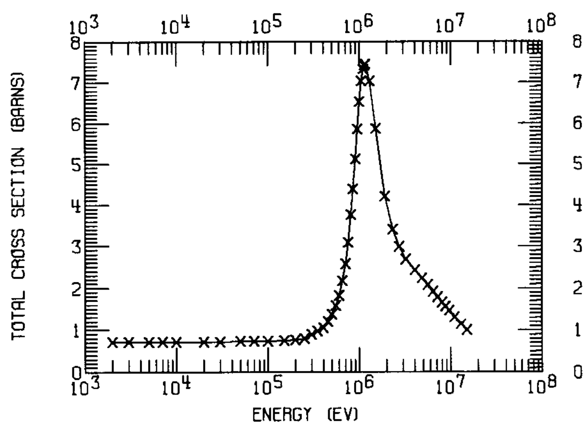
III. GRAPHS AND LISTING

Figures 1-8 are graphs of the ENDF/B File 3 data.[8] The File 3 data are represented by a series of pairs of x and y values with an interpolation rule applying between successive pairs. The interpolation rule might specify, for example, that log y is linear in log x between successive (x,y) pairs. In Figs. 1-8 the axis types have been chosen to correspond to the interpolation rule. Thus in Figs. 1 and 2 a linear axis is used for the total cross section and a logarithmic axis is used for the energy, because linear y versus log x interpolation is specified for this cross section. The total cross section



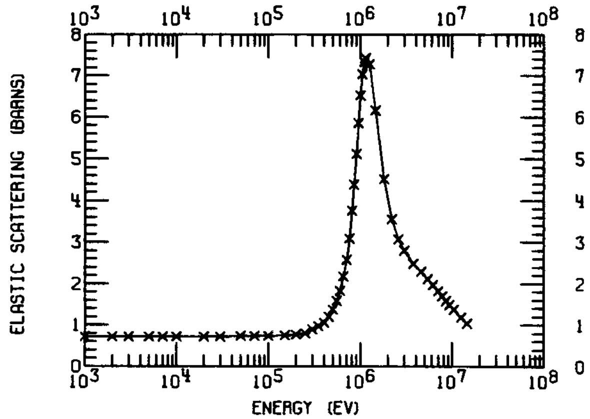
113-691

Fig. 1. Helium Total Cross Section, 10^{-5} eV to 1 keV



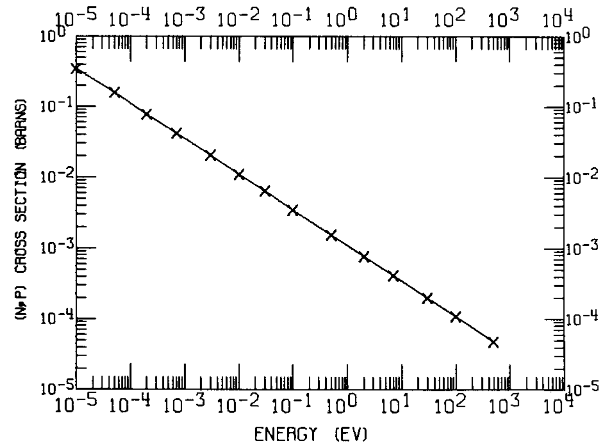
113-682

Fig. 2. Helium Total Cross Section, 1 keV to 15 MeV



113-681

Fig. 3. Helium Elastic Scattering Cross Section



113-686

Fig. 4. Helium (n,p) Cross Section, 10^{-5} eV to 1 keV

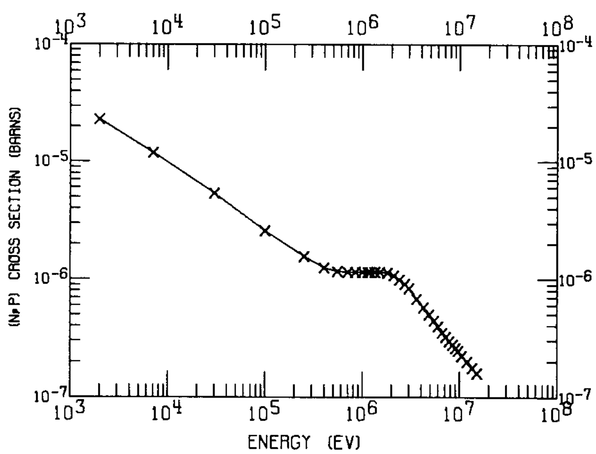


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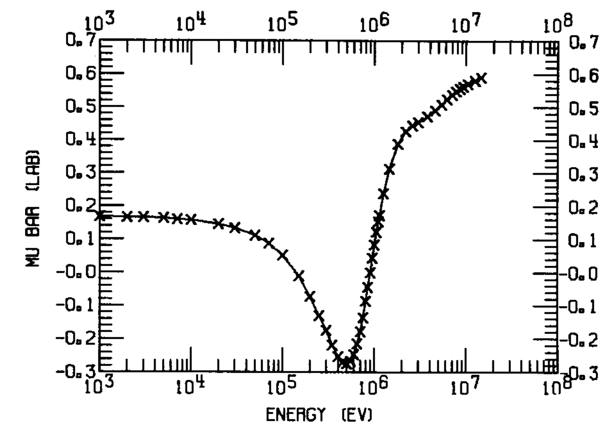
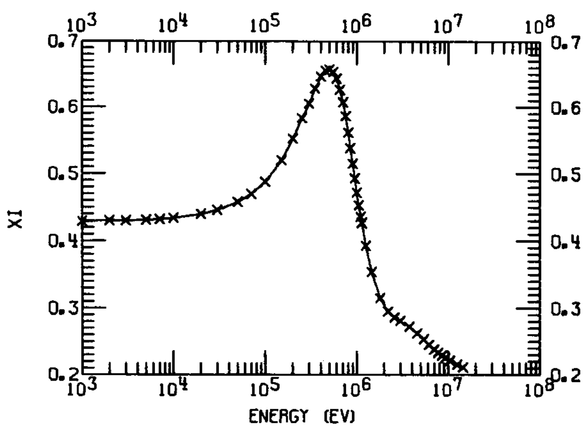
Fig. 5. Helium (n,p) Cross Section, 1 keV to 15 MeV



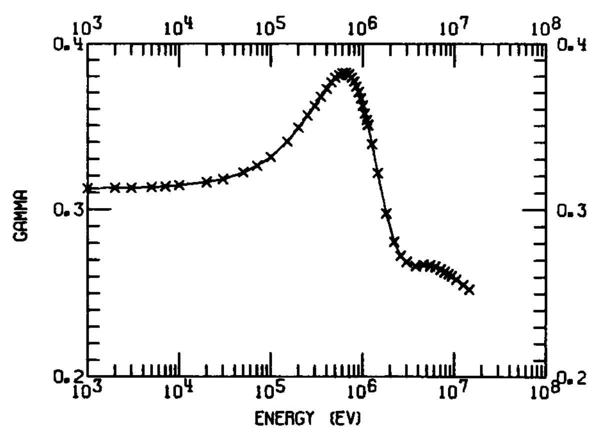
113-696

Fig. 6. Helium Average Elastic Scattering Cosine, $\overline{\mu}_L$



113-698

Fig. 7. Helium Average Logarithmic Energy Decrement, ξ



113-680

Fig. 8. Helium Greuling-Goertzel Parameter, γ

and the (n,p) cross section have been plotted in two energy ranges in Figs. 1 and 2 and Figs 4 and 5, respectively, in order to display the data better. The data in Figs. 3, 6, 7, and 8 for the elastic scattering cross section, $\bar{\mu}_L$, ξ, and γ are not plotted below 1 keV because the values are almost constant at low energies. Not all data points are plotted, especially at high energies, to avoid clutter on the graphs.

Figures 9-12 display the Legendre coefficients for elastic scattering angular distributions in the center-of-mass system, f_1 through f_4. The elastic scattering angular distribution, $d\sigma(E)/d\Omega$, is given by[8]

$$\frac{d\sigma(E)}{d\Omega} = \frac{\sigma_s(E)}{4\pi} \sum_{\ell=0} (2\ell+1)\, f_\ell(E) P_\ell(\mu), \tag{1}$$

where the elastic scattering cross section $\sigma_s(E)$ is tabulated in ENDF/B File 3, and the expansion coefficients $f_\ell(E)$ are presented at a series of

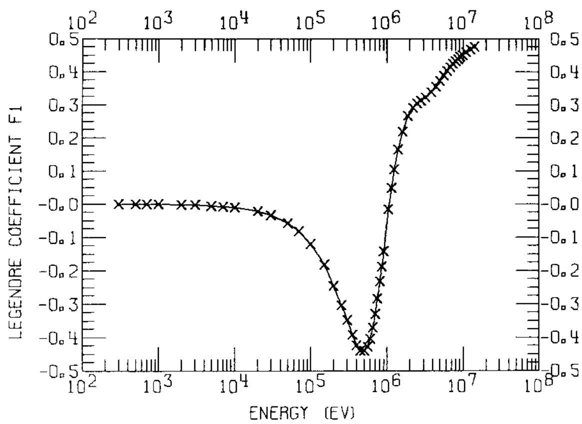


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Fig. 9. Helium Elastic Scattering Legendre Coefficient f_1

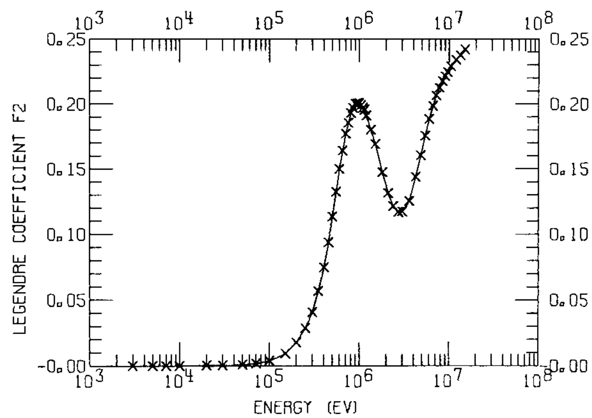

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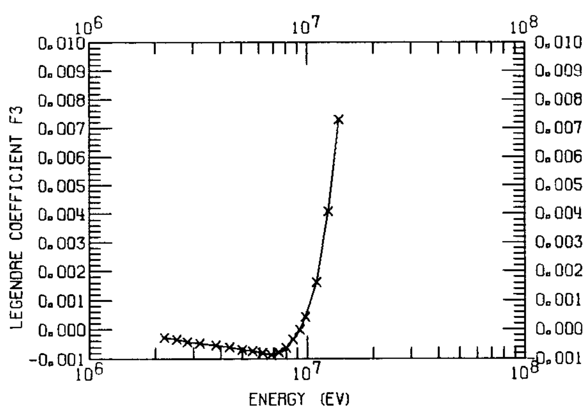
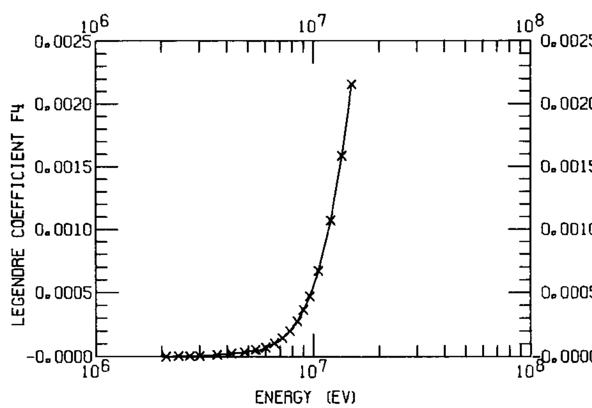
Fig. 10. Helium Elastic Scattering Legendre Coefficient f_2



113-702

Fig. 11. Helium Elastic Scattering Legendre Coefficient f_3



113-674

Fig. 12. Helium Elastic Scattering Legendre Coefficient f_4

energies in File 4. In Figs. 13-31 the angular distributions have been calculated from Eq. 1 at a representative sequence of 19 energies. Note that the angular distributions at the energies shown below 1.2 MeV are peaked in the backward direction, as is typical on the low-energy side of a p-wave resonance. All graphs were drawn with the aid of the CDC-3600 computer and the Calcomp 580 plotter.

The helium data in the ENDF/B format are listed in Appendix D. The listing will not be explained here since all information necessary for understanding the formats involved is in Ref. 8.

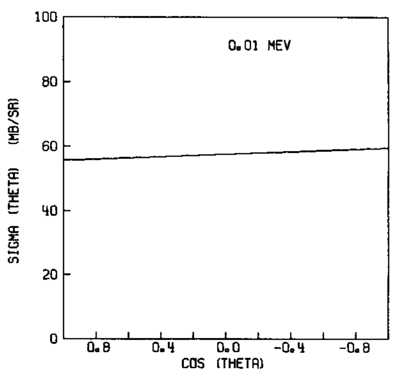


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Fig. 13

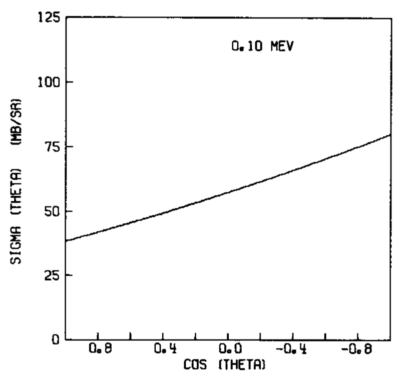

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Fig. 14

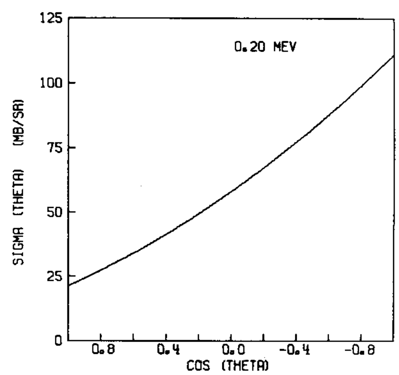

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Fig. 15

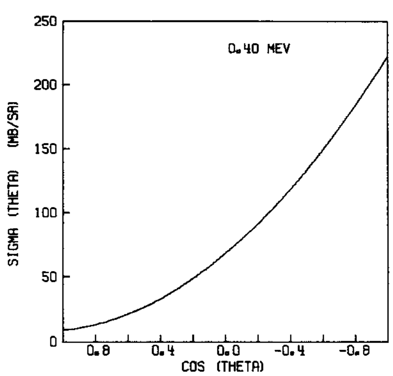

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Fig. 16

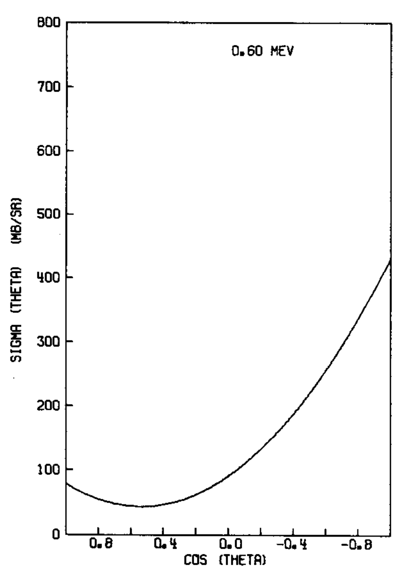

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Fig. 17

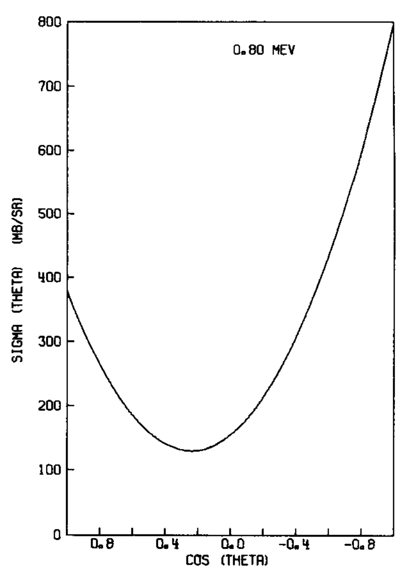

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Fig. 18

Figs. 13-18. Helium Elastic Scattering Angular Distributions

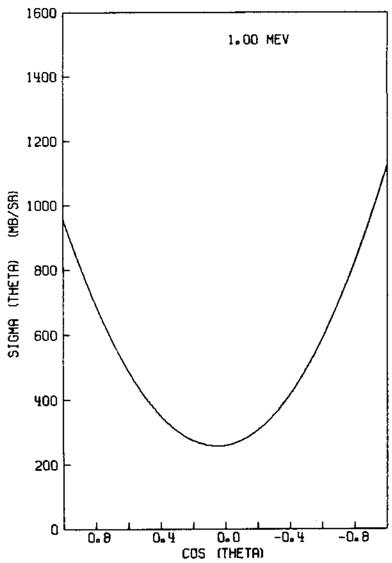

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Fig. 19

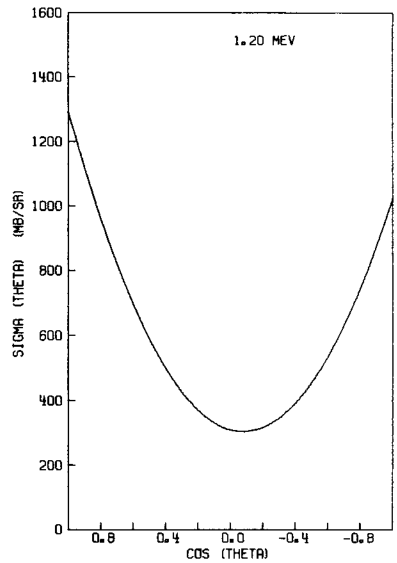

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Fig. 20

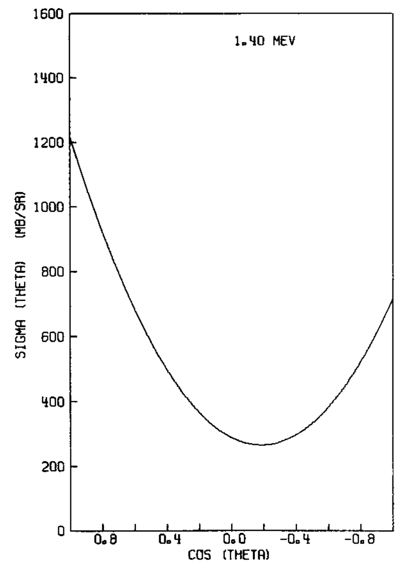

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Fig. 21

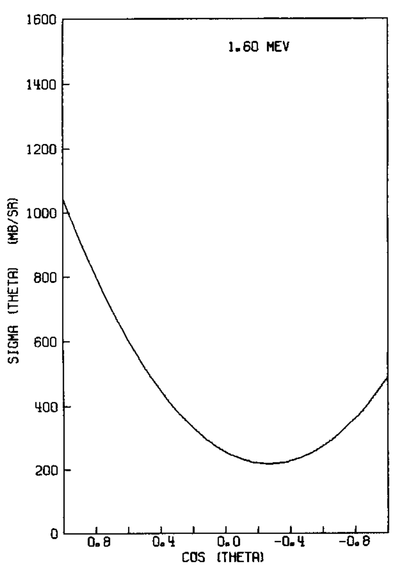

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Fig. 22

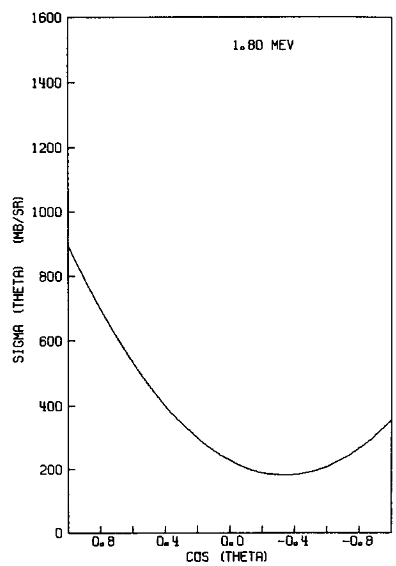

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Fig. 23

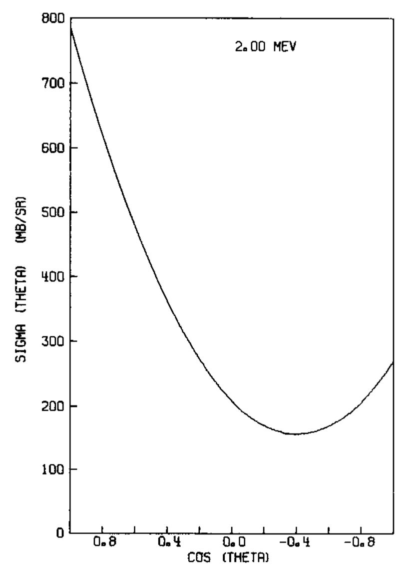

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Fig. 24

Figs. 19-24. Helium Elastic Scattering Angular Distributions

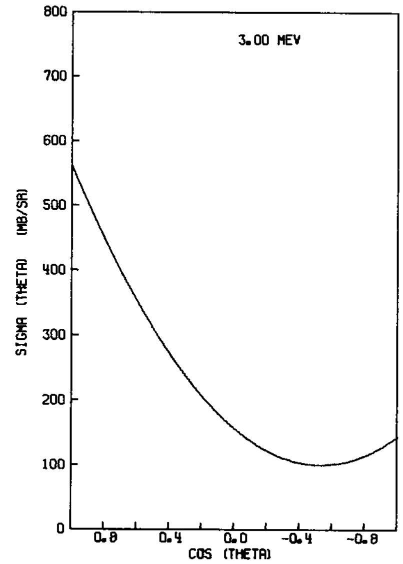

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Fig. 25

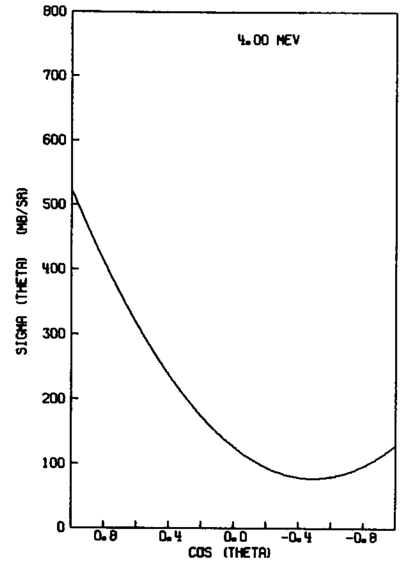

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Fig. 26

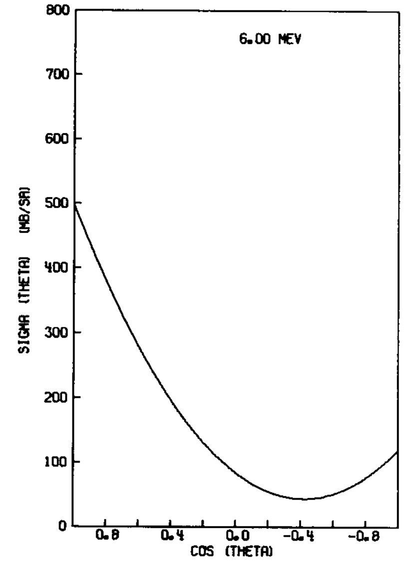

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Fig. 27

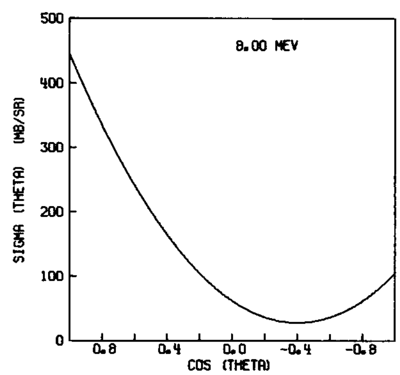

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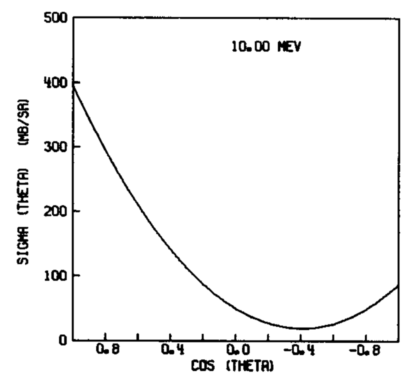
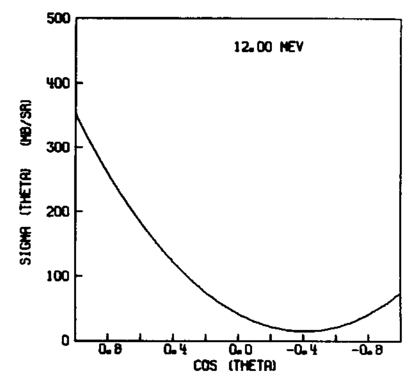
Fig. 28



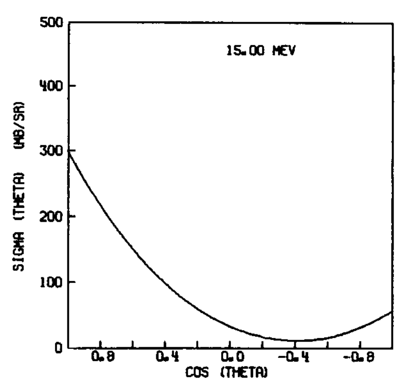
113-687

Fig. 29



113-704

Fig. 30



113-689

Fig. 31

Figs. 25-31

Helium Elastic Scattering Angular Distributions

IV. DISCUSSION

The phase shifts of Ref. 1, which were used in the compilation, are optical-model phase shifts chosen to fit both angular-distribution and polarization data at many energies. The total cross section is also fit within the scatter of the experimental points. Because Ref. 1 is recent and considers the experimental data comprehensively, the data calculated from the phase shifts should be reliable. Another recent set of phase shifts[9] is not very different from that of Ref. 1 and could also have been used in the present work.

As discussed in Ref. 7, the ^{3}He (n,p) cross section is rather well known. Probably more error is introduced into the (n,p) cross section for natural helium by the uncertainty in the ^{3}He isotopic abundance than by the uncertainty in the ^{3}He (n,p) cross section itself.

Previous evaluations of natural helium for reactor calculations include those of Schmidt[10] and of Buckingham et al.[11,12] Schmidt's evaluation includes the (n,p) cross section for ^{3}He and σ_s, $\bar{\mu}_L$, and a set of phase shifts for ^{4}He. Buckingham et al. present separate compilations for ^{3}He and ^{4}He. For ^{3}He, elastic, (n,p), (n,d), and (n,2n) cross sections are given, as well as elastic angular distributions. The ^{4}He evaluation consists of σ_s and angular distributions.

The (n,p) cross section of ^{3}He, which was based on Ref. 7, is not very different from those of previous evaluations,[10,12] as may be seen from Table 3 of Ref. 7.

The values of the elastic scattering cross section are in fairly good agreement with those in the other evaluations.[10,11] Schmidt's values[10] agree with those of the present evaluation at energies below the main resonance and are generally a little larger at higher energies, except for a range on the high-energy side of the main resonance. The English values[11] are higher than the present values at energies below about 1 MeV and lower at higher energies.

The present values of $\bar{\mu}_L$ are in rather good agreement with those shown on Fig. He-3 in Part I of KFK-120[10] at energies above approximately 1 MeV, but do not agree well at lower energies.

APPENDIX A

Equations Relating the Elastic Scattering Cross Section and Legendre Expansion Coefficients to the s-, p-, and d-wave Phase Shifts

The elastic scattering angular distribution, $d\sigma/d\Omega$, in the center-of-mass system is given by[13]

$$\frac{d\sigma}{d\Omega} = \frac{1}{4k^2}(|a|^2 + |b|^2) = \sum_n C_n P_n(\mu), \tag{A.1}$$

where

$$a = \sum_{\ell=0}^{\infty} \left[(\ell+1)(e^{2i\delta_\ell^+} - 1) + \ell(e^{2i\delta_\ell^-} - 1)\right] P_\ell(\mu), \tag{A.2}$$

and

$$b = \sum_{\ell=0}^{\infty} \left(e^{2i\delta_\ell^+} - e^{2i\delta_\ell^-}\right) P_\ell^1(\mu). \tag{A.3}$$

Here μ is the cosine of the center-of-mass scattering angle, $P_\ell(\mu)$ is the Legendre polynomial of order ℓ, and

$$P_\ell^1(\mu) = (1-\mu^2)^{1/2} \frac{d}{d\mu} P_\ell(\mu).$$

The quantity $k = \sqrt{2mE/\hbar^2}$, where E is the energy of relative motion of neutron and nucleus in the center-of-mass system, and m is the reduced mass. The phase shifts δ_ℓ^+ and δ_ℓ^- refer to $j = \ell + 1/2$ and $j = \ell - 1/2$, respectively, where j is the angular momentum quantum number referring to the addition of the orbital and spin angular momenta.

On restricting the sums in Eqs. A.2 and A.3 by considering only s-, p-, and d-wave phase shifts, and using the explicit forms for the Legendre polynomials, we obtain

$$k^2C_0 = \sin^2\delta_0^+ + 2\sin^2\delta_1^+ + \sin^2\delta_1^- + 3\sin^2\delta_2^+ + 2\sin^2\delta_2^-, \tag{A.4}$$

$$\begin{aligned} k^2C_1 = {} & 3\sin^2\delta_0^+ + 6\sin^2\delta_1^+ + 3\sin^2\delta_1^- + \tfrac{18}{5}\sin^2\delta_2^+ + \tfrac{12}{5}\sin^2\delta_2^- \\ & - 2\sin^2(\delta_0^+ - \delta_1^+) - \sin^2(\delta_0^+ - \delta_1^-) - \tfrac{18}{5}\sin^2(\delta_1^+ - \delta_2^+) \\ & - 2\sin^2(\delta_1^- - \delta_2^-) - \tfrac{2}{5}\sin^2(\delta_1^+ - \delta_2^-), \end{aligned} \tag{A.5}$$

$$k^2C_2 = 5\sin^2\delta_0^+ + 4\sin^2\delta_1^+ + 2\sin^2\delta_1^- + \tfrac{51}{7}\sin^2\delta_2^+ + \tfrac{34}{7}\sin^2\delta_2^-$$

$$- 2\sin^2(\delta_1^+ - \delta_1^-) - \tfrac{6}{7}\sin^2(\delta_2^+ - \delta_2^-) - 3\sin^2(\delta_0^+ - \delta_2^+)$$

$$- 2\sin^2(\delta_0^+ - \delta_2^-), \qquad \text{(A.6)}$$

$$k^2C_3 = 6\sin^2\delta_1^+ + 3\sin^2\delta_1^- + \tfrac{27}{5}\sin^2\delta_2^+ + \tfrac{18}{5}\sin^2\delta_2^-$$

$$- \tfrac{12}{5}\sin^2(\delta_1^+ - \delta_2^+) - \tfrac{18}{5}\sin^2(\delta_1^+ - \delta_2^-) - 3\sin^2(\delta_1^- - \delta_2^+), \qquad \text{(A.7)}$$

and

$$k^2C_4 = \tfrac{54}{7}\sin^2\delta_2^+ + \tfrac{36}{7}\sin^2\delta_2^- - \tfrac{36}{7}\sin^2(\delta_2^+ - \delta_2^-). \qquad \text{(A.8)}$$

Equation 1 gives the angular distribution in the ENDF/B normalization. Thus the elastic scattering cross section is $\sigma_s = 4\pi C_0$, and the Legendre coefficients are given by

$$f_\ell = \frac{C_\ell}{(2\ell + 1)\ C_0}.$$

APPENDIX B

Low-energy Phase Shifts from Resonance Parameters

The phase shift, $\delta_{\ell J}$, near an isolated purely scattering resonance with orbital angular momentum ℓ and total angular momentum J is[14]

$$\delta_{\ell J} = \tan^{-1}\left(\frac{R_{\ell J} P_{\ell}}{1 - R_{\ell J}\hat{S}_{\ell}}\right) - \phi_{\ell}, \tag{B.1}$$

where

$$\phi_{\ell} = \tan^{-1}\left(\frac{F_{\ell}}{G_{\ell}}\right) \tag{B.2}$$

with

$$F_{\ell} = \rho j_{\ell}(\rho) \tag{B.3}$$

and

$$G_{\ell} = -\rho n_{\ell}(\rho). \tag{B.4}$$

The functions $j_{\ell}(\rho)$ and $n_{\ell}(\rho)$ are spherical Bessel functions.[15] The quantity ρ is defined by

$$\rho = ka = a\sqrt{2mE/\hbar^2} = a\sqrt{\frac{2m}{\hbar^2}\frac{A}{A+1}E_{lab}} = C\sqrt{E_{lab}},$$

where E is the energy of the relative motion of neutron and target in the center-of-mass system, E_{lab} is the neutron energy in the laboratory system, $m = m_n A/(1 + A)$, with A being the ratio of the target mass to the neutron mass, m_n, and a is the nuclear radius. The penetration and shift factors are

$$P_{\ell} = \frac{\rho}{F_{\ell}^2 + G_{\ell}^2} \tag{B.5}$$

and

$$S_{\ell} = \frac{\rho\left(F_{\ell}F_{\ell}' + G_{\ell}G_{\ell}'\right)}{F_{\ell}^2 + G_{\ell}^2} \tag{B.6}$$

where the prime signifies differentiation with respect to ρ. The $\hat{S}_{\ell}$ in Eq. B.1 is related to S_{ℓ} by $\hat{S}_{\ell} = S_{\ell} - B_{\ell J}$, where $B_{\ell J}$ is a boundary-condition constant.[14] The function $R_{\ell J}$ is

$$R_{\ell J} = \frac{\gamma^2_{\lambda \ell J}}{E_{\lambda \ell J} - E}, \tag{B.7}$$

where $\gamma^2_{\lambda \ell J}$ is the reduced width of the resonance, and $E_{\lambda \ell J}$ is the associated energy eigenvalue.

For $\ell = 1$, the explicit forms of F_ℓ and G_ℓ are

$$F_1 = \frac{\sin \rho - \rho \cos \rho}{\rho} \tag{B.8}$$

and

$$G_1 = \frac{\cos \rho + \rho \sin \rho}{\rho}. \tag{B.9}$$

Using Eqs. B.5-B.9 in conjunction with Eq. B.1 and the boundary condition $B_{\ell J} = 0$ results in

$$\delta_{1J} + \phi_1 = \tan^{-1}\left(\frac{\alpha\rho^3}{1 + \beta\rho^2 + (\alpha + \beta - 1)\rho^4}\right) \approx \frac{\alpha\rho^3}{1 + \beta\rho^2 + (\alpha + \beta - 1)\rho^4}, \tag{B.10}$$

where

$$\alpha = \frac{\gamma^2_{\lambda 1 J}}{E_{\lambda 1 J} + \gamma^2_{\lambda 1 J}} \tag{B.11}$$

and

$$\beta = \frac{E_{\lambda 1 J} - \frac{A}{A+1}\frac{1}{C^2}}{E_{\lambda 1 J} + \gamma^2_{\lambda 1 J}} \tag{B.12}$$

The parameters α and β were determined by fitting the low-energy p-wave phase shifts of Table I of Ref. 1 using Eq. B.10 and a = 3.0 x 10^{-13} cm. The phase shifts at 0.3 and 0.4 MeV were fit for J = 3/2; those at 0.4 and 0.6 MeV were fit for J = 1/2. This procedure gives two linear equations in α and β for both J = 3/2 and J = 1/2. Table II presents the solutions of the equations.

TABLE II. Low-energy Parameters for p-wave Phase Shifts

J	α	β
3/2	2.528	-2.534
1/2	0.857	-0.204

APPENDIX C

Equations for Calculation of $\bar{\mu}_L$, ξ, and γ

Equation 1 gives the angular distribution in the center-of-mass system for elastic scattering. The equations for $\bar{\mu}_L$, ξ, and γ, in terms of the f_ℓ expansion coefficients, derived in Refs. 3-5 and used in FORTRAN program MUXIGA, are given below.

The average cosine of the angle of elastic scattering in the laboratory system is

$$\bar{\mu}_L = \sum_{\ell=0}^{\infty} T_{1\ell} f_\ell, \tag{C.1}$$

where

$$T_{1\ell} = \frac{\ell}{2\ell - 1}\left(\frac{-1}{A}\right)^{\ell-1} - \frac{\ell + 2}{2\ell + 3}\left(\frac{-1}{A}\right)^{\ell+1}, \tag{C.2}$$

A being the ratio of the mass of the scatterer to the neutron mass.

The average logarithmic energy decrement in elastic scattering is

$$\xi = \sum_{\ell=0}^{\infty} \sum_{p=\ell+\delta_{\ell 0}}^{\infty} (1-\alpha)^p A_{p\ell} f_\ell, \tag{C.3}$$

where

$$A_{p\ell} = \frac{(-1)^\ell (2\ell + 1)\ p!p!}{p(p-\ell)!\ (p+\ell+1)!} \tag{C.4}$$

and

$$\alpha = \left(\frac{A - 1}{A + 1}\right)^2.$$

The Greuling-Goertzel parameter, γ, is given by

$$2\xi\gamma = \sum_{\ell=0}^{\infty} \sum_{p=\ell+\delta_{\ell 1}+2\delta_{\ell 0}}^{\infty} (1-\alpha)^p A_{p\ell} C_p f_\ell, \tag{C.5}$$

where

$$C_p = 2 \sum_{q=1}^{p-1} \frac{1}{q}. \qquad (C.6)$$

The $\delta_{\ell 0}$ and $\delta_{\ell 1}$ in Eqs. C.3 and C.5 are Kronecker δ symbols; that is, $\delta_{\ell \ell'} = 0$ for $\ell \neq \ell'$ and $\delta_{\ell \ell'} = 1$ for $\ell = \ell'$.

APPENDIX D

ENDF/B Listing of Helium

```
   2000.0    3.96822          0          0          0          01088 1451
      0.0        0.0          0          0         74          01088 1451
HELIUM CROSS SECTIONS  MATERIAL 1088                              1088 1451
COMPILED BY ED PENNINGTON, ARGONNE NATIONAL LAB., IN JUNE 1968.   1088 1451
NATURAL HELIUM CONSISTS OF 0.00013 PER CENT HE-3 AND 99.99987 PER1088 1451
CENT HE-4.                                                        1088 1451
BECAUSE OF THE LOW ABUNDANCE OF HE-3, ONLY ITS (N,P) CROSS        1088 1451
SECTION, WHICH IS VERY LARGE AT LOW ENERGIES, NEED BE CONSIDERED.1088 1451
ELASTIC SCATTERING IS THE ONLY POSSIBLE REACTION FOR NEUTRONS     1088 1451
INCIDENT ON HE-4 AT ENERGIES BELOW 15 MEV. THUS THE ELASTIC       1088 1451
SCATTERING CROSS SECTION AND VALUES OF MU BAR(LAB), XI, AND GAMMA1088 1451
ARE GIVEN IN FILE 3, AND ELASTIC SCATTERING LEGENDRE COEFFICIENTS1088 1451
ARE GIVEN IN FILE 4. PARAMETERS FOR A FREE GAS THERMAL SCATTERING1088 1451
LAW ARE IN FILE 7.                                                1088 1451
THE ELASTIC SCATTERING CROSS SECTION AND THE LEGENDRE EXPANSION   1088 1451
COEFFICIENTS WERE CALCULATED FROM S-,P-, AND D-WAVE PHASE SHIFTS  1088 1451
USING A FORTRAN PROGRAM WRITTEN FOR THE PURPOSE. THE PHASE SHIFTS1088 1451
WERE READ FROM SMOOTH CURVES BASED ON TABLE I OF REF.1. AT        1088 1451
ENERGIES BELOW THE 300 KEV, LOWER LIMIT OF TABLE I, EACH OF THE   1088 1451
TWO P-WAVE PHASE SHIFTS WAS OBTAINED BY ASSUMING A FUNCTIONAL     1088 1451
FORM BASED ON THE LOW ENERGY LIMIT FOR A SINGLE P-WAVE RESONANCE,1088 1451
WITH PARAMETERS DETERMINED FROM FITTING THE LOW ENERGY PHASE      1088 1451
SHIFTS OF TABLE I. THE S-WAVE PHASE SHIFT BELOW 300 KEV, WAS      1088 1451
CALCULATED USING HARD SPHERE SCATTERING AND A NUCLEAR RADIUS, A=  1088 1451
2.4 FERMI. THIS YIELDS THE THERMAL SCATTERING CROSS SECTION =     1088 1451
4.*PI*A**2= 0.7238 BARNS IN AGREEMENT WITH THE EXPERIMENTAL VALUE1088 1451
OF 0.73+- 0.05 BARNS (REF.2). THE LOW ENERGY S-WAVE PHASE SHIFTS  1088 1451
OF REF.1 ARE CONSISTENT WITH A NUCLEAR RADIUS OF ABOUT 2.48       1088 1451
FERMI, AND SO WOULD YIELD A SOMEWHAT HIGH THERMAL CROSS SECTION.  1088 1451
VALUES OF MU BAR(LAB), XI, AND GAMMA WERE CALCULATED FROM THE     1088 1451
LEGENDRE COEFFICIENTS USING A FORTRAN PROGRAM, MUXIGA. THIS       1088 1451
PROGRAM USES THE EQUATIONS OF REF.3-5.                            1088 1451
AN ELASTIC SCATTERING TRANSFORMATION MATRIX FROM THE CENTER-OF-   1088 1451
MASS TO THE LABORATORY SYSTEM WAS COMPUTED USING CHAD (REF.6).    1088 1451
THE (N,P) CROSS SECTION FOR HE-3 IS THAT RECOMMENDED IN THE       1088 1451
EVALUATION OF HE-3 BY J. ALS-NIELSEN GIVEN IN REF.7. EXTENSION    1088 1451
FROM 10 TO 15 MEV. WAS MADE USING LINEAR EXTRAPOLATION ON A       1088 1451
LOG SIGMA- LOG E SCALE.                                           1088 1451
THE TOTAL CROSS SECTION IS THE SUM OF THE ELASTIC SCATTERING AND  1088 1451
(N,P) CROSS SECTIONS.                                             1088 1451
COMMENTS-                                                         1088 1451
THE PHASE SHIFTS OF REF.1 ARE OPTICAL MODEL PHASE SHIFTS CHOSEN   1088 1451
TO FIT BOTH ANGULAR DISTRIBUTION AND POLARIZATION DATA AT MANY    1088 1451
ENERGIES. THE TOTAL SCATTERING CROSS SECTION IS ALSO FIT WITHIN   1088 1451
THE SCATTER OF THE EXPERIMENTAL POINTS. ANOTHER RECENT SET OF     1088 1451
PHASE SHIFTS (REF.8) IS NOT VERY DIFFERENT FROM THOSE USED HERE,  1088 1451
AND COULD ALSO HAVE BEEN USED IN THE PRESENT WORK. THERE SHOULD   1088 1451
BE NO SERIOUS DISAGREEMENTS WITH EXPERIMENTAL VALUES IN THE HE-4  1088 1451
DATA CALCULATED FROM THE PHASE SHIFTS.                            1088 1451
AS DISCUSSED IN REF.7, THE HE-3 (N,P) CROSS SECTION IS RATHER     1088 1451
WELL KNOWN. PROBABLY MORE ERROR IS INTRODUCED INTO THE (N,P)      1088 1451
CROSS SECTION FOR NATURAL HELIUM BY THE UNCERTAINTY IN THE HE-3   1088 1451
ISOTOPIC ABUNDANCE THAN BY THE UNCERTAINTY IN THE HE-3 (N,P)      1088 1451
CROSS SECTION ITSELF.                                             1088 1451
PREVIOUS EVALUATIONS OF HELIUM FOR REACTOR CALCULATIONS INCLUDE   1088 1451
THOSE OF J.J.SCHMIDT (REF.9) AND B.R.S.BUCKINGHAM ET AL (REF.10).1088 1451
SCHMIDT-S EVALUATION INCLUDES THE (N,P) CROSS SECTION FOR HE-3,   1088 1451
AND SIGMA ELASTIC, MU BAR(LAB), AND A SET OF PHASE SHIFTS FOR     1088 1451
HE-4. BUCKINGHAM ET AL GIVE SEPARATE EVALUATIONS FOR HE-3 AND     1088 1451
HE-4. FOR HE-3 ELASTIC, (N,P), (N,D), AND (N,2N) CROSS SECTIONS   1088 1451
ARE GIVEN, AS WELL AS ELASTIC ANGULAR DISTRIBUTIONS. THE HE-4     1088 1451
EVALUATION GIVES THE ELASTIC CROSS SECTION AND ANGULAR            1088 1451
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DISTRIBUTIONS.                                                       1088 1451    63
THE PRESENT COMPILATION WILL BE DESCRIBED IN DETAIL IN REF.11.       1088 1451    64
REFERENCES-                                                          1088 1451    65
1. G.R.SATCHLER ET AL. NUCLEAR PHYSICS A112,1-31,(1968).             1088 1451    66
2. R.GENIN ET AL. JOURNAL DE PHYSIQUE ET LE RADIUM 24,21-26,1963,1088 1451    67
3. H.AMSTER JOURNAL OF APPLIED PHYSICS 27,3,307,(1956).              1088 1451    68
4. H.AMSTER JOURNAL OF APPLIED PHYSICS 27,6,663,(1956).              1088 1451    69
5. H.AMSTER JOURNAL OF APPLIED PHYSICS 29,4,623-627,(1958).          1088 1451    70
6. R.F.BERLAND NAA-SR-11231,(1965).                                  1088 1451    71
7. E.N.E.A. NEUTRON DATA COMPILATION CENTRE NEWSLETTER NO.6,1967,1088 1451    72
8. B.HOOP,JR. AND H.H.BARSCHALL NUCLEAR PHYSICS 83,65-79,(1966).  1088 1451    73
9. J.J.SCHMIDT KFK-120,PARTS II,III,(1962),PART I,(1966).           1088 1451    74
10.B.R.S.BUCKINGHAM ET AL AWRE O-28/60,(1961).                       1088 1451    75
11.E.M.PENNINGTON ANL-7462,(TO BE ISSUED).                           1088 1451    76
       0.0         0.0          0          0          0         01088 1  0    77
       0.0         0.0          0          0          0         01088 0  0    78
    2000.0    3.96822           0          0          0         01088 3  1    79
       0.0         0.0          0          0          1       1421088 3  1    80
       142           3                                          1088 3  1    81
  1.00E-05 1.0721E+00  2.00E-05 0.9701E+00  3.00E-05 0.9249E+001088 3  1    82
  5.00E-05 0.8796E+00  7.00E-05 0.8555E+00  1.00E-04 0.8339E+001088 3  1    83
  2.00E-04 0.8017E+00  3.00E-04 0.7874E+00  5.00E-04 0.7731E+001088 3  1    84
  7.00E-04 0.7654E+00  1.00E-03 0.7586E+00  2.00E-03 0.7484E+001088 3  1    85
  3.00E-03 0.7439E+00  5.00E-03 0.7394E+00  7.00E-03 0.7370E+001088 3  1    86
  1.00E-02 0.7348E+00  2.00E-02 0.7316E+00  2.53E-02 0.7307E+001088 3  1    87
  3.00E-02 0.7302E+00  5.00E-02 0.7287E+00  7.00E-02 0.7280E+001088 3  1    88
  1.00E-01 0.7273E+00  2.00E-01 0.7263E+00  3.00E-01 0.7258E+001088 3  1    89
  5.00E-01 0.7254E+00  7.00E-01 0.7251E+00  1.00E+00 0.7249E+001088 3  1    90
  2.00E+00 0.7246E+00  3.00E+00 0.7244E+00  5.00E+00 0.7243E+001088 3  1    91
  7.00E+00 0.7242E+00  1.00E+01 0.7241E+00  2.00E+01 0.7240E+001088 3  1    92
  3.00E+01 0.7240E+00  5.00E+01 0.7240E+00  7.00E+01 0.7239E+001088 3  1    93
  1.00E+02 0.7239E+00  2.00E+02 0.7239E+00  3.00E+02 0.7239E+001088 3  1    94
  5.00E+02 0.7238E+00  7.00E+02 0.7238E+00  1.00E+03 0.7238E+001088 3  1    95
  2.00E+03 0.7237E+00  3.00E+03 0.7237E+00  5.00E+03 0.7236E+001088 3  1    96
  7.00E+03 0.7236E+00  1.00E+04 0.7235E+00  2.00E+04 0.7235E+001088 3  1    97
  3.00E+04 0.7234E+00  5.00E+04 0.7241E+00  7.00E+04 0.7256E+001088 3  1    98
  1.00E+05 0.7297E+00  1.50E+05 0.7425E+00  2.00E+05 0.7644E+001088 3  1    99
  2.50E+05 0.7977E+00  3.00E+05 0.8978E+00  3.50E+05 0.9654E+001088 3  1   100
  4.00E+05 0.1056E+01  4.50E+05 0.1197E+01  5.00E+05 0.1373E+011088 3  1   101
  5.50E+05 0.1581E+01  6.00E+05 0.1826E+01  6.50E+05 0.2168E+011088 3  1   102
  7.00E+05 0.2576E+01  7.50E+05 0.3076E+01  8.00E+05 0.3750E+011088 3  1   103
  8.50E+05 0.4380E+01  9.00E+05 0.5114E+01  9.50E+05 0.5844E+011088 3  1   104
  1.00E+06 0.6525E+01  1.05E+06 0.7038E+01  1.10E+06 0.7321E+011088 3  1   105
  1.13E+06 0.7424E+01  1.15E+06 0.7456E+01  1.17E+06 0.7461E+011088 3  1   106
  1.20E+06 0.7432E+01  1.25E+06 0.7278E+01  1.30E+06 0.7040E+011088 3  1   107
  1.35E+06 0.6757E+01  1.40E+06 0.6453E+01  1.45E+06 0.6157E+011088 3  1   108
  1.50E+06 0.5875E+01  1.60E+06 0.5333E+01  1.70E+06 0.4882E+011088 3  1   109
  1.80E+06 0.4509E+01  1.90E+06 0.4211E+01  2.00E+06 0.3944E+011088 3  1   110
  2.10E+06 0.3734E+01  2.20E+06 0.3551E+01  2.30E+06 0.3399E+011088 3  1   111
  2.40E+06 0.3273E+01  2.50E+06 0.3169E+01  2.60E+06 0.3071E+011088 3  1   112
  2.70E+06 0.2988E+01  2.80E+06 0.2911E+01  2.90E+06 0.2849E+011088 3  1   113
  3.00E+06 0.2789E+01  3.20E+06 0.2684E+01  3.40E+06 0.2595E+011088 3  1   114
  3.60E+06 0.2524E+01  3.80E+06 0.2469E+01  4.00E+06 0.2424E+011088 3  1   115
  4.20E+06 0.2373E+01  4.40E+06 0.2325E+01  4.60E+06 0.2278E+011088 3  1   116
  4.80E+06 0.2232E+01  5.00E+06 0.2190E+01  5.20E+06 0.2149E+011088 3  1   117
  5.40E+06 0.2107E+01  5.60E+06 0.2070E+01  5.80E+06 0.2031E+011088 3  1   118
  6.00E+06 0.1994E+01  6.20E+06 0.1957E+01  6.40E+06 0.1921E+011088 3  1   119
  6.60E+06 0.1887E+01  6.80E+06 0.1853E+01  7.00E+06 0.1821E+011088 3  1   120
  7.20E+06 0.1787E+01  7.40E+06 0.1756E+01  7.60E+06 0.1726E+011088 3  1   121
  7.80E+06 0.1696E+01  8.00E+06 0.1667E+01  8.20E+06 0.1640E+011088 3  1   122
  8.40E+06 0.1612E+01  8.60E+06 0.1585E+01  8.80E+06 0.1559E+011088 3  1   123
  9.00E+06 0.1534E+01  9.20E+06 0.1509E+01  9.40E+06 0.1485E+011088 3  1   124
```

9.60E+06	0.1462E+01	9.80E+06	0.1439E+01	1.00E+07	0.1418E+01	1088	3	1	125
1.05E+07	0.1365E+01	1.10E+07	0.1315E+01	1.15E+07	0.1268E+01	1088	3	1	126
1.20E+07	0.1224E+01	1.25E+07	0.1180E+01	1.30E+07	0.1140E+01	1088	3	1	127
1.35E+07	0.1102E+01	1.40E+07	0.1066E+01	1.45E+07	0.1032E+01	1088	3	1	128
1.50E+07	0.9992E+00					1088	3	1	129
0.0	0.0	0	0	0	0	1088	3	0	130
2000.0	3.96822	0	0	0	0	1088	3	2	131
0.0	0.0	0	0	1	142	1088	3	2	132
142	3					1088	3	2	133
1.00E-05	0.7238E+00	2.00E-05	0.7238E+00	3.00E-05	0.7238E+00	1088	3	2	134
5.00E-05	0.7238E+00	7.00E-05	0.7238E+00	1.00E-04	0.7238E+00	1088	3	2	135
2.00E-04	0.7238E+00	3.00E-04	0.7238E+00	5.00E-04	0.7238E+00	1088	3	2	136
7.00E-04	0.7238E+00	1.00E-03	0.7238E+00	2.00E-03	0.7238E+00	1088	3	2	137
3.00E-03	0.7238E+00	5.00E-03	0.7238E+00	7.00E-03	0.7238E+00	1088	3	2	138
1.00E-02	0.7238E+00	2.00E-02	0.7238E+00	2.53E-02	0.7238E+00	1088	3	2	139
3.00E-02	0.7238E+00	5.00E-02	0.7238E+00	7.00E-02	0.7238E+00	1088	3	2	140
1.00E-01	0.7238E+00	2.00E-01	0.7238E+00	3.00E-01	0.7238E+00	1088	3	2	141
5.00E-01	0.7238E+00	7.00E-01	0.7238E+00	1.00E+00	0.7238E+00	1088	3	2	142
2.00E+00	0.7238E+00	3.00E+00	0.7238E+00	5.00E+00	0.7238E+00	1088	3	2	143
7.00E+00	0.7238E+00	1.00E+01	0.7238E+00	2.00E+01	0.7238E+00	1088	3	2	144
3.00E+01	0.7238E+00	5.00E+01	0.7238E+00	7.00E+01	0.7238E+00	1088	3	2	145
1.00E+02	0.7238E+00	2.00E+02	0.7238E+00	3.00E+02	0.7238E+00	1088	3	2	146
5.00E+02	0.7238E+00	7.00E+02	0.7238E+00	1.00E+03	0.7238E+00	1088	3	2	147
2.00E+03	0.7237E+00	3.00E+03	0.7237E+00	5.00E+03	0.7236E+00	1088	3	2	148
7.00E+03	0.7236E+00	1.00E+04	0.7235E+00	2.00E+04	0.7235E+00	1088	3	2	149
3.00E+04	0.7234E+00	5.00E+04	0.7241E+00	7.00E+04	0.7256E+00	1088	3	2	150
1.00E+05	0.7297E+00	1.50E+05	0.7425E+00	2.00E+05	0.7644E+00	1088	3	2	151
2.50E+05	0.7977E+00	3.00E+05	0.8978E+00	3.50E+05	0.9654E+00	1088	3	2	152
4.00E+05	0.1056E+01	4.50E+05	0.1197E+01	5.00E+05	0.1373E+01	1088	3	2	153
5.50E+05	0.1581E+01	6.00E+05	0.1826E+01	6.50E+05	0.2168E+01	1088	3	2	154
7.00E+05	0.2576E+01	7.50E+05	0.3076E+01	8.00E+05	0.3750E+01	1088	3	2	155
8.50E+05	0.4380E+01	9.00E+05	0.5114E+01	9.50E+05	0.5844E+01	1088	3	2	156
1.00E+06	0.6525E+01	1.05E+06	0.7038E+01	1.10E+06	0.7321E+01	1088	3	2	157
1.13E+06	0.7424E+01	1.15E+06	0.7456E+01	1.17E+06	0.7461E+01	1088	3	2	158
1.20E+06	0.7432E+01	1.25E+06	0.7278E+01	1.30E+06	0.7040E+01	1088	3	2	159
1.35E+06	0.6757E+01	1.40E+06	0.6453E+01	1.45E+06	0.6157E+01	1088	3	2	160
1.50E+06	0.5875E+01	1.60E+06	0.5333E+01	1.70E+06	0.4882E+01	1088	3	2	161
1.80E+06	0.4509E+01	1.90E+06	0.4211E+01	2.00E+06	0.3944E+01	1088	3	2	162
2.10E+06	0.3734E+01	2.20E+06	0.3551E+01	2.30E+06	0.3399E+01	1088	3	2	163
2.40E+06	0.3273E+01	2.50E+06	0.3169E+01	2.60E+06	0.3071E+01	1088	3	2	164
2.70E+06	0.2988E+01	2.80E+06	0.2911E+01	2.90E+06	0.2849E+01	1088	3	2	165
3.00E+06	0.2789E+01	3.20E+06	0.2684E+01	3.40E+06	0.2595E+01	1088	3	2	166
3.60E+06	0.2524E+01	3.80E+06	0.2469E+01	4.00E+06	0.2424E+01	1088	3	2	167
4.20E+06	0.2373E+01	4.40E+06	0.2325E+01	4.60E+06	0.2278E+01	1088	3	2	168
4.80E+06	0.2232E+01	5.00E+06	0.2190E+01	5.20E+06	0.2149E+01	1088	3	2	169
5.40E+06	0.2107E+01	5.60E+06	0.2070E+01	5.80E+06	0.2031E+01	1088	3	2	170
6.00E+06	0.1994E+01	6.20E+06	0.1957E+01	6.40E+06	0.1921E+01	1088	3	2	171
6.60E+06	0.1887E+01	6.80E+06	0.1853E+01	7.00E+06	0.1821E+01	1088	3	2	172
7.20E+06	0.1787E+01	7.40E+06	0.1756E+01	7.60E+06	0.1726E+01	1088	3	2	173
7.80E+06	0.1696E+01	8.00E+06	0.1667E+01	8.20E+06	0.1640E+01	1088	3	2	174
8.40E+06	0.1612E+01	8.60E+06	0.1585E+01	8.80E+06	0.1559E+01	1088	3	2	175
9.00E+06	0.1534E+01	9.20E+06	0.1509E+01	9.40E+06	0.1485E+01	1088	3	2	176
9.60E+06	0.1462E+01	9.80E+06	0.1439E+01	1.00E+07	0.1418E+01	1088	3	2	177
1.05E+07	0.1365E+01	1.10E+07	0.1315E+01	1.15E+07	0.1268E+01	1088	3	2	178
1.20E+07	0.1224E+01	1.25E+07	0.1180E+01	1.30E+07	0.1140E+01	1088	3	2	179
1.35E+07	0.1102E+01	1.40E+07	0.1066E+01	1.45E+07	0.1032E+01	1088	3	2	180
1.50E+07	0.9992E+00					1088	3	2	181
0.0	0.0	0	0	0	0	1088	3	0	182
2000.0	3.96822	0	0	0	0	1088	3	103	183
0.0	0.7644E+06	0	0	1	142	1088	3	103	184
142	5					1088	3	103	185
1.00E-05	0.3483E+00	2.00E-05	0.2463E+00	3.00E-05	0.2011E+00	1088	3	103	186

5.00E-05	0.1558E+00	7.00E-05	0.1317E+00	1.00E-04	0.1101E+001088	3103	187
2.00E-04	0.7789E-01	3.00E-04	0.6359E-01	5.00E-04	0.4926E-011088	3103	188
7.00E-04	0.4163E-01	1.00E-03	0.3483E-01	2.00E-03	0.2463E-011088	3103	189
3.00E-03	0.2011E-01	5.00E-03	0.1558E-01	7.00E-03	0.1316E-011088	3103	190
1.00E-02	0.1101E-01	2.00E-02	0.7787E-02	2.53E-02	0.6924E-021088	3103	191
3.00E-02	0.6358E-02	5.00E-02	0.4924E-02	7.00E-02	0.4161E-021088	3103	192
1.00E-01	0.3481E-02	2.00E-01	0.2461E-02	3.00E-01	0.2010E-021088	3103	193
5.00E-01	0.1556E-02	7.00E-01	0.1316E-02	1.00E+00	0.1100E-021088	3103	194
2.00E+00	0.7773E-03	3.00E+00	0.6344E-03	5.00E+00	0.4910E-031088	3103	195
7.00E+00	0.4147E-03	1.00E+01	0.3467E-03	2.00E+01	0.2448E-031088	3103	196
3.00E+01	0.1996E-03	5.00E+01	0.1542E-03	7.00E+01	0.1301E-031088	3103	197
1.00E+02	0.1086E-03	2.00E+02	0.7631E-04	3.00E+02	0.6201E-041088	3103	198
5.00E+02	0.4771E-04	7.00E+02	0.4004E-04	1.00E+03	0.3328E-041088	3103	199
2.00E+03	0.2314E-04	3.00E+03	0.1859E-04	5.00E+03	0.1417E-041088	3103	200
7.00E+03	0.1183E-04	1.00E+04	0.9880E-05	2.00E+04	0.6825E-051088	3103	201
3.00E+04	0.5330E-05	5.00E+04	0.3900E-05	7.00E+04	0.3185E-051088	3103	202
1.00E+05	0.2574E-05	1.50E+05	0.2067E-05	2.00E+05	0.1755E-051088	3103	203
2.50E+05	0.1560E-05	3.00E+05	0.1430E-05	3.50E+05	0.1313E-051088	3103	204
4.00E+05	0.1248E-05	4.50E+05	0.1196E-05	5.00E+05	0.1183E-051088	3103	205
5.50E+05	0.1170E-05	6.00E+05	0.1157E-05	6.50E+05	0.1157E-051088	3103	206
7.00E+05	0.1157E-05	7.50E+05	0.1157E-05	8.00E+05	0.1157E-051088	3103	207
8.50E+05	0.1157E-05	9.00E+05	0.1157E-05	9.50E+05	0.1157E-051088	3103	208
1.00E+06	0.1157E-05	1.05E+06	0.1157E-05	1.10E+06	0.1157E-051088	3103	209
1.13E+06	0.1157E-05	1.15E+06	0.1157E-05	1.17E+06	0.1157E-051088	3103	210
1.20E+06	0.1157E-05	1.25E+06	0.1157E-05	1.30E+06	0.1157E-051088	3103	211
1.35E+06	0.1157E-05	1.40E+06	0.1157E-05	1.45E+06	0.1157E-051088	3103	212
1.50E+06	0.1157E-05	1.60E+06	0.1151E-05	1.70E+06	0.1144E-051088	3103	213
1.80E+06	0.1138E-05	1.90E+06	0.1118E-05	2.00E+06	0.1092E-051088	3103	214
2.10E+06	0.1066E-05	2.20E+06	0.1040E-05	2.30E+06	0.1014E-051088	3103	215
2.40E+06	0.9880E-06	2.50E+06	0.9620E-06	2.60E+06	0.9360E-061088	3103	216
2.70E+06	0.9100E-06	2.80E+06	0.8840E-06	2.90E+06	0.8580E-061088	3103	217
3.00E+06	0.8320E-06	3.20E+06	0.7800E-06	3.40E+06	0.7280E-061088	3103	218
3.60E+06	0.6825E-06	3.80E+06	0.6435E-06	4.00E+06	0.6110E-061088	3103	219
4.20E+06	0.5785E-06	4.40E+06	0.5460E-06	4.60E+06	0.5265E-061088	3103	220
4.80E+06	0.5005E-06	5.00E+06	0.4810E-06	5.20E+06	0.4615E-061088	3103	221
5.40E+06	0.4420E-06	5.60E+06	0.4225E-06	5.80E+06	0.4095E-061088	3103	222
6.00E+06	0.3965E-06	6.20E+06	0.3770E-06	6.40E+06	0.3640E-061088	3103	223
6.60E+06	0.3510E-06	6.80E+06	0.3406E-06	7.00E+06	0.3315E-061088	3103	224
7.20E+06	0.3211E-06	7.40E+06	0.3133E-06	7.60E+06	0.3055E-061088	3103	225
7.80E+06	0.2977E-06	8.00E+06	0.2912E-06	8.20E+06	0.2847E-061088	3103	226
8.40E+06	0.2769E-06	8.60E+06	0.2717E-06	8.80E+06	0.2665E-061088	3103	227
9.00E+06	0.2600E-06	9.20E+06	0.2548E-06	9.40E+06	0.2483E-061088	3103	228
9.60E+06	0.2431E-06	9.80E+06	0.2379E-06	1.00E+07	0.2340E-061088	3103	229
1.05E+07	0.2236E-06	1.10E+07	0.2145E-06	1.15E+07	0.2054E-061088	3103	230
1.20E+07	0.1976E-06	1.25E+07	0.1898E-06	1.30E+07	0.1833E-061088	3103	231
1.35E+07	0.1768E-06	1.40E+07	0.1703E-06	1.45E+07	0.1651E-061088	3103	232
1.50E+07	0.1599E-06				1088	3103	233
0.0	0.0	0	0	0	01088	3 0	234
2000.0	3.96822	0	0	0	01088	3251	235
0.0	0.0	0	0	1	1081088	3251	236
108	3				1088	3251	237
1.00E-05	0.1680E+00	2.53E-02	0.1680E+00	1.00E+02	0.1679E+001088	3251	238
2.00E+02	0.1678E+00	3.00E+02	0.1677E+00	5.00E+02	0.1675E+001088	3251	239
7.00E+02	0.1672E+00	1.00E+03	0.1669E+00	2.00E+03	0.1658E+001088	3251	240
3.00E+03	0.1647E+00	5.00E+03	0.1625E+00	7.00E+03	0.1603E+001088	3251	241
1.00E+04	0.1570E+00	2.00E+04	0.1458E+00	3.00E+04	0.1344E+001088	3251	242
5.00E+04	0.1116E+00	7.00E+04	0.8798E-01	1.00E+05	0.5208E-011088	3251	243
1.50E+05	-0.9740E-02	2.00E+05	-0.7161E-01	2.50E+05	-0.1304E+001088	3251	244
3.00E+05	-0.1739E+00	3.50E+05	-0.2185E+00	4.00E+05	-0.2518E+001088	3251	245
4.50E+05	-0.2702E+00	5.00E+05	-0.2746E+00	5.50E+05	-0.2658E+001088	3251	246
6.00E+05	-0.2457E+00	6.50E+05	-0.2143E+00	7.00E+05	-0.1776E+001088	3251	247
7.50E+05	-0.1357E+00	8.00E+05	-0.8704E-01	8.50E+05	-0.4441E-011088	3251	248

9.00E+05	0.5200E-04	9.50E+05	0.4267E-01	1.00E+06	0.8390E-011088	3251	249
1.05E+06	0.1213E+00	1.10E+06	0.1529E+00	1.13E+06	0.1720E+001088	3251	250
1.15E+06	0.1836E+00	1.17E+06	0.1948E+00	1.20E+06	0.2115E+001088	3251	251
1.25E+06	0.2370E+00	1.30E+06	0.2585E+00	1.35E+06	0.2784E+001088	3251	252
1.40E+06	0.2967E+00	1.45E+06	0.3122E+00	1.50E+06	0.3258E+001088	3251	253
1.60E+06	0.3520E+00	1.70E+06	0.3718E+00	1.80E+06	0.3878E+001088	3251	254
1.90E+06	0.4002E+00	2.00E+06	0.4104E+00	2.10E+06	0.4185E+001088	3251	255
2.20E+06	0.4255E+00	2.30E+06	0.4315E+00	2.40E+06	0.4363E+001088	3251	256
2.50E+06	0.4402E+00	2.60E+06	0.4434E+00	2.70E+06	0.4460E+001088	3251	257
2.80E+06	0.4489E+00	2.90E+06	0.4512E+00	3.00E+06	0.4530E+001088	3251	258
3.20E+06	0.4585E+00	3.40E+06	0.4634E+00	3.60E+06	0.4675E+001088	3251	259
3.80E+06	0.4710E+00	4.00E+06	0.4749E+00	4.20E+06	0.4795E+001088	3251	260
4.40E+06	0.4845E+00	4.60E+06	0.4892E+00	4.80E+06	0.4940E+001088	3251	261
5.00E+06	0.4987E+00	5.20E+06	0.5035E+00	5.40E+06	0.5077E+001088	3251	262
5.60E+06	0.5117E+00	5.80E+06	0.5153E+00	6.00E+06	0.5195E+001088	3251	263
6.20E+06	0.5231E+00	6.40E+06	0.5264E+00	6.60E+06	0.5301E+001088	3251	264
6.80E+06	0.5333E+00	7.00E+06	0.5365E+00	7.20E+06	0.5390E+001088	3251	265
7.40E+06	0.5418E+00	7.60E+06	0.5443E+00	7.80E+06	0.5470E+001088	3251	266
8.00E+06	0.5492E+00	8.20E+06	0.5513E+00	8.40E+06	0.5530E+001088	3251	267
8.60E+06	0.5549E+00	8.80E+06	0.5565E+00	9.00E+06	0.5584E+001088	3251	268
9.20E+06	0.5603E+00	9.40E+06	0.5618E+00	9.60E+06	0.5635E+001088	3251	269
9.80E+06	0.5649E+00	1.00E+07	0.5666E+00	1.05E+07	0.5696E+001088	3251	270
1.10E+07	0.5728E+00	1.15E+07	0.5756E+00	1.20E+07	0.5783E+001088	3251	271
1.25E+07	0.5804E+00	1.30E+07	0.5828E+00	1.35E+07	0.5850E+001088	3251	272
1.40E+07	0.5872E+00	1.45E+07	0.5894E+00	1.50E+07	0.5917E+001088	3251	273
0.0	0.0	0	0	0	01088	3 0	274
2000.0	3.96822	0	0	0	01088	3252	275
0.0	0.0	0	0	1	1081088	3252	276
108	3				1088	3252	277
1.00E-05	0.4282E+00	2.53E-02	0.4282E+00	1.00E+02	0.4282E+001088	3252	278
2.00E+02	0.4283E+00	3.00E+02	0.4284E+00	5.00E+02	0.4285E+001088	3252	279
7.00E+02	0.4286E+00	1.00E+03	0.4287E+00	2.00E+03	0.4293E+001088	3252	280
3.00E+03	0.4299E+00	5.00E+03	0.4310E+00	7.00E+03	0.4322E+001088	3252	281
1.00E+04	0.4339E+00	2.00E+04	0.4397E+00	3.00E+04	0.4455E+001088	3252	282
5.00E+04	0.4574E+00	7.00E+04	0.4696E+00	1.00E+05	0.4881E+001088	3252	283
1.50E+05	0.5201E+00	2.00E+05	0.5521E+00	2.50E+05	0.5826E+001088	3252	284
3.00E+05	0.6051E+00	3.50E+05	0.6281E+00	4.00E+05	0.6454E+001088	3252	285
4.50E+05	0.6550E+00	5.00E+05	0.6572E+00	5.50E+05	0.6527E+001088	3252	286
6.00E+05	0.6423E+00	6.50E+05	0.6261E+00	7.00E+05	0.6071E+001088	3252	287
7.50E+05	0.5855E+00	8.00E+05	0.5603E+00	8.50E+05	0.5382E+001088	3252	288
9.00E+05	0.5152E+00	9.50E+05	0.4932E+00	1.00E+06	0.4719E+001088	3252	289
1.05E+06	0.4525E+00	1.10E+06	0.4362E+00	1.13E+06	0.4263E+001088	3252	290
1.15E+06	0.4203E+00	1.17E+06	0.4145E+00	1.20E+06	0.4059E+001088	3252	291
1.25E+06	0.3927E+00	1.30E+06	0.3816E+00	1.35E+06	0.3712E+001088	3252	292
1.40E+06	0.3618E+00	1.45E+06	0.3538E+00	1.50E+06	0.3467E+001088	3252	293
1.60E+06	0.3331E+00	1.70E+06	0.3229E+00	1.80E+06	0.3146E+001088	3252	294
1.90E+06	0.3082E+00	2.00E+06	0.3029E+00	2.10E+06	0.2988E+001088	3252	295
2.20E+06	0.2951E+00	2.30E+06	0.2920E+00	2.40E+06	0.2895E+001088	3252	296
2.50E+06	0.2875E+00	2.60E+06	0.2858E+00	2.70E+06	0.2845E+001088	3252	297
2.80E+06	0.2830E+00	2.90E+06	0.2818E+00	3.00E+06	0.2809E+001088	3252	298
3.20E+06	0.2781E+00	3.40E+06	0.2755E+00	3.60E+06	0.2734E+001088	3252	299
3.80E+06	0.2716E+00	4.00E+06	0.2696E+00	4.20E+06	0.2672E+001088	3252	300
4.40E+06	0.2646E+00	4.60E+06	0.2622E+00	4.80E+06	0.2597E+001088	3252	301
5.00E+06	0.2573E+00	5.20E+06	0.2548E+00	5.40E+06	0.2526E+001088	3252	302
5.60E+06	0.2506E+00	5.80E+06	0.2487E+00	6.00E+06	0.2465E+001088	3252	303
6.20E+06	0.2447E+00	6.40E+06	0.2430E+00	6.60E+06	0.2411E+001088	3252	304
6.80E+06	0.2394E+00	7.00E+06	0.2378E+00	7.20E+06	0.2365E+001088	3252	305
7.40E+06	0.2350E+00	7.60E+06	0.2337E+00	7.80E+06	0.2323E+001088	3252	306
8.00E+06	0.2312E+00	8.20E+06	0.2301E+00	8.40E+06	0.2293E+001088	3252	307
8.60E+06	0.2283E+00	8.80E+06	0.2274E+00	9.00E+06	0.2265E+001088	3252	308
9.20E+06	0.2255E+00	9.40E+06	0.2247E+00	9.60E+06	0.2238E+001088	3252	309
9.80E+06	0.2231E+00	1.00E+07	0.2222E+00	1.05E+07	0.2207E+001088	3252	310

1,10E+07	0,2190E+00	1.15E+07	0.2176E+00	1,20E+07	0,2162E+00	1088	3	252	311
1,25E+07	0,2151E+00	1.30E+07	0.2139E+00	1,35E+07	0,2127E+00	1088	3	252	312
1,40E+07	0,2116E+00	1.45E+07	0.2104E+00	1,50E+07	0,2093E+00	1088	3	252	313
0,0	0,0	0	0	0	0	1088	3	0	314
2000,0	3,96822	0	0	0	0	1088	3	253	315
0,0	0,0	0	0	1	108	1088	3	253	316
108	3					1088	3	253	317
1,00E-05	0,3121E+00	2.53E-02	0.3121E+00	1,00E+02	0,3121E+00	1088	3	253	318
2,00E+02	0,3122E+00	3.00E+02	0.3122E+00	5,00E+02	0,3122E+00	1088	3	253	319
7,00E+02	0,3122E+00	1.00E+03	0.3123E+00	2,00E+03	0,3125E+00	1088	3	253	320
3,00E+03	0,3127E+00	5.00E+03	0.3131E+00	7,00E+03	0,3135E+00	1088	3	253	321
1,00E+04	0,3141E+00	2.00E+04	0.3161E+00	3,00E+04	0,3180E+00	1088	3	253	322
5,00E+04	0,3219E+00	7.00E+04	0.3257E+00	1,00E+05	0,3312E+00	1088	3	253	323
1,50E+05	0,3402E+00	2.00E+05	0.3485E+00	2,50E+05	0,3561E+00	1088	3	253	324
3,00E+05	0,3617E+00	3.50E+05	0.3675E+00	4,00E+05	0,3724E+00	1088	3	253	325
4,50E+05	0,3762E+00	5.00E+05	0.3790E+00	5,50E+05	0,3808E+00	1088	3	253	326
6,00E+05	0,3818E+00	6.50E+05	0.3817E+00	7,00E+05	0,3809E+00	1088	3	253	327
7,50E+05	0,3791E+00	8.00E+05	0.3765E+00	8,50E+05	0,3736E+00	1088	3	253	328
9,00E+05	0,3702E+00	9.50E+05	0.3662E+00	1,00E+06	0,3618E+00	1088	3	253	329
1,05E+06	0,3572E+00	1.10E+06	0.3530E+00	1,13E+06	0,3501E+00	1088	3	253	330
1,15E+06	0,3482E+00	1.17E+06	0.3464E+00	1,20E+06	0,3435E+00	1088	3	253	331
1,25E+06	0,3388E+00	1.30E+06	0.3344E+00	1,35E+06	0,3300E+00	1088	3	253	332
1,40E+06	0,3256E+00	1.45E+06	0.3216E+00	1,50E+06	0,3179E+00	1088	3	253	333
1,60E+06	0,3100E+00	1.70E+06	0.3034E+00	1,80E+06	0,2975E+00	1088	3	253	334
1,90E+06	0,2925E+00	2.00E+06	0.2879E+00	2,10E+06	0,2842E+00	1088	3	253	335
2,20E+06	0,2808E+00	2.30E+06	0.2779E+00	2,40E+06	0,2756E+00	1088	3	253	336
2,50E+06	0,2738E+00	2.60E+06	0.2722E+00	2,70E+06	0,2711E+00	1088	3	253	337
2,80E+06	0,2699E+00	2.90E+06	0.2691E+00	3,00E+06	0,2687E+00	1088	3	253	338
3,20E+06	0,2671E+00	3.40E+06	0.2661E+00	3,60E+06	0,2658E+00	1088	3	253	339
3,80E+06	0,2664E+00	4.00E+06	0.2671E+00	4,20E+06	0,2672E+00	1088	3	253	340
4,40E+06	0,2671E+00	4.60E+06	0.2671E+00	4,80E+06	0,2670E+00	1088	3	253	341
5,00E+06	0,2669E+00	5.20E+06	0.2666E+00	5,40E+06	0,2665E+00	1088	3	253	342
5,60E+06	0,2664E+00	5.80E+06	0.2664E+00	6,00E+06	0,2661E+00	1088	3	253	343
6,20E+06	0,2659E+00	6.40E+06	0.2656E+00	6,60E+06	0,2652E+00	1088	3	253	344
6,80E+06	0,2648E+00	7.00E+06	0.2644E+00	7,20E+06	0,2641E+00	1088	3	253	345
7,40E+06	0,2636E+00	7.60E+06	0.2634E+00	7,80E+06	0,2628E+00	1088	3	253	346
8,00E+06	0,2624E+00	8.20E+06	0.2622E+00	8,40E+06	0,2620E+00	1088	3	253	347
8,60E+06	0,2616E+00	8.80E+06	0.2614E+00	9,00E+06	0,2610E+00	1088	3	253	348
9,20E+06	0,2604E+00	9.40E+06	0.2601E+00	9,60E+06	0,2597E+00	1088	3	253	349
9,80E+06	0,2594E+00	1.00E+07	0.2590E+00	1,05E+07	0,2583E+00	1088	3	253	350
1,10E+07	0,2576E+00	1.15E+07	0.2568E+00	1,20E+07	0,2559E+00	1088	3	253	351
1,25E+07	0,2552E+00	1.30E+07	0.2543E+00	1,35E+07	0,2536E+00	1088	3	253	352
1,40E+07	0,2529E+00	1.45E+07	0.2522E+00	1,50E+07	0,2515E+00	1088	3	253	353
0.0	0.0	0	0	0	0	1088	3	0	354
0.0	0.0	0	0	0	0	1088	0	0	355
2000.0	3,96822	1	1	0	0	1088	4	2	356
0.0	3,96822	0	2	100	9	1088	4	2	357
1.0000E+00	1.6800E-01	1.2819E-02	0.0	-6,6316E-05	0.0	1088	4	2	358
6,3701E-07	0,0	-7.4839E-09	0.0	0.0	9,6190E-01	1088	4	2	359
2,9686E-01	4,3546E-02	3.1027E-03	0.0	-1,4971E-05	0.0	1088	4	2	360
1.3935E-07	0.0	U.0	-1.5886E-01	9,0195E-01	4,1067E-01	1088	4	2	361
8,8718E-02	1,1085E-02	7.1925E-04	0.0	-3,1239E-06	0.0	1088	4	2	362
0.0	3,5863E-02	-2.7304E-01	8.1319E-01	5,0658E-01	1,4568E-01	1088	4	2	363
2.5474E-02	2,8077E-03	1.6752E-04	0.0	0,0	-8,5905E-03	1088	4	2	364
7,8689E-02	-3,6481E-01	7.0133E-01	5.8110E-01	2,1109E-01	4,7327E-02	1088	4	2	365
7.1261E-03	7,0975E-04	0,0	2.1026E-03	-2,2043E-02	1,2928E-01	1088	4	2	366
-4.3373E-01	5,7179E-01	6.3117E-01	2.8107E-01	7,7131E-02	1,4600E-02	1088	4	2	367
0.0	-5,1992E-04	6.0621E-03	-4.1723E-02	1,8451E-01	-4,7795E-01	1088	4	2	368
4,3070E-01	6,5479E-01	3.5139E-01	1.1474E-01	0.0	1,2929E-04	1088	4	2	369
-1.6456E-03	1,2786E-02	-6.7791E-02	2.4055E-01	-4,9642E-01	2,8461E-01	1088	4	2	370
6.5122E-01	4,1767E-01	0,0	-3.2264E-05	4,4243E-04	-3,7901E-03	1088	4	2	371
2.2986E-02	-9,9735E-02	2.9341E-01	-4.8921E-01	1,4018E-01	6,2111E-01	1088	4	2	372

0.0	8.0695E-06-1.1807E-04	1.0976E-03-7.4043E-03			3.7198E-021088	4	2	373
-1.3644E-01	3.3928E-01-4.5769E-01	3.8210E-03			1088	4	2	374
0.0	0.0	0	0	1	1081088	4	2	375
108	3				1088	4	2	376
0.0	1.00E-05	0	0	1	01088	4	2	377
0.0					1088	4	2	378
0.0	2.53E-02	0	0	1	01088	4	2	379
0.0					1088	4	2	380
0.0	1.00E+02	0	0	2	01088	4	2	381
-1.130E-04	0.0				1088	4	2	382
0.0	2.00E+02	0	0	2	01088	4	2	383
-2.270E-04	0.0				1088	4	2	384
0.0	3.00E+02	0	0	2	01088	4	2	385
-3.400E-04	0.0				1088	4	2	386
0.0	5.00E+02	0	0	2	01088	4	2	387
-5.670E-04	0.0				1088	4	2	388
0.0	7.00E+02	0	0	2	01088	4	2	389
-7.940E-04	0.0				1088	4	2	390
0.0	1.00E+03	0	0	2	01088	4	2	391
-1.135E-03	0.0				1088	4	2	392
0.0	2.00E+03	0	0	2	01088	4	2	393
-2.272E-03	1.000E-06				1088	4	2	394
0.0	3.00E+03	0	0	2	01088	4	2	395
-3.410E-03	3.000E-06				1088	4	2	396
0.0	5.00E+03	0	0	2	01088	4	2	397
-5.691E-03	9.000E-06				1088	4	2	398
0.0	7.00E+03	0	0	2	01088	4	2	399
-7.979E-03	1.700E-05				1088	4	2	400
0.0	1.00E+04	0	0	2	01088	4	2	401
-1.142E-02	3.500E-05				1088	4	2	402
0.0	2.00E+04	0	0	2	01088	4	2	403
-2.303E-02	1.410E-04				1088	4	2	404
0.0	3.00E+04	0	0	2	01088	4	2	405
-3.483E-02	3.230E-04				1088	4	2	406
0.0	5.00E+04	0	0	2	01088	4	2	407
-5.853E-02	9.160E-04				1088	4	2	408
0.0	7.00E+04	0	0	2	01088	4	2	409
-8.289E-02	1.850E-03				1088	4	2	410
0.0	1.00E+05	0	0	2	01088	4	2	411
-1.199E-01	3.916E-03				1088	4	2	412
0.0	1.50E+05	0	0	2	01088	4	2	413
-1.832E-01	9.426E-03				1088	4	2	414
0.0	2.00E+05	0	0	2	01088	4	2	415
-2.462E-01	1.777E-02				1088	4	2	416
0.0	2.50E+05	0	0	2	01088	4	2	417
-3.054E-01	2.902E-02				1088	4	2	418
0.0	3.00E+05	0	0	2	01088	4	2	419
-3.487E-01	4.071E-02				1088	4	2	420
0.0	3.50E+05	0	0	2	01088	4	2	421
-3.924E-01	5.688E-02				1088	4	2	422
0.0	4.00E+05	0	0	2	01088	4	2	423
-4.240E-01	7.510E-02				1088	4	2	424
0.0	4.50E+05	0	0	2	01088	4	2	425
-4.401E-01	9.412E-02				1088	4	2	426
0.0	5.00E+05	0	0	2	01088	4	2	427
-4.414E-01	1.134E-01				1088	4	2	428
0.0	5.50E+05	0	0	2	01088	4	2	429
-4.291E-01	1.322E-01				1088	4	2	430
0.0	6.00E+05	0	0	2	01088	4	2	431
-4.053E-01	1.499E-01				1088	4	2	432
0.0	6.50E+05	0	0	2	01088	4	2	433
-3.704E-01	1.641E-01				1088	4	2	434

0.0	7.00E+05	0	0	2	01088	4	2	435
-3.301E-01	1.769E-01				1088	4	2	436
0.0	7.50E+05	0	0	2	01088	4	2	437
-2.852E-01	1.852E-01				1088	4	2	438
0.0	8.00E+05	0	0	2	01088	4	2	439
-2.333E-01	1.929E-01				1088	4	2	440
0.0	8.50E+05	0	0	2	01088	4	2	441
-1.884E-01	1.967E-01				1088	4	2	442
0.0	9.00E+05	0	0	2	01088	4	2	443
-1.416E-01	1.997E-01				1088	4	2	444
0.0	9.50E+05	0	0	2	01088	4	2	445
-9.717E-02	2.006E-01				1088	4	2	446
0.0	1.00E+06	0	0	2	01088	4	2	447
-5.435E-02	2.003E-01				1088	4	2	448
0.0	1.05E+06	0	0	2	01088	4	2	449
-1.572E-02	1.988E-01				1088	4	2	450
0.0	1.10E+06	0	0	2	01088	4	2	451
1.681E-02	1.970E-01				1088	4	2	452
0.0	1.13E+06	0	0	2	01088	4	2	453
3.635E-02	1.952E-01				1088	4	2	454
0.0	1.15E+06	0	0	2	01088	4	2	455
4.831E-02	1.941E-01				1088	4	2	456
0.0	1.17E+06	0	0	2	01088	4	2	457
5.970E-02	1.929E-01				1088	4	2	458
0.0	1.20E+06	0	0	2	01088	4	2	459
7.677E-02	1.910E-01				1088	4	2	460
0.0	1.25E+06	0	0	2	01088	4	2	461
1.026E-01	1.873E-01				1088	4	2	462
0.0	1.30E+06	0	0	2	01088	4	2	463
1.244E-01	1.837E-01				1088	4	2	464
0.0	1.35E+06	0	0	2	01088	4	2	465
1.445E-01	1.800E-01				1088	4	2	466
0.0	1.40E+06	0	0	2	01088	4	2	467
1.629E-01	1.760E-01				1088	4	2	468
0.0	1.45E+06	0	0	2	01088	4	2	469
1.783E-01	1.723E-01				1088	4	2	470
0.0	1.50E+06	0	0	2	01088	4	2	471
1.919E-01	1.687E-01				1088	4	2	472
0.0	1.60E+06	0	0	2	01088	4	2	473
2.179E-01	1.608E-01				1088	4	2	474
0.0	1.70E+06	0	0	2	01088	4	2	475
2.372E-01	1.538E-01				1088	4	2	476
0.0	1.80E+06	0	0	2	01088	4	2	477
2.528E-01	1.474E-01				1088	4	2	478
0.0	1.90E+06	0	0	2	01088	4	2	479
2.649E-01	1.419E-01				1088	4	2	480
0.0	2.00E+06	0	0	4	01088	4	2	481
2.745E-01	1.357E-01	-2.430E-04	1.000E-06		1088	4	2	482
0.0	2.10E+06	0	0	4	01088	4	2	483
2.821E-01	1.314E-01	-2.440E-04	1.000E-06		1088	4	2	484
0.0	2.20E+06	0	0	4	01088	4	2	485
2.888E-01	1.272E-01	-2.730E-04	1.000E-06		1088	4	2	486
0.0	2.30E+06	0	0	4	01088	4	2	487
2.944E-01	1.239E-01	-3.210E-04	2.000E-06		1088	4	2	488
0.0	2.40E+06	0	0	4	01088	4	2	489
2.989E-01	1.213E-01	-3.130E-04	2.000E-06		1088	4	2	490
0.0	2.50E+06	0	0	4	01088	4	2	491
3.028E-01	1.195E-01	-3.510E-04	2.000E-06		1088	4	2	492
0.0	2.60E+06	0	0	4	01088	4	2	493
3.058E-01	1.180E-01	-3.870E-04	3.000E-06		1088	4	2	494
0.0	2.70E+06	0	0	4	01088	4	2	495
3.084E-01	1.171E-01	-3.940E-04	3.000E-06		1088	4	2	496

0.0	2.80E+06	0	0	4	01088	4	2	497
3.113E-01	1.165E-01	-4.240E-04	4.000E-06		1088	4	2	498
0.0	2.90E+06	0	0	4	01088	4	2	499
3.137E-01	1.166E-01	-4.440E-04	5.000E-06		1088	4	2	500
0.0	3.00E+06	0	0	4	01088	4	2	501
3.157E-01	1.173E-01	-4.680E-04	5.000E-06		1088	4	2	502
0.0	3.20E+06	0	0	4	01088	4	2	503
3.216E-01	1.186E-01	-4.810E-04	7.000E-06		1088	4	2	504
0.0	3.40E+06	0	0	4	01088	4	2	505
3.271E-01	1.210E-01	-5.350E-04	9.000E-06		1088	4	2	506
0.0	3.60E+06	0	0	4	01088	4	2	507
3.321E-01	1.252E-01	-5.480E-04	1.200E-05		1088	4	2	508
0.0	3.80E+06	0	0	4	01088	4	2	509
3.367E-01	1.312E-01	-5.400E-04	1.400E-05		1088	4	2	510
0.0	4.00E+06	0	0	4	01088	4	2	511
3.418E-01	1.381E-01	-5.780E-04	1.700E-05		1088	4	2	512
0.0	4.20E+06	0	0	4	01088	4	2	513
3.476E-01	1.438E-01	-5.920E-04	2.200E-05		1088	4	2	514
0.0	4.40E+06	0	0	4	01088	4	2	515
3.537E-01	1.495E-01	-6.160E-04	2.600E-05		1088	4	2	516
0.0	4.60E+06	0	0	4	01088	4	2	517
3.596E-01	1.552E-01	-6.410E-04	3.000E-05		1088	4	2	518
0.0	4.80E+06	0	0	4	01088	4	2	519
3.654E-01	1.604E-01	-6.740E-04	3.600E-05		1088	4	2	520
0.0	5.00E+06	0	0	4	01088	4	2	521
3.713E-01	1.658E-01	-6.910E-04	4.100E-05		1088	4	2	522
0.0	5.20E+06	0	0	4	01088	4	2	523
3.770E-01	1.707E-01	-7.030E-04	4.700E-05		1088	4	2	524
0.0	5.40E+06	0	0	4	01088	4	2	525
3.821E-01	1.753E-01	-7.400E-04	5.500E-05		1088	4	2	526
0.0	5.60E+06	0	0	4	01088	4	2	527
3.870E-01	1.800E-01	-7.320E-04	6.300E-05		1088	4	2	528
0.0	5.80E+06	0	0	4	01088	4	2	529
3.916E-01	1.844E-01	-7.660E-04	7.200E-05		1088	4	2	530
0.0	6.00E+06	0	0	4	01088	4	2	531
3.966E-01	1.884E-01	-8.190E-04	8.400E-05		1088	4	2	532
0.0	6.20E+06	0	0	4	01088	4	2	533
4.009E-01	1.922E-01	-8.170E-04	9.200E-05		1088	4	2	534
0.0	6.40E+06	0	0	4	01088	4	2	535
4.049E-01	1.953E-01	-8.200E-04	1.050E-04		1088	4	2	536
0.0	6.60E+06	0	0	4	01088	4	2	537
4.092E-01	1.984E-01	-8.480E-04	1.180E-04		1088	4	2	538
0.0	6.80E+06	0	0	4	01088	4	2	539
4.130E-01	2.011E-01	-8.700E-04	1.330E-04		1088	4	2	540
0.0	7.00E+06	0	0	4	01088	4	2	541
4.168E-01	2.039E-01	-8.630E-04	1.470E-04		1088	4	2	542
0.0	7.20E+06	0	0	4	01088	4	2	543
4.198E-01	2.062E-01	-8.140E-04	1.610E-04		1088	4	2	544
0.0	7.40E+06	0	0	4	01088	4	2	545
4.231E-01	2.083E-01	-7.800E-04	1.790E-04		1088	4	2	546
0.0	7.60E+06	0	0	4	01088	4	2	547
4.260E-01	2.106E-01	-7.500E-04	1.950E-04		1088	4	2	548
0.0	7.80E+06	0	0	4	01088	4	2	549
4.291E-01	2.124E-01	-6.990E-04	2.140E-04		1088	4	2	550
0.0	8.00E+06	0	0	4	01088	4	2	551
4.316E-01	2.140E-01	-6.410E-04	2.390E-04		1088	4	2	552
0.0	8.20E+06	0	0	4	01088	4	2	553
4.342E-01	2.159E-01	-5.640E-04	2.650E-04		1088	4	2	554
0.0	8.40E+06	0	0	4	01088	4	2	555
4.362E-01	2.175E-01	-4.670E-04	2.900E-04		1088	4	2	556
0.0	8.60E+06	0	0	4	01088	4	2	557
4.384E-01	2.189E-01	-3.500E-04	3.180E-04		1088	4	2	558

0.0	8.80E+06	0	0	4	01088	4	2	559
4.403E-01	2.202E-01	-2.490E-04	3.480E-04		1088	4	2	560
0.0	9.00E+06	0	0	4	01088	4	2	561
4.424E-01	2.216E-01	-1.320E-04	3.800E-04		1088	4	2	562
0.0	9.20E+06	0	0	4	01088	4	2	563
4.445E-01	2.223E-01	-1.200E-05	4.110E-04		1088	4	2	564
0.0	9.40E+06	0	0	4	01088	4	2	565
4.463E-01	2.234E-01	1.110E-04	4.480E-04		1088	4	2	566
0.0	9.60E+06	0	0	4	01088	4	2	567
4.482E-01	2.245E-01	2.700E-04	4.840E-04		1088	4	2	568
0.0	9.80E+06	0	0	4	01088	4	2	569
4.498E-01	2.254E-01	4.340E-04	5.220E-04		1088	4	2	570
0.0	1.00E+07	0	0	4	01088	4	2	571
4.517E-01	2.265E-01	6.160E-04	5.600E-04		1088	4	2	572
0.0	1.05E+07	0	0	4	01088	4	2	573
4.553E-01	2.287E-01	1.128E-03	6.820E-04		1088	4	2	574
0.0	1.10E+07	0	0	4	01088	4	2	575
4.589E-01	2.310E-01	1.609E-03	7.830E-04		1088	4	2	576
0.0	1.15E+07	0	0	4	01088	4	2	577
4.621E-01	2.326E-01	2.313E-03	9.250E-04		1088	4	2	578
0.0	1.20E+07	0	0	4	01088	4	2	579
4.651E-01	2.340E-01	3.169E-03	1.083E-03		1088	4	2	580
0.0	1.25E+07	0	0	4	01088	4	2	581
4.674E-01	2.351E-01	4.082E-03	1.231E-03		1088	4	2	582
0.0	1.30E+07	0	0	4	01088	4	2	583
4.701E-01	2.362E-01	5.001E-03	1.429E-03		1088	4	2	584
0.0	1.35E+07	0	0	4	01088	4	2	585
4.725E-01	2.374E-01	6.139E-03	1.600E-03		1088	4	2	586
0.0	1.40E+07	0	0	4	01088	4	2	587
4.750E-01	2.388E-01	7.284E-03	1.781E-03		1088	4	2	588
0.0	1.45E+07	0	0	4	01088	4	2	589
4.775E-01	2.402E-01	8.515E-03	1.971E-03		1088	4	2	590
0.0	1.50E+07	0	0	4	01088	4	2	591
4.801E-01	2.418E-01	9.809E-03	2.171E-03		1088	4	2	592
0.0	0.0	0	0	0	01088	4	0	593
0.0	0.0	0	0	0	01088	0	0	594
2000.0	3.96822	0	0	0	01088	7	4	595
0.0	0.0	0	0	12	11088	7	4	596
0.0	59.3	3.96822	1.5	0.0	0.01088	7	4	597
1.0	0.7238	3.96822	0.0	0.0	0.01088	7	4	598
0.0	0.0	0	0	0	01088	7	0	599
0.0	0.0	0	0	0	01088	0	0	600
0.0	0.0	0	0	0	0 0	0	0	601

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REFERENCES

1. G. R. Satchler *et al.*, *An Optical Model for the Scattering of Nucleons from ^{4}He at Energies below 20 MeV*, Nucl. Phys. *A112*, 1-31 (1968).

2. R. Genin *et al.*, *Détermination des Sections Efficaces d'Absorption et de Diffusion des Gaz Rares pour les Neutrons Thermiques*, J. Phys. Radium *24*, 21-26 (1963).

3. H. Amster, *Evaluation of the Cross-section Transformation Matrices of Zweifel and Hurwitz*, J. Appl. Phys. *27*, 3, 307 (1956).

4. H. Amster, *Errata. Evaluation of the Cross-section Transformation Matrices of Zweifel and Hurwitz*, J. Appl. Phys. *27*, 6, 663 (1956).

5. H. Amster, *Heavy Moderator Approximations in Neutron Transport Theory*, J. Appl. Phys. *29*, 4, 623-627 (1958).

6. R. F. Berland, *CHAD, Code to Handle Angular Data*, NAA-SR-11231 (1965).

7. E.N.E.A. Neutron Data Compilation Centre Newsletter No. 6 (1967).

8. H. C. Honeck, *Specifications for an Evaluated Nuclear Data File for Reactor Applications*, BNL 50066 (T-467) ENDF 102 (May 1966), Revised by S. Pearlstein (July 1967).

9. B. Hoop, Jr. and H. H. Barschall, *Scattering of Neutrons by α-particles*, Nucl. Phys. *83*, 65-79 (1966).

10. J. J. Schmidt, *Neutron Cross Sections for Fast Reactor Materials*, KFK-120, Part II. Tables. Part III. Graphs (1962). Part I: Evaluation (1966).

11. B. R. S. Buckingham, K. Parker, and E. D. Pendlebury, *Neutron Cross Sections of Selected Elements and Isotopes for Use in Neutronics Calculations in the Energy Range 0.025 eV-15 MeV*, AWRE O-28/60 (1961).

12. R. Batchelor and K. Parker, *Neutron Cross Sections of He-3 in the Energy Range 0.001 eV-14 MeV, 1963 Interim Revision*, AWRE O-78/64 (1964).

13. N. C. Francis, D. T. Goldman, and C. R. Lubitz, *Calculation of Nuclear Cross Sections*, in Naval Reactors Physics Handbook, Vol. I, A. Radkowsky, Ed., Chap. 2, Sec. 2.2 (1964).

14. A. M. Lane and R. G. Thomas, *R-Matrix Theory of Nuclear Reactions*, Rev. Mod. Phys. *30*, 257-353 (1958).

15. M. A. Preston, *Physics of the Nucleus*, Addison-Wesley Publishing Company, Reading, Mass. (1962), pp. 625-627.