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ASYMMETRY AND ENERGY SPECTRUM OF ELECTRONS IN BOUND-MUON DECAY

R. WATANABE

Advanced Materials and Technology Research Laboratories
Nippon Steel Corporation
Nakahara, Kawasaki 211, Japan

K. MUTO and T. ODA

Department of Physics
Tokyo Institute of Technology
Meguro, Tokyo 152, Japan

T. NIWA and H. OHTSUBO

Department of Physics
Osaka University
Toyonaka, Osaka 560, Japan

R. MORITA

Josai Women's Junior College
Sakado, Saitama 350-02, Japan

and

M. MORITA

Josai International University
Gumyo, Togane, Chiba 283, Japan

Theoretical values for the muon decay rate and the emitted electron energy spectrum and several kinds of asymmetry parameters for the angular distribution of the electrons in bound-muon decay are given in numerical tables and figures for ^{16}O, ^{27}Al, ^{28}Si, ^{40}Ca, ^{56}Fe, ^{90}Zr, ^{96}Mo, ^{118}Sn, ^{208}Pb, and ^{209}Bi. The present results are based on the general formalism of the angular distribution of emitted electrons in bound-muon decay published in Prog. Theor. Phys. **78,** 114 (1987), in terms of the multipole series of the relativistic electron wave functions. The effect of finite nuclear size on the wave functions is properly taken into account for both the bound muon and the emitted electron.

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CONTENTS

INTRODUCTION

Recently, study of phenomena involving muon polarization has been widespread in the fields of particle, nuclear, and solid-state physics. In these investigations, it is essential to determine the muon polarization in the $1s_{1/2}$ orbit of the muonic atom experimentally since this polarization differs from that of the original muon beam due to the depolarization effect in the cascade-down process. The experiment can take the form of measuring the asymmetric angular distribution of the emitted electrons with respect to the direction of the muon spin polarization. This is because parity is not conserved in muon decay, and the asymmetry of the emitted electrons is the product of the degree of muon polarization and the asymmetry parameter. Since the latter is derived from theory, our work is therefore to produce reliable values for this quantity.

The asymmetry parameters can be obtained easily if we know the energy spectrum and the angular distribution of the emitted electrons in the bound-muon decay. In the early 1950s, Porter and Primakoff[1] first pointed out that the decay rate and the electron energy spectrum in bound-muon decay are quite different from those in free-muon decay. Later, the energy spectrum was correctly calculated by Huff[2] and Hänggi et al.[3] by taking into account the effect of the finite nuclear size; the decay rate of a muon in the bound state was shown[4] to depend upon the atomic number Z. There are two publications of limited accuracy on the angular distributions of the emitted electrons in low- and medium-Z regions.[5,6] However, there is now a need for asymmetry parameters of higher accuracy to determine the degree of the initial muon polarization, for example, the initial muon polarization in C in the study of the average polarization of the recoil nucleus in muon capture[7] or the polarizability for the bound-muon spin in Pb and Bi due to their internal magnetic fields.[8,9]

In order to improve the accuracy of the theoretical values for these physical quantities, we have constructed a general formalism for the angular distribution of emitted electrons in bound-muon decay in terms of the multipole series of the relativistic electron wave functions.[10] The effect of finite nuclear size on the wave functions was properly taken into account for both the bound muon and the emitted electron. The electron energy spectrum and several kinds of asymmetry parameters of the angular distribution of electrons were investigated numerically in four typical cases of muonic atoms: ^{16}O, ^{40}Ca, ^{90}Zr, and ^{208}Pb. In the present work, we extend our numerical studies to various additional muonic atoms. We briefly summarize here the formulas required in the numerical calculation of the angular distributions of emitted electrons in bound-muon decay. For details of the derivation, the readers should refer to Ref. 10.

The interaction Hamiltonian density of the charge-exchange type for the muon decay, $\mu \rightarrow e + \nu_\mu + \bar{\nu}_e$, is expressed in vector–axial vector (V–A) theory as

$$H = (G/\sqrt{2})\bar{\psi}_e(x)\gamma_\lambda(1 + \gamma_5)\psi_{\nu_e}(x)\bar{\psi}_{\nu_\mu}(x)\gamma_\lambda(1 + \gamma_5)\psi_\mu(x) + \text{h.c.} \quad (1)$$

Here G is the universal weak coupling constant, $\psi_\alpha(x)$ denotes the field operator of a particle α ($\alpha = \mu, e, \nu_\mu, \nu_e$), and we use the natural units $\hbar = c = 1$ hereafter. We assume that the neutrino and antineutrino are massless and neglect the nuclear recoil energy in bound-muon decay.

The decay probability of the bound muon in the $1s_{1/2}$ state for emission of an electron with energy E, where E includes the electron mass m_e, into a solid angle $d\Omega_e$, is expressed as

$$W(E, \theta)dEd\Omega_e/4\pi = [N(E) + A(E)P\cos\theta]dEd\Omega_e/4\pi. \quad (2)$$

$N(E)$ and $A(E)$ in this equation are the energy spectrum and asymmetry coefficient, respectively. P is the muon polarization in the $1s_{1/2}$ state, and θ is the angle between the muon polarization axis and the electron momentum. Here, we simply omit the effect of the higher order orientation for odd nuclei. The $N(E)$ and $A(E)$ normalized by the free-muon decay rate, $\Lambda_{\rm free} = G^2m_\mu^5/(192\pi^3)$ with m_μ being the muon mass, are expressed in the forms

$$N(E) = (16/\pi m_\mu^5)E\sqrt{E^2 - m_e^2}\sum_{J,\kappa}(2j_\kappa + 1)\int_0^{W-E}k^2dk \times \{[(W - E)^2 - k^2]\{|S^0_{J,\kappa}|^2/[J(J + 1)] + |S^1_{J,\kappa}|^2/[(J + 1)(2J + 1)] + |S^{-1}_{J,\kappa}|^2/[J(2J + 1)]\} + k^2[|S^4_{J,\kappa}|^2 + |(S^1_{J,\kappa} + S^{-1}_{J,\kappa})|^2/(2J + 1)^2] + (W - E)k[(S^{1*}_{J,\kappa} + S^{-1*}_{J,\kappa})S^4_{J,\kappa} + \text{c.c.}]/(2J + 1)\} \quad (3)$$

and

$$A(E) = (16/\pi m_\mu^5)E\sqrt{E^2 - m_e^2} \times \sum_{J,\kappa,\kappa'} i^{l_{\kappa'} - l_\kappa}\exp[i(\delta_\kappa - \delta_{\kappa'})](-)^{j_\kappa + l_{\kappa'} + J} \times \sqrt{1/2}\,(2j_\kappa + 1)(2j_{\kappa'} + 1)W(j_\kappa j_{\kappa'}\tfrac{1}{2}\tfrac{1}{2}; 1J) \times (j_\kappa \tfrac{1}{2} j_{\kappa'} -\tfrac{1}{2} | 10)[1 - (-)^{l_\kappa + l_{\kappa'}}] \times \int_0^{W-E}k^2dk\{[(W - E)^2 - k^2]\{S^{0*}_{J,\kappa'}S^0_{J,\kappa}/[J(J + 1)] + S^{1*}_{J,\kappa'}S^1_{J,\kappa}/[(J + 1)(2J + 1)] + S^{-1*}_{J,\kappa'}S^{-1}_{J,\kappa}/[J(2J + 1)]\} + k^2[S^{4*}_{J,\kappa'}S^4_{J,\kappa} + (S^{1*}_{J,\kappa'} + S^{-1*}_{J,\kappa'})(S^1_{J,\kappa} + S^{-1}_{J,\kappa})/(2J + 1)^2] + (W - E)k[(S^{1*}_{J,\kappa'} + S^{-1*}_{J,\kappa'})S^4_{J,\kappa} + S^{4*}_{J,\kappa'}(S^1_{J,\kappa} + S^{-1}_{J,\kappa})]/(2J + 1)\}, \quad (4)$$

where the matrix elements $S^m_{J,\kappa}$ in Eqs. (3) and (4) are defined as

$$S^0_{J,\kappa} = \frac{1}{2}\int r^2dr\, j_J(kr)\{[1 + (-)^{l_\kappa + J}](1 + \kappa)(g_\kappa G - f_\kappa F) + i[1 - (-)^{l_\kappa + J}](1 - \kappa)(f_\kappa G + g_\kappa F)\}, \quad (5a)$$

$$S^1_{J,\kappa} = \frac{1}{2}\int r^2dr\, j_{J+1}(kr)\{[1 + (-)^{l_\kappa + J}] \times [(J + \kappa + 2)g_\kappa F + (\kappa - J)f_\kappa G] + i[1 - (-)^{l_\kappa + J}] \times [(J - \kappa + 2)f_\kappa F + (J + \kappa)g_\kappa G]\}, \quad (5b)$$

$$S^{-1}_{J,\kappa} = \frac{1}{2}\int r^2dr\, j_{J-1}(kr)\{[1 + (-)^{l_\kappa + J}] \times [(1 + \kappa - J)g_\kappa F + (J + \kappa + 1)f_\kappa G] + i[1 - (-)^{l_\kappa + J}] \times [(1 - \kappa - J)f_\kappa F - (J - \kappa + 1)g_\kappa G]\}, \quad (5c)$$

and

$$S^4_{J,\kappa} = \frac{1}{2}\int r^2dr\, j_J(kr)\{[1 + (-)^{l_\kappa + J}](g_\kappa G + f_\kappa F) + i[1 - (-)^{l_\kappa + J}](f_\kappa G - g_\kappa F)\}. \quad (5d)$$

Here W is the total energy of the bound muon including its rest mass and k is the momentum transfer to the two unobserved neutrinos. The quantum number of the electron, κ, is a nonzero integer which uniquely specifies the orbital angular momentum l_κ and the total angular momentum j_κ as

$$j_\kappa = |\kappa| - \frac{1}{2}, \quad l_\kappa = j_\kappa + \frac{1}{2}\frac{\kappa}{|\kappa|}. \quad (6)$$

The functions $W(abcd;ef)$ and $(jmj'm'|JM)$ in Eq. (4) stand for the Racah and Clebsch–Gordan coefficients, respectively. The g_κ and f_κ are, respectively, the large and small components of the radial wave function of the electron, and δ_κ is the Coulomb phase shift. They are obtained by solving the following Dirac equation numerically,

$$\begin{pmatrix} dg_\kappa/dr \\ df_\kappa/dr \end{pmatrix} = \begin{pmatrix} -(\kappa + 1)/r & E + m_e - V(r) \\ -E + m_e + V(r) & (\kappa - 1)/r \end{pmatrix}\begin{pmatrix} g_\kappa \\ f_\kappa \end{pmatrix}, \quad (7)$$

where $V(r)$ is the Coulomb potential given by the nuclear charge distribution. The normalization of the electron radial wave function is explicitly given in Ref. 11 in connection with the phase shift. Similarly the G and F are, respectively, the large and small components of the radial wave function of the muon in the $1s_{1/2}$ state and are also obtained by solving an analogous Dirac equation (7) after substituting $m_e \to m_\mu$, $E \to W$, $g_\kappa \to G$, $f_\kappa \to F$, and $\kappa \to -1$; the relevant normalization condition is

$$\int_0^\infty (F^2 + G^2)r^2dr = 1. \quad (8)$$

We define the asymmetry by

$$\beta(E) = \frac{A(E)}{N(E)} \tag{9}$$

at a given energy of the emitted electron. In experiments the asymmetry is, however, measured for the integrated energy region between a lower and an upper boundary. Therefore, it is useful to define the asymmetry parameter by

$$\alpha(E, E_{\max}) = \frac{\int_E^{E_{\max}} A(E)dE}{\int_E^{E_{\max}} N(E)dE}. \tag{10}$$

Here E and $E_{\max}$ are the lower cutoff energy and the maximum electron energy from the bound-muon decay, respectively. Because of the normalization adopted in Eqs. (3) and (4), the following two relations hold for the free-muon decay,

$$\int N(E)dE = 1 \quad \text{and} \quad \int A(E)dE = -\frac{1}{3}, \tag{11}$$

where the integrals should be performed over the whole range of E. If we assume the observed integrated energy spectra as

$$\int_E^{E_{\max}} W(E', \theta)dE' \propto [1 + \bar{\alpha}(E, E_{\max})\cos\theta], \tag{12}$$

then we obtain the muon polarization P as

$$P = \bar{\alpha}(E, E_{\max})/\alpha(E, E_{\max}). \tag{13}$$

Note that the resultant P should be independent of the choice of the lower cutoff energy E.

In order to take into account the effect of finite nuclear size on the lepton wave functions, we adopt a nuclear charge distribution of the Fermi type with two parameters,

$$\rho(r) = \rho_0\left[1 + \exp\left(\frac{r-c}{a}\right)\right]^{-1} \tag{14}$$

with

$$\rho_0 = \left(\frac{3}{c^3}\right)\left[1 + \left(\frac{a\pi}{c}\right)^2 - 6\left(\frac{a}{c}\right)^3 \sum_{k=1}^{\infty} \frac{(-1)^k}{k^3} x_0^k\right]^{-1} \quad \text{and}$$

$$x_0 = \exp\left(-\frac{c}{a}\right). \tag{15}$$

Parameters a and c are determined from electron scattering experiments. The Coulomb potential is defined (in natural units) as

$$\begin{aligned} V(r) &= -\alpha Z\left[\frac{1}{r}\int_0^r \rho(r')r'^2dr' + \int_r^{\infty} \rho(r')r'dr'\right] \\ &= -\alpha Z\rho_0\left[\frac{c^2}{2} - \frac{r^2}{6} + \frac{\pi^2a^2}{6} - a^2 \sum_{k=1}^{\infty} \frac{(-1)^k}{k^2} x^k \right. \\ &\quad \left. - \frac{2a^3}{r} \sum_{k=1}^{\infty} \frac{(-1)^k}{k^3}(x_0^k - x^k)\right] \quad \text{for } r < c \\ &= -\alpha Z\rho_0\left[\frac{1}{r}\left\{\frac{c^3}{3} + \frac{\pi^2a^2c}{3} - 2a^3 \sum_{k=1}^{\infty} \frac{(-1)^k}{k^3}(x_0^k - x^{-k})\right\} \right. \\ &\quad \left. + a^2 \sum_{k=1}^{\infty} \frac{(-1)^k}{k^2} x^{-k}\right] \quad \text{for } r > c \end{aligned} \tag{16}$$

with α being the fine-structure constant and

$$x = \exp\left(\frac{r-c}{a}\right). \tag{17}$$

The Dirac equations (7) are solved numerically for the muon in its $1s_{1/2}$ state and for the electron in each quan-

TABLE A

Adopted Charge Parameters, a and c, and Calculated Values of the Muon Binding Energy BE, the rms Radius $\langle r^2\rangle^{1/2}$, and the Decay Rate $\Lambda_{1s_{1/2}}$, Normalized to the Free-Muon Decay, for the $1s_{1/2}$ State

	Nucleus									
Nucleus	^{16}O	^{27}Al	^{28}Si	^{40}Ca	^{56}Fe	^{90}Zr	^{96}Mo	^{118}Sn	^{208}Pb	^{209}Bi
a (fm)	—	0.569	0.569	0.563	0.5935	0.532	0.573	0.584	0.549	0.468
c (fm)	—	2.845	2.935	3.517	3.971	4.66	4.875	5.303	6.624	6.75
BE (MeV)	0.179	0.463	0.535	1.06	1.72	3.68	3.95	5.19	10.5	10.7
$\langle r^2\rangle^{1/2}$ (fm)	55.8	34.9	32.5	23.4	18.7	13.3	13.0	11.7	9.20	9.15
$\Lambda_{2s_{1/2}}$	0.994	0.992	0.991	0.981	0.971	0.936	0.932	0.914	0.847	0.845

Note. A point nucleus is assumed for ^{16}O.

tum state κ. The contribution of the higher quantum states κ to the decay probability [Eq. (2)] is taken into account until we have convergent results for the numerical values.

In Table A, we summarize the adopted numerical values of the charge distribution parameters, a and c,[12] and the calculated values for the muon binding energy, the root-mean-square (rms) radius, and the decay rate, normalized to the free-muon decay, for the $1s_{1/2}$ state. We adopted a point nucleus for ^{16}O. The decay rates were calculated with a precision better than 10^{-3}, which may be useful for possible future experiments with high accuracy.

Finally, the numerical values for the energy spectrum $N(E)$ (MeV^{-1}), asymmetry coefficient $A(E)$ (MeV^{-1}), asymmetry $\beta(E)$, and asymmetry parameter $\alpha(E, E_{max})$ are obtained as functions of the energy E (MeV) of the emitted electron in the bound-muon decay for each muonic atom. They are given in Table I for the muonic ^{16}O, ^{27}Al, ^{28}Si, ^{40}Ca, ^{56}Fe, ^{90}Zr, ^{96}Mo, ^{118}Sn, ^{208}Pb, and ^{209}Bi atoms.

For purposes of comparison with free-muon decay, the energy spectra $N(E)$, asymmetry coefficients $A(E)$, and asymmetry parameters $\alpha(E, E_{max})$ are also given in Figs. I, II, and III, respectively.

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EXPLANATION OF TABLES AND FIGURES

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

In Table I, the energy spectrum, asymmetry coefficient, asymmetry, and asymmetry parameter are given as functions of energy of the emitted electron in bound-muon decay of ^{16}O, ^{27}Al, ^{28}Si, ^{40}Ca, ^{56}Fe, ^{90}Zr, ^{96}Mo, ^{118}Sn, ^{208}Pb, and ^{209}Bi. A Fermi-type nuclear charge distribution with two parameters a and c is assumed except for ^{16}O, for which a point nucleus is assumed. The numerical values for a and c are summarized in Table A, together with the calculated values of the muon binding energy, rms radius, and decay rate normalized to that for free-muon decay, for the $1s_{1/2}$ state.

E	Total energy (MeV) of the emitted electron including its rest mass
$N(E)$	Energy spectrum (MeV^{-1}) [see Eq. (2)]
$A(E)$	Asymmetry coefficient (MeV^{-1}) [see Eq. (2)]
$\beta(E)$	Asymmetry [$A(E)/N(E)$, Eq. (9)]
$\alpha(E, E_{max})$	Asymmetry parameter [see Eq. (10)]

FIGURE I. Comparison of Energy Spectra for Free- and Bound-Muon Decays

FIGURE II. Comparison of Asymmetry Coefficients for Free- and Bound-Muon Decays

FIGURE III. Comparison of Asymmetry Parameters for Free- and Bound-Muon Decays

The energy spectrum, asymmetry coefficient, and asymmetry parameter are also plotted, respectively, in Figs. I, II, and III, for comparison with those for the free-muon decay.

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

See page 170 for Explanation of Table and Figures

^{16}O

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.332
1.0	0.427E-04	0.119E-04	0.279E+00	-0.332
2.0	0.182E-03	0.553E-04	0.304E+00	-0.332
3.0	0.403E-03	0.121E-03	0.301E+00	-0.333
4.0	0.701E-03	0.205E-03	0.293E+00	-0.333
5.0	0.107E-02	0.304E-03	0.284E+00	-0.333
6.0	0.150E-02	0.413E-03	0.275E+00	-0.334
7.0	0.200E-02	0.530E-03	0.265E+00	-0.335
8.0	0.256E-02	0.651E-03	0.254E+00	-0.337
9.0	0.317E-02	0.773E-03	0.243E+00	-0.338
10.0	0.384E-02	0.892E-03	0.232E+00	-0.340
11.0	0.456E-02	0.101E-02	0.221E+00	-0.343
12.0	0.532E-02	0.111E-02	0.209E+00	-0.346
13.0	0.613E-02	0.121E-02	0.197E+00	-0.349
14.0	0.698E-02	0.129E-02	0.184E+00	-0.353
15.0	0.786E-02	0.135E-02	0.171E+00	-0.357
16.0	0.878E-02	0.139E-02	0.158E+00	-0.361
17.0	0.973E-02	0.140E-02	0.144E+00	-0.366
18.0	0.107E-01	0.139E-02	0.130E+00	-0.372
19.0	0.117E-01	0.135E-02	0.115E+00	-0.378
20.0	0.127E-01	0.127E-02	0.100E+00	-0.385
21.0	0.138E-01	0.116E-02	0.842E-01	-0.392
22.0	0.148E-01	0.101E-02	0.679E-01	-0.400
23.0	0.159E-01	0.811E-03	0.510E-01	-0.408
24.0	0.170E-01	0.568E-03	0.334E-01	-0.417
25.0	0.181E-01	0.275E-03	0.152E-01	-0.426
26.0	0.192E-01	-0.698E-04	-0.364E-02	-0.436
27.0	0.202E-01	-0.471E-03	-0.233E-01	-0.446
28.0	0.213E-01	-0.931E-03	-0.437E-01	-0.458
29.0	0.224E-01	-0.145E-02	-0.649E-01	-0.469
30.0	0.234E-01	-0.204E-02	-0.870E-01	-0.482
31.0	0.245E-01	-0.270E-02	-0.110E+00	-0.495
32.0	0.255E-01	-0.342E-02	-0.134E+00	-0.509
33.0	0.265E-01	-0.423E-02	-0.159E+00	-0.524
34.0	0.275E-01	-0.510E-02	-0.186E+00	-0.539
35.0	0.285E-01	-0.606E-02	-0.213E+00	-0.555
36.0	0.294E-01	-0.711E-02	-0.242E+00	-0.572
37.0	0.303E-01	-0.824E-02	-0.272E+00	-0.590
38.0	0.312E-01	-0.946E-02	-0.304E+00	-0.608
39.0	0.320E-01	-0.108E-01	-0.337E+00	-0.628
40.0	0.327E-01	-0.122E-01	-0.372E+00	-0.648
41.0	0.335E-01	-0.137E-01	-0.409E+00	-0.669
42.0	0.341E-01	-0.153E-01	-0.448E+00	-0.691
43.0	0.348E-01	-0.170E-01	-0.489E+00	-0.714
44.0	0.353E-01	-0.188E-01	-0.532E+00	-0.738
45.0	0.358E-01	-0.207E-01	-0.578E+00	-0.762
46.0	0.362E-01	-0.226E-01	-0.626E+00	-0.788
47.0	0.364E-01	-0.246E-01	-0.676E+00	-0.813
48.0	0.364E-01	-0.265E-01	-0.729E+00	-0.839
49.0	0.358E-01	-0.280E-01	-0.782E+00	-0.864
50.0	0.340E-01	-0.283E-01	-0.834E+00	-0.888
51.0	0.293E-01	-0.258E-01	-0.878E+00	-0.907
52.0	0.207E-01	-0.188E-01	-0.910E+00	-0.922
53.0	0.108E-01	-0.998E-02	-0.927E+00	-0.929
54.0	0.434E-02	-0.404E-02	-0.932E+00	-0.930
55.0	0.158E-02	-0.147E-02	-0.931E+00	-0.926
56.0	0.587E-03	-0.544E-03	-0.927E+00	-0.921
57.0	0.235E-03	-0.216E-03	-0.922E+00	-0.916
58.0	0.102E-03	-0.933E-04	-0.917E+00	-0.911
59.0	0.476E-04	-0.434E-04	-0.912E+00	-0.907
60.0	0.238E-04	-0.216E-04	-0.908E+00	-0.904
65.0	0.144E-05	-0.129E-05	-0.898E+00	-0.901
70.0	0.163E-06	-0.148E-06	-0.904E+00	-0.912
75.0	0.244E-07	-0.224E-07	-0.919E+00	-0.929
80.0	0.400E-08	-0.375E-08	-0.938E+00	-0.948
85.0	0.622E-09	-0.596E-09	-0.958E+00	-0.966
90.0	0.774E-10	-0.756E-10	-0.977E+00	-0.982
95.0	0.570E-11	-0.565E-11	-0.991E+00	-0.993
100.0	0.973E-13	-0.971E-13	-0.998E+00	-0.998

^{27}Al

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.332
1.0	0.485E-04	0.134E-04	0.277E+00	-0.332
2.0	0.203E-03	0.613E-04	0.302E+00	-0.332
3.0	0.447E-03	0.133E-03	0.298E+00	-0.333
4.0	0.773E-03	0.224E-03	0.290E+00	-0.333
5.0	0.117E-02	0.330E-03	0.281E+00	-0.334
6.0	0.164E-02	0.445E-03	0.271E+00	-0.334
7.0	0.217E-02	0.567E-03	0.261E+00	-0.336
8.0	0.276E-02	0.692E-03	0.250E+00	-0.337
9.0	0.341E-02	0.815E-03	0.239E+00	-0.339
10.0	0.410E-02	0.935E-03	0.228E+00	-0.341
11.0	0.485E-02	0.105E-02	0.216E+00	-0.344
12.0	0.563E-02	0.115E-02	0.204E+00	-0.347
13.0	0.646E-02	0.124E-02	0.191E+00	-0.350
14.0	0.733E-02	0.131E-02	0.178E+00	-0.354
15.0	0.823E-02	0.136E-02	0.165E+00	-0.358
16.0	0.916E-02	0.139E-02	0.151E+00	-0.363
17.0	0.101E-01	0.139E-02	0.137E+00	-0.368
18.0	0.111E-01	0.136E-02	0.123E+00	-0.374
19.0	0.121E-01	0.130E-02	0.108E+00	-0.380
20.0	0.131E-01	0.121E-02	0.920E-01	-0.387
21.0	0.142E-01	0.108E-02	0.759E-01	-0.395
22.0	0.152E-01	0.902E-03	0.592E-01	-0.402
23.0	0.163E-01	0.682E-03	0.418E-01	-0.411
24.0	0.174E-01	0.415E-03	0.239E-01	-0.420
25.0	0.185E-01	0.969E-04	0.525E-02	-0.429
26.0	0.195E-01	-0.275E-03	-0.141E-01	-0.439
27.0	0.206E-01	-0.705E-03	-0.342E-01	-0.450
28.0	0.217E-01	-0.119E-02	-0.551E-01	-0.462
29.0	0.227E-01	-0.175E-02	-0.769E-01	-0.474
30.0	0.238E-01	-0.237E-02	-0.995E-01	-0.486
31.0	0.248E-01	-0.305E-02	-0.123E+00	-0.499
32.0	0.258E-01	-0.382E-02	-0.148E+00	-0.513
33.0	0.268E-01	-0.465E-02	-0.174E+00	-0.528
34.0	0.278E-01	-0.556E-02	-0.200E+00	-0.543
35.0	0.287E-01	-0.656E-02	-0.229E+00	-0.560
36.0	0.296E-01	-0.764E-02	-0.258E+00	-0.576
37.0	0.305E-01	-0.880E-02	-0.289E+00	-0.594
38.0	0.313E-01	-0.101E-01	-0.321E+00	-0.612
39.0	0.321E-01	-0.114E-01	-0.355E+00	-0.631
40.0	0.328E-01	-0.128E-01	-0.391E+00	-0.651
41.0	0.335E-01	-0.143E-01	-0.428E+00	-0.671
42.0	0.340E-01	-0.159E-01	-0.468E+00	-0.693
43.0	0.346E-01	-0.176E-01	-0.509E+00	-0.714
44.0	0.350E-01	-0.193E-01	-0.552E+00	-0.737
45.0	0.352E-01	-0.210E-01	-0.596E+00	-0.759
46.0	0.353E-01	-0.226E-01	-0.642E+00	-0.782
47.0	0.350E-01	-0.241E-01	-0.689E+00	-0.805
48.0	0.341E-01	-0.250E-01	-0.735E+00	-0.827
49.0	0.323E-01	-0.251E-01	-0.779E+00	-0.847
50.0	0.291E-01	-0.238E-01	-0.818E+00	-0.866
51.0	0.243E-01	-0.206E-01	-0.851E+00	-0.881
52.0	0.181E-01	-0.158E-01	-0.876E+00	-0.893
53.0	0.118E-01	-0.106E-01	-0.892E+00	-0.900
54.0	0.688E-02	-0.620E-02	-0.901E+00	-0.905
55.0	0.367E-02	-0.332E-02	-0.906E+00	-0.906
56.0	0.188E-02	-0.170E-02	-0.907E+00	-0.906
57.0	0.953E-03	-0.864E-03	-0.907E+00	-0.904
58.0	0.491E-03	-0.445E-03	-0.905E+00	-0.903
59.0	0.259E-03	-0.234E-03	-0.903E+00	-0.901
60.0	0.141E-03	-0.127E-03	-0.902E+00	-0.900
65.0	0.997E-05	-0.896E-05	-0.899E+00	-0.901
70.0	0.111E-05	-0.101E-05	-0.908E+00	-0.912
75.0	0.154E-06	-0.142E-06	-0.923E+00	-0.929
80.0	0.228E-07	-0.215E-07	-0.943E+00	-0.948
85.0	0.318E-08	-0.306E-08	-0.962E+00	-0.966
90.0	0.354E-09	-0.347E-09	-0.980E+00	-0.981
95.0	0.233E-10	-0.231E-10	-0.992E+00	-0.992
100.0	0.358E-12	-0.357E-12	-0.998E+00	-0.998

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

See page 170 for Explanation of Table and Figures

^{28}Si

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.332
1.0	0.498E-04	0.138E-04	0.276E+00	-0.332
2.0	0.208E-03	0.626E-04	0.301E+00	-0.332
3.0	0.457E-03	0.136E-03	0.297E+00	-0.333
4.0	0.790E-03	0.229E-03	0.290E+00	-0.333
5.0	0.120E-02	0.336E-03	0.280E+00	-0.334
6.0	0.167E-02	0.453E-03	0.270E+00	-0.334
7.0	0.221E-02	0.576E-03	0.260E+00	-0.336
8.0	0.281E-02	0.701E-03	0.249E+00	-0.337
9.0	0.347E-02	0.826E-03	0.238E+00	-0.339
10.0	0.417E-02	0.945E-03	0.227E+00	-0.341
11.0	0.492E-02	0.106E-02	0.215E+00	-0.344
12.0	0.572E-02	0.116E-02	0.203E+00	-0.347
13.0	0.655E-02	0.124E-02	0.190E+00	-0.350
14.0	0.743E-02	0.131E-02	0.177E+00	-0.354
15.0	0.833E-02	0.136E-02	0.164E+00	-0.359
16.0	0.927E-02	0.139E-02	0.150E+00	-0.364
17.0	0.102E-01	0.139E-02	0.136E+00	-0.369
18.0	0.112E-01	0.136E-02	0.121E+00	-0.375
19.0	0.122E-01	0.129E-02	0.106E+00	-0.381
20.0	0.133E-01	0.119E-02	0.899E-01	-0.388
21.0	0.143E-01	0.105E-02	0.736E-01	-0.395
22.0	0.154E-01	0.873E-03	0.568E-01	-0.403
23.0	0.164E-01	0.647E-03	0.394E-01	-0.412
24.0	0.175E-01	0.372E-03	0.213E-01	-0.421
25.0	0.186E-01	0.464E-04	0.250E-02	-0.430
26.0	0.197E-01	-0.334E-03	-0.170E-01	-0.440
27.0	0.207E-01	-0.772E-03	-0.372E-01	-0.451
28.0	0.218E-01	-0.127E-02	-0.583E-01	-0.463
29.0	0.229E-01	-0.183E-02	-0.802E-01	-0.475
30.0	0.239E-01	-0.246E-02	-0.103E+00	-0.487
31.0	0.249E-01	-0.316E-02	-0.127E+00	-0.501
32.0	0.259E-01	-0.393E-02	-0.152E+00	-0.515
33.0	0.269E-01	-0.478E-02	-0.178E+00	-0.529
34.0	0.278E-01	-0.570E-02	-0.205E+00	-0.545
35.0	0.288E-01	-0.671E-02	-0.233E+00	-0.561
36.0	0.297E-01	-0.779E-02	-0.263E+00	-0.578
37.0	0.305E-01	-0.897E-02	-0.294E+00	-0.595
38.0	0.313E-01	-0.102E-01	-0.326E+00	-0.613
39.0	0.321E-01	-0.116E-01	-0.360E+00	-0.632
40.0	0.328E-01	-0.130E-01	-0.396E+00	-0.652
41.0	0.335E-01	-0.145E-01	-0.434E+00	-0.672
42.0	0.340E-01	-0.161E-01	-0.473E+00	-0.693
43.0	0.345E-01	-0.177E-01	-0.514E+00	-0.715
44.0	0.349E-01	-0.194E-01	-0.557E+00	-0.737
45.0	0.350E-01	-0.211E-01	-0.601E+00	-0.759
46.0	0.350E-01	-0.226E-01	-0.646E+00	-0.781
47.0	0.345E-01	-0.239E-01	-0.692E+00	-0.803
48.0	0.335E-01	-0.246E-01	-0.736E+00	-0.825
49.0	0.314E-01	-0.245E-01	-0.778E+00	-0.844
50.0	0.281E-01	-0.229E-01	-0.816E+00	-0.862
51.0	0.233E-01	-0.198E-01	-0.847E+00	-0.877
52.0	0.175E-01	-0.152E-01	-0.870E+00	-0.888
53.0	0.117E-01	-0.104E-01	-0.886E+00	-0.896
54.0	0.705E-02	-0.631E-02	-0.896E+00	-0.900
55.0	0.392E-02	-0.354E-02	-0.901E+00	-0.902
56.0	0.210E-02	-0.189E-02	-0.903E+00	-0.902
57.0	0.111E-02	-0.999E-03	-0.903E+00	-0.902
58.0	0.588E-03	-0.530E-03	-0.902E+00	-0.901
59.0	0.318E-03	-0.287E-03	-0.901E+00	-0.900
60.0	0.176E-03	-0.159E-03	-0.900E+00	-0.899
65.0	0.131E-04	-0.118E-04	-0.899E+00	-0.901
70.0	0.148E-05	-0.134E-05	-0.908E+00	-0.912
75.0	0.206E-06	-0.190E-06	-0.924E+00	-0.929
80.0	0.305E-07	-0.287E-07	-0.943E+00	-0.948
85.0	0.423E-08	-0.407E-08	-0.963E+00	-0.966
90.0	0.468E-09	-0.458E-09	-0.980E+00	-0.981
95.0	0.304E-10	-0.301E-10	-0.992E+00	-0.992
100.0	0.449E-12	-0.449E-12	-0.998E+00	-0.998

^{40}Ca

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.332
1.0	0.589E-04	0.160E-04	0.272E+00	-0.332
2.0	0.240E-03	0.712E-04	0.297E+00	-0.332
3.0	0.526E-03	0.153E-03	0.292E+00	-0.332
4.0	0.901E-03	0.256E-03	0.284E+00	-0.332
5.0	0.136E-02	0.373E-03	0.275E+00	-0.333
6.0	0.189E-02	0.500E-03	0.264E+00	-0.334
7.0	0.249E-02	0.631E-03	0.254E+00	-0.335
8.0	0.314E-02	0.762E-03	0.242E+00	-0.337
9.0	0.385E-02	0.890E-03	0.231E+00	-0.339
10.0	0.462E-02	0.101E-02	0.219E+00	-0.342
11.0	0.542E-02	0.112E-02	0.206E+00	-0.345
12.0	0.626E-02	0.121E-02	0.194E+00	-0.348
13.0	0.715E-02	0.129E-02	0.180E+00	-0.352
14.0	0.806E-02	0.134E-02	0.167E+00	-0.356
15.0	0.901E-02	0.137E-02	0.153E+00	-0.361
16.0	0.998E-02	0.138E-02	0.138E+00	-0.366
17.0	0.110E-01	0.135E-02	0.123E+00	-0.372
18.0	0.120E-01	0.129E-02	0.108E+00	-0.378
19.0	0.130E-01	0.119E-02	0.918E-01	-0.385
20.0	0.141E-01	0.106E-02	0.753E-01	-0.392
21.0	0.151E-01	0.880E-03	0.582E-01	-0.400
22.0	0.162E-01	0.656E-03	0.405E-01	-0.408
23.0	0.173E-01	0.383E-03	0.222E-01	-0.417
24.0	0.183E-01	0.585E-04	0.319E-02	-0.426
25.0	0.194E-01	-0.320E-03	-0.165E-01	-0.436
26.0	0.205E-01	-0.756E-03	-0.370E-01	-0.447
27.0	0.215E-01	-0.125E-02	-0.582E-01	-0.458
28.0	0.226E-01	-0.181E-02	-0.803E-01	-0.470
29.0	0.236E-01	-0.244E-02	-0.103E+00	-0.482
30.0	0.246E-01	-0.313E-02	-0.127E+00	-0.495
31.0	0.256E-01	-0.389E-02	-0.152E+00	-0.509
32.0	0.265E-01	-0.473E-02	-0.178E+00	-0.523
33.0	0.275E-01	-0.564E-02	-0.205E+00	-0.538
34.0	0.284E-01	-0.662E-02	-0.234E+00	-0.553
35.0	0.292E-01	-0.768E-02	-0.263E+00	-0.569
36.0	0.301E-01	-0.883E-02	-0.294E+00	-0.586
37.0	0.308E-01	-0.100E-01	-0.326E+00	-0.604
38.0	0.315E-01	-0.113E-01	-0.359E+00	-0.621
39.0	0.321E-01	-0.127E-01	-0.394E+00	-0.640
40.0	0.327E-01	-0.141E-01	-0.430E+00	-0.659
41.0	0.331E-01	-0.155E-01	-0.468E+00	-0.678
42.0	0.334E-01	-0.169E-01	-0.506E+00	-0.698
43.0	0.336E-01	-0.183E-01	-0.546E+00	-0.718
44.0	0.335E-01	-0.196E-01	-0.586E+00	-0.738
45.0	0.331E-01	-0.207E-01	-0.626E+00	-0.758
46.0	0.324E-01	-0.215E-01	-0.665E+00	-0.777
47.0	0.310E-01	-0.218E-01	-0.704E+00	-0.796
48.0	0.291E-01	-0.215E-01	-0.740E+00	-0.813
49.0	0.264E-01	-0.204E-01	-0.772E+00	-0.829
50.0	0.229E-01	-0.183E-01	-0.801E+00	-0.843
51.0	0.188E-01	-0.155E-01	-0.825E+00	-0.856
52.0	0.146E-01	-0.123E-01	-0.843E+00	-0.866
53.0	0.106E-01	-0.912E-02	-0.858E+00	-0.873
54.0	0.730E-02	-0.634E-02	-0.869E+00	-0.879
55.0	0.477E-02	-0.418E-02	-0.876E+00	-0.883
56.0	0.301E-02	-0.265E-02	-0.882E+00	-0.886
57.0	0.185E-02	-0.164E-02	-0.885E+00	-0.888
58.0	0.113E-02	-0.100E-02	-0.888E+00	-0.890
59.0	0.687E-03	-0.610E-03	-0.889E+00	-0.890
60.0	0.422E-03	-0.376E-03	-0.889E+00	-0.891
65.0	0.413E-04	-0.370E-04	-0.896E+00	-0.899
70.0	0.512E-05	-0.465E-05	-0.908E+00	-0.913
75.0	0.751E-06	-0.693E-06	-0.923E+00	-0.930
80.0	0.107E-06	-0.101E-06	-0.946E+00	-0.951
85.0	0.144E-07	-0.139E-07	-0.965E+00	-0.968
90.0	0.150E-08	-0.148E-08	-0.981E+00	-0.983
95.0	0.886E-10	-0.880E-10	-0.993E+00	-0.993
100.0	0.998E-12	-0.996E-12	-0.998E+00	-0.998

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

See page 170 for Explanation of Table and Figures

^{56}Fe

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.331
1.0	0.704E-04	0.188E-04	0.267E+00	-0.331
2.0	0.280E-03	0.814E-04	0.291E+00	-0.331
3.0	0.605E-03	0.173E-03	0.286E+00	-0.331
4.0	0.103E-02	0.287E-03	0.278E+00	-0.332
5.0	0.155E-02	0.414E-03	0.268E+00	-0.333
6.0	0.214E-02	0.551E-03	0.257E+00	-0.334
7.0	0.281E-02	0.690E-03	0.246E+00	-0.335
8.0	0.353E-02	0.826E-03	0.234E+00	-0.337
9.0	0.431E-02	0.956E-03	0.222E+00	-0.340
10.0	0.513E-02	0.107E-02	0.209E+00	-0.342
11.0	0.600E-02	0.118E-02	0.196E+00	-0.345
12.0	0.691E-02	0.126E-02	0.183E+00	-0.349
13.0	0.785E-02	0.132E-02	0.169E+00	-0.353
14.0	0.881E-02	0.136E-02	0.155E+00	-0.358
15.0	0.981E-02	0.137E-02	0.140E+00	-0.363
16.0	0.108E-01	0.135E-02	0.124E+00	-0.369
17.0	0.118E-01	0.129E-02	0.109E+00	-0.375
18.0	0.129E-01	0.119E-02	0.923E-01	-0.381
19.0	0.140E-01	0.105E-02	0.754E-01	-0.389
20.0	0.150E-01	0.870E-03	0.579E-01	-0.396
21.0	0.161E-01	0.642E-03	0.399E-01	-0.405
22.0	0.172E-01	0.364E-03	0.212E-01	-0.413
23.0	0.182E-01	0.330E-04	0.181E-02	-0.423
24.0	0.193E-01	-0.352E-03	-0.183E-01	-0.433
25.0	0.204E-01	-0.795E-03	-0.391E-01	-0.443
26.0	0.214E-01	-0.130E-02	-0.607E-01	-0.454
27.0	0.224E-01	-0.186E-02	-0.831E-01	-0.466
28.0	0.235E-01	-0.249E-02	-0.106E+00	-0.478
29.0	0.245E-01	-0.319E-02	-0.131E+00	-0.491
30.0	0.254E-01	-0.396E-02	-0.156E+00	-0.504
31.0	0.264E-01	-0.479E-02	-0.182E+00	-0.518
32.0	0.273E-01	-0.569E-02	-0.209E+00	-0.532
33.0	0.281E-01	-0.667E-02	-0.237E+00	-0.547
34.0	0.289E-01	-0.771E-02	-0.266E+00	-0.563
35.0	0.297E-01	-0.881E-02	-0.297E+00	-0.579
36.0	0.304E-01	-0.998E-02	-0.328E+00	-0.596
37.0	0.310E-01	-0.112E-01	-0.361E+00	-0.613
38.0	0.316E-01	-0.124E-01	-0.395E+00	-0.630
39.0	0.320E-01	-0.137E-01	-0.429E+00	-0.648
40.0	0.323E-01	-0.150E-01	-0.465E+00	-0.666
41.0	0.324E-01	-0.162E-01	-0.501E+00	-0.685
42.0	0.324E-01	-0.174E-01	-0.537E+00	-0.703
43.0	0.321E-01	-0.184E-01	-0.574E+00	-0.721
44.0	0.315E-01	-0.192E-01	-0.610E+00	-0.739
45.0	0.306E-01	-0.197E-01	-0.645E+00	-0.757
46.0	0.292E-01	-0.198E-01	-0.679E+00	-0.774
47.0	0.273E-01	-0.194E-01	-0.711E+00	-0.790
48.0	0.249E-01	-0.185E-01	-0.741E+00	-0.805
49.0	0.221E-01	-0.170E-01	-0.767E+00	-0.819
50.0	0.189E-01	-0.150E-01	-0.791E+00	-0.831
51.0	0.156E-01	-0.126E-01	-0.810E+00	-0.842
52.0	0.123E-01	-0.101E-01	-0.827E+00	-0.851
53.0	0.928E-02	-0.780E-02	-0.840E+00	-0.859
54.0	0.676E-02	-0.575E-02	-0.851E+00	-0.865
55.0	0.476E-02	-0.409E-02	-0.859E+00	-0.871
56.0	0.325E-02	-0.282E-02	-0.866E+00	-0.875
57.0	0.218E-02	-0.190E-02	-0.871E+00	-0.878
58.0	0.144E-02	-0.126E-02	-0.875E+00	-0.881
59.0	0.945E-03	-0.830E-03	-0.878E+00	-0.883
60.0	0.617E-03	-0.543E-03	-0.881E+00	-0.884
65.0	0.745E-04	-0.666E-04	-0.894E+00	-0.899
70.0	0.999E-05	-0.909E-05	-0.910E+00	-0.916
75.0	0.144E-05	-0.134E-05	-0.930E+00	-0.936
80.0	0.205E-06	-0.195E-06	-0.951E+00	-0.956
85.0	0.260E-07	-0.252E-07	-0.971E+00	-0.973
90.0	0.247E-08	-0.244E-08	-0.986E+00	-0.987
95.0	0.123E-09	-0.123E-09	-0.994E+00	-0.994
100.0	0.891E-12	-0.882E-12	-0.990E+00	-0.990

^{90}Zr

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.327
1.0	0.111E-03	0.280E-04	0.252E+00	-0.327
2.0	0.414E-03	0.113E-03	0.273E+00	-0.327
3.0	0.870E-03	0.232E-03	0.267E+00	-0.328
4.0	0.145E-02	0.374E-03	0.258E+00	-0.329
5.0	0.214E-02	0.528E-03	0.247E+00	-0.330
6.0	0.292E-02	0.685E-03	0.235E+00	-0.331
7.0	0.377E-02	0.838E-03	0.222E+00	-0.333
8.0	0.468E-02	0.979E-03	0.209E+00	-0.336
9.0	0.565E-02	0.110E-02	0.195E+00	-0.339
10.0	0.665E-02	0.121E-02	0.181E+00	-0.342
11.0	0.769E-02	0.128E-02	0.167E+00	-0.346
12.0	0.875E-02	0.133E-02	0.151E+00	-0.351
13.0	0.984E-02	0.133E-02	0.136E+00	-0.356
14.0	0.109E-01	0.130E-02	0.119E+00	-0.362
15.0	0.120E-01	0.123E-02	0.102E+00	-0.368
16.0	0.132E-01	0.112E-02	0.850E-01	-0.375
17.0	0.143E-01	0.954E-03	0.669E-01	-0.383
18.0	0.154E-01	0.741E-03	0.482E-01	-0.390
19.0	0.165E-01	0.477E-03	0.289E-01	-0.399
20.0	0.176E-01	0.157E-03	0.896E-02	-0.408
21.0	0.187E-01	-0.218E-03	-0.117E-01	-0.417
22.0	0.197E-01	-0.650E-03	-0.330E-01	-0.428
23.0	0.208E-01	-0.114E-02	-0.550E-01	-0.438
24.0	0.218E-01	-0.169E-02	-0.778E-01	-0.449
25.0	0.228E-01	-0.230E-02	-0.101E+00	-0.461
26.0	0.237E-01	-0.298E-02	-0.126E+00	-0.473
27.0	0.246E-01	-0.371E-02	-0.151E+00	-0.486
28.0	0.255E-01	-0.450E-02	-0.176E+00	-0.499
29.0	0.263E-01	-0.534E-02	-0.203E+00	-0.512
30.0	0.271E-01	-0.624E-02	-0.230E+00	-0.526
31.0	0.278E-01	-0.718E-02	-0.258E+00	-0.541
32.0	0.284E-01	-0.817E-02	-0.287E+00	-0.555
33.0	0.290E-01	-0.918E-02	-0.317E+00	-0.571
34.0	0.294E-01	-0.102E-01	-0.347E+00	-0.586
35.0	0.298E-01	-0.112E-01	-0.378E+00	-0.602
36.0	0.300E-01	-0.123E-01	-0.409E+00	-0.618
37.0	0.301E-01	-0.132E-01	-0.440E+00	-0.634
38.0	0.300E-01	-0.141E-01	-0.471E+00	-0.650
39.0	0.297E-01	-0.149E-01	-0.503E+00	-0.666
40.0	0.293E-01	-0.156E-01	-0.534E+00	-0.683
41.0	0.286E-01	-0.161E-01	-0.564E+00	-0.698
42.0	0.276E-01	-0.164E-01	-0.594E+00	-0.714
43.0	0.264E-01	-0.164E-01	-0.623E+00	-0.729
44.0	0.249E-01	-0.162E-01	-0.651E+00	-0.744
45.0	0.232E-01	-0.157E-01	-0.677E+00	-0.758
46.0	0.212E-01	-0.149E-01	-0.701E+00	-0.772
47.0	0.190E-01	-0.138E-01	-0.724E+00	-0.785
48.0	0.168E-01	-0.125E-01	-0.744E+00	-0.796
49.0	0.144E-01	-0.110E-01	-0.763E+00	-0.807
50.0	0.121E-01	-0.946E-02	-0.780E+00	-0.817
51.0	0.997E-02	-0.792E-02	-0.794E+00	-0.827
52.0	0.801E-02	-0.647E-02	-0.807E+00	-0.835
53.0	0.629E-02	-0.515E-02	-0.819E+00	-0.843
54.0	0.483E-02	-0.401E-02	-0.829E+00	-0.850
55.0	0.364E-02	-0.305E-02	-0.838E+00	-0.856
56.0	0.270E-02	-0.228E-02	-0.845E+00	-0.862
57.0	0.197E-02	-0.168E-02	-0.852E+00	-0.867
58.0	0.142E-02	-0.122E-02	-0.858E+00	-0.872
59.0	0.102E-02	-0.879E-03	-0.864E+00	-0.877
60.0	0.720E-03	-0.626E-03	-0.869E+00	-0.881
65.0	0.120E-03	-0.107E-03	-0.892E+00	-0.899
70.0	0.189E-04	-0.173E-04	-0.914E+00	-0.920
75.0	0.288E-05	-0.269E-05	-0.936E+00	-0.941
80.0	0.402E-06	-0.385E-06	-0.957E+00	-0.961
85.0	0.465E-07	-0.454E-07	-0.975E+00	-0.977
90.0	0.363E-08	-0.359E-08	-0.988E+00	-0.989
95.0	0.113E-09	-0.112E-09	-0.996E+00	-0.996
100.0	0.814E-13	-0.810E-13	-0.996E+00	-0.996

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

See page 170 for Explanation of Table and Figures

^{96}Mo

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.327
1.0	0.119E-03	0.298E-04	0.250E+00	-0.327
2.0	0.440E-03	0.119E-03	0.271E+00	-0.327
3.0	0.918E-03	0.243E-03	0.265E+00	-0.327
4.0	0.153E-02	0.390E-03	0.255E+00	-0.328
5.0	0.224E-02	0.547E-03	0.244E+00	-0.329
6.0	0.305E-02	0.707E-03	0.232E+00	-0.331
7.0	0.393E-02	0.862E-03	0.219E+00	-0.333
8.0	0.487E-02	0.100E-02	0.206E+00	-0.336
9.0	0.586E-02	0.113E-02	0.192E+00	-0.339
10.0	0.689E-02	0.122E-02	0.178E+00	-0.343
11.0	0.795E-02	0.129E-02	0.163E+00	-0.347
12.0	0.903E-02	0.133E-02	0.147E+00	-0.352
13.0	0.101E-01	0.133E-02	0.131E+00	-0.357
14.0	0.112E-01	0.129E-02	0.115E+00	-0.363
15.0	0.124E-01	0.121E-02	0.977E-01	-0.369
16.0	0.135E-01	0.108E-02	0.800E-01	-0.376
17.0	0.146E-01	0.900E-03	0.617E-01	-0.384
18.0	0.157E-01	0.671E-03	0.427E-01	-0.392
19.0	0.168E-01	0.388E-03	0.231E-01	-0.401
20.0	0.179E-01	0.507E-04	0.283E-02	-0.410
21.0	0.190E-01	-0.344E-03	-0.181E-01	-0.419
22.0	0.200E-01	-0.796E-03	-0.397E-01	-0.430
23.0	0.211E-01	-0.131E-02	-0.621E-01	-0.440
24.0	0.221E-01	-0.188E-02	-0.851E-01	-0.452
25.0	0.231E-01	-0.251E-02	-0.109E+00	-0.463
26.0	0.240E-01	-0.320E-02	-0.133E+00	-0.476
27.0	0.249E-01	-0.395E-02	-0.159E+00	-0.488
28.0	0.257E-01	-0.476E-02	-0.185E+00	-0.502
29.0	0.265E-01	-0.562E-02	-0.212E+00	-0.515
30.0	0.273E-01	-0.653E-02	-0.239E+00	-0.529
31.0	0.279E-01	-0.748E-02	-0.268E+00	-0.544
32.0	0.285E-01	-0.846E-02	-0.296E+00	-0.559
33.0	0.290E-01	-0.947E-02	-0.326E+00	-0.574
34.0	0.294E-01	-0.105E-01	-0.356E+00	-0.589
35.0	0.297E-01	-0.115E-01	-0.387E+00	-0.605
36.0	0.299E-01	-0.125E-01	-0.418E+00	-0.621
37.0	0.299E-01	-0.134E-01	-0.449E+00	-0.637
38.0	0.297E-01	-0.143E-01	-0.480E+00	-0.653
39.0	0.294E-01	-0.150E-01	-0.511E+00	-0.669
40.0	0.288E-01	-0.156E-01	-0.541E+00	-0.685
41.0	0.280E-01	-0.160E-01	-0.571E+00	-0.701
42.0	0.270E-01	-0.162E-01	-0.600E+00	-0.716
43.0	0.257E-01	-0.162E-01	-0.628E+00	-0.731
44.0	0.242E-01	-0.158E-01	-0.655E+00	-0.746
45.0	0.224E-01	-0.152E-01	-0.680E+00	-0.760
46.0	0.204E-01	-0.143E-01	-0.704E+00	-0.773
47.0	0.182E-01	-0.132E-01	-0.726E+00	-0.785
48.0	0.160E-01	-0.119E-01	-0.746E+00	-0.797
49.0	0.137E-01	-0.105E-01	-0.764E+00	-0.808
50.0	0.115E-01	-0.898E-02	-0.780E+00	-0.818
51.0	0.945E-02	-0.751E-02	-0.795E+00	-0.827
52.0	0.759E-02	-0.612E-02	-0.807E+00	-0.835
53.0	0.596E-02	-0.488E-02	-0.819E+00	-0.843
54.0	0.459E-02	-0.380E-02	-0.828E+00	-0.850
55.0	0.347E-02	-0.290E-02	-0.837E+00	-0.856
56.0	0.258E-02	-0.218E-02	-0.845E+00	-0.862
57.0	0.189E-02	-0.161E-02	-0.852E+00	-0.867
58.0	0.137E-02	-0.117E-02	-0.858E+00	-0.873
59.0	0.980E-03	-0.847E-03	-0.864E+00	-0.877
60.0	0.696E-03	-0.605E-03	-0.869E+00	-0.882
65.0	0.117E-03	-0.104E-03	-0.893E+00	-0.900
70.0	0.184E-04	-0.168E-04	-0.915E+00	-0.922
75.0	0.276E-05	-0.258E-05	-0.937E+00	-0.943
80.0	0.375E-06	-0.360E-06	-0.958E+00	-0.962
85.0	0.418E-07	-0.408E-07	-0.976E+00	-0.978
90.0	0.308E-08	-0.305E-08	-0.989E+00	-0.990
95.0	0.858E-10	-0.855E-10	-0.996E+00	-0.996
100.0	0.341E-13	-0.340E-13	-0.995E+00	-0.995

^{118}Sn

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.324
1.0	0.160E-03	0.384E-04	0.241E+00	-0.324
2.0	0.564E-03	0.146E-03	0.260E+00	-0.325
3.0	0.115E-02	0.291E-03	0.253E+00	-0.325
4.0	0.188E-02	0.457E-03	0.243E+00	-0.326
5.0	0.273E-02	0.630E-03	0.231E+00	-0.328
6.0	0.367E-02	0.799E-03	0.218E+00	-0.329
7.0	0.467E-02	0.956E-03	0.205E+00	-0.332
8.0	0.574E-02	0.109E-02	0.191E+00	-0.335
9.0	0.684E-02	0.120E-02	0.176E+00	-0.339
10.0	0.797E-02	0.128E-02	0.161E+00	-0.343
11.0	0.912E-02	0.132E-02	0.145E+00	-0.348
12.0	0.103E-01	0.132E-02	0.128E+00	-0.353
13.0	0.115E-01	0.127E-02	0.111E+00	-0.359
14.0	0.126E-01	0.118E-02	0.935E-01	-0.366
15.0	0.138E-01	0.104E-02	0.751E-01	-0.373
16.0	0.149E-01	0.839E-03	0.562E-01	-0.381
17.0	0.161E-01	0.588E-03	0.366E-01	-0.389
18.0	0.172E-01	0.281E-03	0.163E-01	-0.398
19.0	0.183E-01	-0.835E-04	-0.456E-02	-0.407
20.0	0.194E-01	-0.506E-03	-0.261E-01	-0.417
21.0	0.204E-01	-0.988E-03	-0.484E-01	-0.428
22.0	0.214E-01	-0.153E-02	-0.713E-01	-0.439
23.0	0.224E-01	-0.213E-02	-0.949E-01	-0.450
24.0	0.234E-01	-0.279E-02	-0.119E+00	-0.462
25.0	0.242E-01	-0.350E-02	-0.144E+00	-0.474
26.0	0.251E-01	-0.426E-02	-0.170E+00	-0.487
27.0	0.259E-01	-0.508E-02	-0.196E+00	-0.500
28.0	0.266E-01	-0.593E-02	-0.223E+00	-0.514
29.0	0.272E-01	-0.683E-02	-0.251E+00	-0.528
30.0	0.278E-01	-0.775E-02	-0.279E+00	-0.542
31.0	0.283E-01	-0.869E-02	-0.307E+00	-0.557
32.0	0.286E-01	-0.964E-02	-0.336E+00	-0.572
33.0	0.289E-01	-0.106E-01	-0.366E+00	-0.587
34.0	0.290E-01	-0.115E-01	-0.395E+00	-0.602
35.0	0.290E-01	-0.123E-01	-0.425E+00	-0.618
36.0	0.289E-01	-0.131E-01	-0.455E+00	-0.633
37.0	0.285E-01	-0.138E-01	-0.484E+00	-0.649
38.0	0.280E-01	-0.144E-01	-0.513E+00	-0.664
39.0	0.273E-01	-0.148E-01	-0.542E+00	-0.679
40.0	0.264E-01	-0.150E-01	-0.570E+00	-0.695
41.0	0.253E-01	-0.151E-01	-0.597E+00	-0.709
42.0	0.239E-01	-0.149E-01	-0.623E+00	-0.724
43.0	0.224E-01	-0.145E-01	-0.648E+00	-0.738
44.0	0.206E-01	-0.139E-01	-0.672E+00	-0.751
45.0	0.188E-01	-0.130E-01	-0.694E+00	-0.764
46.0	0.168E-01	-0.120E-01	-0.714E+00	-0.776
47.0	0.148E-01	-0.109E-01	-0.733E+00	-0.787
48.0	0.128E-01	-0.962E-02	-0.751E+00	-0.798
49.0	0.109E-01	-0.834E-02	-0.767E+00	-0.808
50.0	0.906E-02	-0.708E-02	-0.781E+00	-0.818
51.0	0.740E-02	-0.588E-02	-0.795E+00	-0.826
52.0	0.594E-02	-0.479E-02	-0.806E+00	-0.835
53.0	0.468E-02	-0.383E-02	-0.817E+00	-0.842
54.0	0.363E-02	-0.300E-02	-0.827E+00	-0.849
55.0	0.277E-02	-0.232E-02	-0.835E+00	-0.856
56.0	0.209E-02	-0.176E-02	-0.843E+00	-0.862
57.0	0.155E-02	-0.132E-02	-0.850E+00	-0.868
58.0	0.114E-02	-0.977E-03	-0.857E+00	-0.874
59.0	0.830E-03	-0.716E-03	-0.863E+00	-0.879
60.0	0.599E-03	-0.520E-03	-0.869E+00	-0.884
65.0	0.107E-03	-0.956E-04	-0.896E+00	-0.903
70.0	0.172E-04	-0.158E-04	-0.920E+00	-0.926
75.0	0.254E-05	-0.240E-05	-0.943E+00	-0.948
80.0	0.327E-06	-0.315E-06	-0.964E+00	-0.967
85.0	0.327E-07	-0.321E-07	-0.980E+00	-0.982
90.0	0.197E-08	-0.195E-08	-0.992E+00	-0.992
95.0	0.330E-10	-0.329E-10	-0.996E+00	-0.996
100.0	0.224E-16	-0.223E-16	-0.993E+00	-0.993

TABLE I. Energy Spectrum, Asymmetry Coefficient, Asymmetry, and Asymmetry Parameter

See page 170 for Explanation of Table and Figures

^{208}Pb

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.310
1.0	0.635E-03	0.126E-03	0.198E+00	-0.310
2.0	0.179E-02	0.374E-03	0.210E+00	-0.311
3.0	0.319E-02	0.638E-03	0.200E+00	-0.312
4.0	0.471E-02	0.883E-03	0.187E+00	-0.314
5.0	0.629E-02	0.109E-02	0.173E+00	-0.318
6.0	0.788E-02	0.124E-02	0.158E+00	-0.322
7.0	0.945E-02	0.133E-02	0.141E+00	-0.327
8.0	0.110E-01	0.136E-02	0.124E+00	-0.333
9.0	0.125E-01	0.132E-02	0.106E+00	-0.339
10.0	0.139E-01	0.120E-02	0.867E-01	-0.347
11.0	0.152E-01	0.102E-02	0.670E-01	-0.355
12.0	0.165E-01	0.768E-03	0.465E-01	-0.363
13.0	0.177E-01	0.447E-03	0.252E-01	-0.372
14.0	0.189E-01	0.601E-04	0.318E-02	-0.382
15.0	0.200E-01	-0.391E-03	-0.195E-01	-0.393
16.0	0.210E-01	-0.902E-03	-0.429E-01	-0.404
17.0	0.220E-01	-0.147E-02	-0.669E-01	-0.415
18.0	0.229E-01	-0.209E-02	-0.915E-01	-0.427
19.0	0.237E-01	-0.276E-02	-0.117E+00	-0.439
20.0	0.244E-01	-0.347E-02	-0.142E+00	-0.452
21.0	0.251E-01	-0.422E-02	-0.168E+00	-0.465
22.0	0.256E-01	-0.500E-02	-0.195E+00	-0.478
23.0	0.261E-01	-0.579E-02	-0.222E+00	-0.492
24.0	0.265E-01	-0.659E-02	-0.249E+00	-0.506
25.0	0.268E-01	-0.739E-02	-0.276E+00	-0.520
26.0	0.269E-01	-0.818E-02	-0.304E+00	-0.535
27.0	0.270E-01	-0.894E-02	-0.331E+00	-0.549
28.0	0.269E-01	-0.966E-02	-0.359E+00	-0.564
29.0	0.267E-01	-0.103E-01	-0.386E+00	-0.579
30.0	0.264E-01	-0.109E-01	-0.413E+00	-0.593
31.0	0.259E-01	-0.114E-01	-0.440E+00	-0.608
32.0	0.253E-01	-0.118E-01	-0.466E+00	-0.623
33.0	0.246E-01	-0.121E-01	-0.492E+00	-0.637
34.0	0.237E-01	-0.122E-01	-0.517E+00	-0.652
35.0	0.226E-01	-0.123E-01	-0.542E+00	-0.666
36.0	0.215E-01	-0.122E-01	-0.566E+00	-0.680
37.0	0.202E-01	-0.119E-01	-0.589E+00	-0.694
38.0	0.188E-01	-0.115E-01	-0.611E+00	-0.707
39.0	0.174E-01	-0.110E-01	-0.633E+00	-0.720
40.0	0.159E-01	-0.104E-01	-0.654E+00	-0.733
41.0	0.144E-01	-0.966E-02	-0.672E+00	-0.745
42.0	0.128E-01	-0.886E-02	-0.691E+00	-0.757
43.0	0.113E-01	-0.802E-02	-0.708E+00	-0.768
44.0	0.987E-02	-0.715E-02	-0.725E+00	-0.779
45.0	0.850E-02	-0.629E-02	-0.740E+00	-0.789
46.0	0.722E-02	-0.545E-02	-0.755E+00	-0.799
47.0	0.606E-02	-0.465E-02	-0.768E+00	-0.809
48.0	0.501E-02	-0.391E-02	-0.781E+00	-0.818
49.0	0.409E-02	-0.325E-02	-0.793E+00	-0.827
50.0	0.330E-02	-0.265E-02	-0.804E+00	-0.835
51.0	0.263E-02	-0.214E-02	-0.814E+00	-0.843
52.0	0.207E-02	-0.170E-02	-0.824E+00	-0.851
53.0	0.161E-02	-0.134E-02	-0.833E+00	-0.858
54.0	0.124E-02	-0.104E-02	-0.842E+00	-0.865
55.0	0.940E-03	-0.799E-03	-0.850E+00	-0.872
56.0	0.707E-03	-0.607E-03	-0.858E+00	-0.878
57.0	0.527E-03	-0.456E-03	-0.866E+00	-0.884
58.0	0.389E-03	-0.340E-03	-0.873E+00	-0.889
59.0	0.285E-03	-0.250E-03	-0.880E+00	-0.893
60.0	0.206E-03	-0.183E-03	-0.887E+00	-0.897
65.0	0.370E-04	-0.339E-04	-0.917E+00	-0.924
70.0	0.552E-05	-0.520E-05	-0.943E+00	-0.948
75.0	0.667E-06	-0.643E-06	-0.965E+00	-0.967
80.0	0.587E-07	-0.576E-07	-0.981E+00	-0.982
85.0	0.294E-08	-0.292E-08	-0.992E+00	-0.992
90.0	0.360E-10	-0.358E-10	-0.995E+00	-0.995

^{209}Bi

E	$N(E)$	$A(E)$	$\beta(E)$	$\alpha(E, E_{max})$
0.511	-	-	-	-0.309
1.0	0.667E-03	0.131E-03	0.196E+00	-0.309
2.0	0.186E-02	0.387E-03	0.208E+00	-0.310
3.0	0.330E-02	0.654E-03	0.198E+00	-0.311
4.0	0.486E-02	0.900E-03	0.185E+00	-0.314
5.0	0.647E-02	0.110E-02	0.171E+00	-0.317
6.0	0.808E-02	0.125E-02	0.155E+00	-0.321
7.0	0.966E-02	0.134E-02	0.139E+00	-0.327
8.0	0.112E-01	0.136E-02	0.121E+00	-0.332
9.0	0.127E-01	0.131E-02	0.103E+00	-0.339
10.0	0.141E-01	0.119E-02	0.841E-01	-0.347
11.0	0.155E-01	0.994E-03	0.643E-01	-0.355
12.0	0.168E-01	0.731E-03	0.436E-01	-0.364
13.0	0.180E-01	0.400E-03	0.222E-01	-0.373
14.0	0.191E-01	0.181E-05	0.948E-04	-0.383
15.0	0.202E-01	-0.460E-03	-0.227E-01	-0.393
16.0	0.212E-01	-0.981E-03	-0.462E-01	-0.405
17.0	0.222E-01	-0.156E-02	-0.704E-01	-0.416
18.0	0.230E-01	-0.219E-02	-0.951E-01	-0.428
19.0	0.238E-01	-0.287E-02	-0.120E+00	-0.440
20.0	0.245E-01	-0.358E-02	-0.146E+00	-0.453
21.0	0.252E-01	-0.434E-02	-0.172E+00	-0.466
22.0	0.257E-01	-0.511E-02	-0.199E+00	-0.480
23.0	0.262E-01	-0.591E-02	-0.226E+00	-0.494
24.0	0.265E-01	-0.671E-02	-0.253E+00	-0.508
25.0	0.268E-01	-0.750E-02	-0.280E+00	-0.522
26.0	0.269E-01	-0.828E-02	-0.308E+00	-0.536
27.0	0.269E-01	-0.903E-02	-0.335E+00	-0.551
28.0	0.268E-01	-0.973E-02	-0.363E+00	-0.565
29.0	0.266E-01	-0.104E-01	-0.390E+00	-0.580
30.0	0.263E-01	-0.109E-01	-0.417E+00	-0.595
31.0	0.258E-01	-0.114E-01	-0.444E+00	-0.610
32.0	0.251E-01	-0.118E-01	-0.470E+00	-0.624
33.0	0.243E-01	-0.121E-01	-0.496E+00	-0.639
34.0	0.234E-01	-0.122E-01	-0.521E+00	-0.653
35.0	0.224E-01	-0.122E-01	-0.545E+00	-0.667
36.0	0.212E-01	-0.121E-01	-0.569E+00	-0.681
37.0	0.199E-01	-0.118E-01	-0.592E+00	-0.695
38.0	0.185E-01	-0.114E-01	-0.614E+00	-0.708
39.0	0.171E-01	-0.108E-01	-0.635E+00	-0.721
40.0	0.156E-01	-0.102E-01	-0.655E+00	-0.734
41.0	0.140E-01	-0.947E-02	-0.675E+00	-0.746
42.0	0.125E-01	-0.867E-02	-0.693E+00	-0.758
43.0	0.110E-01	-0.783E-02	-0.710E+00	-0.769
44.0	0.960E-02	-0.697E-02	-0.726E+00	-0.780
45.0	0.825E-02	-0.612E-02	-0.741E+00	-0.790
46.0	0.700E-02	-0.529E-02	-0.756E+00	-0.800
47.0	0.586E-02	-0.451E-02	-0.769E+00	-0.810
48.0	0.485E-02	-0.379E-02	-0.782E+00	-0.819
49.0	0.395E-02	-0.314E-02	-0.794E+00	-0.828
50.0	0.319E-02	-0.256E-02	-0.805E+00	-0.836
51.0	0.253E-02	-0.207E-02	-0.815E+00	-0.844
52.0	0.199E-02	-0.164E-02	-0.825E+00	-0.852
53.0	0.155E-02	-0.129E-02	-0.834E+00	-0.859
54.0	0.119E-02	-0.100E-02	-0.843E+00	-0.866
55.0	0.903E-03	-0.769E-03	-0.851E+00	-0.873
56.0	0.679E-03	-0.583E-03	-0.859E+00	-0.879
57.0	0.506E-03	-0.438E-03	-0.867E+00	-0.884
58.0	0.373E-03	-0.326E-03	-0.874E+00	-0.890
59.0	0.273E-03	-0.240E-03	-0.881E+00	-0.894
60.0	0.198E-03	-0.176E-03	-0.887E+00	-0.898
65.0	0.353E-04	-0.324E-04	-0.918E+00	-0.925
70.0	0.523E-05	-0.494E-05	-0.944E+00	-0.948
75.0	0.624E-06	-0.603E-06	-0.965E+00	-0.968
80.0	0.539E-07	-0.529E-07	-0.982E+00	-0.983
85.0	0.259E-08	-0.257E-08	-0.992E+00	-0.992
90.0	0.284E-10	-0.283E-10	-0.995E+00	-0.995

FIGURE I. Comparison of Energy Spectra for Free- and Bound-Muon Decays
See page 170 for Explanation of Table and Figures

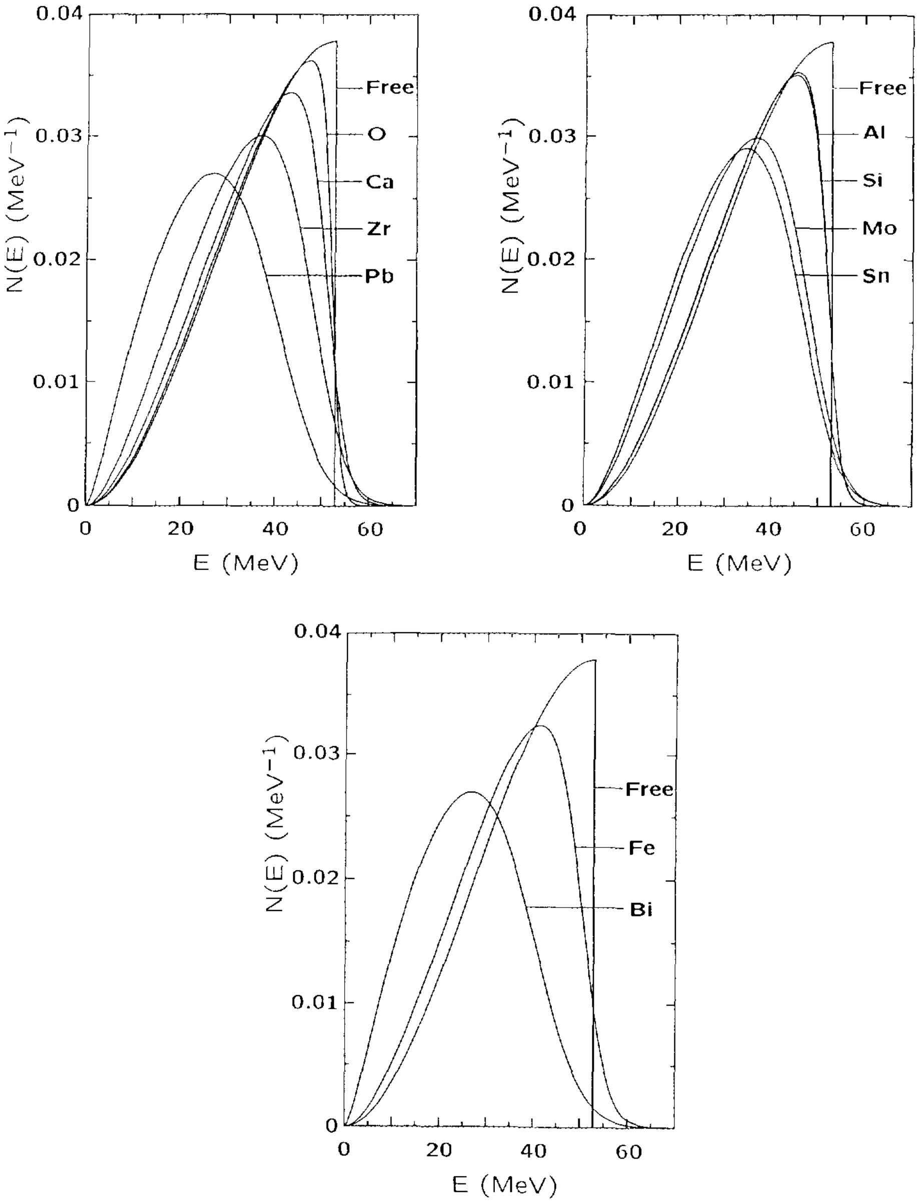

FIGURE II. Comparison of Asymmetry Coefficients for Free- and Bound-Muon Decays
See page 170 for Explanation of Table and Figures

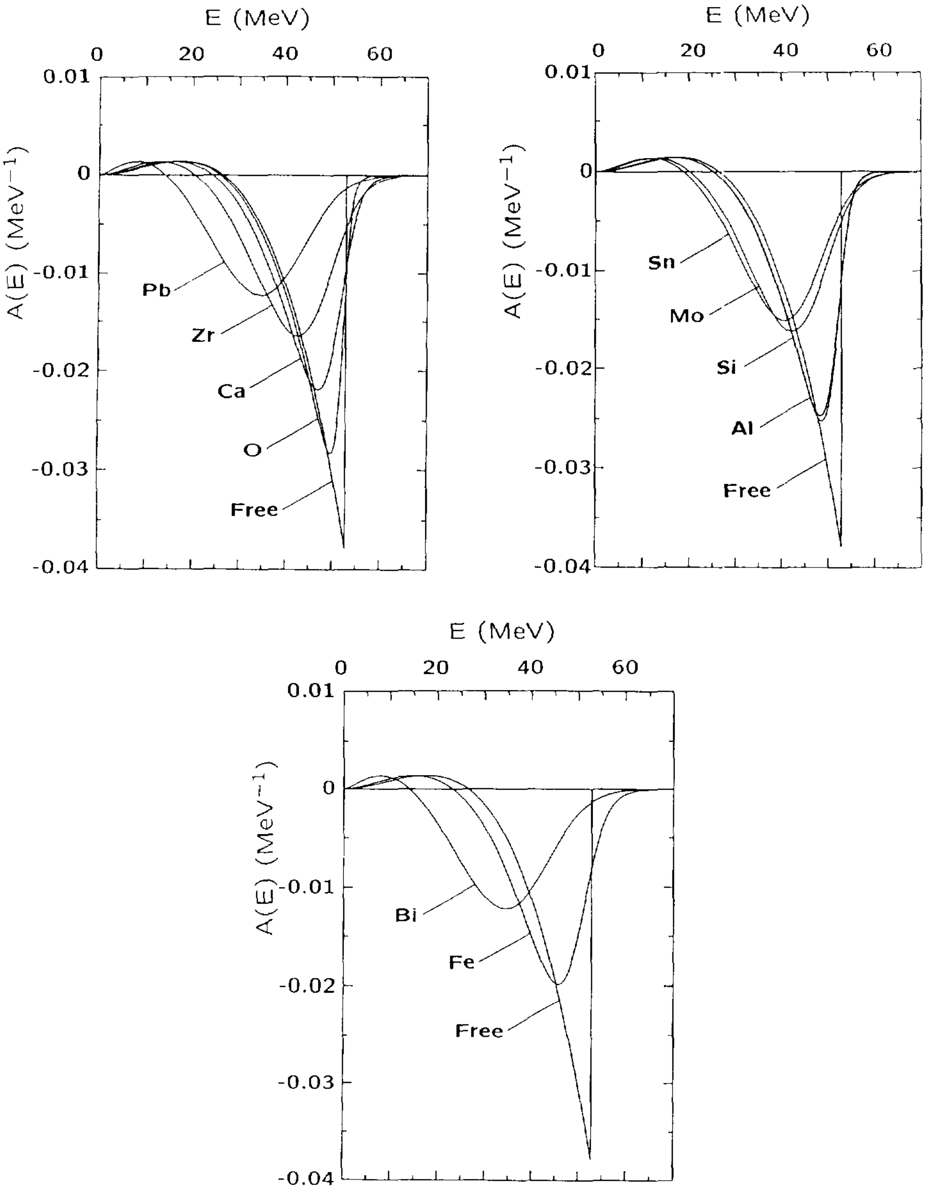

FIGURE III. Comparison of Asymmetry Parameters for Free- and Bound-Muon Decays

See page 170 for Explanation of Table and Figures