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Electric Quadrupole Transitions in Odd-Mass Spherical Nuclei*

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Experimental $B(E2)$ values are tabulated for transitions in odd-mass spherical nuclei and compared with predictions of the pairing-plus-quadrupole model including up to two phonons. Of the well over 100 cases, agreement within a factor of 2 is obtained for $\approx\frac{2}{3}$, indicating the general validity of the theory and suggesting its use as a guide to yet unmeasured cases.

I. INTRODUCTION

A few years ago the reduced electric quadrupole transition probabilities between the low-lying states of odd-mass spherical nuclei were tabulated by Sorensen[1] and compared with the pairing-plus-quadrupole model including wave-function components up to one phonon. Since then, a large number of additional experimental data have been accumulated, and in certain regions new information about the single-particle parameters has become available.[2] Therefore, a more complete calculation which includes wave-function components up to two phonons is presented.

II. CALCULATION

The approximations used by Kisslinger and Sorensen (KS)[3] to treat the pairing-plus-quadrupole Hamiltonian for odd-mass spherical nuclei lead to, e.g., for an odd-neutron case,

$$\begin{aligned} H_{\rm odd} = {} & \sum_{jm} E_j^n \beta_m^{j\dagger}\beta_m^j + \omega\sum_\mu \Gamma_\mu^{2\dagger}\Gamma_\mu^2 \\ & + \bar\chi \sum_{j_1j_2\mu}(-1)^\mu Q_{j_1j_2}^n \eta_{n\mu}^2(j_1j_2)[\Gamma_{-\mu}^{2\dagger} + (-1)^\mu\Gamma_\mu^2]\,, \end{aligned} \tag{1}$$

where E_j is the quasiparticle excitation energy, $\beta^\dagger$ the quasiparticle creation operator, $\Gamma^\dagger$ the phonon creation operator, and ω the phonon excitation energy. $\bar\chi$ is an effective coupling constant depending on ω and defined in Ref. 3. Also

$$\begin{aligned} Q_{j_1j_2} = {} & (-1)^{j_1-1/2}\left(\frac{(2j_1+1)(2j_2+1)}{20\pi}\right)^{1/2} C_{1/2\;-1/2\;0}^{j_1\;\;\;j_2\;\;\;\;2} \\ & \times\langle j_1 \,|\, r^2 \,|\, j_2\rangle (U_{j_1}U_{j_2} - V_{j_1}V_{j_2})\,, \end{aligned} \tag{2}$$

$$\eta_\mu^2(j_1j_2) = \sum_{m_1m_2} C_{m_1\;m_2\;\mu}^{j_1\;\;j_2\;\;2}\, \beta_{m_1}^{j_1\dagger}\beta_{-m_2}^{j_2}(-1)^{j_2-m_2}\,. \tag{3}$$

$\langle j_1 \,|\, r^2 \,|\, j_2\rangle$ uses harmonic-oscillator radial functions, $\hbar\omega = 41A^{-1/3}$ MeV, and U, V are the usual occupation factors of the pairing theory.

The wave functions resulting from the diagonalization procedure are of the form

$$\begin{aligned} |\,\Psi_j\rangle = {} & C_{j0\,0}^{\;\;\;\;j}\,\beta^{j\dagger}\,|\,\Psi_0\rangle + \sum_{j'} C_{j'1\,2}^{\;\;\;\;\;j}[\beta^{j'\dagger}\Gamma^{\dagger 2}]^j\,|\,\Psi_0\rangle \\ & + \sum_{j'J} C_{j'2\,J}^{\;\;\;\;\;j}[\beta^{j'\dagger}(\Gamma^{\dagger 2}\Gamma^{\dagger 2})^J]^j\,|\,\Psi_0\rangle\,, \end{aligned} \tag{4}$$

where the C's are the coefficients of the basis states. Then the reduced transition probability is given by

$$\begin{aligned} \frac{B(E2)_{j_i\to j_f}}{2j_f+1} = {} & \Bigg\{ e_{\rm eff} C_{j_i0\,0}^{\;\;\;\;\;j_i} C_{j_f0\,0}^{\;\;\;\;\;j_f} Q_{j_fj_i}\left[\frac{5}{(2j_i+1)(2j_f+1)}\right]^{1/2} + e_{\rm eff}\sqrt{5}\sum_{j'j''}(-1)^{j_i+j'}Q_{j'j''}\Bigg(C_{j'1\,2}^{\;\;\;\;\;j_f} C_{j''1\,2}^{\;\;\;\;\;j_i} \\ & \times\begin{Bmatrix} j_f & j' & 2 \\ j'' & j_i & 2 \end{Bmatrix} + \sum_{J\,\text{even}} C_{j'2\,J}^{\;\;\;\;\;j_f} C_{j''2\,J}^{\;\;\;\;\;j_i}\begin{Bmatrix} j_f & j_i & 2 \\ j'' & j' & J \end{Bmatrix}\Bigg) + \left[\frac{B(E2)_{0+\to 2+}}{5}\right]^{1/2}\Bigg[\frac{C_{j_i0\,0}^{\;\;\;\;\;j_i} C_{j_i1\,2}^{\;\;\;\;\;j_f}}{(2j_i+1)^{1/2}} + C_{j_f0\,0}^{\;\;\;\;\;j_f} C_{j_f1\,2}^{\;\;\;\;\;j_i} \\ & \times\frac{(-1)^{j_i-j_f}}{(2j_f+1)^{1/2}} + 2\sum_{j',J\,\text{even}}(2J+1)^{1/2}(-1)^{j_f+j'}\Bigg(C_{j'1\,2}^{\;\;\;\;\;j_f} C_{j'2\,J}^{\;\;\;\;\;j_i}\begin{Bmatrix} j_i & J & j' \\ 2 & j_f & 2 \end{Bmatrix} + C_{j'1\,2}^{\;\;\;\;\;j_i} C_{j'2\,J}^{\;\;\;\;\;j_f}\begin{Bmatrix} j_f & J & j' \\ 2 & j_i & 2 \end{Bmatrix}\Bigg)\Bigg]\Bigg\}^2 . \end{aligned} \tag{5}$$

The factor $2j_f+1$ on the left side of Eq. (5) is included to make it symmetric in j_i and j_f. The terms containing Q come from the noncollective (particle) part of the quadrupole transition operator. Except for very slow transitions, these are small as compared to the terms containing $B(E2)_{0+\to 2+}$, which come from the collective (phonon) part of the quadrupole operator. Equation (5) treats the phonons as harmonic and thus does not include the effect of diagonal (2+→ 2+) collective quadrupole matrix elements, even though large phonon 2+ quadrupole moments have been observed in some cases.

III. PARAMETERS USED

Within each shell single-particle energies are given a smooth A dependence of the following form

$$\begin{aligned} \epsilon_{j_p}(A) = {} & \epsilon_{j_p}^0(A_0)(A_0/A)^{1/3} + \alpha_{j_p}(A_0/A)^{2/3}[1-(A/A_0)^{1/3}] \\ & + \Delta\epsilon_{j_p}^0(N, Z)\,. \end{aligned} \tag{6}$$

If in the shell both $j_p = l_p \pm \frac{1}{2}$ states are present,

$$\alpha_{l_p+1/2} = -\frac{[\epsilon_{l_p-1/2}^0(A_0) - \epsilon_{l_p+1/2}^0(A_0)]l_p}{2l_p+1}\,,$$

$$\alpha_{l_p-1/2} = +\frac{[\epsilon_{l_p-1/2}^0(A_0) - \epsilon_{l_p+1/2}^0(A_0)](l_p+1)}{2l_p+1}\,. \tag{7}$$

If only one of the levels is present in the shell,

$$\begin{aligned} \alpha_{l_p+1/2} &= -7A_0^{-2/3}\,l_p \text{ MeV}\,, \\ \alpha_{l_p-1/2} &= +7A_0^{-2/3}(l_p+1) \text{ MeV}\,. \end{aligned} \tag{8}$$

$\Delta\epsilon_{jp}(N, Z)$ is the special shift given in some cases. In Table I we give a list of $\epsilon_j^0(A_0)$ along with the regions in which they are used.

Proton levels in the region $20 < Z < 50$ and $50 < Z < 76$ are essentially the same as used by KS[3] except for a special shift for $Z = 51$ isotopes. Proton $\epsilon_j^0(A_0)$'s used in the regions $76 \leqslant Z < 82$ and $Z > 82$ are the experimental single-particle levels[4] for ^{207}Tl and ^{209}Bi, respectively. Neutron $\epsilon_j^0(A_0)$'s for the regions $20 < N < 50$, $82 < N \leqslant 90$, and $78 < N < 82$ are those derived from experiment by Cohen[2] from the levels of $^{89}_{40}\mathrm{Zn}_{49}$, $^{141}_{58}\mathrm{Ce}_{83}$, and $^{139}_{58}\mathrm{Ce}_{81}$. In these and in other regions, the special shifts were given from the point of view of getting better $B(E2)$ values for odd-mass nuclei. Neutron levels for the regions $50 < N < 78$ and $114 < N < 126$ are the

TABLE I. Single-particle levels in MeV.

Proton level $20 < Z < 50$

Level	$1f_{7/2}$	$1f_{5/2}$	$2p_{3/2}$	$2p_{1/2}$	$1g_{9/2}$	
$\epsilon_j^0(A_0)$	−3.50	0.50	0.00	1.80	2.80	$A_0=90$

$\Delta\epsilon^0_{f_{7/2}}=\Delta\epsilon^0_{f_{5/2}}=-0.11(N-40)$ for $20 < Z < 38$
$\Delta\epsilon^0_{g_{9/2}}=-0.055(Z-40)$ for $38 < Z < 50$

Proton levels $50 < Z < 76$

Level	$1g_{7/2}$	$2d_{5/2}$	$1h_{11/2}$	$2d_{3/2}$	$3s_{1/2}$	
$\epsilon_j^0(A_0)$	0	0.8	2.1	2.6	2.95	$A_0=207$

$\Delta\epsilon^0_{g_{7/2}}=0.125(75-N)$ for $Z=51$

Proton levels $76 \leq Z < 82$

Level	$1g_{7/2}$	$2d_{5/2}$	$1h_{11/2}$	$2d_{3/2}$	$3s_{1/2}$	
$\epsilon_j^0(A_0)$	0	1.81	2.14	3.13	3.48	$A_0=207$

$\Delta\epsilon^0_{h_{11/2}}=0.5$; $\Delta\epsilon^0_{d_{3/2}}=-0.1$ except for Ir and Tl isotopes. For Ir isotopes

$\Delta\epsilon^0_{h_{11/2}}=0.5$; $\Delta\epsilon^0_{d_{3/2}}=-0.05$

For Tl no special shifts.

Proton levels $82 < Z$

Level	$1h_{9/2}$	$2f_{7/2}$	$1i_{13/2}$	$2f_{5/2}$	$3p_{3/2}$	$3p_{1/2}$	
$\epsilon_j^0(A_0)$	0	0.70	1.62	2.83	3.10	3.64	$A_0=209$

Neutron levels $20 < N < 50$

Level	$1f_{7/2}$	$2p_{3/2}$	$1f_{5/2}$	$2p_{1/2}$	$1g_{9/2}$
$\epsilon_j^0(A_0)$	−4.50	0	−0.4	1.0	1.5

$\Delta\epsilon^0_{g_{9/2}}=-0.055\ (Z-40)$

Neutron levels $50 < N < 78$

Level	$2d_{5/2}$	$1g_{7/2}$	$3s_{1/2}$	$1h_{11/2}$	$2d_{3/2}$	
$\epsilon_j^0(A_0)$	0	0.8	2.0	2.5	2.8	$A_0=120$

$\Delta\epsilon^0_{g_{7/2}}=0.14(48-Z)$ for $Z < 48$
$=-0.1$ for $Z=48$
$=\Delta\epsilon^0_{h_{11/2}}=0.15(50-Z)$ for $Z > 50$
$\Delta\epsilon^0_{s_{1/2}}=-0.2$ for $Z=50$
$\Delta\epsilon^0_{d_{3/2}}=0.05(50-Z)$ for $Z > 50$

TABLE I *(Continued)*

Neutron levels $78 < N < 82$

Level	$1g_{7/2}$	$2d_{5/2}$	$1h_{11/2}$	$3s_{1/2}$	$2d_{3/2}$	
$\epsilon_j^0(A_0)$	−1.20	0	0.80	1.33	1.60	$A_0=139$

Neutron levels $82 < N \leq 90$

Level	$2f_{7/2}$	$3p_{3/2}$	$1h_{9/2}$	$2f_{5/2}$	$3p_{1/2}$	$1i_{13/2}$	
$\epsilon_j^0(A_0)$	0	0.83	1.55	1.88	2.25	2.80	$A_0=141$

Neutron levels $114 < N < 126$

Level	$1h_{9/2}$	$2f_{7/2}$	$1i_{13/2}$	$3p_{3/2}$	$2f_{5/2}$	$3p_{1/2}$	
$\epsilon_j^0(A_0)$	−1.09	0	0.70	1.45	1.77	2.34	$A_0=207$

$\Delta\epsilon^0_{i_{13/2}}=+0.2$ except for $Z=82$

Neutron levels $N > 126$

Level	$2g_{9/2}$	$1i_{11/2}$	$1j_{15/2}$	$3d_{5/2}$	$4s_{1/2}$	$3d_{3/2}$	$2g_{7/2}$	
$\epsilon_j^0(A_0)$	0	0.776	1.417	1.562	2.029	2.488	2.536	$A_0=209$

same as those used by KS except for a number of special shifts. For $N > 126$, the experimental single-particle energies[4] for ^{209}Pb are used.

The quadrupole-force strength is chosen to fit the average of the 2+ energies of the neighboring even-even nuclei except for single-particle or single-hole cases, for which the 2+ energy of the neighboring single-closed-shell nucleus is used.

The pairing-force strength G is chosen to reproduce the average odd-even mass differences. For odd-neutron cases below the deformed region, $G=G_n=G_p=23/A$ is used. For odd protons less than 49, $G=24/A$ is used, and it is increased to $25/A$ for In isotopes. For nuclei below the deformed region with odd-proton number greater than 49, $G=23/A$ is used. In the lead region, both for odd-neutron and odd-proton cases $G_n=23/A$ and $G_p=25/A$ is used.

For $B(E2)_{0+\to 2+}$ in Eq. (5), the average of the experimental[5] $B(E2)_{0+\to 2+}$ of the neighboring even-even nuclei is used, though for one-hole or one-particle cases $B(E2)_{0+\to 2+}$ of the neighboring single-closed-shell nucleus is used.[1]

The calculated theoretical values of the transition probabilities are listed in Table II and Table III for odd-neutron and odd-proton cases, respectively. The experimental values with which these values may be compared are given whenever available. Most of these numbers were taken from the literature, while some of them were calculated

TABLE II. Reduced $E2$ transition probabilities for odd-neutron spherical nuclei. The first and second columns list the isotope, and the levels between which the transition occurs. Columns three, four, and five list the single-particle, theoretical, and experimental $B(E2)$ values divided by $2j_f+1$, where j_f is the final angular momentum, in units of $e^2\times10^{-50}$.

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
$^{59}_{28}\mathrm{Ni}_{31}$	$p_{3/2}$ $p_{1/2}$	0.068	0.865	
	$f_{5/2}$ $p_{1/2}$	0.068	0.755	
	$f_{5/2}$ $p_{3/2}$	0.010	0.084	
$^{61}_{28}\mathrm{Ni}_{33}$	$p_{3/2}$ $p_{1/2}$	0.071	0.719	
	$f_{5/2}$ $p_{1/2}$	0.071	0.543	
	$f_{5/2}$ $p_{3/2}$	0.010	0.025	0.012[a]
$^{63}_{28}\mathrm{Ni}_{35}$	$p_{3/2}$ $p_{1/2}$	0.074	0.334	
	$f_{5/2}$ $p_{1/2}$	0.074	0.154	
	$f_{5/2}$ $p_{3/2}$	0.011	0.006	
$^{65}_{30}\mathrm{Zn}_{35}$	$p_{3/2}$ $p_{1/2}$	0.078	0.860	
	$f_{5/2}$ $p_{1/2}$	0.078	0.381	0.17[b]
	$f_{5/2}$ $p_{3/2}$	0.011	0.019	
$^{67}_{30}\mathrm{Zn}_{37}$	$p_{3/2}$ $p_{1/2}$	0.081	0.005	
	$f_{5/2}$ $p_{1/2}$	0.081	0.001	0.01[c]
	$f_{5/2}$ $p_{3/2}$	0.012	0.084	0.52[c]
$^{71}_{32}\mathrm{Ge}_{39}$	$p_{3/2}$ $p_{1/2}$	0.087	0.94	
	$f_{5/2}$ $p_{1/2}$	0.087	0.68	0.22[b]
	$f_{5/2}$ $p_{3/2}$	0.012	0.219	
$^{73}_{32}\mathrm{Ge}_{41}$	$p_{3/2}$ $p_{1/2}$	0.091	2.49	
	$f_{5/2}$ $p_{1/2}$	0.091	2.27	
	$f_{5/2}$ $p_{3/2}$	0.013	0.407	
$^{77}_{34}\mathrm{Se}_{43}$	$p_{3/2}$ $p_{1/2}$	0.097	4.67	4.25[c]
	$f_{5/2}$ $p_{1/2}$	0.097	4.65	0.15 ±0.05[c]
	$f_{5/2}$ $p_{3/2}$	0.014	0.57	
$^{83}_{36}\mathrm{Kr}_{47}$	$p_{3/2}$ $p_{1/2}$	0.108	2.36	
	$f_{5/2}$ $p_{1/2}$	0.108	2.43	
	$f_{5/2}$ $p_{3/2}$	0.015	0.178	
$^{89}_{38}\mathrm{Sr}_{51}$	$d_{3/2}$ $s_{1/2}$	0.118	0.44	
	$d_{5/2}$ $s_{1/2}$	0.118	1.15	
	$d_{5/2}$ $d_{3/2}$	0.017	0.59	
$^{91}_{40}\mathrm{Zr}_{51}$	$d_{3/2}$ $s_{1/2}$	0.122	0.309	
	$d_{5/2}$ $s_{1/2}$	0.122	0.462	
	$d_{5/2}$ $d_{3/2}$	0.017	0.129	
$^{93}_{40}\mathrm{Zr}_{53}$	$d_{3/2}$ $s_{1/2}$	0.125	0.975	
	$d_{5/2}$ $s_{1/2}$	0.125	0.736	
	$d_{5/2}$ $d_{3/2}$	0.018	0.193	
$^{93}_{42}\mathrm{Mo}_{51}$	$d_{3/2}$ $s_{1/2}$	0.125	1.12	
	$d_{5/2}$ $s_{1/2}$	0.125	1.03	
	$d_{5/2}$ $d_{3/2}$	0.018	0.269	
$^{95}_{42}\mathrm{Mo}_{53}$	$d_{3/2}$ $s_{1/2}$	0.129	2.70	
	$d_{5/2}$ $s_{1/2}$	0.129	2.02	
	$d_{5/2}$ $d_{3/2}$	0.018	0.404	0.88 ±0.08[d]
	$g_{7/2}$ $d_{5/2}$	0.006	0.196	
	$g_{7/2}$ $d_{3/2}$	0.083	1.02	
$^{97}_{42}\mathrm{Mo}_{55}$	$d_{3/2}$ $s_{1/2}$	0.132	2.68	
	$d_{5/2}$ $s_{1/2}$	0.132	1.47	
	$d_{5/2}$ $d_{3/2}$	0.019	0.120	
	$g_{7/2}$ $d_{5/2}$	0.006	0.030	
	$g_{7/2}$ $d_{3/2}$	0.085	1.46	
$^{99}_{44}\mathrm{Ru}_{55}$	$d_{3/2}$ $s_{1/2}$	0.136	4.98	
	$d_{5/2}$ $s_{1/2}$	0.136	3.91	
	$d_{5/2}$ $d_{3/2}$	0.019	0.360	
	$g_{7/2}$ $d_{5/2}$	0.006	0.075	
	$g_{7/2}$ $d_{3/2}$	0.087	2.63	
$^{101}_{44}\mathrm{Ru}_{57}$	$d_{3/2}$ $s_{1/2}$	0.140	6.52	
	$d_{5/2}$ $s_{1/2}$	0.140	2.9	
	$d_{5/2}$ $d_{3/2}$	0.020	0.44	
	$g_{7/2}$ $d_{5/2}$	0.007	0.055	
	$g_{7/2}$ $d_{3/2}$	0.090	3.90	
$^{105}_{46}\mathrm{Pd}_{59}$	$d_{3/2}$ $s_{1/2}$	0.147	6.02	
	$d_{5/2}$ $s_{1/2}$	0.147	0.532	
	$d_{5/2}$ $d_{3/2}$	0.021	0.120	
	$g_{7/2}$ $d_{5/2}$	0.007	0.002	
	$g_{7/2}$ $d_{3/2}$	0.095	3.66	
$^{107}_{46}\mathrm{Pd}_{61}$	$d_{3/2}$ $s_{1/2}$	0.151	7.32	
	$d_{5/2}$ $s_{1/2}$	0.151	0.273	
	$d_{5/2}$ $d_{3/2}$	0.022	0.060	
	$g_{7/2}$ $d_{5/2}$	0.007	0.192	
	$g_{7/2}$ $d_{3/2}$	0.097	4.87	
$^{109}_{48}\mathrm{Cd}_{61}$	$d_{3/2}$ $s_{1/2}$	0.155	5.37	
	$d_{5/2}$ $s_{1/2}$	0.155	0.041	0.0098[b]
	$d_{5/2}$ $d_{3/2}$	0.022	0.068	
	$g_{7/2}$ $d_{5/2}$	0.007	0.179	
	$g_{7/2}$ $d_{3/2}$	0.099	2.03	
$^{111}_{48}\mathrm{Cd}_{63}$	$d_{3/2}$ $s_{1/2}$	0.158	5.25	2.75 ±0.23[d]
	$d_{5/2}$ $s_{1/2}$	0.158	0.568	0.038 ±0.008[e]
	$d_{5/2}$ $d_{3/2}$	0.023	0.027	
	$g_{7/2}$ $d_{5/2}$	0.007	0.325	0.925[b]
	$g_{7/2}$ $d_{3/2}$	0.102	0.940	
$^{113}_{48}\mathrm{Cd}_{65}$	$d_{3/2}$ $s_{1/2}$	0.162	5.49	2.75 ±0.23[d]
	$d_{5/2}$ $s_{1/2}$	0.162	3.26	5.07 ±0.55[d]
	$d_{5/2}$ $d_{3/2}$	0.023	0.003	
$^{115}_{48}\mathrm{Cd}_{67}$	$d_{3/2}$ $s_{1/2}$	0.166	5.42	
	$d_{5/2}$ $s_{1/2}$	0.166	5.36	
	$d_{5/2}$ $d_{3/2}$	0.024	0.018	

TABLE II (*Continued*)

Isotope	Transition	$\frac{B(E2)_{\mathrm{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{th.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{expt.}}}{2j_f+1}$
$^{115}_{50}\mathrm{Sn}_{65}$	$d_{3/2}$ $s_{1/2}$	0.166	1.19	
	$d_{5/2}$ $s_{1/2}$	0.166	0.718	
	$d_{5/2}$ $d_{3/2}$	0.024	0.000	
	$g_{7/2}$ $d_{5/2}$	0.008	0.057	
	$g_{7/2}$ $d_{3/2}$	0.107	0.042	
$^{117}_{50}\mathrm{Sn}_{67}$	$d_{3/2}$ $s_{1/2}$	0.170	0.577	$0.1^{+0.1}_{-0.06}$[f]
	$d_{5/2}$ $s_{1/2}$	0.170	1.344	
	$d_{5/2}$ $d_{3/2}$	0.024	0.009	
	$g_{7/2}$ $d_{5/2}$	0.008	0.045	
	$g_{7/2}$ $d_{3/2}$	0.109	0.000	
$^{119}_{50}\mathrm{Sn}_{69}$	$d_{3/2}$ $s_{1/2}$	0.174	0.096	<0.2[g]
	$d_{5/2}$ $s_{1/2}$	0.174	1.90	
	$d_{5/2}$ $d_{3/2}$	0.025	0.033	
	$g_{7/2}$ $d_{5/2}$	0.008	0.035	
	$g_{7/2}$ $d_{3/2}$	0.112	0.043	
$^{121}_{52}\mathrm{Te}_{69}$	$d_{3/2}$ $s_{1/2}$	0.178	4.06	4.6 ±1.3[h]
$^{123}_{52}\mathrm{Te}_{71}$	$d_{3/2}$ $s_{1/2}$	0.182	1.13	0.85 ±0.20[h]
$^{125}_{52}\mathrm{Te}_{73}$	$d_{3/2}$ $s_{1/2}$	0.186	0.289	0.8 ±0.5[i]
	$d_{5/2}$ $s_{1/2}$	0.186	6.429	
	$d_{5/2}$ $d_{3/2}$	0.027	0.206	
	$g_{7/2}$ $d_{5/2}$	0.009	0.094	
	$g_{7/2}$ $d_{3/2}$	0.119	1.86	
$^{127}_{52}\mathrm{Te}_{75}$	$d_{3/2}$ $s_{1/2}$	0.190	1.66	
	$d_{5/2}$ $s_{1/2}$	0.190	5.65	
	$d_{5/2}$ $d_{3/2}$	0.027	0.277	
$^{129}_{52}\mathrm{Te}_{77}$	$d_{3/2}$ $s_{1/2}$	0.194	2.13	
	$d_{5/2}$ $s_{1/2}$	0.194	4.35	
	$d_{5/2}$ $d_{3/2}$	0.028	0.532	
$^{127}_{54}\mathrm{Xe}_{73}$	$d_{3/2}$ $s_{1/2}$	0.190	1.32	
	$d_{5/2}$ $s_{1/2}$	0.190	7.81	
	$d_{5/2}$ $d_{3/2}$	0.027	0.138	
$^{129}_{54}\mathrm{Xe}_{75}$	$d_{3/2}$ $s_{1/2}$	0.194	2.22	1.7 ±0.6[i]
	$d_{5/2}$ $s_{1/2}$	0.194	6.84	
	$d_{5/2}$ $d_{3/2}$	0.028	0.284	
$^{131}_{54}\mathrm{Xe}_{77}$	$d_{3/2}$ $s_{1/2}$	0.198	2.72	<18[i]
	$d_{5/2}$ $s_{1/2}$	0.198	5.14	1.7[j]
	$d_{5/2}$ $d_{3/2}$	0.028	0.286	4.2[j]
$^{133}_{56}\mathrm{Ba}_{77}$	$d_{3/2}$ $s_{1/2}$	0.202	3.77	
	$d_{5/2}$ $s_{1/2}$	0.202	8.87	
	$d_{5/2}$ $d_{3/2}$	0.029	0.379	
$^{135}_{56}\mathrm{Ba}_{79}$	$d_{3/2}$ $s_{1/2}$	0.206	3.62	0.39[k]
	$d_{5/2}$ $s_{1/2}$	0.206	7.44	
	$d_{5/2}$ $d_{3/2}$	0.029	0.645	
	$g_{7/2}$ $d_{5/2}$	0.009	0.116	
	$g_{7/2}$ $d_{3/2}$	0.132	4.26	2.25[k]

TABLE II (*Continued*)

Isotope	Transition	$\frac{B(E2)_{\mathrm{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{th.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{expt.}}}{2j_f+1}$
$^{137}_{56}\mathrm{Ba}_{81}$	$d_{3/2}$ $s_{1/2}$	0.210	0.727	0.65[l]
$^{139}_{56}\mathrm{Ba}_{83}$	$p_{3/2}$ $f_{7/2}$	0.137	0.697	
$^{139}_{58}\mathrm{Ce}_{81}$	$d_{3/2}$ $s_{1/2}$	0.214	0.665	
$^{141}_{58}\mathrm{Ce}_{83}$	$p_{3/2}$ $f_{7/2}$	0.140	0.551	
$^{143}_{60}\mathrm{Nd}_{83}$	$p_{3/2}$ $f_{7/2}$	0.143	0.429	1.18 ±0.32[m]
$^{145}_{60}\mathrm{Nd}_{85}$	$p_{3/2}$ $f_{7/2}$	0.145	3.64	1.42[b]
	$f_{7/2}$ $f_{5/2}$	0.011	0.228	
	$f_{5/2}$ $p_{3/2}$	0.032	1.35	
$^{147}_{62}\mathrm{Sm}_{85}$	$p_{3/2}$ $f_{7/2}$	0.148	5.07	0.23[c]
	$f_{7/2}$ $f_{5/2}$	0.011	0.378	0.57 ±0.12[c]
	$f_{5/2}$ $p_{3/2}$	0.033	2.06	1.36[b]
$^{149}_{62}\mathrm{Sm}_{87}$	$p_{3/2}$ $f_{7/2}$	0.151	7.41	
	$f_{7/2}$ $f_{5/2}$	0.011	0.359	
	$f_{5/2}$ $p_{3/2}$	0.034	1.79	
$^{193}_{78}\mathrm{Pt}_{115}$	$f_{5/2}$ $p_{1/2}$	0.331	20.0	
	$p_{3/2}$ $p_{1/2}$	0.331	17.0	
	$f_{5/2}$ $p_{3/2}$	0.047	0.162	2.5 ±1.3[n]
$^{195}_{78}\mathrm{Pt}_{117}$	$f_{5/2}$ $p_{1/2}$	0.336	11.4	3.5 ±1.0[o]
	$p_{3/2}$ $p_{1/2}$	0.336	7.73	4.67 ±1.33[o]
	$f_{5/2}$ $p_{3/2}$	0.048	0.236	0.8 ±0.3[n]
$^{197}_{78}\mathrm{Pt}_{119}$	$f_{5/2}$ $p_{1/2}$	0.341	4.80	3.3 ±0.4[p]
	$p_{3/2}$ $p_{1/2}$	0.341	5.27	
	$f_{5/2}$ $p_{3/2}$	0.049	1.49	
$^{193}_{80}\mathrm{Hg}_{113}$	$f_{5/2}$ $p_{1/2}$	0.331	17.6	
	$p_{3/2}$ $p_{1/2}$	0.331	16.9	
	$f_{5/2}$ $p_{3/2}$	0.047	0.91	4.0 ±1.5[n]
$^{195}_{80}\mathrm{Hg}_{115}$	$f_{5/2}$ $p_{1/2}$	0.336	12.2	11.5[q]
	$p_{3/2}$ $p_{1/2}$	0.336	9.61	
	$f_{5/2}$ $p_{3/2}$	0.048	0.139	4.1 ±1.0[n]
$^{197}_{80}\mathrm{Hg}_{117}$	$f_{5/2}$ $p_{1/2}$	0.341	6.70	3.5[q]
	$p_{3/2}$ $p_{1/2}$	0.341	4.10	
	$f_{5/2}$ $p_{3/2}$	0.049	0.088	
$^{199}_{80}\mathrm{Hg}_{119}$	$f_{5/2}$ $p_{1/2}$	0.345	3.44	6.25 ±1.26[r]
	$p_{3/2}$ $p_{1/2}$	0.345	2.75	5.28 ±0.75[r]
	$f_{5/2}$ $p_{3/2}$	0.049	0.876	1.0 ±0.2[n]
$^{201}_{80}\mathrm{Hg}_{121}$	$f_{5/2}$ $p_{1/2}$	0.350	0.133	
	$p_{3/2}$ $p_{1/2}$	0.350	3.14	
	$f_{5/2}$ $p_{3/2}$	0.050	1.01	

TABLE II *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
${}^{203}_{82}\text{Pb}_{121}$	$f_{5/2}$ $p_{1/2}$	0.354	0.027	0.115 ±0.005[q]
	$p_{3/2}$ $p_{1/2}$	0.354	0.013	
	$f_{5/2}$ $p_{3/2}$	0.051	0.066	
${}^{205}_{82}\text{Pb}_{123}$	$f_{5/2}$ $p_{1/2}$	0.359	0.038	
	$p_{3/2}$ $p_{1/2}$	0.359	0.164	
	$f_{5/2}$ $p_{3/2}$	0.051	0.111	

TABLE II *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
${}^{207}_{82}\text{Pb}_{125}$	$f_{5/2}$ $p_{1/2}$	0.37	0.37	0.30 ±0.10[s]
	$p_{3/2}$ $p_{1/2}$	0.37	0.37	0.40 ±0.20[s]
	$f_{5/2}$ $p_{3/2}$	0.052	0.052	
${}^{209}_{82}\text{Pb}_{127}$	$s_{1/2}$ $d_{5/2}$	0.37	0.37	0.25[t]

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TABLE III. Reduced transition probabilities for odd-proton nuclei. The first and second columns list the isotope, and the levels between which the transition occurs. Columns three, four, and five list the single-particle, theoretical and experimental $B(E2)$ values divided by $2j_f+1$, where j_f is the final angular momentum, in units of $e^2 \times 10^{-50}$.

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
${}^{63}_{29}\text{Cu}_{34}$	$p_{3/2}$ $p_{1/2}$	0.074	2.03	0.58 ±0.06[a]
	$f_{5/2}$ $p_{1/2}$	0.074	2.15	
	$f_{5/2}$ $p_{3/2}$	0.011	0.272	0.58 ±0.06[a]
	$f_{7/2}$ $p_{3/2}$	0.048	0.768	0.50 ±0.06[a]
	$f_{7/2}$ $f_{5/2}$	0.003	0.016	
${}^{65}_{29}\text{Cu}_{36}$	$p_{3/2}$ $p_{1/2}$	0.078	1.83	0.51 ±0.06[a]
	$f_{5/2}$ $p_{1/2}$	0.078	1.92	0.134 ±0.015[b]
	$f_{5/2}$ $p_{3/2}$	0.011	0.267	0.58 ±0.06[a]
	$f_{7/2}$ $p_{3/2}$	0.050	0.925	0.54 ±0.10[a]
	$f_{7/2}$ $f_{5/2}$	0.004	0.020	
${}^{69}_{31}\text{Ga}_{38}$	$p_{3/2}$ $p_{1/2}$	0.084	1.92	0.40 ±0.08[c]
	$f_{5/2}$ $p_{1/2}$	0.084	1.830	
	$f_{5/2}$ $p_{3/2}$	0.012	0.127	
${}^{71}_{31}\text{Ga}_{40}$	$p_{3/2}$ $p_{1/2}$	0.087	2.77	0.6 ±0.1[c]
	$f_{5/2}$ $p_{1/2}$	0.087	2.48	
	$f_{5/2}$ $p_{3/2}$	0.012	0.174	

TABLE III *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
${}^{73}_{33}\text{As}_{40}$	$p_{3/2}$ $p_{1/2}$	0.091	3.61	
	$f_{5/2}$ $p_{1/2}$	0.091	3.81	
	$f_{5/2}$ $p_{3/2}$	0.013	0.019	.04[d]
${}^{75}_{33}\text{As}_{42}$	$p_{3/2}$ $p_{1/2}$	0.094	4.82	0.81 ±0.07[e]
	$f_{5/2}$ $p_{1/2}$	0.094	4.75	3.80[e]
	$f_{5/2}$ $p_{3/2}$	0.013	0.015	0.75 ±0.07[e]
${}^{77}_{33}\text{As}_{44}$	$p_{3/2}$ $p_{1/2}$	0.097	4.46	
	$f_{5/2}$ $p_{1/2}$	0.097	4.22	
	$f_{5/2}$ $p_{3/2}$	0.014	0.014	
${}^{77}_{35}\text{Br}_{42}$	$p_{3/2}$ $p_{1/2}$	0.097	4.25	
	$f_{5/2}$ $p_{1/2}$	0.097	2.04	
	$f_{5/2}$ $p_{3/2}$	0.014	1.91	
${}^{79}_{35}\text{Br}_{44}$	$p_{3/2}$ $p_{1/2}$	0.101	3.05	
	$f_{5/2}$ $p_{1/2}$	0.101	1.72	
	$f_{5/2}$ $p_{3/2}$	0.014	0.631	0.66 ±0.06[f]
${}^{81}_{35}\text{Br}_{46}$	$p_{3/2}$ $p_{1/2}$	0.104	1.96	
	$f_{5/2}$ $p_{1/2}$	0.104	0.928	
	$f_{5/2}$ $p_{3/2}$	0.015	0.219	0.092 ±0.008[c]

TABLE III *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\mathrm{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{th.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{expt.}}}{2j_f+1}$
${}^{83}_{37}\mathrm{Rb}_{46}$	$p_{3/2}$ $p_{1/2}$	0.108	2.02	
	$f_{5/2}$ $p_{1/2}$	0.108	0.727	
	$f_{5/2}$ $p_{3/2}$	0.015	0.368	
${}^{85}_{37}\mathrm{Rb}_{48}$	$p_{3/2}$ $p_{1/2}$	0.111	1.07	
	$f_{5/2}$ $p_{1/2}$	0.111	0.296	
	$f_{5/2}$ $p_{3/2}$	0.016	0.221	0.077[g]
${}^{89}_{39}\mathrm{Y}_{50}$	$p_{3/2}$ $p_{1/2}$	0.118	0.40	
	$f_{5/2}$ $p_{1/2}$	0.118	0.171	
	$f_{5/2}$ $p_{3/2}$	0.017	0.110	
${}^{91}_{41}\mathrm{Nb}_{50}$	$p_{3/2}$ $p_{1/2}$	0.122	0.891	
	$f_{5/2}$ $p_{1/2}$	0.122	0.530	
	$f_{5/2}$ $p_{3/2}$	0.017	0.112	
${}^{103}_{45}\mathrm{Rh}_{58}$	$p_{3/2}$ $p_{1/2}$	0.143	10.0	5.23 ± 0.38[h]
	$f_{5/2}$ $p_{1/2}$	0.143	9.74	6.55 ± 0.47[h]
	$f_{5/2}$ $p_{3/2}$	0.021	0.677	
${}^{107}_{47}\mathrm{Ag}_{60}$	$p_{3/2}$ $p_{1/2}$	0.151	9.49	5.4 ± 0.4[h]
	$f_{5/2}$ $p_{1/2}$	0.151	9.25	5.57 ± 0.38[h]
	$f_{5/2}$ $p_{3/2}$	0.022	0.525	
${}^{109}_{47}\mathrm{Ag}_{62}$	$p_{3/2}$ $p_{1/2}$	0.155	10.0	6.23 ± 0.43[h]
	$f_{5/2}$ $p_{1/2}$	0.155	9.77	6.3 ± 0.43[h]
	$f_{5/2}$ $p_{3/2}$	0.022	0.580	
${}^{113}_{49}\mathrm{In}_{64}$	$p_{3/2}$ $p_{1/2}$	0.162	4.46	
	$f_{5/2}$ $p_{1/2}$	0.162	4.17	
	$f_{5/2}$ $p_{3/2}$	0.023	0.260	
${}^{115}_{49}\mathrm{In}_{66}$	$p_{3/2}$ $p_{1/2}$	0.166	4.19	
	$f_{5/2}$ $p_{1/2}$	0.166	3.91	
	$f_{5/2}$ $p_{3/2}$	0.024	0.241	
${}^{117}_{49}\mathrm{In}_{68}$	$p_{3/2}$ $p_{1/2}$	0.170	4.45	
	$f_{5/2}$ $p_{1/2}$	0.170	4.17	
	$f_{5/2}$ $p_{3/2}$	0.024	0.241	
${}^{121}_{51}\mathrm{Sb}_{70}$	$g_{7/2}$ $d_{5/2}$	0.008	0.166	
	$d_{3/2}$ $g_{7/2}$	0.114	1.32	1.04[i]
	$d_{3/2}$ $d_{5/2}$	0.025	0.365	0.19 ± 0.05[j]
	$s_{1/2}$ $s_{5/2}$	0.178	2.59	1.35 ± 0.15[j]
	$s_{1/2}$ $d_{3/2}$	0.178	2.49	
${}^{123}_{51}\mathrm{Sb}_{72}$	$g_{7/2}$ $d_{5/2}$	0.009	0.159	0.072 ± 0.012[j]
	$d_{3/2}$ $g_{7/2}$	0.117	1.40	0.70 ± 0.10[j]
	$d_{3/2}$ $d_{5/2}$	0.026	0.339	
	$s_{1/2}$ $d_{5/2}$	0.182	2.71	
	$s_{1/2}$ $d_{3/2}$	0.182	2.10	
${}^{125}_{53}\mathrm{I}_{72}$	$g_{7/2}$ $d_{5/2}$	0.009	0.551	0.74 ± 0.02[k]
	$d_{3/2}$ $g_{7/2}$	0.119	3.22	1.81 ± 0.05[k]
	$d_{3/2}$ $d_{5/2}$	0.027	0.816	1.19 ± 0.05[k]
	$s_{1/2}$ $d_{5/2}$	0.186	6.83	2.05 ± 0.13[k]
	$s_{1/2}$ $d_{3/2}$	0.186	7.16	0.47 ± 0.20[k]
${}^{127}_{53}\mathrm{I}_{74}$	$g_{7/2}$ $d_{5/2}$	0.009	0.421	0.68 ± 0.14[l]
	$d_{3/2}$ $g_{7/2}$	0.122	2.69	1.40 ± 0.03[k]
	$d_{3/2}$ $d_{5/2}$	0.027	0.668	1.18 ± 0.22[k]
	$s_{1/2}$ $d_{5/2}$	0.190	5.70	≈1.16[k]
	$s_{1/2}$ $d_{3/2}$	0.190	5.47	<1.00
${}^{129}_{53}\mathrm{I}_{76}$	$g_{7/2}$ $d_{5/2}$	0.009	0.276	1.22 ± 0.11[m]

TABLE III *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\mathrm{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{th.}}}{2j_f+1}$	$\frac{B(E2)_{\mathrm{expt.}}}{2j_f+1}$
${}^{131}_{53}\mathrm{I}_{78}$	$g_{7/2}$ $d_{5/2}$	0.009	0.167	0.65 ± 0.65[m]
${}^{131}_{55}\mathrm{Cs}_{76}$	$g_{7/2}$ $d_{5/2}$	0.009	0.447	0.041 ± 0.003[n]
	$d_{3/2}$ $g_{7/2}$	0.127	2.23	3.35 ± 0.16[n]
	$d_{3/2}$ $d_{5/2}$	0.028	0.786	
	$s_{1/2}$ $d_{5/2}$	0.198	6.09	
	$s_{1/2}$ $d_{3/2}$	0.198	7.06	
${}^{133}_{55}\mathrm{Cs}_{78}$	$g_{7/2}$ $d_{5/2}$	0.010	0.173	0.37 ± 0.07[l]
	$d_{3/2}$ $g_{7/2}$	0.130	1.71	3.25 ± 0.65[l]
	$d_{3/2}$ $d_{5/2}$	0.029	0.610	
	$s_{1/2}$ $d_{5/2}$	0.202	4.76	
	$s_{1/2}$ $d_{3/2}$	0.202	4.32	
${}^{137}_{57}\mathrm{La}_{80}$	$g_{7/2}$ $d_{5/2}$	0.010	0.008	
${}^{139}_{57}\mathrm{La}_{82}$	$g_{7/2}$ $d_{5/2}$	0.010	0.001	$0.006^{+0.009}_{-0.006}$[o]
	$d_{3/2}$ $g_{7/2}$	0.137	0.805	
${}^{141}_{59}\mathrm{Pr}_{82}$	$g_{7/2}$ $d_{5/2}$	0.010	0.001	0.021 ± 0.016[p]
	$d_{3/2}$ $d_{5/2}$	0.031	1.290	
	$s_{1/2}$ $d_{5/2}$	0.218	1.62	
${}^{143}_{59}\mathrm{Pr}_{84}$	$g_{7/2}$ $d_{5/2}$	0.011	0.00	0.054[q]
${}^{145}_{61}\mathrm{Pm}_{84}$	$g_{7/2}$ $d_{5/2}$	0.011	0.080	0.08 ± 0.03[r]
	$d_{3/2}$ $d_{5/2}$	0.032	1.84	
	$s_{1/2}$ $d_{5/2}$	0.226	3.89	
${}^{147}_{61}\mathrm{Pm}_{86}$	$g_{7/2}$ $d_{5/2}$	0.011	0.092	0.10 ± 0.03[r]
	$d_{3/2}$ $g_{7/2}$	0.148	0.801	
${}^{149}_{61}\mathrm{Pm}_{88}$	$g_{7/2}$ $d_{5/2}$	0.011	0.050	$0.18^{+0.08}_{-0.04}$[r]
${}^{189}_{77}\mathrm{Ir}_{112}$	$s_{1/2}$ $d_{3/2}$	0.322	1.93	$2.1^{+0.3}_{-0.6}$[s]
	$d_{5/2}$ $d_{3/2}$	0.046	3.12	
	$d_{5/2}$ $s_{1/2}$	0.322	12.7	
	$g_{7/2}$ $d_{3/2}$	0.207	16.1	
	$g_{7/2}$ $d_{5/2}$	0.015	0.12	
${}^{191}_{77}\mathrm{Ir}_{114}$	$s_{1/2}$ $d_{3/2}$	0.327	3.54	$3.3^{+1.6}_{-0.8}$[s]
	$d_{5/2}$ $d_{3/2}$	0.047	5.42	15.4 ± 2.5[t]
	$d_{5/2}$ $s_{1/2}$	0.327	10.7	
	$g_{7/2}$ $d_{3/2}$	0.210	17.0	9.75 ± 0.25[t]
	$g_{7/2}$ $d_{5/2}$	0.016	0.010	
${}^{193}_{77}\mathrm{Ir}_{116}$	$s_{1/2}$ $d_{3/2}$	0.331	3.38	3.8 ± 0.5[u]
	$d_{5/2}$ $d_{3/2}$	0.047	6.20	8.5 ± 3.8[u]
	$d_{5/2}$ $s_{1/2}$	0.331	6.78	
	$g_{7/2}$ $d_{3/2}$	0.213	13.6	7.63 ± 0.83[v]
	$g_{7/2}$ $d_{5/2}$	0.016	0.007	1.67[v]
${}^{193}_{79}\mathrm{Au}_{114}$	$s_{1/2}$ $d_{3/2}$	0.331	10.4	$6.6^{+1.2}_{-2.0}$[s]
	$d_{5/2}$ $d_{3/2}$	0.047	11.4	
	$d_{5/2}$ $s_{1/2}$	0.331	14.2	
${}^{195}_{79}\mathrm{Au}_{116}$	$s_{1/2}$ $d_{3/2}$	0.336	7.00	6.4 ± 0.8[s]
	$d_{5/2}$ $d_{3/2}$	0.048	8.31	
	$d_{5/2}$ $s_{1/2}$	0.336	10.0	
${}^{197}_{79}\mathrm{Au}_{118}$	$s_{1/2}$ $d_{3/2}$	0.341	4.36	5.0 ± 0.8[s]
	$d_{5/2}$ $d_{3/2}$	0.049	5.85	5.6 ± 0.45[v]
	$d_{5/2}$ $s_{1/2}$	0.341	6.86	
	$g_{7/2}$ $d_{3/2}$	0.219	8.41	5.0 ± 0.63[w]
	$g_{7/2}$ $d_{5/2}$	0.016	0.212	0.94 ± 0.09[w]

TABLE III *(Continued)*

Isotope	Transition	$\frac{B(E2)_{\text{s.p.}}}{2j_f+1}$	$\frac{B(E2)_{\text{th.}}}{2j_f+1}$	$\frac{B(E2)_{\text{expt.}}}{2j_f+1}$
$^{199}_{79}\text{Au}_{120}$	$s_{1/2}$ $d_{3/2}$	0.345	2.60	$5.0^{+1.7}_{-1.0}$ [s]
	$d_{5/2}$ $d_{3/2}$	0.049	5.20	>0.33[x]
	$d_{5/2}$ $s_{1/2}$	0.345	7.03	>1.7[x]
	$g_{7/2}$ $d_{3/2}$	0.222	8.11	>1.3[x]
	$g_{7/2}$ $d_{5/2}$	0.016	0.179	
$^{201}_{81}\text{Tl}_{120}$	$s_{1/2}$ $d_{3/2}$	0.350	3.72	6.2 ± 1.6[s]
	$d_{5/2}$ $d_{3/2}$	0.050	0.149	
	$d_{5/2}$ $s_{1/2}$	0.350	5.02	
$^{203}_{81}\text{Tl}_{122}$	$s_{1/2}$ $d_{3/2}$	0.354	2.97	3.1 ± 0.35[v]
	$d_{5/2}$ $d_{3/2}$	0.051	0.074	0.11[d]
	$d_{5/2}$ $s_{1/2}$	0.354	3.40	3.50 ± 0.45[v]
$^{205}_{81}\text{Tl}_{124}$	$s_{1/2}$ $d_{3/2}$	0.359	2.374	2.5 ± 0.25[v]
	$d_{5/2}$ $d_{3/2}$	0.051	0.029	⩽0.15[v]
	$d_{5/2}$ $s_{1/2}$	0.359	1.987	1.9 ± 0.2[v]
$^{207}_{81}\text{Tl}_{126}$	$s_{1/2}$ $d_{3/2}$	0.364	0.364	⩾0.25[s]
	$d_{5/2}$ $d_{3/2}$	0.052	0.052	
	$d_{5/2}$ $s_{1/2}$	0.364	0.364	
$^{209}_{83}\text{Bi}_{126}$	$f_{7/2}$ $h_{9/2}$	0.008	0.008	⩽0.016[t]
$^{211}_{83}\text{Bi}_{128}$	$f_{7/2}$ $h_{9/2}$	0.008	0.087	0.066 ± 0.007[t]

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when information about lifetime measurements could be gathered. In the latter case, the $B(E2)$ value is related to the partial lifetime by[1]

$$\frac{1}{\tau_\gamma(E2)}=\frac{4}{75}\pi\frac{E^5}{\hbar^6C^5}B(E2)\,. \tag{9}$$

The experimental and theoretical values can be compared with the single-particle estimate and calculated using the formula[1]

$$\frac{B(E2)^{\text{s.p.}}_{j_i\to j_f}}{2j_f+1}=e^2\frac{\langle f|r^2|i\rangle^2}{4\pi}\left(C^{j_i\ \ j_f\ \ 2}_{1/2\ -1/2\ 0}\right)^2. \tag{10}$$

$e_{\text{eff}}=1e$ $(2e)$ for odd-neutron (proton) nuclei are used.

IV. DISCUSSION OF THE RESULTS

The results of the present calculation differ appreciably from the results of Ref. 1 in a number of cases. If the single-particle energies are unchanged, these differences arise mainly from the extension to two phonons, which usually increase the $B(E2)$ value by less than a factor of 2. On the other hand, shifts of single-particle energies near the Fermi energy cause very large changes for some of the slower transitions.

The theoretical results are seen to range from a small fraction of the single-particle rate to more than 200 times the single-particle rate, though very large rates occur only for nuclei whose even neighbors have particularly large $B(E2)_{0^+\to2^+}$ rates. The small rates are not so common, and they occur usually only if the factor $(U_i\,U_f - V_i\,V_f)$ is quite small. The exact isotope for which this occurs depends sensitively on the original choice of the

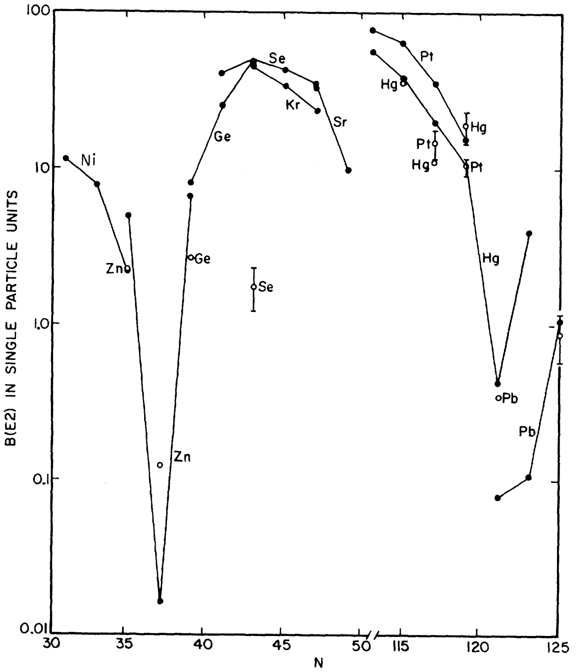

FIG. 1. $B(E2)$ values for $p_{1/2}$, $f_{5/2}$ odd-neutron transitions. The theoretical points are connected by solid lines, and the experimental points, open circles, are given with their error bars when known.

single-particle energies. This is illustrated in Fig. 1 where the odd-neutron $p_{1/2}f_{1/2}$ transition rates in single-particle units have been plotted for various isotopes against the neutron number. It can be seen that the rates exhibit a sharp minimum at neutron number 37, as is also experimentally observed. The transition rate rises sharply away from $N=37$, and it falls slowly again as the closed shell $N=50$ is approached. This is because the transitions become less collective near the shell closures. The phenomenon of a minimum in the transition probability is again clearly exhibited in the lead region at neutron number 121. For the $p_{1/2}f_{5/2}$ transition for odd protons, the theoretical numbers show a minimum near $Z\sim 37$, though there are no experimental measurements in the region with which to compare.

For neutron transitions $s_{1/2}d_{3/2}$, $s_{1/2}d_{5/2}$, and proton transition $g_{7/2}d_{5/2}$, for which the data show clear minima, theoretically calculated values reproduce the positions of the minima quite well. For transitions $d_{3/2}d_{5/2}$, $d_{3/2}g_{7/2}$, and $p_{1/2}p_{3/2}$, for which no measurements have been made in the region of retardation, minima are predicted at odd-particle numbers 65, 67, and 37, respectively.

It can be seen that over-all agreement between theory and experiment is quite good. Out of the 47 odd-neutron experimental values available, 26 agree with theory to within a factor of 2. In addition, in the case of transitions which lie at or near the theoretical minima, as, e.g., the $f_{5/2}p_{1/2}$ transition in ^{67}Zn, $d_{5/2}s_{1/2}$ in ^{109}Cd, and the $d_{3/2}s_{1/2}$ in ^{117}Sn, better agreement can be achieved by changing the single-particle energies. In order to avoid giving too many special shifts, this was not attempted, especially since the over-all trend in these regions is correctly reproduced by theory.

Similarly, for the odd-proton transitions, out of 77 experimental measurements reported, 57 agree with theory to within a factor of 2.

In the results presented, there are a few cases of $E2$ transitions which disagree with the theoretical value by an order of magnitude or so. Typical of these are the $f_{5/2}p_{1/2}$ transition in $^{77}_{34}\mathrm{Se}_{43}$ and $^{65}_{29}\mathrm{Cu}_{36}$ and the $f_{5/2}p_{3/2}$ transition in $^{75}_{33}\mathrm{As}_{42}$. The coupling scheme employed does not seem to be good for these cases. A few other cases where minor single-particle level adjustments fail to reproduce experimental values are the $d_{5/2}d_{3/2}$ transition in $^{131}_{54}\mathrm{Xe}_{77}$, the $d_{3/2}s_{1/2}$ transition in $^{135}_{56}\mathrm{Ba}_{79}$, the $p_{3/2}f_{7/2}$ transition in $^{147}_{62}\mathrm{Sm}_{85}$, and the $g_{7/2}d_{5/2}$ transition in ^{131}Cs.

The theoretical numbers agree well enough with the existing data that it is hoped that this compilation can be used as a guide to experimenters for odd-mass $E2$ transition rates. On the other hand, precise results are not expected, since the anharmonic phonon effects, not included in Eq. (5), may be significant in many cases.

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