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Heavy-Ion Total and Absorption Cross Sections Above 25 MeV/Nucleon

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INTRODUCTION

The high-energy heavy-ion (HZE) component of galactic cosmic rays is expected to become of major radiobiological significance in future manned space flights. In the approaching era of career astronauts and space workers, it is expected that low-intensity HZE particle exposure will accumulate to biologically significant levels for the first time in the history of the space program. Analyses of self-shielding factors, as well as determinations of personal and bulk shield requirements, require an accurate heavy-ion transport theory as input. The latter, in turn, requires accurate interaction cross sections as its input.

In previous work (refs. 1 to 10), a comprehensive nuclear interaction theory capable of describing HZE particle absorption, total, and abrasion cross sections has been developed for use as input into a transport theory under concurrent development (refs. 11 and 12). In the present report, this HZE interaction theory is used to generate extensive tables of heavy-ion cross sections at incident energies between 25 MeV/nucleon and 22.5 GeV/nucleon, which are of interest in cosmic-ray shielding studies. As such, this work represents an improved and updated version of the original tables presented in reference 3. Comparisons with available experimental data for nucleus-nucleus collisions are also made.

SYMBOLS

A	nuclear mass number
a	parameter in harmonic well function, fm
$B(e)$	average slope parameter of nucleon-nucleon scattering amplitude, fm^2
$\vec{b}$	projectile impact parameter vector, fm
$\tilde{C}$	average correlation function
c	Woods-Saxon surface diffuseness, fm
E_{lab}	projectile laboratory energy per unit mass, GeV/nucleon
e	two-nucleon kinetic energy in their center of mass frame, GeV
Im $\chi(\vec{b})$	imaginary part of eikonal phase shift function
$\vec{k}$	projectile momentum vector relative to target, fm^{-1}
k_F	Fermi momentum wave number, fm^{-1}
m	nucleon mass, kg
R	radius at half-density, fm

Re $\chi(\vec{b})$	real part of eikonal phase shift function
$\vec{r}$	position vector, fm
r_p	proton root-mean-square charge radius, fm
s	defined in equation (12)
t	skin thickness, fm
$\tilde{t}$	average two-nucleon transition amplitude, MeV
$U(\vec{x})$	reduced potential, MeV^2
$W(\vec{x})$	optical potential (defined in eq. (5)), MeV
$\vec{x}$	relative position vector of projectile ($\vec{x} = \vec{b} + \vec{z}$), fm
$\vec{y}$	two-nucleon relative position vector, fm
$\vec{z}$	position vector of projectile in beam direction, fm
$\alpha(e)$	average ratio of real part to imaginary part of nucleon-nucleon scattering amplitude
β	defined in equation (16)
γ	harmonic well distribution parameter (see eq. (10))
$\vec{\xi}_T$	collection of constituent relative coordinates for target, fm
ρ	nuclear density, fm^{-3}
ρ_o	normalization constant in equations (10) and (13), fm^{-3}
$\sigma(e)$	average nucleon-nucleon total cross section, mb
σ_{abs}	heavy-ion absorption cross section, mb
σ_{tot}	heavy-ion total cross section, mb
$\chi(\vec{b})$	eikonal phase shift function

Subscripts:

A	matter
c	charge
n	neutron
P	projectile

p proton

T target

Abbreviations:

HW harmonic well

HZE high-energy heavy-ion

WS Woods-Saxon

Arrows over symbols indicate vectors.

THEORETICAL DEVELOPMENT

From eikonal scattering theory, the collision total and absorption cross sections are given by

$$\sigma_{tot} = 4\pi\int_0^\infty \{1 - \exp[-\mathrm{Im}\ \chi(\vec{b})]\ \cos[\mathrm{Re}\ \chi(\vec{b})]\}b\ db \tag{1}$$

and

$$\sigma_{abs} = 2\pi\int_0^\infty \{1 - \exp[-2\ \mathrm{Im}\ \chi(\vec{b})]\}b\ db \tag{2}$$

where the complex phase function, in terms of the reduced potential U is

$$\chi(\vec{b}) = -\frac{1}{2k}\int_{-\infty}^{\infty} U(\vec{b},z)\ dz \tag{3}$$

For composite particle scattering, the reduced potential is written as

$$U(\vec{x}) = 2mA_PA_T(A_P + A_T)^{-1}\ W(\vec{x}) \tag{4}$$

where m is the nucleon mass, A_P is the nuclear mass number of the projectile, and A_T is the nuclear mass number of the target. From references 7 and 8, the nucleus-nucleus optical potential including Pauli correlation effects is

$$W(\vec{x}) = A_PA_T\int d^3\vec{\xi}_T\ \rho_T(\vec{\xi}_T)\int d^3\vec{y}\ \rho_P(\vec{x}+\vec{y}+\vec{\xi}_T)\ \tilde{t}(e,\vec{y})\ [1 - \tilde{C}(\vec{y})] \tag{5}$$

In equation (5), $\tilde{t}$ is the constituent-averaged energy-dependent two-body transition amplitude

$$\tilde{t}(e,\vec{y}) = -\left(\frac{e}{m}\right)^{1/2} \sigma(e)\ [\alpha(e) + i][2\pi\ B(e)]^{-3/2}\ \exp\left[\frac{-y^2}{2B(e)}\right] \tag{6}$$

and the correlation function is taken to be

$$\tilde{C}(\vec{y}) = 0.25\ \exp\left(\frac{-k_F{}^2 y^2}{10}\right) \tag{7}$$

For the analyses of this work, the Fermi momentum is assumed to be that of infinite matter, $k_F = 1.36\ fm^{-1}$.

Nuclear Density Distributions

The correct nuclear density distributions ρ_j (j = P,T) to use in equation (5) are the nuclear ground state, single-particle number densities for the collision pair. Since these are not experimentally known, the number densities are obtained from their experimental charge density distributions by assuming

$$\rho_c(\vec{r}) = \int \rho_p(\vec{r}')\ \rho_A(\vec{r}+\vec{r}')\ d^3\vec{r}' \tag{8}$$

where ρ_c is the nuclear charge distribution, ρ_p is the proton charge distribution, and ρ_A is the desired nuclear single-particle density. All density distributions in equation (8) are normalized to unity. The proton charge distribution is taken to be the usual Gaussian form

$$\rho_p(\vec{r}) = \left(\frac{3}{2\pi r_p{}^2}\right)^{3/2} \exp\left(\frac{-3r^2}{2r_p{}^2}\right) \tag{9}$$

where $r_p = 0.87$ fm (ref. 13) is the proton root-mean-square charge radius.

For nuclei lighter than neon (A < 20), the nuclear charge distribution is the harmonic well (HW) form given by (ref. 14)

$$\rho_c(r) = \rho_o\left[1 + \gamma\left(\frac{r}{a}\right)^2\right] \exp\left(\frac{-r^2}{a^2}\right) \tag{10}$$

where ρ_o is the normalization constant, r is the radial coordinate, and a and γ are charge parameters. Values for a and γ, used herein, are listed in table 1. Substituting equations (9) and (10) into equation (8) yields (ref. 7)

$$\rho_A(r) = \frac{\rho_o a^3}{8s^3}\left(1 + \frac{3\gamma}{2} - \frac{3\gamma a^2}{8s^2} + \frac{\gamma a^2 r^2}{16s^4}\right) \exp\left(\frac{-r^2}{4s^2}\right) \tag{11}$$

where

$$s^2 = \frac{a^2}{4} - \frac{r_p^2}{6} \tag{12}$$

For neon and heavier nuclei ($A > 20$) the nuclear charge distribution is taken to be the Woods-Saxon (WS) form given by reference 4

$$\rho_c(r) = \frac{\rho_o}{1 + \exp[(r - R)/c]} \tag{13}$$

where R is the radius at half-density, and the diffuseness c is related to the nuclear skin thickness t through

$$c = \frac{t}{4.4} \tag{14}$$

Values for R and t, used herein, are listed in table 1. Most values are taken from reference 14. Inserting equations (9) and (13) into equation (8) yields after some simplification (ref. 4), a number density ρ_A which is of the WS form (see eq. (13)) with the same R, but different overall normalization factor ρ_o and surface thickness. The latter is given by

$$t_A = \frac{8.8 r_p}{3^{1/2}}\left[\ln\left(\frac{3\beta - 1}{3 - \beta}\right)\right]^{-1} \tag{15}$$

where

$$\beta = \exp\left(\frac{4.4 r_p}{t_c 3^{1/2}}\right) \tag{16}$$

with t_c denoting the charge skin thickness obtained by using equation (14), from the charge distribution surface diffuseness values listed in reference 14.

Nucleon-Nucleon Scattering Parameters

The nucleon-nucleon scattering parameters $\alpha(e)$, $\sigma(e)$, and $B(e)$ used in the energy-dependent two-body transition amplitude (eq. (6)) are obtained by performing a spline interpolation of values taken from various compilations (refs. 15 through 19). The results are displayed in figures 1 through 6 as a function of incident energy. No curves for neutron-neutron scattering parameters are displayed, since little or no experimental data exist for these collisions. For computational purposes, it is assumed that the neutron-neutron parameters are adequately represented by the proton-proton scattering parameters for each energy considered. Although this assumption may be valid for high energies, it possibly contributes to some of the disagreement between theory and experiment at low energies (<100 MeV/nucleon). Finally, details of the constituent-averaging of equation (6) are given in reference 3.

HEAVY-ION COLLISION RESULTS

Using the formalism described in the previous sections, total and absorption cross sections for selected heavy ions with various target nuclei have been calculated. The results are given in tables 2 to 23. The projectile and target nuclei were selected for their applicability to cosmic-ray shielding studies and for their availability at heavy-ion accelerator facilities. No significant errors are expected for values obtained by interpolating between the target mass numbers of nuclei displayed in the tables. Comparisons between these theoretical predictions and the limited number of available experimental results (refs. 20 through 26) are displayed in figures 7 to 10. The agreement at higher energies is excellent (within 3 percent). For low energies ($\approx$25 MeV/nucleon), where the validity of the eikonal approximation is questionable, the discrepancy increases to $\approx$20 percent. At the higher energies, the major sources of disagreement are possible uncertainties in the experimental scattering and charge distribution parameters. Additional sources of error at low energies include the neglect of off-shell and many-body effects (ref. 27), as well as the questionable validity of the eikonal formalism itself.

CONCLUDING REMARKS

Extensive tables of heavy-ion total and absorption cross sections for use in cosmic-ray shielding studies have been generated over a broad range of energies. Comparisons between some of the calculated cross sections and the limited amount of experimental data show substantial agreement (within 3 percent) at higher energies. For low energies ($\approx$25 MeV/nucleon), where the validity of the eikonal approximation is questionable, the discrepancy increases to $\approx$20 percent. Clearly, however, additional experimental data are needed at all displayed energies.

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TABLE 1.- NUCLEAR CHARGE DISTRIBUTION PARAMETERS FROM ELECTRON SCATTERING DATA

Nucleus	Distribution (*)	γ (HW) or t, fm (WS)	a, fm (HW) or R, fm (WS)
^{4}He	HW	0	1.33
^{7}Li	HW	.327	1.77
^{9}Be	HW	.611	1.791
^{11}B	HW	.811	1.69
^{12}C	HW	1.247	1.649
^{14}N	HW	1.291	1.729
^{16}O	HW	1.544	1.833
^{20}Ne	WS	2.517	2.74
^{27}Al	WS	2.284	3.07
^{40}Ar	WS	2.693	3.47
^{56}Fe	WS	2.611	3.971
^{64}Cu	WS	2.504	4.20
^{80}Br	WS	2.306	4.604
^{108}Ag	WS	2.354	5.139
^{138}Ba	WS	2.621	5.618
^{208}Pb	WS	2.416	6.624

*HW - harmonic well (eq. (10)); WS - Woods-Saxon (eq. (13)).

TABLE 2. - HELIUM-NUCLEUS TOTAL CROSS SECTION

Helium-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	683.	1276.	1554.	1759.	2401.	2745.	2841.	2815.	3540.	4265.	5190.
50.	558.	1089.	1335.	1551.	2106.	2443.	2550.	2584.	3245.	3903.	4821.
75.	500.	1002.	1233.	1454.	1971.	2305.	2416.	2474.	3106.	3735.	4648.
100.	452.	928.	1146.	1371.	1859.	2188.	2302.	2379.	2987.	3593.	4499.
125.	416.	874.	1083.	1311.	1777.	2103.	2218.	2308.	2900.	3488.	4390.
150.	384.	828.	1029.	1258.	1707.	2029.	2146.	2245.	2822.	3397.	4293.
175.	350.	775.	968.	1199.	1630.	1948.	2065.	2174.	2735.	3295.	4183.
200.	315.	714.	897.	1133.	1543.	1855.	1973.	2091.	2635.	3177.	4057.
225.	297.	681.	857.	1095.	1494.	1804.	1921.	2045.	2580.	3112.	3986.
250.	285.	658.	830.	1068.	1460.	1767.	1885.	2012.	2540.	3065.	3936.
275.	276.	641.	808.	1046.	1432.	1738.	1855.	1985.	2507.	3028.	3895.
300.	271.	630.	796.	1033.	1415.	1719.	1837.	1969.	2487.	3004.	3869.
350.	264.	614.	775.	1012.	1387.	1690.	1807.	1942.	2454.	2966.	3828.
400.	269.	621.	783.	1018.	1396.	1698.	1816.	1949.	2463.	2977.	3839.
500.	288.	653.	821.	1056.	1445.	1750.	1866.	1994.	2518.	3041.	3907.
600.	307.	686.	860.	1094.	1495.	1803.	1919.	2041.	2575.	3108.	3979.
700.	321.	709.	888.	1121.	1530.	1840.	1957.	2075.	2616.	3155.	4031.
800.	328.	721.	901.	1135.	1548.	1859.	1976.	2092.	2637.	3179.	4057.
900.	333.	730.	911.	1146.	1561.	1874.	1990.	2105.	2652.	3198.	4076.
1000.	337.	737.	920.	1154.	1572.	1885.	2002.	2116.	2665.	3212.	4093.
1250.	347.	753.	939.	1174.	1597.	1912.	2029.	2142.	2696.	3247.	4131.
1500.	352.	761.	949.	1185.	1610.	1926.	2043.	2157.	2712.	3266.	4152.
1750.	354.	765.	953.	1190.	1616.	1933.	2050.	2164.	2720.	3274.	4162.
2000.	356.	768.	957.	1195.	1621.	1938.	2056.	2171.	2728.	3282.	4171.
2500.	357.	771.	959.	1198.	1624.	1943.	2061.	2176.	2733.	3288.	4178.
3000.	356.	770.	958.	1198.	1624.	1942.	2060.	2177.	2733.	3287.	4178.
3500.	355.	768.	956.	1196.	1621.	1939.	2057.	2175.	2730.	3284.	4174.
4000.	353.	764.	951.	1192.	1615.	1933.	2051.	2170.	2724.	3276.	4166.
5000.	349.	758.	944.	1184.	1606.	1923.	2042.	2161.	2714.	3264.	4153.
6000.	347.	754.	940.	1180.	1600.	1917.	2036.	2156.	2708.	3257.	4145.
7000.	346.	752.	936.	1177.	1596.	1913.	2032.	2152.	2703.	3251.	4139.
8000.	344.	749.	933.	1174.	1592.	1909.	2028.	2149.	2699.	3246.	4134.
9000.	343.	747.	931.	1172.	1589.	1906.	2025.	2146.	2695.	3242.	4130.
10000.	342.	745.	929.	1170.	1586.	1903.	2022.	2144.	2693.	3239.	4127.
12500.	341.	742.	924.	1167.	1581.	1898.	2017.	2141.	2688.	3233.	4120.
15000.	340.	740.	921.	1165.	1577.	1894.	2014.	2139.	2685.	3229.	4117.
17500.	339.	737.	918.	1162.	1574.	1890.	2010.	2137.	2682.	3225.	4113.
20000.	338.	735.	916.	1160.	1571.	1888.	2008.	2136.	2679.	3221.	4109.
22500.	338.	734.	914.	1159.	1569.	1886.	2006.	2135.	2678.	3219.	4108.

TABLE 3. - HELIUM-NUCLEUS ABSORPTION CROSS SECTION

Helium-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	393.	714.	867.	965.	1324.	1498.	1541.	1501.	1891.	2282.	2746.
50.	307.	586.	716.	821.	1120.	1289.	1339.	1341.	1687.	2031.	2491.
75.	270.	529.	650.	758.	1032.	1199.	1252.	1269.	1596.	1921.	2377.
100.	242.	486.	599.	709.	965.	1129.	1184.	1213.	1525.	1837.	2289.
125.	226.	461.	569.	681.	927.	1089.	1145.	1180.	1484.	1787.	2237.
150.	216.	446.	551.	664.	904.	1065.	1121.	1160.	1459.	1758.	2206.
175.	209.	434.	537.	650.	885.	1046.	1103.	1144.	1440.	1734.	2181.
200.	203.	424.	526.	640.	871.	1032.	1088.	1132.	1424.	1716.	2162.
225.	198.	417.	518.	632.	861.	1020.	1077.	1122.	1413.	1702.	2148.
250.	195.	412.	512.	626.	853.	1012.	1069.	1115.	1404.	1692.	2137.
275.	193.	409.	508.	623.	848.	1007.	1064.	1111.	1399.	1686.	2130.
300.	192.	408.	507.	621.	846.	1005.	1062.	1109.	1397.	1683.	2127.
350.	191.	405.	504.	618.	842.	1001.	1058.	1106.	1393.	1678.	2122.
400.	195.	412.	512.	627.	853.	1012.	1069.	1116.	1405.	1693.	2137.
500.	208.	432.	536.	650.	883.	1044.	1101.	1144.	1439.	1732.	2180.
600.	219.	450.	556.	670.	910.	1073.	1129.	1168.	1468.	1768.	2217.
700.	227.	463.	571.	684.	929.	1092.	1148.	1185.	1489.	1792.	2243.
800.	231.	468.	578.	691.	937.	1101.	1157.	1193.	1499.	1803.	2255.
900.	233.	472.	582.	695.	943.	1107.	1163.	1198.	1505.	1810.	2263.
1000.	235.	475.	585.	698.	947.	1111.	1167.	1202.	1510.	1816.	2269.
1250.	239.	480.	591.	704.	954.	1119.	1175.	1210.	1519.	1826.	2279.
1500.	240.	482.	593.	707.	958.	1123.	1179.	1214.	1523.	1831.	2285.
1750.	241.	483.	594.	708.	959.	1124.	1181.	1216.	1525.	1832.	2287.
2000.	241.	483.	594.	709.	959.	1125.	1181.	1218.	1526.	1833.	2288.
2500.	242.	483.	594.	709.	959.	1125.	1181.	1218.	1526.	1833.	2289.
3000.	241.	483.	593.	709.	958.	1123.	1180.	1218.	1526.	1832.	2288.
3500.	240.	481.	591.	707.	956.	1121.	1178.	1217.	1524.	1829.	2285.
4000.	239.	480.	590.	706.	953.	1119.	1176.	1215.	1521.	1826.	2282.
5000.	238.	477.	587.	703.	950.	1115.	1172.	1212.	1517.	1822.	2277.
6000.	237.	476.	586.	702.	948.	1113.	1170.	1210.	1515.	1820.	2275.
7000.	237.	476.	585.	701.	947.	1112.	1169.	1209.	1515.	1818.	2274.
8000.	236.	475.	584.	701.	946.	1112.	1169.	1209.	1514.	1818.	2273.
9000.	236.	475.	584.	701.	946.	1112.	1169.	1209.	1514.	1818.	2273.
10000.	237.	475.	584.	701.	946.	1112.	1169.	1210.	1515.	1818.	2274.
12500.	237.	475.	584.	701.	946.	1112.	1170.	1211.	1515.	1819.	2275.
15000.	237.	476.	584.	702.	947.	1112.	1170.	1212.	1517.	1819.	2276.
17500.	237.	476.	584.	702.	946.	1113.	1170.	1213.	1517.	1820.	2277.
20000.	237.	476.	584.	703.	946.	1113.	1171.	1214.	1518.	1820.	2277.
22500.	238.	476.	585.	703.	947.	1113.	1171.	1215.	1519.	1821.	2278.

TABLE 4. - LITHIUM-NUCLEUS TOTAL CROSS SECTION

Lithium-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1120.	1867.	2196.	2476.	3197.	3609.	3733.	3765.	4564.	5354.	6421.
50.	922.	1604.	1900.	2191.	2829.	3232.	3365.	3448.	4185.	4913.	5964.
75.	830.	1480.	1762.	2056.	2657.	3055.	3190.	3293.	4003.	4702.	5745.
100.	752.	1375.	1644.	1941.	2512.	2905.	3043.	3161.	3848.	4523.	5557.
125.	694.	1299.	1558.	1857.	2407.	2796.	2935.	3064.	3734.	4392.	5419.
150.	642.	1233.	1484.	1784.	2317.	2702.	2841.	2978.	3634.	4278.	5297.
175.	585.	1162.	1403.	1704.	2219.	2599.	2738.	2882.	3523.	4152.	5162.
200.	527.	1081.	1313.	1615.	2109.	2483.	2622.	2774.	3397.	4011.	5009.
225.	497.	1036.	1262.	1565.	2049.	2419.	2558.	2714.	3328.	3932.	4924.
250.	477.	1005.	1227.	1530.	2006.	2374.	2514.	2672.	3279.	3877.	4864.
275.	462.	981.	1199.	1503.	1973.	2339.	2478.	2639.	3240.	3834.	4816.
300.	454.	966.	1182.	1486.	1953.	2317.	2457.	2619.	3217.	3807.	4787.
350.	441.	943.	1156.	1459.	1920.	2282.	2421.	2585.	3178.	3763.	4739.
400.	449.	952.	1165.	1468.	1932.	2294.	2433.	2597.	3191.	3779.	4755.
500.	480.	996.	1215.	1518.	1993.	2358.	2498.	2657.	3261.	3858.	4840.
600.	511.	1041.	1266.	1569.	2056.	2425.	2564.	2718.	3333.	3940.	4927.
700.	533.	1073.	1302.	1605.	2100.	2471.	2610.	2762.	3383.	3997.	4989.
800.	544.	1089.	1320.	1623.	2122.	2494.	2634.	2784.	3408.	4026.	5020.
900.	552.	1100.	1333.	1636.	2138.	2512.	2651.	2800.	3427.	4047.	5043.
1000.	558.	1110.	1343.	1647.	2151.	2525.	2665.	2814.	3442.	4064.	5061.
1250.	572.	1131.	1368.	1672.	2181.	2557.	2697.	2845.	3478.	4103.	5105.
1500.	579.	1142.	1380.	1685.	2196.	2574.	2714.	2862.	3497.	4124.	5128.
1750.	582.	1147.	1385.	1691.	2203.	2581.	2721.	2869.	3505.	4133.	5138.
2000.	584.	1151.	1390.	1696.	2208.	2587.	2728.	2876.	3513.	4141.	5148.
2500.	585.	1153.	1392.	1700.	2212.	2591.	2732.	2882.	3518.	4147.	5154.
3000.	584.	1152.	1391.	1699.	2211.	2590.	2731.	2881.	3518.	4145.	5153.
3500.	582.	1149.	1387.	1696.	2206.	2586.	2727.	2878.	3514.	4140.	5148.
4000.	578.	1144.	1381.	1690.	2199.	2578.	2719.	2871.	3506.	4131.	5139.
5000.	572.	1135.	1372.	1681.	2188.	2566.	2708.	2860.	3493.	4117.	5123.
6000.	569.	1130.	1367.	1675.	2181.	2559.	2701.	2854.	3485.	4109.	5114.
7000.	566.	1127.	1362.	1671.	2176.	2554.	2695.	2849.	3480.	4102.	5107.
8000.	564.	1123.	1358.	1667.	2172.	2549.	2690.	2844.	3474.	4096.	5101.
9000.	562.	1120.	1355.	1664.	2168.	2545.	2686.	2841.	3470.	4091.	5096.
10000.	560.	1118.	1352.	1661.	2164.	2542.	2683.	2838.	3467.	4087.	5091.
12500.	556.	1112.	1346.	1656.	2157.	2535.	2676.	2833.	3460.	4079.	5083.
15000.	554.	1109.	1341.	1653.	2152.	2530.	2672.	2829.	3456.	4074.	5078.
17500.	551.	1105.	1337.	1649.	2148.	2525.	2667.	2826.	3451.	4069.	5072.
20000.	549.	1102.	1334.	1646.	2144.	2521.	2663.	2823.	3448.	4064.	5068.
22500.	548.	1100.	1332.	1645.	2142.	2519.	2661.	2822.	3446.	4062.	5065.

TABLE 5. - LITHIUM-NUCLEUS ABSORPTION CROSS SECTION

Lithium-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	640.	1040.	1218.	1354.	1751.	1959.	2016.	2009.	2434.	2856.	3395.
50.	505.	860.	1015.	1158.	1496.	1699.	1763.	1791.	2174.	2551.	3080.
75.	446.	781.	926.	1071.	1385.	1585.	1650.	1692.	2056.	2416.	2938.
100.	400.	720.	858.	1004.	1301.	1498.	1564.	1615.	1966.	2311.	2829.
125.	374.	684.	818.	965.	1252.	1447.	1514.	1570.	1913.	2251.	2765.
150.	358.	663.	794.	942.	1223.	1417.	1484.	1543.	1882.	2215.	2726.
175.	346.	647.	775.	924.	1200.	1393.	1461.	1522.	1857.	2186.	2696.
200.	337.	634.	761.	910.	1183.	1374.	1443.	1505.	1837.	2164.	2672.
225.	329.	624.	750.	899.	1169.	1360.	1429.	1493.	1823.	2147.	2654.
250.	324.	617.	742.	891.	1159.	1350.	1419.	1484.	1812.	2135.	2641.
275.	321.	612.	737.	886.	1154.	1344.	1413.	1478.	1806.	2128.	2634.
300.	319.	610.	734.	884.	1151.	1341.	1409.	1476.	1802.	2124.	2630.
350.	317.	607.	730.	880.	1146.	1336.	1404.	1471.	1797.	2118.	2623.
400.	324.	617.	741.	891.	1160.	1350.	1419.	1485.	1813.	2136.	2642.
500.	344.	644.	772.	922.	1198.	1391.	1459.	1522.	1856.	2186.	2695.
600.	362.	669.	800.	949.	1233.	1426.	1495.	1554.	1894.	2230.	2741.
700.	375.	686.	819.	968.	1256.	1451.	1519.	1577.	1920.	2259.	2772.
800.	380.	694.	828.	977.	1267.	1462.	1530.	1587.	1932.	2273.	2787.
900.	384.	699.	833.	983.	1274.	1469.	1538.	1594.	1940.	2282.	2796.
1000.	387.	702.	837.	987.	1279.	1474.	1543.	1599.	1946.	2288.	2803.
1250.	392.	709.	844.	994.	1287.	1484.	1552.	1608.	1956.	2299.	2816.
1500.	394.	711.	848.	998.	1291.	1488.	1556.	1613.	1961.	2305.	2821.
1750.	394.	712.	848.	999.	1292.	1489.	1557.	1614.	1962.	2306.	2823.
2000.	394.	712.	848.	999.	1292.	1489.	1558.	1615.	1963.	2306.	2824.
2500.	393.	711.	847.	999.	1291.	1488.	1557.	1615.	1962.	2305.	2823.
3000.	392.	710.	846.	997.	1289.	1486.	1555.	1614.	1961.	2303.	2821.
3500.	391.	708.	844.	995.	1286.	1484.	1553.	1612.	1958.	2300.	2818.
4000.	389.	706.	841.	993.	1283.	1481.	1550.	1609.	1955.	2296.	2814.
5000.	387.	703.	838.	989.	1279.	1476.	1545.	1605.	1950.	2291.	2809.
6000.	386.	701.	836.	988.	1277.	1474.	1543.	1603.	1948.	2288.	2806.
7000.	385.	700.	835.	987.	1276.	1472.	1542.	1602.	1947.	2287.	2804.
8000.	385.	700.	834.	986.	1275.	1472.	1541.	1601.	1946.	2286.	2803.
9000.	384.	699.	834.	986.	1274.	1471.	1541.	1601.	1946.	2286.	2803.
10000.	384.	699.	834.	986.	1274.	1471.	1541.	1601.	1946.	2286.	2803.
12500.	384.	699.	833.	986.	1274.	1471.	1541.	1602.	1946.	2286.	2804.
15000.	384.	699.	833.	986.	1274.	1471.	1541.	1603.	1947.	2286.	2804.
17500.	383.	699.	832.	986.	1273.	1471.	1541.	1603.	1947.	2286.	2804.
20000.	383.	698.	832.	986.	1273.	1471.	1541.	1604.	1947.	2286.	2805.
22500.	383.	699.	832.	987.	1273.	1471.	1541.	1604.	1948.	2287.	2805.

TABLE 6. - BERYLLIUM-NUCLEUS TOTAL CROSS SECTION

Beryllium-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1257.	2046.	2393.	2681.	3440.	3864.	3989.	4011.	4842.	5663.	6753.
50.	1051.	1776.	2090.	2388.	3063.	3479.	3613.	3689.	4458.	5215.	6291.
75.	954.	1648.	1947.	2250.	2886.	3298.	3436.	3534.	4273.	5001.	6070.
100.	873.	1540.	1825.	2132.	2738.	3145.	3286.	3400.	4116.	4820.	5881.
125.	813.	1460.	1737.	2046.	2631.	3034.	3176.	3301.	4000.	4688.	5742.
150.	759.	1392.	1660.	1971.	2538.	2938.	3080.	3214.	3899.	4573.	5619.
175.	698.	1317.	1576.	1889.	2437.	2832.	2975.	3117.	3787.	4445.	5483.
200.	632.	1233.	1483.	1796.	2325.	2714.	2857.	3007.	3660.	4302.	5329.
225.	598.	1187.	1431.	1745.	2263.	2649.	2792.	2946.	3590.	4223.	5244.
250.	575.	1155.	1394.	1709.	2219.	2603.	2747.	2903.	3540.	4167.	5184.
275.	558.	1129.	1366.	1681.	2185.	2567.	2710.	2870.	3501.	4123.	5136.
300.	548.	1113.	1348.	1664.	2165.	2545.	2689.	2849.	3478.	4097.	5107.
350.	533.	1089.	1320.	1636.	2131.	2510.	2653.	2815.	3439.	4053.	5059.
400.	541.	1098.	1330.	1646.	2143.	2522.	2665.	2827.	3452.	4068.	5075.
500.	575.	1144.	1381.	1697.	2206.	2588.	2731.	2888.	3522.	4148.	5160.
600.	609.	1191.	1434.	1749.	2270.	2655.	2798.	2950.	3595.	4231.	5248.
700.	634.	1224.	1471.	1786.	2316.	2702.	2845.	2994.	3646.	4289.	5310.
800.	646.	1241.	1490.	1805.	2338.	2726.	2869.	3017.	3672.	4318.	5341.
900.	655.	1253.	1504.	1819.	2355.	2744.	2887.	3034.	3691.	4339.	5364.
1000.	662.	1263.	1515.	1830.	2368.	2758.	2901.	3047.	3706.	4356.	5383.
1250.	678.	1286.	1540.	1856.	2399.	2791.	2934.	3079.	3743.	4397.	5428.
1500.	686.	1297.	1553.	1870.	2415.	2808.	2952.	3097.	3762.	4418.	5451.
1750.	689.	1302.	1559.	1876.	2422.	2816.	2960.	3105.	3771.	4427.	5462.
2000.	691.	1307.	1563.	1881.	2428.	2822.	2966.	3112.	3779.	4436.	5472.
2500.	693.	1309.	1566.	1885.	2432.	2827.	2971.	3118.	3785.	4442.	5479.
3000.	692.	1308.	1565.	1884.	2430.	2826.	2970.	3118.	3784.	4441.	5478.
3500.	689.	1305.	1562.	1881.	2426.	2821.	2966.	3114.	3780.	4436.	5473.
4000.	685.	1300.	1555.	1875.	2419.	2814.	2958.	3107.	3772.	4427.	5463.
5000.	678.	1291.	1546.	1866.	2407.	2802.	2946.	3096.	3759.	4412.	5448.
6000.	675.	1286.	1540.	1860.	2401.	2794.	2939.	3090.	3752.	4404.	5439.
7000.	672.	1282.	1536.	1856.	2395.	2789.	2934.	3085.	3746.	4397.	5431.
8000.	669.	1278.	1532.	1852.	2391.	2784.	2929.	3080.	3741.	4391.	5425.
9000.	667.	1275.	1528.	1849.	2387.	2780.	2925.	3077.	3737.	4386.	5420.
10000.	665.	1273.	1525.	1846.	2383.	2776.	2922.	3074.	3733.	4382.	5416.
12500.	661.	1267.	1519.	1841.	2376.	2770.	2915.	3069.	3727.	4375.	5408.
15000.	658.	1263.	1515.	1838.	2372.	2765.	2911.	3066.	3723.	4370.	5403.
17500.	655.	1260.	1511.	1834.	2367.	2760.	2906.	3063.	3719.	4364.	5398.
20000.	653.	1257.	1507.	1831.	2363.	2757.	2903.	3060.	3715.	4360.	5394.
22500.	652.	1255.	1505.	1830.	2361.	2755.	2901.	3059.	3713.	4358.	5392.

TABLE 7. - BERYLLIUM-NUCLEUS ABSORPTION CROSS SECTION

Beryllium-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	712.	1133.	1319.	1459.	1876.	2090.	2148.	2134.	2576.	3013.	3563.
50.	571.	947.	1112.	1258.	1615.	1824.	1889.	1913.	2311.	2704.	3245.
75.	508.	865.	1020.	1169.	1502.	1708.	1775.	1813.	2193.	2567.	3102.
100.	460.	802.	949.	1100.	1415.	1619.	1687.	1735.	2101.	2461.	2991.
125.	433.	766.	908.	1061.	1365.	1567.	1636.	1689.	2047.	2400.	2927.
150.	416.	744.	884.	1037.	1335.	1536.	1605.	1662.	2016.	2363.	2888.
175.	403.	727.	864.	1018.	1312.	1512.	1581.	1640.	1990.	2335.	2858.
200.	393.	713.	849.	1003.	1294.	1493.	1563.	1624.	1971.	2312.	2834.
225.	385.	703.	838.	992.	1280.	1479.	1549.	1611.	1956.	2295.	2816.
250.	379.	696.	830.	984.	1270.	1468.	1538.	1602.	1945.	2283.	2803.
275.	376.	691.	824.	979.	1264.	1462.	1532.	1596.	1938.	2275.	2795.
300.	374.	689.	822.	977.	1261.	1459.	1529.	1593.	1935.	2272.	2791.
350.	371.	685.	818.	973.	1256.	1453.	1524.	1589.	1930.	2266.	2785.
400.	379.	695.	829.	984.	1270.	1468.	1539.	1602.	1946.	2284.	2804.
500.	401.	724.	861.	1016.	1310.	1509.	1579.	1640.	1989.	2334.	2856.
600.	420.	750.	890.	1044.	1345.	1546.	1616.	1673.	2028.	2378.	2903.
700.	434.	767.	910.	1064.	1369.	1571.	1641.	1696.	2054.	2408.	2935.
800.	440.	775.	919.	1073.	1380.	1582.	1652.	1706.	2066.	2422.	2949.
900.	444.	781.	925.	1079.	1387.	1590.	1659.	1713.	2074.	2431.	2959.
1000.	447.	784.	929.	1083.	1392.	1595.	1665.	1719.	2080.	2437.	2966.
1250.	452.	791.	936.	1091.	1401.	1605.	1674.	1728.	2091.	2449.	2978.
1500.	454.	794.	939.	1094.	1405.	1609.	1679.	1733.	2096.	2454.	2985.
1750.	454.	795.	940.	1095.	1406.	1610.	1680.	1734.	2098.	2456.	2987.
2000.	454.	795.	940.	1096.	1406.	1611.	1681.	1735.	2098.	2456.	2987.
2500.	454.	795.	939.	1095.	1405.	1610.	1680.	1735.	2098.	2455.	2987.
3000.	453.	793.	938.	1094.	1403.	1608.	1678.	1734.	2096.	2453.	2985.
3500.	451.	791.	936.	1092.	1401.	1605.	1676.	1732.	2094.	2450.	2982.
4000.	450.	789.	933.	1090.	1398.	1602.	1673.	1729.	2091.	2447.	2978.
5000.	447.	786.	929.	1086.	1393.	1598.	1668.	1725.	2086.	2441.	2972.
6000.	446.	784.	927.	1084.	1391.	1595.	1666.	1723.	2083.	2438.	2969.
7000.	445.	783.	926.	1083.	1390.	1594.	1664.	1722.	2082.	2437.	2968.
8000.	444.	782.	926.	1083.	1389.	1593.	1664.	1722.	2081.	2436.	2967.
9000.	444.	782.	925.	1083.	1389.	1593.	1664.	1722.	2081.	2436.	2967.
10000.	444.	782.	925.	1083.	1389.	1593.	1664.	1722.	2082.	2436.	2967.
12500.	444.	782.	925.	1083.	1388.	1593.	1664.	1723.	2082.	2436.	2968.
15000.	444.	782.	925.	1083.	1388.	1593.	1664.	1724.	2083.	2437.	2969.
17500.	443.	782.	924.	1083.	1388.	1593.	1664.	1724.	2083.	2437.	2969.
20000.	443.	781.	924.	1083.	1388.	1592.	1664.	1725.	2083.	2437.	2969.
22500.	443.	782.	925.	1084.	1388.	1593.	1665.	1726.	2084.	2437.	2970.

TABLE 8. - BORON-NUCLEUS TOTAL CROSS SECTION

Boron-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1262.	2055.	2408.	2679.	3466.	3882.	3997.	3986.	4833.	5673.	6746.
50.	1070.	1799.	2120.	2402.	3100.	3510.	3637.	3683.	4467.	5241.	6303.
75.	980.	1680.	1985.	2272.	2931.	3337.	3468.	3538.	4292.	5037.	6093.
100.	904.	1578.	1870.	2161.	2789.	3191.	3325.	3413.	4144.	4864.	5914.
125.	849.	1503.	1787.	2081.	2686.	3085.	3221.	3321.	4035.	4739.	5783.
150.	802.	1439.	1714.	2010.	2598.	2994.	3130.	3240.	3940.	4629.	5668.
175.	748.	1369.	1635.	1933.	2502.	2894.	3031.	3150.	3835.	4509.	5540.
200.	687.	1290.	1547.	1847.	2395.	2782.	2920.	3049.	3716.	4374.	5396.
225.	653.	1247.	1498.	1799.	2336.	2720.	2859.	2992.	3651.	4299.	5316.
250.	631.	1216.	1464.	1765.	2295.	2677.	2816.	2953.	3604.	4247.	5259.
275.	613.	1192.	1437.	1739.	2262.	2643.	2782.	2921.	3568.	4206.	5215.
300.	603.	1178.	1420.	1723.	2243.	2622.	2761.	2902.	3546.	4181.	5188.
350.	587.	1154.	1394.	1697.	2211.	2589.	2728.	2871.	3510.	4139.	5144.
400.	594.	1163.	1403.	1706.	2223.	2601.	2740.	2882.	3522.	4154.	5159.
500.	627.	1206.	1452.	1754.	2283.	2663.	2802.	2939.	3589.	4230.	5239.
600.	660.	1251.	1502.	1803.	2344.	2727.	2866.	2997.	3657.	4308.	5322.
700.	683.	1282.	1537.	1839.	2388.	2773.	2911.	3039.	3705.	4363.	5381.
800.	695.	1298.	1555.	1856.	2410.	2796.	2934.	3060.	3730.	4391.	5410.
900.	703.	1310.	1568.	1870.	2426.	2813.	2951.	3076.	3748.	4412.	5433.
1000.	710.	1320.	1579.	1881.	2439.	2827.	2965.	3089.	3763.	4429.	5451.
1250.	726.	1342.	1604.	1906.	2469.	2858.	2997.	3120.	3798.	4468.	5493.
1500.	735.	1353.	1617.	1919.	2485.	2875.	3014.	3137.	3817.	4489.	5517.
1750.	738.	1358.	1622.	1926.	2492.	2883.	3022.	3146.	3827.	4498.	5528.
2000.	741.	1363.	1627.	1931.	2498.	2890.	3029.	3153.	3835.	4507.	5538.
2500.	744.	1366.	1631.	1936.	2502.	2895.	3034.	3159.	3841.	4513.	5545.
3000.	743.	1365.	1630.	1935.	2501.	2894.	3033.	3160.	3841.	4513.	5545.
3500.	741.	1363.	1627.	1932.	2497.	2890.	3030.	3157.	3837.	4508.	5541.
4000.	737.	1357.	1621.	1927.	2490.	2883.	3023.	3150.	3830.	4500.	5532.
5000.	730.	1349.	1612.	1918.	2479.	2871.	3011.	3140.	3818.	4486.	5517.
6000.	727.	1344.	1606.	1913.	2473.	2865.	3005.	3134.	3811.	4478.	5508.
7000.	724.	1341.	1602.	1909.	2468.	2859.	2999.	3129.	3805.	4472.	5502.
8000.	722.	1338.	1598.	1905.	2464.	2855.	2995.	3125.	3801.	4466.	5496.
9000.	720.	1335.	1595.	1903.	2460.	2851.	2991.	3123.	3797.	4462.	5492.
10000.	718.	1333.	1593.	1900.	2457.	2848.	2988.	3120.	3794.	4459.	5488.
12500.	714.	1328.	1587.	1896.	2451.	2842.	2983.	3116.	3789.	4452.	5482.
15000.	712.	1325.	1584.	1894.	2447.	2839.	2980.	3115.	3786.	4448.	5478.
17500.	709.	1322.	1580.	1891.	2443.	2835.	2976.	3112.	3783.	4444.	5474.
20000.	707.	1320.	1578.	1889.	2440.	2832.	2973.	3110.	3780.	4441.	5471.
22500.	706.	1318.	1576.	1888.	2439.	2830.	2972.	3109.	3779.	4439.	5469.

TABLE 9. - BORON-NUCLEUS ABSORPTION CROSS SECTION

Boron-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	709.	1131.	1321.	1452.	1885.	2095.	2147.	2115.	2565.	3013.	3552.
50.	577.	956.	1124.	1262.	1632.	1838.	1898.	1906.	2313.	2715.	3247.
75.	519.	879.	1037.	1178.	1523.	1726.	1789.	1813.	2200.	2583.	3112.
100.	475.	820.	970.	1113.	1439.	1640.	1705.	1740.	2114.	2482.	3007.
125.	449.	785.	931.	1076.	1392.	1591.	1657.	1697.	2063.	2424.	2946.
150.	434.	765.	908.	1053.	1363.	1562.	1628.	1672.	2033.	2389.	2909.
175.	422.	748.	890.	1036.	1341.	1539.	1605.	1652.	2009.	2362.	2881.
200.	412.	736.	875.	1022.	1323.	1521.	1587.	1636.	1991.	2340.	2858.
225.	405.	726.	865.	1012.	1310.	1507.	1574.	1624.	1977.	2324.	2841.
250.	400.	719.	857.	1004.	1301.	1497.	1564.	1616.	1967.	2313.	2829.
275.	397.	715.	852.	1000.	1295.	1491.	1558.	1611.	1961.	2306.	2822.
300.	395.	713.	850.	997.	1292.	1488.	1556.	1608.	1958.	2302.	2818.
350.	393.	709.	846.	994.	1287.	1483.	1551.	1604.	1953.	2296.	2812.
400.	400.	719.	857.	1004.	1301.	1497.	1565.	1617.	1968.	2314.	2830.
500.	420.	746.	887.	1035.	1339.	1537.	1604.	1652.	2009.	2361.	2880.
600.	438.	771.	915.	1061.	1372.	1571.	1638.	1683.	2045.	2403.	2924.
700.	451.	787.	933.	1080.	1396.	1595.	1662.	1704.	2070.	2432.	2954.
800.	457.	795.	942.	1088.	1406.	1607.	1673.	1715.	2082.	2445.	2968.
900.	461.	800.	948.	1094.	1413.	1614.	1680.	1721.	2090.	2454.	2977.
1000.	463.	804.	952.	1098.	1418.	1619.	1685.	1726.	2095.	2460.	2984.
1250.	468.	810.	959.	1106.	1427.	1629.	1695.	1735.	2106.	2472.	2997.
1500.	471.	814.	962.	1110.	1431.	1633.	1700.	1740.	2111.	2477.	3003.
1750.	471.	815.	963.	1111.	1433.	1634.	1701.	1742.	2113.	2479.	3005.
2000.	472.	815.	964.	1112.	1433.	1635.	1702.	1744.	2114.	2480.	3006.
2500.	472.	815.	963.	1112.	1432.	1635.	1702.	1744.	2114.	2480.	3007.
3000.	471.	814.	962.	1111.	1431.	1633.	1700.	1743.	2113.	2478.	3005.
3500.	469.	812.	960.	1109.	1428.	1630.	1698.	1741.	2111.	2475.	3002.
4000.	468.	810.	957.	1106.	1425.	1628.	1695.	1739.	2108.	2472.	2999.
5000.	465.	807.	954.	1103.	1421.	1623.	1691.	1735.	2103.	2466.	2993.
6000.	464.	805.	952.	1101.	1419.	1621.	1688.	1733.	2101.	2464.	2990.
7000.	463.	804.	951.	1100.	1418.	1620.	1687.	1732.	2100.	2462.	2989.
8000.	463.	804.	951.	1100.	1417.	1619.	1686.	1732.	2099.	2462.	2988.
9000.	463.	804.	950.	1100.	1417.	1619.	1686.	1732.	2099.	2462.	2988.
10000.	463.	804.	950.	1100.	1417.	1619.	1687.	1733.	2099.	2462.	2989.
12500.	463.	804.	950.	1101.	1417.	1619.	1687.	1734.	2100.	2462.	2990.
15000.	463.	804.	951.	1101.	1417.	1620.	1688.	1735.	2102.	2463.	2991.
17500.	463.	804.	950.	1102.	1417.	1620.	1688.	1736.	2102.	2464.	2992.
20000.	463.	804.	950.	1102.	1417.	1620.	1688.	1737.	2103.	2464.	2992.
22500.	464.	804.	951.	1103.	1417.	1620.	1689.	1738.	2104.	2465.	2993.

TABLE 10. - CARBON-NUCLEUS TOTAL CROSS SECTION

Carbon-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1275.	2073.	2431.	2696.	3498.	3912.	4024.	3997.	4855.	5706.	6773.
50.	1089.	1824.	2148.	2425.	3135.	3544.	3668.	3702.	4495.	5279.	6337.
75.	1001.	1707.	2016.	2298.	2969.	3374.	3503.	3562.	4325.	5080.	6133.
100.	927.	1607.	1903.	2190.	2829.	3230.	3362.	3441.	4180.	4910.	5958.
125.	874.	1534.	1821.	2111.	2728.	3126.	3260.	3352.	4074.	4787.	5829.
150.	827.	1471.	1750.	2042.	2641.	3036.	3172.	3273.	3981.	4680.	5717.
175.	775.	1401.	1672.	1967.	2546.	2938.	3074.	3186.	3878.	4562.	5592.
200.	714.	1324.	1584.	1881.	2440.	2827.	2965.	3086.	3762.	4429.	5450.
225.	681.	1281.	1536.	1834.	2382.	2767.	2904.	3031.	3697.	4355.	5372.
250.	658.	1251.	1502.	1801.	2341.	2724.	2862.	2992.	3652.	4303.	5316.
275.	641.	1227.	1475.	1775.	2309.	2690.	2828.	2961.	3616.	4262.	5272.
300.	630.	1213.	1459.	1759.	2289.	2669.	2808.	2942.	3594.	4237.	5245.
350.	614.	1189.	1433.	1734.	2258.	2636.	2775.	2912.	3558.	4196.	5202.
400.	621.	1197.	1442.	1743.	2269.	2648.	2786.	2922.	3570.	4210.	5216.
500.	653.	1240.	1490.	1790.	2328.	2709.	2847.	2977.	3635.	4284.	5295.
600.	686.	1284.	1540.	1838.	2389.	2773.	2910.	3034.	3701.	4360.	5376.
700.	709.	1316.	1575.	1873.	2432.	2817.	2954.	3075.	3749.	4414.	5433.
800.	721.	1331.	1593.	1891.	2453.	2840.	2977.	3096.	3773.	4442.	5462.
900.	729.	1343.	1606.	1904.	2469.	2857.	2994.	3111.	3791.	4462.	5485.
1000.	736.	1353.	1616.	1915.	2483.	2871.	3008.	3125.	3806.	4479.	5503.
1250.	753.	1375.	1641.	1940.	2513.	2903.	3040.	3155.	3841.	4518.	5545.
1500.	761.	1387.	1654.	1953.	2529.	2920.	3057.	3173.	3861.	4540.	5568.
1750.	765.	1392.	1660.	1960.	2536.	2928.	3065.	3181.	3870.	4550.	5580.
2000.	768.	1396.	1665.	1966.	2542.	2934.	3072.	3189.	3878.	4558.	5590.
2500.	770.	1400.	1668.	1970.	2547.	2940.	3078.	3195.	3885.	4565.	5598.
3000.	770.	1399.	1668.	1970.	2546.	2939.	3077.	3196.	3885.	4565.	5598.
3500.	768.	1396.	1664.	1967.	2542.	2935.	3074.	3193.	3882.	4561.	5594.
4000.	764.	1391.	1659.	1962.	2535.	2928.	3067.	3187.	3874.	4552.	5585.
5000.	758.	1383.	1650.	1953.	2524.	2917.	3055.	3177.	3862.	4539.	5570.
6000.	754.	1379.	1644.	1948.	2518.	2910.	3049.	3171.	3855.	4530.	5562.
7000.	751.	1375.	1640.	1944.	2513.	2905.	3044.	3166.	3850.	4524.	5555.
8000.	749.	1372.	1637.	1941.	2508.	2900.	3039.	3162.	3845.	4519.	5550.
9000.	747.	1369.	1634.	1938.	2505.	2897.	3036.	3160.	3842.	4515.	5546.
10000.	745.	1367.	1631.	1936.	2502.	2894.	3033.	3158.	3839.	4512.	5542.
12500.	742.	1363.	1626.	1932.	2496.	2888.	3028.	3154.	3835.	4505.	5536.
15000.	739.	1360.	1623.	1930.	2493.	2885.	3025.	3153.	3832.	4502.	5533.
17500.	737.	1357.	1620.	1927.	2489.	2881.	3022.	3151.	3829.	4498.	5530.
20000.	735.	1355.	1617.	1925.	2486.	2878.	3019.	3149.	3827.	4495.	5527.
22500.	734.	1354.	1616.	1924.	2484.	2877.	3018.	3148.	3826.	4493.	5525.

TABLE 11. - CARBON-NUCLEUS ABSORPTION CROSS SECTION

Carbon-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	714.	1138.	1330.	1458.	1900.	2108.	2159.	2117.	2574.	3029.	3564.
50.	585.	967.	1136.	1272.	1649.	1854.	1913.	1915.	2326.	2734.	3264.
75.	529.	891.	1051.	1190.	1541.	1744.	1806.	1824.	2216.	2605.	3131.
100.	486.	833.	985.	1127.	1459.	1660.	1724.	1753.	2131.	2506.	3028.
125.	460.	799.	947.	1090.	1412.	1611.	1676.	1712.	2082.	2448.	2968.
150.	445.	779.	925.	1068.	1384.	1582.	1648.	1687.	2052.	2414.	2932.
175.	433.	763.	906.	1051.	1362.	1559.	1625.	1667.	2029.	2386.	2904.
200.	424.	751.	893.	1037.	1344.	1541.	1608.	1652.	2011.	2365.	2882.
225.	417.	741.	882.	1027.	1331.	1528.	1594.	1640.	1997.	2349.	2865.
250.	412.	735.	874.	1020.	1322.	1518.	1585.	1632.	1987.	2338.	2853.
275.	409.	731.	870.	1015.	1316.	1512.	1579.	1627.	1981.	2331.	2846.
300.	407.	728.	867.	1013.	1313.	1509.	1576.	1624.	1978.	2327.	2842.
350.	405.	725.	863.	1009.	1308.	1505.	1571.	1621.	1973.	2321.	2836.
400.	412.	735.	874.	1020.	1322.	1518.	1585.	1633.	1988.	2338.	2854.
500.	432.	762.	904.	1050.	1359.	1557.	1623.	1667.	2028.	2384.	2902.
600.	450.	785.	931.	1076.	1392.	1591.	1657.	1697.	2063.	2425.	2945.
700.	462.	802.	950.	1094.	1415.	1615.	1680.	1718.	2087.	2453.	2975.
800.	468.	810.	958.	1102.	1426.	1626.	1691.	1727.	2099.	2466.	2989.
900.	472.	815.	964.	1108.	1433.	1633.	1698.	1734.	2107.	2475.	2998.
1000.	475.	818.	968.	1112.	1437.	1638.	1703.	1739.	2112.	2481.	3005.
1250.	480.	825.	975.	1120.	1447.	1648.	1713.	1748.	2123.	2493.	3017.
1500.	482.	828.	979.	1124.	1451.	1652.	1718.	1753.	2128.	2499.	3024.
1750.	483.	829.	980.	1125.	1452.	1654.	1719.	1756.	2130.	2501.	3026.
2000.	483.	830.	980.	1126.	1453.	1654.	1720.	1757.	2132.	2502.	3028.
2500.	483.	829.	980.	1126.	1452.	1654.	1720.	1758.	2132.	2502.	3028.
3000.	482.	828.	979.	1125.	1451.	1653.	1719.	1757.	2131.	2500.	3027.
3500.	481.	827.	977.	1123.	1448.	1650.	1717.	1755.	2129.	2497.	3024.
4000.	480.	825.	974.	1121.	1445.	1647.	1714.	1753.	2126.	2494.	3020.
5000.	477.	822.	971.	1118.	1441.	1643.	1709.	1749.	2121.	2489.	3015.
6000.	476.	820.	969.	1116.	1439.	1641.	1707.	1747.	2119.	2486.	3012.
7000.	475.	819.	968.	1115.	1438.	1640.	1706.	1746.	2118.	2485.	3011.
8000.	475.	819.	968.	1115.	1437.	1639.	1705.	1746.	2117.	2484.	3010.
9000.	475.	819.	967.	1115.	1437.	1639.	1705.	1746.	2117.	2484.	3010.
10000.	475.	819.	967.	1115.	1437.	1639.	1706.	1747.	2118.	2484.	3011.
12500.	475.	819.	968.	1116.	1437.	1639.	1706.	1748.	2119.	2485.	3012.
15000.	476.	819.	968.	1117.	1437.	1640.	1707.	1750.	2120.	2486.	3013.
17500.	476.	819.	968.	1117.	1437.	1640.	1707.	1751.	2121.	2486.	3014.
20000.	476.	819.	968.	1117.	1437.	1640.	1708.	1751.	2121.	2487.	3015.
22500.	476.	820.	968.	1118.	1438.	1641.	1709.	1752.	2122.	2488.	3016.

TABLE 12. - NITROGEN-NUCLEUS TOTAL CROSS SECTION

Nitrogen-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1397.	2231.	2602.	2879.	3706.	4133.	4249.	4227.	5105.	5976.	7069.
50.	1198.	1969.	2306.	2595.	3330.	3752.	3880.	3917.	4731.	5535.	6620.
75.	1105.	1845.	2168.	2462.	3157.	3575.	3708.	3770.	4555.	5329.	6408.
100.	1025.	1741.	2050.	2349.	3012.	3426.	3563.	3644.	4405.	5155.	6227.
125.	968.	1664.	1964.	2266.	2907.	3319.	3457.	3551.	4295.	5028.	6095.
150.	919.	1598.	1890.	2195.	2817.	3225.	3365.	3469.	4199.	4917.	5979.
175.	863.	1525.	1808.	2115.	2719.	3123.	3264.	3378.	4092.	4795.	5851.
200.	799.	1443.	1717.	2027.	2609.	3009.	3151.	3275.	3972.	4658.	5705.
225.	763.	1399.	1667.	1978.	2549.	2947.	3088.	3218.	3905.	4583.	5625.
250.	738.	1367.	1631.	1943.	2507.	2902.	3045.	3178.	3859.	4530.	5568.
275.	719.	1342.	1604.	1916.	2473.	2868.	3010.	3146.	3822.	4487.	5523.
300.	708.	1327.	1587.	1899.	2453.	2846.	2989.	3126.	3799.	4462.	5496.
350.	690.	1303.	1560.	1873.	2420.	2812.	2955.	3095.	3763.	4420.	5451.
400.	697.	1311.	1569.	1882.	2432.	2825.	2967.	3106.	3775.	4435.	5466.
500.	732.	1356.	1619.	1931.	2493.	2888.	3030.	3163.	3842.	4511.	5547.
600.	767.	1402.	1671.	1982.	2556.	2953.	3094.	3222.	3910.	4589.	5630.
700.	792.	1435.	1708.	2018.	2601.	3000.	3140.	3264.	3959.	4645.	5689.
800.	804.	1452.	1726.	2037.	2623.	3023.	3164.	3285.	3984.	4673.	5719.
900.	813.	1464.	1740.	2050.	2640.	3041.	3181.	3302.	4003.	4694.	5741.
1000.	821.	1474.	1751.	2062.	2653.	3055.	3195.	3315.	4019.	4711.	5760.
1250.	838.	1497.	1777.	2088.	2685.	3088.	3229.	3347.	4055.	4752.	5804.
1500.	848.	1509.	1790.	2102.	2701.	3105.	3246.	3365.	4074.	4773.	5827.
1750.	852.	1515.	1796.	2109.	2708.	3113.	3255.	3374.	4084.	4784.	5839.
2000.	855.	1520.	1801.	2114.	2715.	3120.	3262.	3382.	4092.	4792.	5849.
2500.	858.	1523.	1805.	2119.	2719.	3126.	3268.	3388.	4099.	4799.	5857.
3000.	857.	1523.	1804.	2119.	2719.	3125.	3267.	3389.	4099.	4799.	5857.
3500.	855.	1520.	1801.	2116.	2715.	3121.	3264.	3386.	4096.	4795.	5853.
4000.	850.	1514.	1795.	2110.	2708.	3114.	3256.	3379.	4088.	4786.	5844.
5000.	844.	1506.	1786.	2101.	2696.	3102.	3245.	3369.	4076.	4772.	5829.
6000.	840.	1501.	1780.	2096.	2690.	3095.	3238.	3363.	4068.	4764.	5820.
7000.	837.	1497.	1776.	2092.	2684.	3090.	3233.	3358.	4063.	4757.	5813.
8000.	834.	1494.	1772.	2088.	2680.	3085.	3228.	3354.	4058.	4752.	5808.
9000.	832.	1491.	1769.	2085.	2676.	3082.	3225.	3351.	4055.	4748.	5804.
10000.	830.	1489.	1766.	2083.	2673.	3078.	3222.	3349.	4052.	4744.	5800.
12500.	827.	1484.	1761.	2079.	2668.	3073.	3216.	3345.	4047.	4738.	5794.
15000.	824.	1482.	1758.	2077.	2664.	3069.	3213.	3344.	4044.	4734.	5791.
17500.	821.	1479.	1754.	2074.	2660.	3066.	3210.	3342.	4041.	4730.	5787.
20000.	819.	1476.	1751.	2072.	2657.	3063.	3207.	3340.	4039.	4727.	5784.
22500.	818.	1475.	1750.	2071.	2655.	3061.	3206.	3339.	4038.	4725.	5783.

TABLE 13. - NITROGEN-NUCLEUS ABSORPTION CROSS SECTION

Nitrogen-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	780.	1222.	1421.	1555.	2009.	2224.	2276.	2238.	2705.	3169.	3718.
50.	643.	1042.	1218.	1360.	1750.	1961.	2022.	2026.	2447.	2865.	3408.
75.	583.	963.	1120.	1274.	1638.	1847.	1911.	1930.	2333.	2732.	3271.
100.	536.	902.	1060.	1208.	1553.	1760.	1825.	1857.	2245.	2630.	3165.
125.	509.	866.	1021.	1170.	1504.	1709.	1776.	1813.	2194.	2570.	3103.
150.	493.	845.	997.	1147.	1474.	1679.	1747.	1788.	2164.	2535.	3066.
175.	480.	828.	978.	1129.	1451.	1656.	1723.	1767.	2139.	2507.	3037.
200.	471.	815.	963.	1114.	1434.	1637.	1705.	1751.	2121.	2485.	3015.
225.	463.	805.	952.	1104.	1420.	1623.	1692.	1739.	2106.	2469.	2997.
250.	458.	798.	944.	1096.	1410.	1613.	1682.	1730.	2096.	2457.	2985.
275.	454.	794.	939.	1091.	1404.	1607.	1676.	1725.	2090.	2449.	2977.
300.	453.	792.	937.	1089.	1401.	1604.	1673.	1723.	2087.	2446.	2974.
350.	450.	788.	933.	1085.	1396.	1599.	1668.	1718.	2082.	2440.	2968.
400.	458.	798.	944.	1096.	1410.	1613.	1682.	1731.	2097.	2457.	2986.
500.	479.	826.	976.	1127.	1449.	1653.	1721.	1766.	2138.	2504.	3035.
600.	498.	851.	1004.	1155.	1483.	1689.	1756.	1798.	2175.	2546.	3079.
700.	511.	869.	1023.	1173.	1507.	1713.	1780.	1819.	2200.	2575.	3110.
800.	517.	877.	1032.	1182.	1518.	1724.	1792.	1830.	2212.	2589.	3124.
900.	521.	882.	1038.	1188.	1525.	1732.	1799.	1836.	2220.	2598.	3134.
1000.	524.	886.	1042.	1192.	1530.	1737.	1804.	1842.	2225.	2604.	3141.
1250.	530.	893.	1050.	1200.	1539.	1747.	1814.	1851.	2236.	2616.	3153.
1500.	532.	896.	1053.	1204.	1544.	1752.	1819.	1856.	2242.	2622.	3160.
1750.	533.	897.	1054.	1206.	1545.	1753.	1821.	1859.	2244.	2624.	3163.
2000.	533.	898.	1055.	1207.	1545.	1754.	1822.	1860.	2245.	2625.	3164.
2500.	533.	897.	1054.	1207.	1545.	1754.	1822.	1861.	2246.	2625.	3164.
3000.	532.	896.	1053.	1206.	1543.	1752.	1820.	1860.	2244.	2624.	3163.
3500.	531.	895.	1051.	1204.	1541.	1750.	1818.	1858.	2242.	2621.	3160.
4000.	529.	892.	1049.	1202.	1538.	1747.	1815.	1856.	2239.	2617.	3156.
5000.	527.	889.	1045.	1198.	1534.	1742.	1810.	1852.	2234.	2612.	3151.
6000.	525.	887.	1043.	1196.	1531.	1740.	1808.	1850.	2232.	2609.	3148.
7000.	525.	887.	1042.	1195.	1530.	1739.	1807.	1849.	2231.	2608.	3146.
8000.	524.	886.	1042.	1195.	1529.	1738.	1806.	1848.	2230.	2607.	3146.
9000.	524.	886.	1041.	1195.	1529.	1738.	1806.	1848.	2230.	2607.	3146.
10000.	524.	886.	1041.	1195.	1529.	1738.	1807.	1849.	2231.	2607.	3146.
12500.	525.	886.	1042.	1196.	1529.	1738.	1807.	1850.	2232.	2608.	3148.
15000.	525.	887.	1042.	1197.	1530.	1739.	1808.	1852.	2233.	2609.	3149.
17500.	525.	887.	1042.	1197.	1530.	1739.	1808.	1853.	2234.	2609.	3150.
20000.	525.	887.	1042.	1197.	1530.	1739.	1808.	1854.	2234.	2610.	3150.
22500.	525.	887.	1042.	1198.	1530.	1740.	1809.	1855.	2235.	2611.	3152.

TABLE 14. - OXYGEN-NUCLEUS TOTAL CROSS SECTION

Oxygen-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1549.	2424.	2809.	3104.	3955.	4398.	4521.	4509.	5409.	6300.	7427.
50.	1332.	2144.	2496.	2803.	3561.	4000.	4134.	4181.	5017.	5841.	6959.
75.	1231.	2013.	2349.	2661.	3380.	3815.	3954.	4025.	4832.	5626.	6738.
100.	1144.	1900.	2224.	2541.	3227.	3658.	3801.	3891.	4674.	5444.	6549.
125.	1081.	1818.	2132.	2453.	3117.	3545.	3689.	3792.	4558.	5311.	6411.
150.	1027.	1748.	2053.	2376.	3022.	3447.	3593.	3706.	4457.	5196.	6290.
175.	967.	1669.	1967.	2292.	2919.	3340.	3487.	3609.	4345.	5069.	6156.
200.	896.	1582.	1870.	2197.	2803.	3220.	3368.	3500.	4219.	4926.	6004.
225.	856.	1534.	1816.	2145.	2740.	3154.	3302.	3440.	4150.	4847.	5920.
250.	829.	1500.	1779.	2109.	2695.	3108.	3256.	3397.	4100.	4791.	5861.
275.	807.	1474.	1749.	2080.	2660.	3071.	3219.	3364.	4062.	4747.	5814.
300.	795.	1457.	1731.	2062.	2639.	3049.	3197.	3343.	4038.	4721.	5786.
350.	774.	1431.	1702.	2034.	2605.	3013.	3162.	3310.	4000.	4678.	5740.
400.	782.	1440.	1712.	2044.	2617.	3026.	3174.	3321.	4013.	4692.	5755.
500.	820.	1488.	1765.	2096.	2681.	3092.	3240.	3382.	4083.	4772.	5839.
600.	859.	1538.	1820.	2150.	2747.	3161.	3308.	3444.	4155.	4853.	5925.
700.	886.	1573.	1859.	2188.	2794.	3209.	3356.	3488.	4206.	4911.	5987.
800.	900.	1591.	1879.	2207.	2818.	3234.	3381.	3511.	4232.	4941.	6018.
900.	910.	1604.	1893.	2222.	2835.	3252.	3399.	3528.	4251.	4962.	6042.
1000.	918.	1614.	1905.	2234.	2849.	3267.	3414.	3542.	4268.	4980.	6061.
1250.	937.	1639.	1932.	2261.	2882.	3302.	3448.	3576.	4305.	5022.	6106.
1500.	947.	1652.	1946.	2276.	2899.	3320.	3467.	3594.	4326.	5044.	6130.
1750.	951.	1658.	1953.	2283.	2907.	3328.	3476.	3603.	4336.	5055.	6142.
2000.	955.	1663.	1958.	2289.	2913.	3335.	3483.	3611.	4344.	5064.	6153.
2500.	958.	1666.	1962.	2294.	2918.	3341.	3489.	3618.	4351.	5071.	6161.
3000.	957.	1665.	1961.	2294.	2917.	3340.	3488.	3618.	4351.	5071.	6161.
3500.	954.	1662.	1957.	2291.	2913.	3336.	3484.	3615.	4347.	5066.	6156.
4000.	950.	1657.	1951.	2285.	2905.	3328.	3477.	3608.	4339.	5057.	6146.
5000.	943.	1648.	1941.	2275.	2894.	3316.	3464.	3597.	4326.	5042.	6131.
6000.	938.	1642.	1935.	2269.	2887.	3308.	3457.	3591.	4319.	5034.	6122.
7000.	935.	1638.	1931.	2265.	2881.	3303.	3452.	3585.	4313.	5027.	6115.
8000.	932.	1635.	1927.	2261.	2876.	3298.	3447.	3581.	4308.	5021.	6109.
9000.	930.	1632.	1923.	2258.	2873.	3294.	3443.	3578.	4304.	5017.	6105.
10000.	927.	1629.	1920.	2256.	2869.	3291.	3440.	3576.	4301.	5013.	6101.
12500.	923.	1624.	1915.	2251.	2863.	3285.	3434.	3572.	4296.	5006.	6094.
15000.	920.	1621.	1911.	2248.	2859.	3281.	3431.	3570.	4293.	5003.	6091.
17500.	917.	1618.	1907.	2245.	2855.	3277.	3427.	3567.	4289.	4998.	6087.
20000.	915.	1615.	1904.	2243.	2851.	3274.	3424.	3565.	4287.	4995.	6083.
22500.	913.	1613.	1903.	2242.	2850.	3272.	3423.	3565.	4285.	4993.	6082.

TABLE 15. - OXYGEN-NUCLEUS ABSORPTION CROSS SECTION

Oxygen-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	862.	1326.	1532.	1674.	2140.	2363.	2419.	2386.	2863.	3338.	3904.
50.	714.	1134.	1317.	1468.	1869.	2089.	2153.	2161.	2594.	3022.	3582.
75.	648.	1049.	1222.	1376.	1752.	1969.	2036.	2061.	2475.	2883.	3439.
100.	597.	984.	1149.	1306.	1662.	1878.	1947.	1982.	2382.	2776.	3328.
125.	568.	946.	1107.	1265.	1611.	1825.	1895.	1937.	2328.	2714.	3264.
150.	550.	923.	1082.	1241.	1580.	1793.	1864.	1909.	2296.	2677.	3225.
175.	536.	905.	1062.	1221.	1556.	1768.	1839.	1887.	2271.	2648.	3195.
200.	525.	891.	1046.	1206.	1537.	1749.	1820.	1871.	2251.	2626.	3171.
225.	517.	881.	1034.	1195.	1523.	1734.	1806.	1858.	2236.	2608.	3153.
250.	511.	873.	1026.	1187.	1513.	1724.	1795.	1849.	2225.	2596.	3140.
275.	508.	868.	1021.	1182.	1506.	1717.	1789.	1843.	2219.	2588.	3132.
300.	506.	866.	1018.	1179.	1503.	1714.	1786.	1840.	2215.	2584.	3128.
350.	503.	862.	1014.	1175.	1498.	1709.	1781.	1836.	2210.	2578.	3122.
400.	511.	873.	1026.	1187.	1513.	1724.	1796.	1849.	2226.	2596.	3141.
500.	535.	903.	1059.	1220.	1553.	1766.	1837.	1887.	2269.	2645.	3193.
600.	555.	930.	1089.	1249.	1589.	1803.	1874.	1920.	2307.	2689.	3239.
700.	570.	948.	1109.	1269.	1614.	1828.	1899.	1942.	2334.	2719.	3270.
800.	576.	957.	1119.	1278.	1625.	1840.	1911.	1953.	2346.	2734.	3285.
900.	581.	962.	1125.	1284.	1633.	1848.	1918.	1960.	2355.	2743.	3295.
1000.	584.	966.	1129.	1289.	1638.	1854.	1924.	1966.	2361.	2749.	3302.
1250.	589.	973.	1137.	1297.	1648.	1864.	1934.	1976.	2372.	2762.	3315.
1500.	592.	977.	1141.	1301.	1652.	1869.	1939.	1981.	2378.	2768.	3322.
1750.	593.	978.	1142.	1303.	1654.	1870.	1941.	1983.	2380.	2770.	3325.
2000.	593.	978.	1143.	1303.	1654.	1871.	1942.	1984.	2381.	2771.	3326.
2500.	593.	978.	1142.	1303.	1654.	1871.	1942.	1985.	2381.	2771.	3326.
3000.	592.	977.	1141.	1302.	1652.	1869.	1940.	1984.	2380.	2769.	3324.
3500.	590.	975.	1138.	1300.	1649.	1866.	1937.	1982.	2377.	2766.	3321.
4000.	589.	973.	1136.	1298.	1646.	1863.	1934.	1979.	2374.	2762.	3318.
5000.	586.	969.	1132.	1294.	1641.	1858.	1930.	1975.	2369.	2757.	3312.
6000.	584.	967.	1130.	1292.	1639.	1856.	1927.	1973.	2367.	2754.	3309.
7000.	584.	966.	1129.	1291.	1638.	1854.	1926.	1972.	2365.	2752.	3307.
8000.	583.	966.	1128.	1291.	1637.	1854.	1925.	1972.	2365.	2751.	3306.
9000.	583.	966.	1128.	1291.	1637.	1854.	1925.	1972.	2365.	2751.	3307.
10000.	583.	966.	1128.	1291.	1637.	1854.	1925.	1972.	2365.	2752.	3307.
12500.	583.	966.	1128.	1291.	1637.	1854.	1926.	1974.	2366.	2752.	3308.
15000.	583.	966.	1128.	1292.	1637.	1855.	1927.	1975.	2367.	2753.	3310.
17500.	583.	966.	1128.	1292.	1637.	1855.	1927.	1976.	2368.	2753.	3310.
20000.	583.	966.	1128.	1293.	1637.	1855.	1927.	1977.	2368.	2754.	3311.
22500.	584.	967.	1129.	1293.	1638.	1855.	1928.	1978.	2370.	2755.	3312.

TABLE 16. - NEON-NUCLEUS TOTAL CROSS SECTION

Neon-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1669.	2580.	2979.	3281.	4165.	4618.	4741.	4722.	5647.	6563.	7710.
50.	1445.	2292.	2658.	2970.	3762.	4209.	4344.	4382.	5243.	6093.	7229.
75.	1340.	2157.	2508.	2825.	3576.	4020.	4160.	4222.	5054.	5874.	7004.
100.	1252.	2043.	2381.	2702.	3421.	3861.	4004.	4085.	4894.	5689.	6812.
125.	1188.	1960.	2288.	2612.	3308.	3746.	3891.	3985.	4776.	5554.	6672.
150.	1132.	1888.	2208.	2535.	3212.	3647.	3793.	3897.	4675.	5438.	6550.
175.	1071.	1809.	2121.	2450.	3108.	3539.	3686.	3801.	4562.	5310.	6416.
200.	1001.	1721.	2023.	2355.	2992.	3418.	3567.	3692.	4436.	5167.	6265.
225.	962.	1672.	1969.	2303.	2928.	3352.	3501.	3631.	4367.	5088.	6181.
250.	934.	1638.	1931.	2266.	2883.	3305.	3455.	3589.	4318.	5033.	6123.
275.	912.	1611.	1901.	2237.	2847.	3269.	3418.	3555.	4279.	4989.	6076.
300.	899.	1595.	1883.	2219.	2826.	3246.	3396.	3535.	4255.	4962.	6048.
350.	878.	1569.	1854.	2191.	2792.	3211.	3361.	3502.	4217.	4920.	6002.
400.	885.	1578.	1864.	2201.	2804.	3224.	3373.	3514.	4231.	4935.	6018.
500.	924.	1627.	1918.	2254.	2869.	3291.	3440.	3575.	4301.	5014.	6102.
600.	963.	1677.	1974.	2308.	2936.	3360.	3509.	3637.	4374.	5097.	6189.
700.	991.	1712.	2014.	2347.	2984.	3409.	3557.	3682.	4425.	5155.	6251.
800.	1005.	1730.	2034.	2367.	3008.	3434.	3582.	3705.	4452.	5185.	6282.
900.	1016.	1744.	2048.	2382.	3025.	3453.	3601.	3723.	4471.	5207.	6306.
1000.	1024.	1755.	2060.	2394.	3040.	3468.	3616.	3737.	4488.	5225.	6325.
1250.	1044.	1780.	2088.	2422.	3073.	3503.	3651.	3771.	4525.	5267.	6371.
1500.	1054.	1793.	2102.	2437.	3090.	3521.	3670.	3789.	4546.	5290.	6395.
1750.	1059.	1799.	2109.	2445.	3098.	3530.	3679.	3799.	4557.	5301.	6408.
2000.	1063.	1805.	2115.	2451.	3105.	3538.	3686.	3807.	4565.	5310.	6418.
2500.	1066.	1808.	2119.	2456.	3110.	3543.	3692.	3814.	4572.	5317.	6426.
3000.	1065.	1808.	2118.	2456.	3109.	3542.	3692.	3814.	4572.	5317.	6427.
3500.	1063.	1805.	2115.	2452.	3105.	3538.	3688.	3811.	4569.	5312.	6422.
4000.	1058.	1799.	2108.	2446.	3098.	3531.	3680.	3804.	4561.	5303.	6412.
5000.	1051.	1790.	2098.	2437.	3086.	3518.	3668.	3793.	4548.	5288.	6397.
6000.	1046.	1784.	2092.	2431.	3079.	3511.	3661.	3787.	4540.	5280.	6388.
7000.	1043.	1780.	2087.	2426.	3073.	3505.	3655.	3782.	4534.	5273.	6381.
8000.	1040.	1777.	2083.	2423.	3068.	3500.	3651.	3778.	4529.	5268.	6375.
9000.	1038.	1774.	2080.	2420.	3065.	3497.	3647.	3775.	4526.	5263.	6371.
10000.	1036.	1771.	2077.	2417.	3062.	3493.	3644.	3772.	4523.	5260.	6367.
12500.	1031.	1767.	2072.	2413.	3055.	3488.	3638.	3769.	4518.	5253.	6361.
15000.	1028.	1764.	2069.	2411.	3052.	3484.	3635.	3767.	4515.	5250.	6358.
17500.	1026.	1761.	2065.	2408.	3048.	3480.	3632.	3765.	4512.	5246.	6354.
20000.	1023.	1758.	2062.	2406.	3045.	3477.	3629.	3763.	4510.	5242.	6351.
22500.	1022.	1757.	2061.	2405.	3043.	3476.	3628.	3762.	4509.	5241.	6350.

TABLE 17. - NEON-NUCLEUS ABSORPTION CROSS SECTION

Neon-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	927.	1407.	1621.	1768.	2250.	2478.	2534.	2499.	2988.	3475.	4051.
50.	772.	1210.	1400.	1554.	1972.	2196.	2261.	2265.	2711.	3151.	3720.
75.	704.	1123.	1304.	1460.	1852.	2074.	2141.	2162.	2588.	3009.	3574.
100.	653.	1056.	1229.	1388.	1761.	1981.	2050.	2082.	2494.	2901.	3462.
125.	622.	1018.	1186.	1347.	1708.	1927.	1997.	2035.	2440.	2838.	3397.
150.	604.	995.	1161.	1322.	1677.	1895.	1966.	2007.	2407.	2801.	3358.
175.	590.	976.	1140.	1302.	1653.	1870.	1941.	1985.	2382.	2771.	3328.
200.	579.	962.	1125.	1287.	1634.	1850.	1922.	1968.	2362.	2748.	3304.
225.	571.	951.	1113.	1276.	1619.	1836.	1907.	1955.	2346.	2731.	3286.
250.	565.	944.	1104.	1267.	1609.	1825.	1897.	1946.	2336.	2718.	3272.
275.	561.	939.	1099.	1262.	1602.	1818.	1891.	1941.	2329.	2711.	3265.
300.	559.	937.	1096.	1260.	1599.	1815.	1887.	1938.	2326.	2707.	3261.
350.	556.	933.	1092.	1256.	1594.	1810.	1882.	1933.	2320.	2701.	3254.
400.	565.	944.	1104.	1268.	1609.	1825.	1897.	1947.	2336.	2719.	3273.
500.	589.	974.	1138.	1301.	1650.	1867.	1939.	1985.	2380.	2769.	3325.
600.	610.	1002.	1168.	1330.	1686.	1905.	1976.	2018.	2419.	2813.	3372.
700.	625.	1020.	1189.	1351.	1712.	1931.	2002.	2041.	2446.	2844.	3404.
800.	631.	1029.	1199.	1360.	1723.	1943.	2014.	2052.	2458.	2858.	3419.
900.	636.	1035.	1205.	1367.	1731.	1951.	2022.	2060.	2467.	2867.	3429.
1000.	639.	1039.	1210.	1371.	1737.	1957.	2028.	2065.	2473.	2874.	3436.
1250.	645.	1046.	1218.	1380.	1747.	1967.	2038.	2075.	2484.	2887.	3450.
1500.	648.	1050.	1222.	1384.	1751.	1973.	2043.	2081.	2490.	2893.	3457.
1750.	649.	1051.	1223.	1386.	1753.	1974.	2045.	2083.	2492.	2895.	3459.
2000.	649.	1052.	1223.	1386.	1753.	1975.	2046.	2085.	2494.	2896.	3461.
2500.	649.	1052.	1223.	1387.	1753.	1974.	2046.	2085.	2494.	2896.	3461.
3000.	648.	1050.	1221.	1385.	1751.	1973.	2044.	2084.	2493.	2894.	3459.
3500.	646.	1048.	1219.	1383.	1748.	1970.	2042.	2082.	2490.	2891.	3456.
4000.	645.	1046.	1217.	1381.	1745.	1967.	2039.	2080.	2487.	2887.	3452.
5000.	642.	1043.	1213.	1377.	1740.	1962.	2034.	2075.	2482.	2882.	3447.
6000.	640.	1041.	1211.	1375.	1738.	1960.	2031.	2073.	2479.	2879.	3444.
7000.	640.	1040.	1210.	1374.	1737.	1958.	2030.	2072.	2478.	2877.	3442.
8000.	639.	1039.	1209.	1374.	1736.	1958.	2029.	2072.	2478.	2877.	3441.
9000.	639.	1039.	1209.	1374.	1736.	1957.	2029.	2072.	2478.	2877.	3441.
10000.	639.	1039.	1209.	1374.	1736.	1958.	2030.	2073.	2478.	2877.	3442.
12500.	639.	1040.	1209.	1375.	1736.	1958.	2030.	2074.	2479.	2878.	3443.
15000.	640.	1040.	1209.	1376.	1736.	1959.	2031.	2076.	2481.	2879.	3445.
17500.	640.	1040.	1209.	1376.	1736.	1959.	2031.	2076.	2481.	2879.	3445.
20000.	640.	1040.	1209.	1376.	1736.	1959.	2032.	2077.	2482.	2879.	3446.
22500.	640.	1041.	1210.	1377.	1737.	1960.	2033.	2078.	2483.	2881.	3447.

TABLE 18. - ALUMINUM-NUCLEUS TOTAL CROSS SECTION

Aluminum-nucleus total cross section, mb, for -

Energy MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1752.	2687.	3105.	3382.	4326.	4773.	4881.	4798.	5767.	6726.	7856.
50.	1547.	2420.	2803.	3094.	3936.	4381.	4505.	4493.	5392.	6279.	7407.
75.	1451.	2294.	2662.	2960.	3757.	4200.	4330.	4348.	5217.	6072.	7197.
100.	1369.	2187.	2541.	2845.	3607.	4048.	4183.	4225.	5068.	5896.	7018.
125.	1309.	2108.	2453.	2762.	3500.	3938.	4076.	4134.	4959.	5769.	6888.
150.	1256.	2040.	2377.	2689.	3407.	3844.	3984.	4054.	4864.	5659.	6774.
175.	1198.	1964.	2292.	2609.	3306.	3740.	3882.	3965.	4759.	5538.	6649.
200.	1131.	1879.	2198.	2519.	3194.	3625.	3769.	3865.	4641.	5403.	6507.
225.	1093.	1832.	2146.	2469.	3132.	3561.	3706.	3809.	4576.	5328.	6429.
250.	1067.	1799.	2109.	2434.	3089.	3517.	3662.	3770.	4530.	5276.	6374.
275.	1045.	1773.	2080.	2406.	3055.	3482.	3627.	3738.	4493.	5235.	6331.
300.	1032.	1757.	2062.	2389.	3034.	3460.	3606.	3720.	4471.	5210.	6304.
350.	1011.	1732.	2034.	2362.	3001.	3426.	3572.	3689.	4436.	5169.	6262.
400.	1017.	1741.	2044.	2372.	3014.	3439.	3585.	3700.	4449.	5184.	6277.
500.	1054.	1788.	2096.	2422.	3077.	3504.	3649.	3757.	4515.	5261.	6357.
600.	1092.	1836.	2150.	2475.	3142.	3571.	3715.	3816.	4584.	5340.	6439.
700.	1120.	1871.	2188.	2512.	3188.	3618.	3762.	3857.	4633.	5395.	6497.
800.	1134.	1888.	2208.	2531.	3212.	3643.	3786.	3879.	4658.	5424.	6527.
900.	1144.	1901.	2222.	2545.	3229.	3661.	3804.	3896.	4677.	5446.	6550.
1000.	1152.	1912.	2234.	2557.	3244.	3676.	3819.	3910.	4693.	5463.	6569.
1250.	1172.	1937.	2262.	2585.	3276.	3710.	3853.	3942.	4730.	5504.	6613.
1500.	1183.	1951.	2277.	2600.	3294.	3729.	3872.	3961.	4751.	5527.	6638.
1750.	1188.	1957.	2284.	2608.	3302.	3738.	3881.	3971.	4762.	5538.	6650.
2000.	1193.	1963.	2290.	2615.	3310.	3745.	3889.	3980.	4771.	5548.	6661.
2500.	1196.	1968.	2295.	2620.	3315.	3752.	3896.	3987.	4779.	5556.	6670.
3000.	1196.	1967.	2294.	2621.	3315.	3751.	3896.	3989.	4779.	5556.	6671.
3500.	1194.	1965.	2291.	2618.	3311.	3748.	3893.	3986.	4776.	5552.	6667.
4000.	1190.	1959.	2285.	2612.	3304.	3740.	3885.	3980.	4769.	5543.	6658.
5000.	1183.	1950.	2275.	2603.	3292.	3729.	3874.	3970.	4757.	5529.	6644.
6000.	1179.	1945.	2270.	2598.	3285.	3722.	3867.	3964.	4750.	5521.	6636.
7000.	1175.	1941.	2265.	2593.	3280.	3716.	3862.	3959.	4744.	5515.	6629.
8000.	1173.	1938.	2261.	2590.	3276.	3712.	3857.	3956.	4740.	5510.	6624.
9000.	1170.	1935.	2259.	2588.	3272.	3709.	3854.	3953.	4737.	5506.	6620.
10000.	1169.	1933.	2256.	2586.	3270.	3706.	3852.	3952.	4735.	5503.	6618.
12500.	1165.	1929.	2252.	2583.	3265.	3701.	3847.	3950.	4731.	5499.	6613.
15000.	1163.	1927.	2249.	2581.	3262.	3698.	3845.	3950.	4730.	5496.	6612.
17500.	1161.	1925.	2246.	2579.	3258.	3695.	3843.	3948.	4728.	5493.	6609.
20000.	1159.	1923.	2244.	2578.	3256.	3693.	3841.	3947.	4726.	5491.	6607.
22500.	1158.	1922.	2242.	2577.	3255.	3692.	3840.	3948.	4726.	5490.	6607.

TABLE 19. - ALUMINUM-NUCLEUS ABSORPTION CROSS SECTION

Aluminum-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	959.	1452.	1675.	1809.	2325.	2549.	2596.	2523.	3037.	3548.	4112.
50.	818.	1269.	1468.	1611.	2056.	2278.	2336.	2312.	2778.	3239.	3802.
75.	756.	1187.	1377.	1523.	1940.	2161.	2223.	2219.	2665.	3105.	3666.
100.	708.	1125.	1306.	1456.	1852.	2072.	2137.	2146.	2577.	3002.	3561.
125.	679.	1088.	1265.	1417.	1802.	2021.	2087.	2104.	2527.	2942.	3500.
150.	663.	1066.	1241.	1394.	1772.	1990.	2057.	2079.	2496.	2907.	3464.
175.	649.	1049.	1222.	1376.	1748.	1966.	2034.	2059.	2472.	2879.	3436.
200.	639.	1036.	1207.	1362.	1730.	1948.	2016.	2044.	2454.	2858.	3413.
225.	631.	1026.	1195.	1351.	1716.	1933.	2002.	2032.	2440.	2841.	3397.
250.	625.	1018.	1187.	1343.	1706.	1923.	1992.	2023.	2430.	2830.	3384.
275.	622.	1014.	1182.	1339.	1700.	1917.	1986.	2018.	2424.	2822.	3377.
300.	620.	1011.	1179.	1336.	1697.	1914.	1983.	2016.	2421.	2819.	3374.
350.	617.	1008.	1175.	1332.	1692.	1909.	1978.	2012.	2416.	2813.	3368.
400.	625.	1018.	1187.	1344.	1706.	1924.	1993.	2025.	2431.	2831.	3386.
500.	648.	1048.	1220.	1375.	1746.	1965.	2033.	2060.	2472.	2878.	3435.
600.	668.	1074.	1249.	1403.	1782.	2001.	2068.	2091.	2509.	2921.	3479.
700.	682.	1092.	1269.	1423.	1807.	2026.	2093.	2112.	2535.	2950.	3509.
800.	689.	1100.	1278.	1432.	1818.	2038.	2105.	2123.	2547.	2964.	3524.
900.	693.	1106.	1285.	1438.	1826.	2046.	2112.	2130.	2555.	2973.	3534.
1000.	697.	1110.	1289.	1443.	1831.	2051.	2118.	2135.	2561.	2980.	3541.
1250.	703.	1118.	1297.	1451.	1841.	2062.	2129.	2145.	2572.	2992.	3554.
1500.	706.	1121.	1301.	1456.	1846.	2067.	2134.	2151.	2578.	2999.	3561.
1750.	707.	1123.	1303.	1458.	1848.	2069.	2136.	2154.	2581.	3001.	3564.
2000.	708.	1124.	1304.	1459.	1848.	2070.	2137.	2156.	2582.	3003.	3566.
2500.	708.	1124.	1304.	1459.	1848.	2070.	2138.	2157.	2583.	3003.	3567.
3000.	707.	1123.	1303.	1459.	1847.	2069.	2137.	2157.	2583.	3002.	3566.
3500.	706.	1121.	1301.	1457.	1844.	2066.	2134.	2155.	2580.	2999.	3563.
4000.	704.	1119.	1298.	1455.	1841.	2063.	2131.	2153.	2577.	2996.	3560.
5000.	701.	1116.	1294.	1451.	1837.	2059.	2127.	2149.	2573.	2990.	3554.
6000.	700.	1114.	1292.	1449.	1834.	2056.	2124.	2147.	2571.	2988.	3552.
7000.	699.	1113.	1292.	1448.	1833.	2055.	2123.	2146.	2569.	2986.	3550.
8000.	699.	1113.	1291.	1448.	1833.	2055.	2123.	2146.	2569.	2986.	3550.
9000.	699.	1113.	1291.	1448.	1833.	2055.	2123.	2146.	2569.	2986.	3550.
10000.	699.	1113.	1291.	1449.	1833.	2055.	2123.	2147.	2570.	2986.	3551.
12500.	700.	1114.	1292.	1450.	1833.	2056.	2124.	2149.	2572.	2988.	3553.
15000.	701.	1115.	1293.	1451.	1834.	2057.	2126.	2151.	2574.	2989.	3555.
17500.	701.	1115.	1293.	1452.	1834.	2057.	2126.	2153.	2575.	2990.	3556.
20000.	701.	1115.	1293.	1453.	1835.	2058.	2127.	2154.	2576.	2991.	3557.
22500.	702.	1116.	1294.	1453.	1835.	2059.	2128.	2155.	2577.	2992.	3559.

TABLE 20. - ARGON-NUCLEUS TOTAL CROSS SECTION

Argon-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	2366.	3445.	3908.	4260.	5267.	5778.	5915.	5900.	6927.	7939.	9203.
50.	2088.	3103.	3533.	3896.	4808.	5314.	5464.	5506.	6471.	7416.	8668.
75.	1958.	2944.	3358.	3725.	4595.	5098.	5253.	5319.	6255.	7169.	8416.
100.	1848.	2808.	3209.	3581.	4417.	4917.	5075.	5160.	6072.	6962.	8202.
125.	1768.	2709.	3101.	3476.	4289.	4786.	4946.	5045.	5939.	6811.	8046.
150.	1699.	2624.	3007.	3385.	4179.	4673.	4835.	4944.	5824.	6681.	7911.
175.	1622.	2531.	2905.	3286.	4059.	4550.	4714.	4834.	5698.	6540.	7763.
200.	1536.	2426.	2791.	3176.	3927.	4414.	4580.	4711.	5558.	6382.	7597.
225.	1488.	2369.	2728.	3115.	3854.	4339.	4505.	4643.	5480.	6296.	7506.
250.	1453.	2328.	2684.	3072.	3803.	4287.	4454.	4595.	5426.	6235.	7442.
275.	1426.	2296.	2649.	3038.	3763.	4246.	4413.	4558.	5383.	6188.	7392.
300.	1409.	2277.	2628.	3018.	3739.	4221.	4388.	4535.	5358.	6159.	7362.
350.	1381.	2246.	2594.	2985.	3700.	4181.	4348.	4498.	5316.	6113.	7313.
400.	1390.	2257.	2606.	2997.	3715.	4196.	4364.	4512.	5332.	6131.	7331.
500.	1438.	2314.	2669.	3059.	3790.	4273.	4440.	4582.	5411.	6220.	7424.
600.	1487.	2374.	2734.	3123.	3867.	4352.	4518.	4654.	5493.	6312.	7521.
700.	1522.	2416.	2780.	3168.	3921.	4407.	4573.	4705.	5551.	6377.	7589.
800.	1540.	2438.	2803.	3191.	3949.	4436.	4601.	4731.	5581.	6410.	7623.
900.	1553.	2454.	2821.	3209.	3969.	4457.	4622.	4751.	5603.	6434.	7649.
1000.	1564.	2466.	2835.	3223.	3985.	4474.	4639.	4767.	5621.	6454.	7670.
1250.	1588.	2496.	2867.	3255.	4023.	4513.	4678.	4805.	5663.	6500.	7719.
1500.	1601.	2512.	2884.	3273.	4043.	4534.	4699.	4826.	5686.	6525.	7746.
1750.	1607.	2519.	2892.	3281.	4052.	4544.	4709.	4836.	5697.	6537.	7760.
2000.	1612.	2526.	2899.	3288.	4059.	4552.	4718.	4845.	5706.	6547.	7771.
2500.	1616.	2530.	2903.	3294.	4065.	4558.	4724.	4853.	5714.	6555.	7780.
3000.	1615.	2530.	2903.	3294.	4064.	4557.	4724.	4853.	5714.	6554.	7780.
3500.	1612.	2526.	2899.	3290.	4060.	4553.	4720.	4850.	5710.	6549.	7775.
4000.	1606.	2519.	2891.	3283.	4051.	4544.	4711.	4842.	5701.	6539.	7764.
5000.	1597.	2508.	2879.	3272.	4037.	4530.	4697.	4829.	5687.	6523.	7748.
6000.	1592.	2502.	2873.	3265.	4029.	4522.	4689.	4822.	5678.	6514.	7738.
7000.	1588.	2497.	2867.	3260.	4023.	4516.	4683.	4816.	5672.	6507.	7730.
8000.	1584.	2493.	2863.	3256.	4018.	4510.	4678.	4812.	5667.	6501.	7724.
9000.	1581.	2490.	2859.	3253.	4014.	4506.	4674.	4809.	5663.	6496.	7720.
10000.	1578.	2487.	2856.	3250.	4010.	4503.	4670.	4806.	5660.	6492.	7716.
12500.	1573.	2481.	2849.	3245.	4004.	4496.	4664.	4802.	5654.	6485.	7709.
15000.	1570.	2478.	2846.	3242.	3999.	4492.	4661.	4800.	5652.	6482.	7706.
17500.	1566.	2474.	2842.	3239.	3995.	4488.	4657.	4798.	5648.	6477.	7702.
20000.	1563.	2471.	2838.	3237.	3992.	4485.	4654.	4796.	5645.	6474.	7699.
22500.	1562.	2470.	2837.	3236.	3990.	4483.	4653.	4795.	5644.	6472.	7697.

TABLE 21. - ARGON-NUCLEUS ABSORPTION CROSS SECTION

Argon-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1297.	1862.	2107.	2279.	2823.	3079.	3142.	3109.	3649.	4183.	4819.
50.	1105.	1627.	1849.	2028.	2507.	2760.	2832.	2839.	3335.	3823.	4451.
75.	1021.	1524.	1737.	1919.	2370.	2621.	2696.	2719.	3197.	3665.	4289.
100.	957.	1445.	1650.	1834.	2266.	2516.	2593.	2627.	3090.	3544.	4164.
125.	919.	1399.	1600.	1786.	2206.	2455.	2533.	2573.	3029.	3474.	4092.
150.	897.	1372.	1570.	1757.	2171.	2418.	2497.	2541.	2992.	3433.	4049.
175.	879.	1350.	1546.	1734.	2143.	2390.	2469.	2516.	2963.	3400.	4015.
200.	865.	1334.	1528.	1716.	2121.	2368.	2447.	2497.	2941.	3375.	3989.
225.	855.	1321.	1514.	1703.	2105.	2351.	2431.	2482.	2924.	3356.	3969.
250.	847.	1312.	1504.	1693.	2093.	2339.	2419.	2471.	2912.	3342.	3955.
275.	843.	1306.	1497.	1687.	2086.	2332.	2412.	2465.	2905.	3334.	3946.
300.	840.	1303.	1494.	1684.	2082.	2328.	2408.	2462.	2901.	3330.	3942.
350.	837.	1299.	1489.	1679.	2076.	2322.	2403.	2457.	2895.	3323.	3935.
400.	847.	1312.	1504.	1694.	2093.	2339.	2420.	2473.	2913.	3344.	3956.
500.	877.	1348.	1543.	1732.	2141.	2388.	2468.	2516.	2963.	3400.	4014.
600.	904.	1380.	1578.	1767.	2183.	2431.	2510.	2555.	3007.	3450.	4066.
700.	922.	1403.	1603.	1791.	2212.	2460.	2539.	2582.	3038.	3484.	4102.
800.	930.	1413.	1614.	1802.	2225.	2474.	2553.	2594.	3052.	3500.	4119.
900.	936.	1420.	1621.	1809.	2234.	2483.	2562.	2603.	3061.	3511.	4129.
1000.	940.	1425.	1627.	1815.	2240.	2490.	2568.	2609.	3068.	3518.	4137.
1250.	947.	1433.	1636.	1824.	2251.	2501.	2580.	2620.	3081.	3532.	4152.
1500.	950.	1438.	1641.	1829.	2257.	2507.	2586.	2626.	3087.	3539.	4160.
1750.	951.	1439.	1642.	1831.	2258.	2509.	2588.	2629.	3090.	3541.	4162.
2000.	952.	1440.	1643.	1832.	2258.	2509.	2589.	2630.	3091.	3542.	4164.
2500.	951.	1439.	1642.	1832.	2258.	2509.	2589.	2631.	3091.	3541.	4164.
3000.	950.	1438.	1641.	1831.	2256.	2507.	2587.	2630.	3090.	3539.	4162.
3500.	948.	1436.	1638.	1828.	2253.	2504.	2584.	2627.	3087.	3536.	4159.
4000.	946.	1433.	1635.	1825.	2249.	2500.	2580.	2624.	3083.	3532.	4154.
5000.	943.	1429.	1630.	1821.	2244.	2495.	2575.	2619.	3078.	3526.	4148.
6000.	941.	1427.	1628.	1819.	2241.	2492.	2572.	2617.	3075.	3523.	4145.
7000.	940.	1425.	1627.	1818.	2240.	2491.	2571.	2616.	3073.	3521.	4143.
8000.	939.	1425.	1626.	1817.	2239.	2490.	2570.	2615.	3073.	3520.	4142.
9000.	939.	1425.	1626.	1817.	2239.	2490.	2570.	2615.	3073.	3520.	4142.
10000.	939.	1425.	1626.	1817.	2239.	2490.	2570.	2616.	3073.	3520.	4143.
12500.	939.	1425.	1626.	1818.	2239.	2490.	2571.	2617.	3074.	3521.	4144.
15000.	940.	1426.	1627.	1819.	2239.	2491.	2572.	2619.	3076.	3522.	4146.
17500.	940.	1426.	1626.	1819.	2239.	2491.	2572.	2620.	3076.	3523.	4147.
20000.	940.	1426.	1626.	1820.	2239.	2491.	2573.	2621.	3077.	3523.	4147.
22500.	940.	1426.	1627.	1821.	2240.	2492.	2573.	2622.	3078.	3524.	4149.

TABLE 22. - IRON-NUCLEUS TOTAL CROSS SECTION

Iron-nucleus total cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	2715.	3868.	4363.	4723.	5805.	6334.	6470.	6428.	7515.	8585.	9883.
50.	2427.	3517.	3978.	4350.	5332.	5858.	6009.	6030.	7051.	8051.	9342.
75.	2293.	3353.	3798.	4176.	5114.	5637.	5794.	5842.	6833.	7802.	9088.
100.	2178.	3213.	3645.	4028.	4930.	5451.	5612.	5682.	6649.	7591.	8872.
125.	2095.	3111.	3533.	3921.	4798.	5317.	5481.	5566.	6514.	7439.	8715.
150.	2022.	3022.	3436.	3828.	4684.	5202.	5368.	5464.	6398.	7307.	8580.
175.	1941.	2925.	3330.	3726.	4561.	5075.	5244.	5352.	6270.	7163.	8430.
200.	1849.	2816.	3211.	3611.	4424.	4935.	5105.	5227.	6127.	7003.	8263.
225.	1798.	2755.	3145.	3548.	4349.	4858.	5029.	5158.	6048.	6914.	8171.
250.	1762.	2713.	3099.	3504.	4296.	4804.	4976.	5109.	5993.	6852.	8106.
275.	1732.	2679.	3063.	3469.	4254.	4762.	4934.	5071.	5949.	6804.	8055.
300.	1714.	2659.	3041.	3448.	4229.	4736.	4909.	5048.	5923.	6774.	8025.
350.	1684.	2626.	3005.	3414.	4189.	4695.	4868.	5011.	5880.	6727.	7975.
400.	1693.	2638.	3018.	3426.	4204.	4710.	4883.	5024.	5896.	6745.	7993.
500.	1744.	2698.	3083.	3490.	4281.	4789.	4961.	5095.	5977.	6835.	8087.
600.	1796.	2760.	3151.	3556.	4360.	4870.	5041.	5168.	6060.	6928.	8184.
700.	1833.	2805.	3199.	3603.	4417.	4927.	5097.	5220.	6119.	6994.	8253.
800.	1852.	2827.	3224.	3627.	4445.	4957.	5126.	5247.	6149.	7028.	8288.
900.	1866.	2844.	3242.	3645.	4466.	4978.	5148.	5267.	6172.	7053.	8315.
1000.	1878.	2857.	3256.	3660.	4483.	4996.	5166.	5284.	6190.	7074.	8337.
1250.	1905.	2889.	3291.	3694.	4523.	5037.	5207.	5323.	6234.	7121.	8387.
1500.	1919.	2906.	3309.	3713.	4544.	5059.	5229.	5345.	6258.	7147.	8415.
1750.	1925.	2914.	3317.	3722.	4554.	5070.	5240.	5356.	6270.	7160.	8429.
2000.	1931.	2921.	3324.	3729.	4562.	5078.	5249.	5366.	6280.	7171.	8441.
2500.	1935.	2926.	3330.	3736.	4568.	5085.	5256.	5374.	6289.	7179.	8451.
3000.	1935.	2925.	3329.	3736.	4567.	5085.	5256.	5375.	6289.	7179.	8451.
3500.	1931.	2922.	3325.	3732.	4563.	5080.	5252.	5371.	6285.	7174.	8446.
4000.	1925.	2915.	3317.	3725.	4554.	5071.	5243.	5363.	6276.	7164.	8436.
5000.	1916.	2904.	3305.	3713.	4540.	5057.	5229.	5351.	6261.	7147.	8419.
6000.	1910.	2897.	3298.	3706.	4532.	5048.	5220.	5343.	6253.	7138.	8409.
7000.	1906.	2892.	3293.	3701.	4525.	5042.	5214.	5338.	6246.	7131.	8401.
8000.	1902.	2888.	3288.	3697.	4520.	5037.	5209.	5333.	6241.	7124.	8395.
9000.	1899.	2884.	3284.	3693.	4516.	5032.	5205.	5330.	6237.	7120.	8390.
10000.	1896.	2881.	3281.	3691.	4512.	5029.	5201.	5327.	6234.	7116.	8387.
12500.	1891.	2876.	3275.	3686.	4505.	5023.	5196.	5324.	6229.	7110.	8381.
15000.	1887.	2873.	3271.	3684.	4501.	5019.	5193.	5323.	6227.	7106.	8378.
17500.	1884.	2869.	3267.	3681.	4497.	5015.	5189.	5321.	6224.	7102.	8375.
20000.	1881.	2866.	3264.	3679.	4494.	5012.	5186.	5319.	6221.	7099.	8372.
22500.	1879.	2865.	3262.	3678.	4492.	5010.	5185.	5318.	6220.	7098.	8371.

TABLE 23. - IRON-NUCLEUS ABSORPTION CROSS SECTION

Iron-nucleus absorption cross section, mb, for -

Energy, MeV/amu	He	C	O	Al	Ar	Fe	Cu	Br	Ag	Ba	Pb
25.	1475.	2077.	2338.	2513.	3098.	3363.	3424.	3375.	3946.	4511.	5162.
50.	1277.	1836.	2074.	2257.	2772.	3035.	3107.	3102.	3628.	4144.	4790.
75.	1190.	1730.	1958.	2145.	2631.	2893.	2968.	2981.	3487.	3983.	4626.
100.	1122.	1648.	1868.	2059.	2524.	2784.	2862.	2888.	3380.	3860.	4501.
125.	1083.	1601.	1816.	2009.	2462.	2722.	2801.	2834.	3317.	3789.	4428.
150.	1060.	1572.	1785.	1979.	2426.	2685.	2765.	2801.	3280.	3747.	4384.
175.	1041.	1550.	1761.	1955.	2397.	2655.	2736.	2776.	3251.	3714.	4350.
200.	1026.	1533.	1742.	1937.	2374.	2632.	2714.	2756.	3228.	3688.	4323.
225.	1015.	1519.	1728.	1923.	2357.	2615.	2697.	2741.	3211.	3669.	4303.
250.	1007.	1510.	1717.	1913.	2345.	2603.	2685.	2731.	3198.	3655.	4289.
275.	1003.	1504.	1711.	1907.	2338.	2595.	2677.	2724.	3191.	3646.	4280.
300.	1000.	1501.	1708.	1904.	2334.	2591.	2674.	2721.	3187.	3642.	4276.
350.	996.	1496.	1702.	1900.	2328.	2585.	2668.	2716.	3181.	3635.	4269.
400.	1008.	1510.	1717.	1914.	2345.	2603.	2686.	2732.	3199.	3656.	4290.
500.	1039.	1548.	1758.	1954.	2394.	2653.	2734.	2776.	3250.	3712.	4349.
600.	1067.	1581.	1795.	1990.	2437.	2697.	2778.	2815.	3294.	3763.	4401.
700.	1086.	1604.	1820.	2014.	2467.	2727.	2808.	2842.	3325.	3798.	4437.
800.	1095.	1615.	1832.	2026.	2481.	2742.	2822.	2855.	3340.	3814.	4454.
900.	1101.	1622.	1840.	2033.	2490.	2751.	2831.	2863.	3349.	3825.	4465.
1000.	1105.	1627.	1845.	2039.	2497.	2758.	2837.	2870.	3356.	3832.	4473.
1250.	1113.	1637.	1855.	2049.	2509.	2770.	2850.	2882.	3370.	3847.	4488.
1500.	1117.	1642.	1860.	2055.	2514.	2776.	2856.	2888.	3377.	3854.	4496.
1750.	1118.	1643.	1862.	2057.	2516.	2778.	2858.	2891.	3379.	3856.	4499.
2000.	1118.	1644.	1862.	2058.	2517.	2779.	2859.	2893.	3381.	3858.	4501.
2500.	1118.	1644.	1862.	2058.	2516.	2779.	2859.	2894.	3381.	3858.	4502.
3000.	1117.	1642.	1860.	2057.	2514.	2777.	2858.	2893.	3380.	3856.	4500.
3500.	1115.	1640.	1858.	2054.	2511.	2774.	2855.	2890.	3377.	3852.	4497.
4000.	1113.	1637.	1855.	2051.	2508.	2770.	2851.	2887.	3373.	3848.	4492.
5000.	1109.	1633.	1850.	2047.	2502.	2764.	2846.	2882.	3368.	3842.	4486.
6000.	1107.	1631.	1848.	2045.	2499.	2762.	2843.	2880.	3365.	3839.	4483.
7000.	1106.	1629.	1846.	2043.	2498.	2760.	2841.	2879.	3364.	3837.	4481.
8000.	1106.	1629.	1846.	2043.	2497.	2759.	2841.	2878.	3363.	3836.	4480.
9000.	1106.	1629.	1845.	2043.	2497.	2759.	2841.	2878.	3363.	3836.	4480.
10000.	1106.	1629.	1846.	2043.	2497.	2759.	2841.	2879.	3364.	3837.	4481.
12500.	1106.	1629.	1846.	2044.	2497.	2760.	2842.	2881.	3365.	3838.	4483.
15000.	1107.	1630.	1847.	2045.	2498.	2761.	2843.	2883.	3367.	3839.	4484.
17500.	1107.	1630.	1847.	2046.	2498.	2761.	2844.	2884.	3368.	3840.	4485.
20000.	1107.	1631.	1847.	2046.	2498.	2762.	2844.	2885.	3369.	3840.	4486.
22500.	1107.	1631.	1848.	2047.	2499.	2763.	2845.	2886.	3370.	3842.	4488.

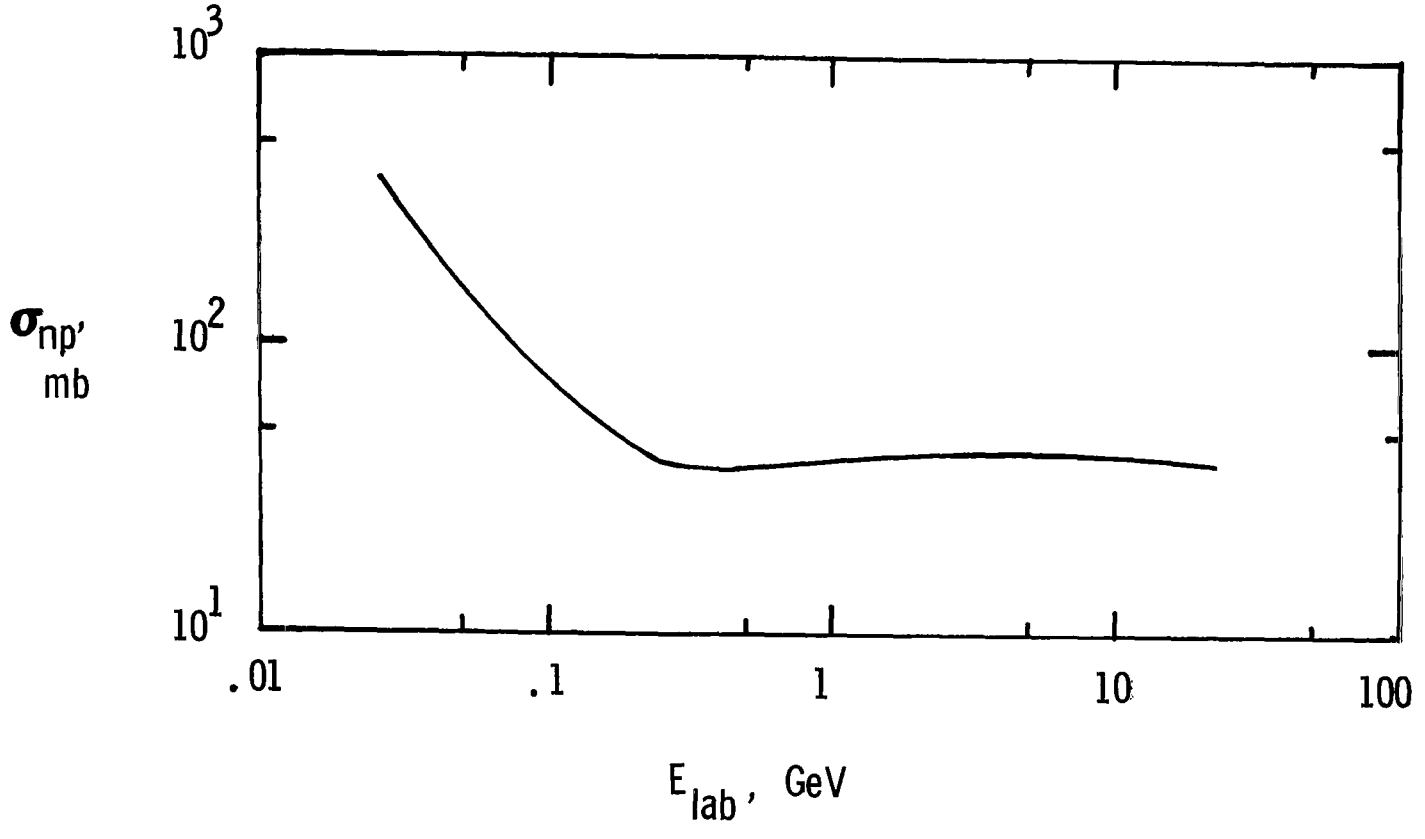

Figure 1.- Neutron-proton total cross section as a function of incident energy.

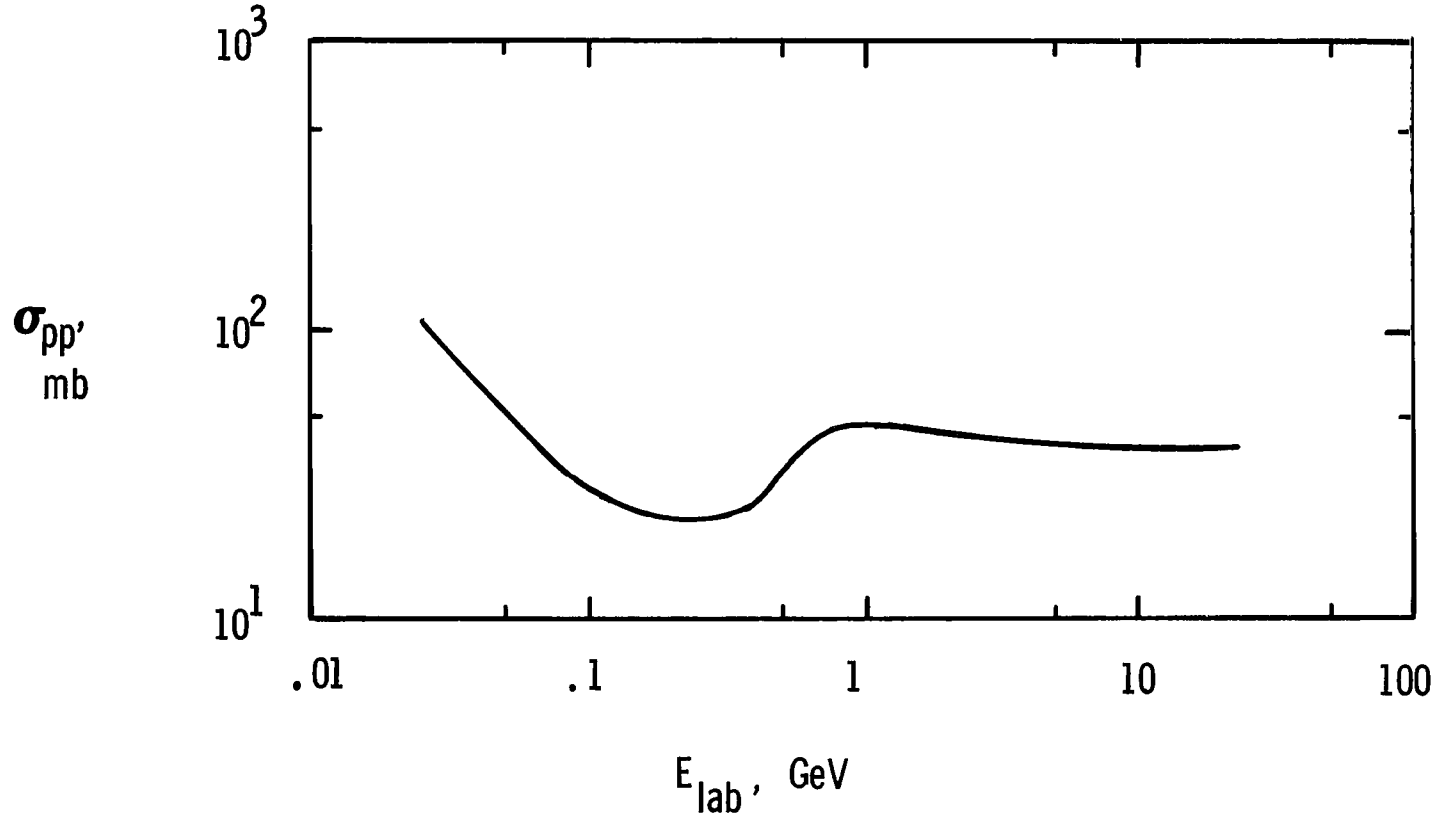

Figure 2.- Proton-proton total cross section as a function of incident energy.

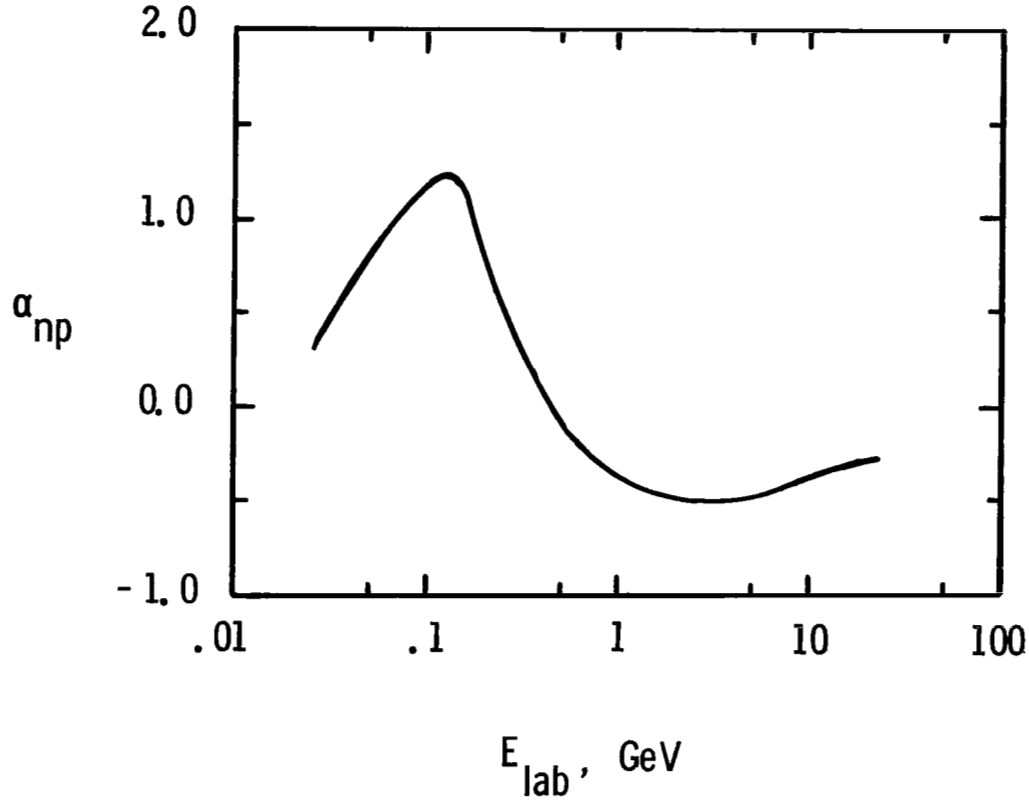

Figure 3.- Ratio of real part to imaginary part of the forward neutron-proton scattering amplitude as a function of incident energy.

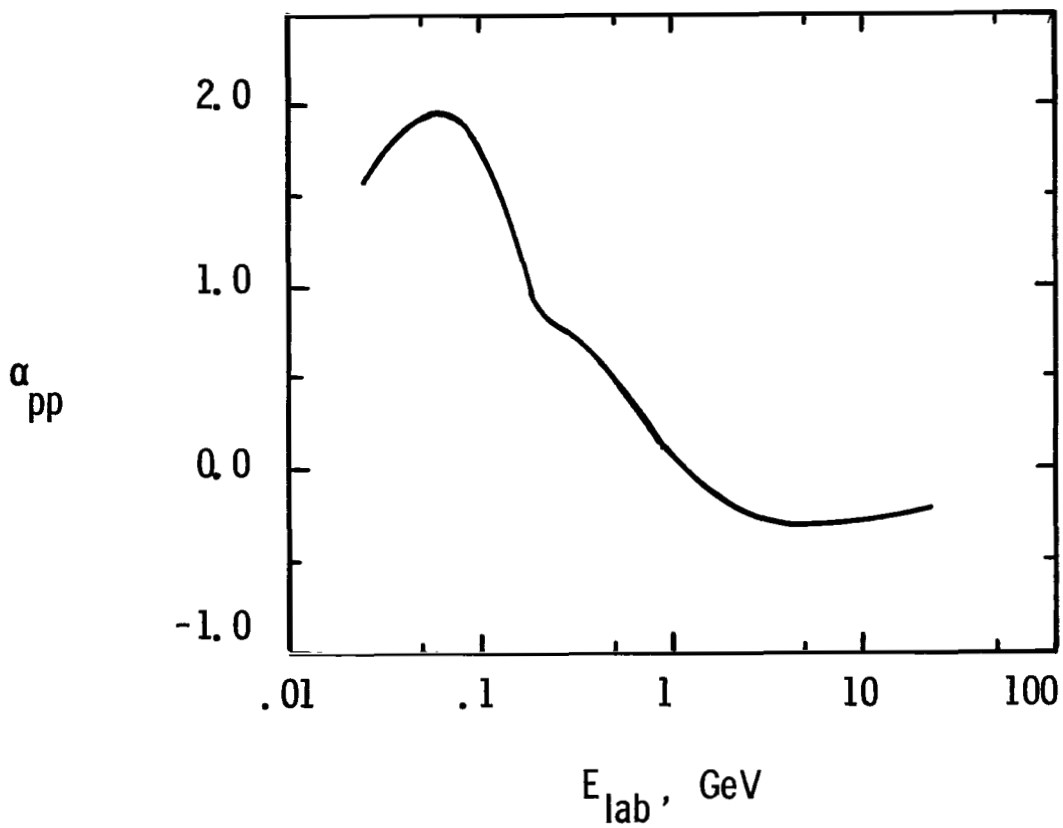

Figure 4.- Ratio of real part to imaginary part of the forward proton-proton scattering amplitude as a function of incident energy.

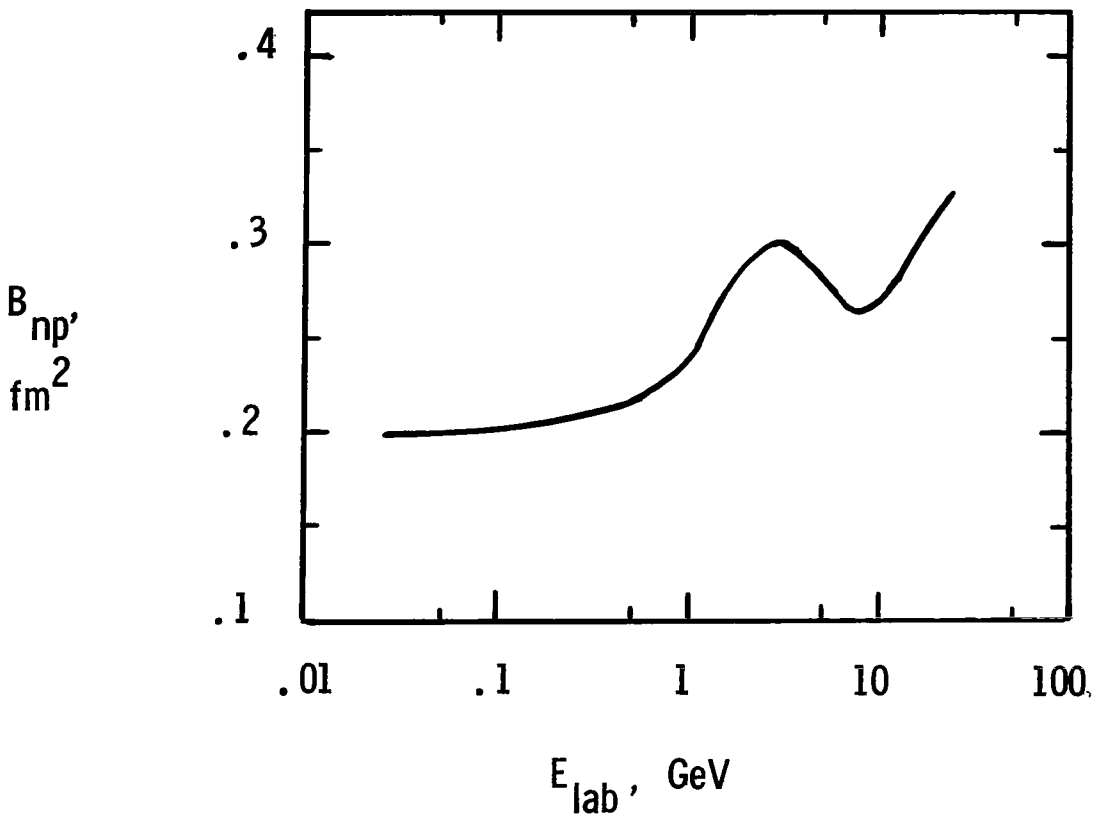

Figure 5.- Neutron-proton scattering slope parameter as a function of incident energy.

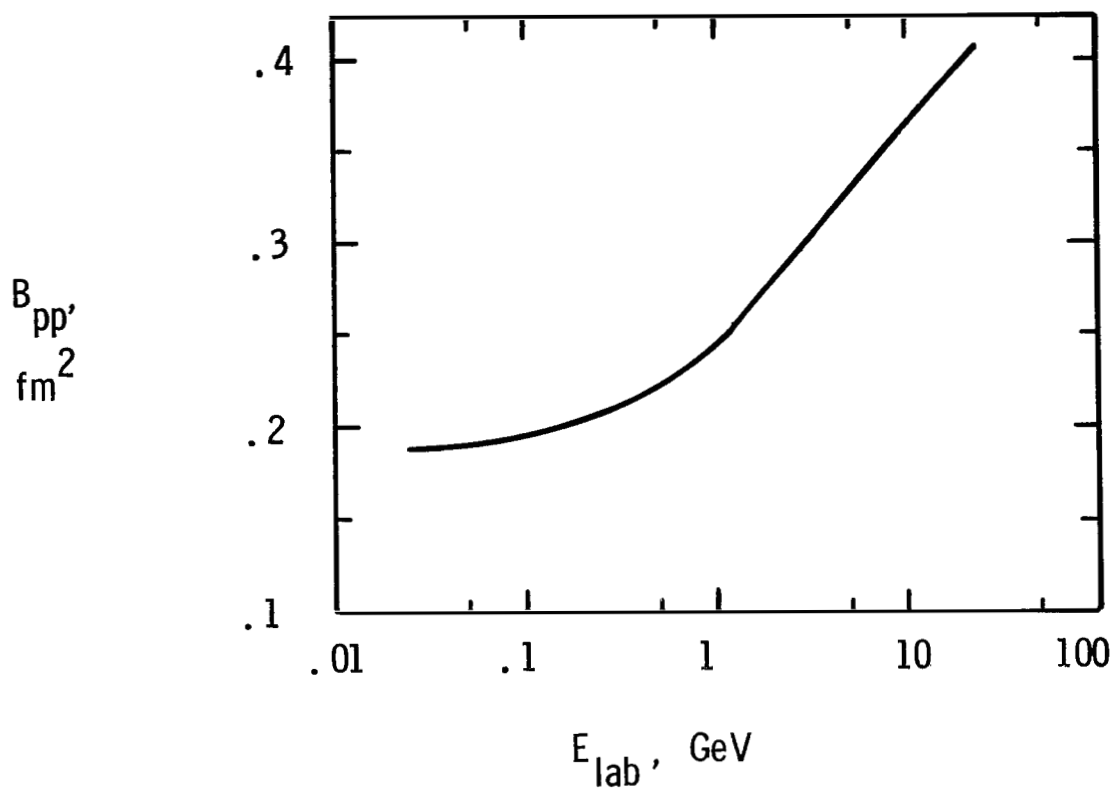

Figure 6.- Proton-proton scattering slope parameter as a function of incident energy.

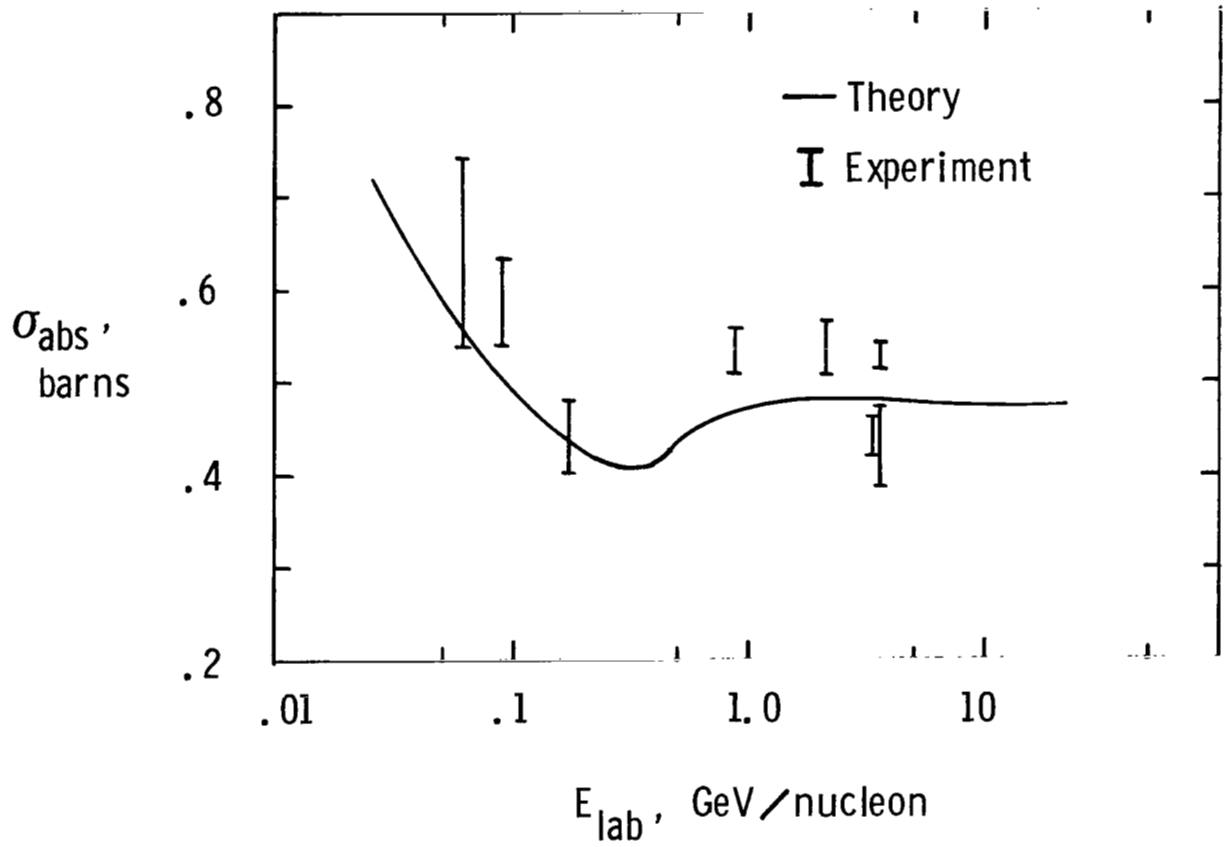

Figure 7.- Absorption cross sections for helium-carbon scattering as a function of incident energy.

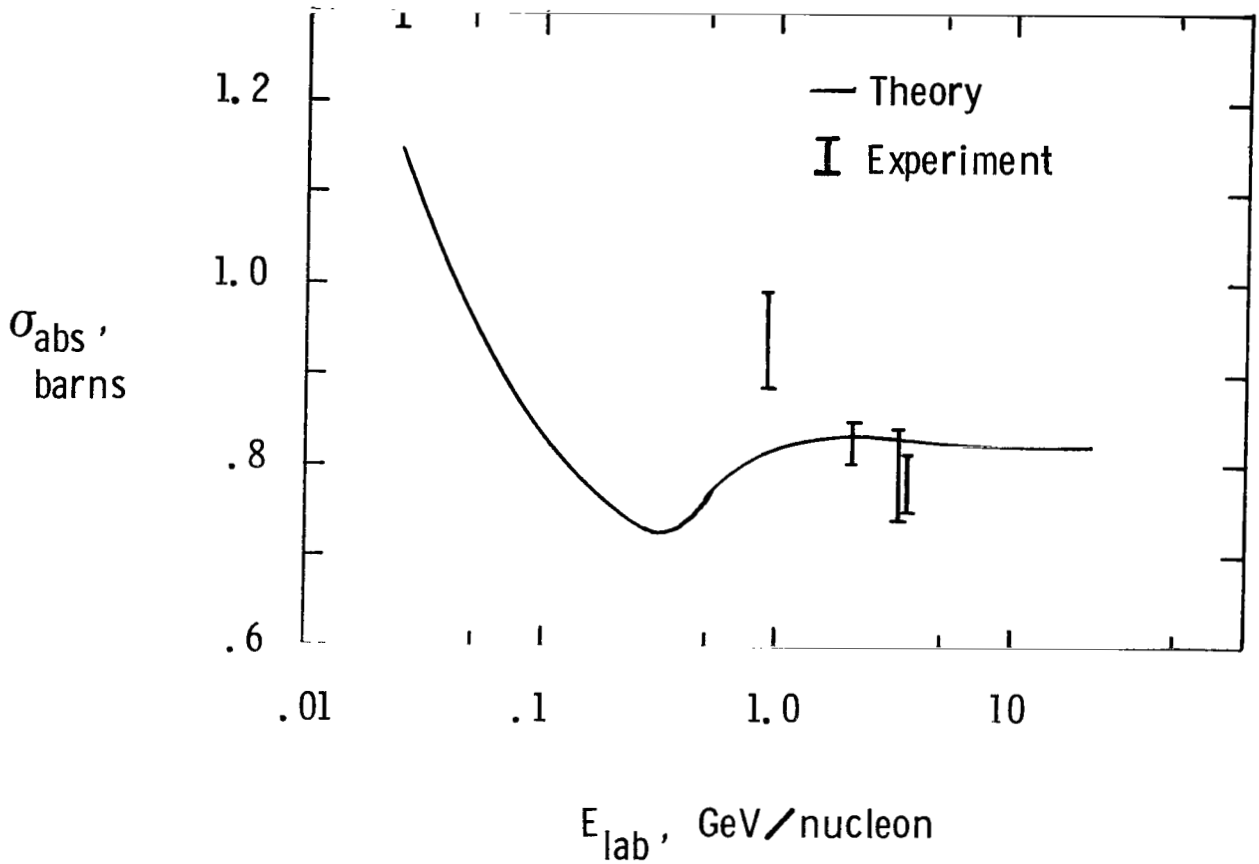

Figure 8.- Absorption cross sections for carbon-carbon scattering as a function of incident energy.

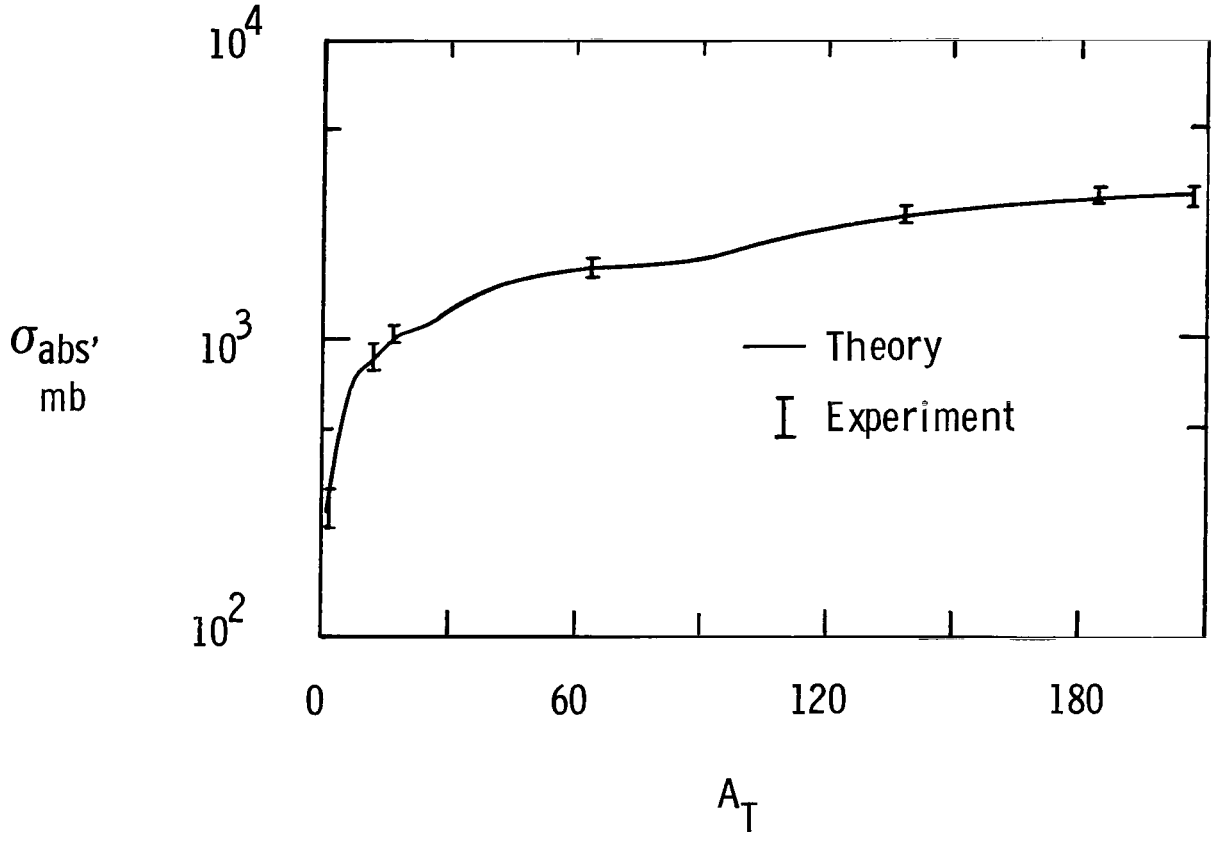

Figure 9.- Absorption cross sections as a function of target mass number for carbon projectiles at 2.1 GeV/nucleon.

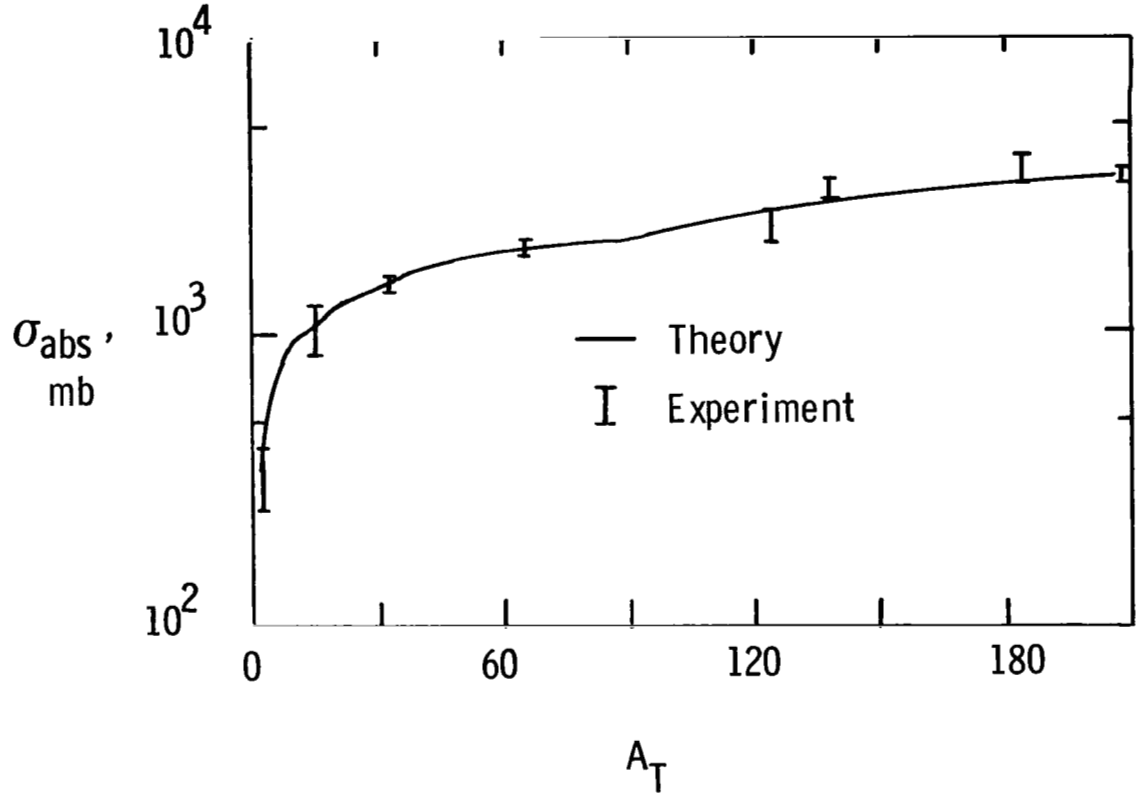

Figure 10.- Absorption cross sections as a function of target mass number for oxygen projectiles at 2.1 GeV/nucleon.

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16. Abstract

Within the context of a double-folding optical potential approximation to the exact nucleus-nucleus multiple-scattering series, eikonal scattering theory is used to generate tables of heavy-ion total and absorption cross sections at incident kinetic energies above 25 MeV/nucleon for use in cosmic-ray high-energy heavy-ion transport and shielding studies. Comparisons of predictions with nucleus-nucleus experimental data show excellent agreement except at the lowest energies, where the eikonal approximation may not be completely valid. Even at the lowest energies, however, agreement is typically within 20 percent.

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