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MATRIX ELEMENTS OF ATOMIC INTERACTION OPERATORS
FOR d^n CONFIGURATIONS*

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January 1969

ABSTRACT

The matrix elements of the Coulomb, Spin-Orbit, Orbit-Orbit, Spin-Spin, and Spin-Other-Orbit operators for d^n ($n = 2, \dots, 8$) configurations are computed and tabulated for general usage.

* This research was supported by NASA contract NAS 9-5384 for the Manned Spacecraft Center, National Aeronautics and Space Administration.

FACILITY FORM 602

N 69-18143	
(ACCESSION NUMBER)	(THRU)
67	1
(PAGES)	(CODE)
NASA-CR-99504	06
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

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Introduction:

The conventional methods for treating the spectra of the transition metal elements are well known, being described by Condon-Shortley¹ in their classic work. Although the original assumptions remain virtually unchanged today, the analysis has been greatly enhanced through the use of irreducible tensor techniques developed by Racah². Over the past several decades, numerous researchers have extended and applied these techniques to the study of complex atomic spectra.

To facilitate the theoretical study of many-electron atoms and ions, the matrix elements of important atomic

¹E. U. Condon and G. H. Shortley, The Theory of Atomic Spectra (Cambridge University Press, Cambridge, England, 1959).

²G. Racah, Phys. Rev. 63, 438 (1942); 63, 367 (1943); 76, 1352 (1949).

interaction operators have been calculated and presented in one form or another by active researchers. As a result, tabulated matrix elements of the following operators for d^n configurations are available:

- a) Coulomb interaction, Refs. (2), (3).
- b) Spin-Orbit interaction, Refs. (3), (4).
- c) Orbit-Orbit interaction, Refs. (5), (6).
- d) Spin-Other-Orbit interaction, Refs. (7), (8).
- e) Spin-Spin interaction, Refs. (8), (9).

With the exception of the Coulomb, Spin-Orbit and Orbit-Orbit interactions, the matrix tables compiled and published have not generally been in a form that allowed

³C. W. Nielson and G. F. Koster, Spectroscopic Coefficients for p^n , d^n and f^n Configurations (M.I.T. Press, Cambridge, Mass., 1964).

⁴R. E. Trees, Phys. Rev. 92, 308 (1953).

⁵R. Dagis, F. Rudzikas, J. Vizbaraitė, and A. Jucys, Liet. Fiz. Rinkiny. 3, 159 (1963). Available as Argonne National Laboratory Transl. No. 106, Oct. 1964.

⁶S. Fraga and G. Malli, J. Chem. Phys. 46, 4754 (1967).

⁷H. Horie, Progr. Theoret. Phys. 10, 296 (1953).

⁸T. M. Dunn and W. Li, J. Chem. Phys. 46, 2907 (1967).

⁹R. E. Trees, Phys. Rev. 82, 683 (1951).

the user to immediately construct the required Hamiltonian matrix. In most instances a multiplicative 6-j factor is necessary to complete the calculation. This is relatively easy to do provided a table of the required 6-j symbols is readily available. However, such tables are not always present.

In this paper we use the matrix operators in irreducible tensor form to calculate and report the matrix elements of the above noted atomic interaction operators. The elements are tabulated in a form that allows immediate construction of the Hamiltonian matrix provided the required radial integrals F^k , ζ_{nl} , and M^k for the desired transition metal ion are known. These tables will also enable researchers to carry out linear or nonlinear least squares calculations when a phenomenological fitting of the radial parameters is desired.

Matrix Elements

The application of irreducible tensor techniques to the theoretical description of atomic spectra has been fully discussed in numerous books and journal articles. The most notable for our purposes have been the works of Judd¹⁰ Wybourne¹¹, and more recently, Fraga and Malli¹². Wybourne and

¹⁰B. R. Judd, Operator Techniques in Atomic Spectroscopy (McGraw-Hill Book Company, New York, 1963).

¹¹B. G. Wybourne, Spectroscopic Properties of Rare Earths (Interscience Publishers, New York, 1965).

¹²S. Fraga and G. Malli, Many-Electron Systems; Properties and Interactions (W. B. Sanders Company, Philadelphia, Pa., 1968).

Fraga and Malli have extensive bibliographies covering the literature in this area of research. Rather than needlessly duplicate their discussions, we shall briefly comment on and indicate the tensor operator form of the various atomic interaction operators considered in this paper.

The basic energy level structure for most transition metal ions is predicted by the Hamiltonian,

$$H = H_0 + H_c + H_{so} \quad (1)$$

In this expression, H_0 is the so-called "zero-order" Hamiltonian, which affects only the energy of an entire configuration. H_c is the Coulomb interaction operator describing the electrostatic interaction energy of the n electrons of a given d^n configurations. This interaction produces the basic term splitting observed in the spectra. H_{so} is the magnetic dipole-dipole interaction energy between the spin-dipole of a d^n electron and its orbit-dipole. This interaction produces the basic term multiplet structure observed in spectra of the transition metals.

Although there is fairly good agreement between the overall energy level structure predicted by the Hamiltonian of Eq. (1) and the experimentally observed spectra of the transition metal ions, this model is still very poor. For instance, "good" agreement between theory and experiment is only obtainable for the ground state multiplet. In comparing the higher multiplets, a marked disparity is

observed, namely a divergence of term separation in the model relative to the observed spectra. This is generally attributed to several factors such as lack of configuration interaction in the model and also poor radial wavefunctions used in calculating the various radial factors involved¹³. There is further disparity observed in comparing the separation in J-states of a given multiplet with that experimentally observed. However, this is usually not too severe so long as the LS coupling scheme remains applicable. Discrepancies within a given J-multiplet can, hopefully be corrected by introducing additional magnetic interactions into our model such as Spin-Spin and Spin-Other-Orbit. These interactions and their matrix elements make up the subject of this paper.

The interaction operators can be simply grouped according to their effect on the energy structure of the theoretical model, namely those that affect term spacing and those affecting multiplet structure spacing.

We shall consider first two operators affecting term spacing, the Coulomb interaction and the Orbit-Orbit interaction.

¹³J. C. Slater, Quantum Theory of Atomic Structure Vol. I (McGraw-Hill Book Company, New York, 1960).

The general expression for the Coulomb interaction in d^n configurations is given by a multiple application of the tensor operator expression,

$$\begin{aligned}
 & (d^n v SL | H_c | d^n v' SL) \\
 &= \left\{ \frac{n}{n-2} \right\} \sum_{v_1 v'_1 S_1 L_1} (d^n v SL \{ | d^{n-1} (v_1 S_1 L_1) (SL) \}) \\
 & \times (d^{n-1} (v'_1 S_1 L_1) SL \{ | d^n v' SL \}) (d^{n-1} v_1 S_1 L_1 | H_c | d^{n-1} v'_1 S_1 L_1) \quad (2)
 \end{aligned}$$

where $(d^n v SL \{ | d^{n-1} (v_1 S_1 L_1) \})$ are the coefficients of fractional parentage for d^n configurations defined and tabulated by Racah² and Nielson and Koster³. The electrostatic interaction for two equivalent d electrons is given by

$$(d^2 SL | H_c | d^2 SL) = \sum_{k=0,2,4} (-1)^L (2 || C^k || 2)^2 \begin{Bmatrix} 2 & 2 & k \\ 2 & 2 & L \end{Bmatrix} F^k \quad (3)$$

where F^k is the Slater integral^{1,3}.

The Orbit-Orbit interaction for d^n configurations is given by

$$(d^n v SL | H_{oo} | d^n v SL) = \alpha L(L+1) + \beta G(R_5) + n\delta \quad (4)$$

The parameters α , β , δ and the Casimir operator for $G(R_5)$ are defined by^{5,10}

$$\begin{aligned}\alpha &= -2(M^{(0)} - 6M^{(2)}/49) \quad , \\ \beta &= -360M^{(2)}/49 \quad , \\ \delta &= 12(M^{(0)} + 2M^{(2)}/7) \quad ,\end{aligned}$$

$$G(R_5) = \{v(12-v)/2 - 2S(S+1)\}/6 \quad . \quad (5)$$

The symbol $M^{(k-1)}$ represents a radial integral, defined by Marvin¹⁴,

$$M^{(k-1)} = \left(\frac{1}{4c^2}\right) \int_{r_j}^{\infty} \int_{r_1}^{\infty} P_{nd}^2(r_1) \left(\frac{r_1^{k-1}}{r_j^{k+2}}\right) P_{nd}^2(r_j) dr_1 dr_j \quad . \quad (6)$$

We now consider interactions affecting spacing within a term multiplet. The three operators describing this effect are the Spin-Orbit operator H_{so} , the Spin-Spin operator H_{ss} , and the Spin-Other-Orbit operator H_{soo} .

The Spin-Orbit interaction for d^n configurations is given by

$$\begin{aligned}& (d^n vSLJ | H_{so} | d^n v'S'L'J) \\ &= (-1)^{S'+L+J} (30)^{1/2} \begin{Bmatrix} S & S' & 1 \\ L' & L & J \end{Bmatrix} (d^n vSL || V^{11} || d^n v'S'L') \zeta_{nd} \quad (7)\end{aligned}$$

¹⁴H. H. Marvin, Phys. Rev. 71, 102 (1947).

The Spin-Spin interaction for d^n configurations is given by

$$\begin{aligned}
 & (d^n_{vSLJ} | H_{ss} | d^n_{v'S'L'J}) \\
 &= (-1)^{S'+L+J} \begin{Bmatrix} S & S' & 2 \\ L' & L & J \end{Bmatrix} \sum_k Z_k M^{(k-1)} \\
 & \times \sum_{v'',S'',L''} (d^n_{vSL} || V^{1,k-1} || d^n_{v'',S'',L''}) \\
 & \times (d^n_{v'',S'',L''} || V^{1,k+1} || d^n_{v'S'L'}) \\
 & \times (-1)^{S+L+S'+L'} \begin{Bmatrix} S & S' & 2 \\ 1 & 1 & S'' \end{Bmatrix} \begin{Bmatrix} L' & L & 2 \\ k-1 & k+1 & L'' \end{Bmatrix} \quad (8)
 \end{aligned}$$

where

$$\begin{aligned}
 Z_k &= -4\{5k(k+1)(2k-1)(2k+1)(2k+3)\}^{1/2} \\
 & \times (2 || C^{k-1} || 2)(2 || C^{k+1} || 2) .
 \end{aligned}$$

The Spin-Other-Orbit interaction for d^n configurations is given by

$$\begin{aligned}
 & (d^n_{vSLJ} | H_{soo} | d^n_{v'S'L'J}) \\
 &= (-1)^{S+L+J} \begin{Bmatrix} S & S' & 1 \\ L' & L & J \end{Bmatrix} \times \left\{ (d^n_{vSL} || H_{soo}^1 || d^n_{v'S'L'}) \right. \\
 & \left. + (d^n_{vSL} || H_{soo}^2 || d^n_{v'S'L'}) \right\} \quad (9)
 \end{aligned}$$

where

$$\begin{aligned}
& (d^n_{vSL} || H_{soo}^1 || d^n_{v'S'L'}) = \left\{ -2nM^0 + 6/(10)^{1/2} \right. \\
& \times \sum_{k=1}^3 \sum_{K=k-1}^{k+1} (-1)^{k+K} (2 || c^K || 2) (2 || U^{(K,k)} || 2) \\
& \times \left. \begin{Bmatrix} K & 2 & 2 \\ 2 & k & 1 \end{Bmatrix} M^{k-1} \right\} \times (d^n_{vSL} || v^{11} || d^n_{v'S'L'}) (30)^{1/2} \quad (9a)
\end{aligned}$$

and

$$\begin{aligned}
& (d^n_{vSL} || H_{soo}^2 || d^n_{v'S'L'}) \\
& = -2(3)^{1/2} \sum_{k=1}^3 \sum_{K=k-1}^{k+1} (-1)^{k+K+L+L'} (2 || c^K || 2) \\
& \times (2 || U^{(K,k)} || 2) M^{k-1} \left[\sum_{v''L''} (d^n_{vSL} || U^K || d^n_{v''SL''}) \right. \\
& \times (d^n_{v''SL''} || v^{1k} || d^n_{v'S'L'}) \left. \begin{Bmatrix} L & K & L'' \\ k & L' & 1 \end{Bmatrix} \right. \\
& + 2 \sum_{v''L''} (d^n_{vSL} || U^k || d^n_{v''SL''}) \times \\
& \left. (d^n_{v''SL''} || v^{1K} || d^n_{v'S'L'}) \begin{Bmatrix} L & k & L'' \\ K & L' & 1 \end{Bmatrix} \right] . \quad (9b)
\end{aligned}$$

The term with $k = 1, K = 0$ must be omitted from the summation for the first term in the brackets of Eq. (9b).

$U^{(K,k)}$ is a quantity defined by Horie⁷ as

$$(2||U^{k-1,k}||2)$$

$$= (-1)^{(k-1)/2} (5) \{ (k+1)(2k-1)(2k+1)/3 \}^{1/2}$$

$$\times \left\{ \frac{(k-1)!(k+1)!(4-k)!}{(4+k+1)!} \right\}^{1/2}$$

$$\times \left(\frac{4+k+1}{2} \right)! / \left[\left(\frac{k-1}{2} \right)! \left(\frac{k+1}{2} \right)! \left(\frac{4-k-1}{2} \right)! \right] ,$$

$$(2||U^{k+1,k}||2)$$

$$= - \left[\frac{k(2k+3)}{(k+1)(2k-1)} \right]^{1/2} (2||U^{k-1,k}||2) .$$

The reduced matrix elements occurring in Eqs. (3), (7), (8), (9a) and (9b) are given by the following expressions:

$$(2||c^{(k)}||2) = 5 \begin{pmatrix} 2 & k & 2 \\ 0 & 0 & 0 \end{pmatrix} , \quad (10)$$

$$(d^n_{vSL} || U^{(k)} || d^n_{v'SL'})$$

$$= n \{ [L][L'] \}^{1/2} \sum_{\bar{v}\bar{S}\bar{L}} (d^n_{vSL} \{ | d^{n-1}_{\bar{v}\bar{S}\bar{L}} \})$$

$$\times (d^{n-1}_{\bar{v}\bar{S}\bar{L}} | d^n_{v'SL'}) (-1)^{\bar{L}+L+k} \begin{Bmatrix} L & k & L' \\ 2 & \bar{L} & 2 \end{Bmatrix} , \quad (11)$$

and

$$(d^n_{vSL} || V^{(1k)} || d^n_{v'S'L'}) = n(3/2)^{1/2} \{ [S][S'] [L][L'] \}^{1/2}$$

$$\times \sum_{\bar{v}\bar{S}\bar{L}} (d^n_{vSL} \{ | d^{n-1}_{\bar{v}\bar{S}\bar{L}} \}) (d^{n-1}_{\bar{v}\bar{S}\bar{L}} | d^n_{v'S'L'})$$

$$\times \begin{Bmatrix} S & S' & 1 \\ 1/2 & 1/2 & \bar{S} \end{Bmatrix} \begin{Bmatrix} L & L' & k \\ 2 & 2 & \bar{L} \end{Bmatrix} (-1)^{\bar{S}+\bar{L}+S+L+3/2+k} , \quad (12)$$

where $[\alpha] = 2\alpha+1$.

In Eqs. (3), (7) - (12),

$$\begin{pmatrix} a & b & c \\ 0 & 0 & 0 \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} a & b & c \\ d & e & f \end{pmatrix}$$

are the Wigner 3-j and 6-j symbols. The reduced matrix elements of the tensor operators $U^{(k)}$ and $V^{(11)}$ have been tabulated by Nielson and Koster³.

Description of Tables:

Tables I - IV present a tabulation of the matrix elements of the Hamiltonian operator,

$$H = H_0 + H_c + H_{00} + H_{s0} + H_{ss} + H_{s00} ,$$

for d^2 , d^3 , d^4 and d^5 configurations, respectively. Matrix elements for the conjugate configurations d^{10-n} may be obtained directly from these tables. In relating the d^{10-n} and d^n configurations, the following prescriptions may be used.

- a) Under conjugation, the relative electrostatic energies of the terms in d^{10-n} and d^n remain the same¹. In other words, the off-diagonal matrix elements, $(H_c)_{ij}$, in d^{10-n} can be taken to be the same as the corresponding ones in d^n while the diagonal elements, $(H_c)_{ii}$, in d^{10-n} differ by an additive constant from those in d^n . For d^6 , d^7 and d^8 configurations, the prescription is,

$$\begin{aligned} & (d^{10-n}_{vSL} | H_c | d^{10-n}_{v'SL}) \\ &= (d^n_{vSL} | H_c | d^n_{v'SL}) + \delta(v, v') W(d^{10-n}) \end{aligned}$$

where¹⁵

$$W(d^6) = 9F^0 - \frac{14}{49} F^2 - \frac{126}{441} F^4$$

$$W(d^7) = 18F^0 - \frac{28}{49} F^2 - \frac{252}{441} F^4$$

$$W(d^8) = 27F^0 - \frac{42}{49} F^2 - \frac{378}{441} F^4$$

- b) The Spin-Orbit matrix element under conjugation remains the same in magnitude but opposite in sign, hence

$$\begin{aligned} & (d^{10-n}_{vLSJ} | H_{so} | d^{10-n}_{v'L'S'J}) \\ & = -(d^n_{vLSJ} | H_{so} | d^n_{v'L'S'J}) \end{aligned}$$

- c) The Orbit-Orbit matrix element under conjugation undergoes the transformation $n \rightarrow 10-n$ in Eq. 4.

This results in the following relation,

$$(d^{10-n}_{vLS} | H_{oo} | d^{10-n}_{vLS}) = (d^n_{vLS} | H_{oo} | d^n_{vLS}) + \Omega(d^{10-n}),$$

where⁵

$$\Omega(d^{10-n}) = (120-24n)M^0 + \left(\frac{240}{7} - \frac{48n}{7}\right)M^2$$

- d) The Spin-Spin matrix element remains unchanged under conjugation, thus

$$(d^{10-n}_{vLSJ} | H_{ss} | d^{10-n}_{v'L'S'J}) = (d^n_{vLSJ} | H_{ss} | d^n_{v'L'S'J})$$

- e) The Spin-Other-Orbit matrix elements are related under conjugation by the expression¹⁶,

¹⁵J. Hinze and H. H. Jaffe, J. Chem. Phys. 38, 1834 (1963).

¹⁶B. R. Judd, H. M. Crosswhite, and Hannah Crosswhite, Phys. Rev. 169, 130 (1968).

$$\begin{aligned}
& (d^{10-n}_{vLSJ} | H_{soo} | d^{10-n}_{v'L'S'J}) = (d^n_{vLSJ} | H_{soo} | d^n_{v'L'S'J}) \\
& + \zeta' (d^n_{vLSJ} | \sum_1 \hat{l}_1 \cdot \hat{s}_1 | d^n_{v'L'S'J})
\end{aligned} \tag{18}$$

where

$$\zeta' = 14M^0 - \frac{4}{7}M^2$$

and

$$(d^n_{vLSJ} | \sum_1 \hat{l}_1 \cdot \hat{s}_1 | d^n_{v'L'S'J})$$

is the coefficient of the Spin-Orbit interaction radial integral ζ_{nd} tabulated in Tables I - IV.

The matrix tables were produced in single precision on the UNIVAC 1108 computer. Where possible, the calculations were checked against available tables in the literature and an accuracy of at least 7-significant figures was observed. However, the values are listed to eight digits in the tables.

The matrix elements are tabulated in J-blocks. For each J-block, all interaction matrices are presented before another J-block is noted. The states $|vLS\rangle$ labeling a given J-block are listed in parentheses beside the J-value. The following comments should be noted in using the tables.

- a) The diagonal and off-diagonal terms of the Coulomb operator H_c for a given J-block are listed separately when off-diagonal terms occur. The numbers presented are the coefficients of the Slater integrals F^k .

The diagonal elements are listed in column formation, each column referring to a corresponding state above. When present, the off-diagonal terms are noted explicitly.

- b) The diagonal terms of the Orbit-Orbit operator H_{oo} are presented in the same manner as the diagonal Coulomb terms. The numbers listed are the coefficients of the radial integrals M^k . There are no off-diagonal terms.
- c) The Spin-Orbit operator H_{so} matrix is listed in its entirety, where each element of the matrix is to be multiplied by the radial integral ζ_{nd}^{10} .
- d) The matrices of the Spin-Other-Orbit operator H_{soo} and Spin-Spin operator H_{ss} are presented in their entireties. The coefficients of M^0 and M^2 are listed one below the other.

Acknowledgement

We wish to express our gratitude to Mrs. D. A. Barton and Miss S. J. Witty for their assistance in the preparation of this work.

This research was performed under government contract NAS 9-5384.

TABLE I. MATRIX ELEMENTS OF THE d^2 CONFIGURATION

$J = 4 \quad ({}^3F, {}^1G)$	
Coulomb (Diagonal Matrix Elements)	
F^0	+ 1.0 + 1.0
F^2	- 0.16326529 + 0.081632647
F^4	- 0.020408162 ; + 0.0022675735
Orbit-Orbit (Diagonal Matrix Elements)	
M^0	0.0 -16.0
M^2	+ 2.4489796 ; - 0.48979586
Spin-Orbit	
	+ 1.4999997 + 0.99999984
	+ 0.99999983 0.0

TABLE I. (continued)

Spin-Other-Orbit		
M^0	-11.571425	+ 3.1428556
M^2	+ 3.1224481	+ 0.89795890
M^0	+ 3.1428557	0.0
M^2	+ 0.89795890	0.0
Spin-Spin		
M^0	+ 0.28571416	0.0
M^2	- 1.5510197	0.0
M^0	0.0	0.0
M^2	0.0	0.0
$J = 3 \quad ({}^3F)$		
Coulomb		
F^0	+ 1.0	
F^2	- 0.16326529	
F^4	- 0.020408162	

TABLE I. (continued)

Orbit-Orbit
M^0 0.0
M^2 + 2.4489796
Spin-Orbit
- 0.49999990
Spin-Other-Orbit
M^0 + 3.8571416
M^2 - 1.0408160
Spin-Spin
M^0 - 0.85714247
M^2 + 4.6530590
$J = 2$ ($\frac{3}{2}P$, $\frac{1}{2}D$, $\frac{3}{2}F$)

TABLE I. (continued)

Coulomb (Diagonal Matrix Elements)			
F^0	+ 1.0	+ 1.0	+ 1.0
F^2	+ 0.14285713	- 0.061224485	- 0.16326529
F^4	- 0.19047617	+ 0.081632647	- 0.020408162
Orbit-Orbit (Diagonal Matrix Elements)			
M^0	+20.0	+12.0	0.0
M^2	0.0	- 3.9183674	+ 2.4489796
Spin-Orbit			
	+ 0.49999991	+ 1.4491374	0.0
	+ 1.4491374	0.0	- 1.5491930
	0.0	- 1.5491930	- 1.99999996
Spin-Other-Orbit			
M^0	- 5.9999982	+ 2.0701952	0.0
M^2	-10.285710	+ 1.1829692	0.0
M^0	+ 2.0701952	0.0	- 3.3196982
M^2	+ 1.1829692	0.0	+ 2.3712134

TABLE I. (continued)

M^0	0.0	- 3.3196982	+15.428566
M^2	0.0	+ 2.3712132	- 4.1632641
Spin-Spin			
M^0	- 0.39999983	0.0	+ 2.5657067
M^2	- 0.68571397	0.0	- 4.7648836
M^0	0.0	0.0	0.0
M^2	0.0	0.0	0.0
M^0	+ 2.5657067	0.0	+ 0.68571397
M^2	- 4.7648837	0.0	- 3.7224472
$J = 1 \quad ({}^3P_2)$			
Coulomb			
F^0	+ 1.0		
F^2	+ 0.14285713		
F^4	- 0.19047617		
Orbit-Orbit			
M^0	+20.0		
M^2	0.0		

TABLE I. (continued)

Spin-Orbit
- 0.49999990
Spin-Other-Orbit
$M^0 + 5.9999981$
$M^2 + 10.285710$
Spin-Spin
$M^0 + 1.9999991$
$M^2 + 3.4285698$
$J = 0 \left(\begin{smallmatrix} 1s \\ 0 \end{smallmatrix}, \begin{smallmatrix} 3p \\ 2 \end{smallmatrix} \right)$
Coulomb (Diagonal Matrix Elements)
$F^0 + 1.0$ + 1.0
$F^2 + 0.28571425$ + 0.14285713
$F^4 + 0.28571425$; - 0.19047617

TABLE I. (continued)

Orbit-Orbit (Diagonal Matrix Elements)

 M^0 +23.999999 +20.0
 M^2 +6.8571429 ; 0.0

Spin-Orbit

 M^0 0.0 - 2.4494893
 M^2 - 2.4494894 - 0.99999982

Spin-Other-Orbit

 M^0 0.0 - 2.4494880
 M^2 0.0 - 0.69985434
 M^0 + 2.4494881 +11.999996
 M^2 - 0.69985421 +20.571420

Spin-Spin

 M^0 0.0 0.0
 M^2 0.0 0.0
 M^0 0.0 - 3.9999983
 M^2 0.0 - 6.8571397

TABLE II: MATRIX ELEMENTS FOR d^3 CONFIGURATIONS

$J = 5.5 \left(\begin{smallmatrix} 2 \\ 3 \end{smallmatrix} H \right)$	
Coulomb	
F^0	+ 3.0
F^2	- 0.12244896
F^4	- 0.027210881
Orbit-Orbit	
M^0	-24.0
M^2	+ 2.9387755
Spin-Orbit	
+ 0.5	
Spin-Other-Orbit	
M^0	-13.142852
M^2	+ 2.6734682

TABLE II. (continued)

Spin-Spin		
M^0	0.0	
M^2	0.0	
$J = 4.5 \left({}^2_H, {}^2_G, {}^4_F, {}^3_F \right)$		
Coulomb (Diagonal Matrix Elements)		
F^0	+ 3.0	+ 3.0
F^2	- 0.12244896	- 0.22448976 - 0.30612241
F^4	- 0.027210881; + 0.029478455;	- 0.16326529
Orbit-Orbit (Diagonal Matrix Elements)		
M^0	-24.0	+12.0
M^2	+ 2.9387755 ; + 0.48979592 ;	+ 5.8775511
Spin-Orbit		
	- 0.6	- 1.6248073 0.0
	- 1.6248073	+ 0.6 + 1.5811385
	0.0	+ 1.5811385 + 1.5

TABLE II. (continued)

Spin-Other-Orbit			
M^0	+15.771423	- 0.23211391	0.0
M^2	- 3.2081619	- 1.0610987	0.0
M^0	- 0.23211383	- 9.7714253	- 0.45175510
M^2	- 1.0610988	+ 4.0040799	+ 3.2590809
M^0	0.0	- 0.45175502	-24.428562
M^2	0.0	+ 3.2590808	- 0.55102041
Spin-Spin			
M^0	0.0	0.0	+ 1.4680259
M^2	0.0	0.0	- 1.6777438
M^0	0.0	0.0	+ 0.81315673
M^2	0.0	0.0	- 2.8654093
M^0	+ 1.4680259	+ 0.81315672	- 0.57142833
M^2	- 1.6777439	- 2.8654093	- 0.57142837
$J = 3.5 \left(\begin{smallmatrix} 2 \\ 3 \end{smallmatrix} G, \begin{smallmatrix} 2 \\ 3 \end{smallmatrix} F, \begin{smallmatrix} 4 \\ 3 \end{smallmatrix} F \right)$			
Coulomb (Diagonal Matrix Elements)			
F^0	+ 3.0	+ 3.0	+ 3.0

C

TABLE II. (continued)

$$F^2 - 0.22448976 + 0.18367344 - 0.30612241$$

$$F^4 + 0.029478455; - 0.19727889 ; - 0.16326529$$

Orbit-Orbit (Diagonal Matrix Elements)

$$M^0 - 4.0 \quad +12.0 \quad +12.0$$

$$M^2 + 0.48979592; - 1.4693878 ; + 5.8775511$$

Spin-Orbit

$$- 0.75 \quad + 0.9682456 \quad + 0.79056925$$

$$+ 0.96824565 - 0.25 \quad - 0.61237229$$

$$+ 0.79056925 - 0.61237229 \quad 0.0$$

Spin-Other-Orbit

$$M^0 +12.214282 \quad - 1.9364917 \quad - 0.22587755$$

$$M^2 - 5.0051001 \quad + 0.33592196 \quad + 1.6295405$$

$$M^0 - 1.9364918 \quad - 8.7857107 \quad - 1.5746709$$

$$M^2 + 0.33592201 \quad - 8.0969353 \quad - 5.5113495$$

$$M^0 - 0.22587751 \quad - 1.5746709 \quad 0.0$$

$$M^2 + 1.6295404 \quad - 5.5113497 \quad 0.0$$

TABLE II. (continued)

Spin-Spin		
M^0	0.0	0.0
M^2	0.0	0.0
		- 2.0328918
		+ 7.1635234
M^0	0.0	0.0
M^2	0.0	0.0
		- 1.2247443
		+ 0.64986429
M^0	- 2.0328918	- 1.2247443
M^2	+ 7.1635233	+ 0.64986423
		+ 1.1428567
		+ 1.1428568
$J = 2.5 \left(\begin{smallmatrix} 2_F \\ 3 \end{smallmatrix}, \begin{smallmatrix} 4_F \\ 3 \end{smallmatrix}, \begin{smallmatrix} 2_D \\ 3 \end{smallmatrix}, \begin{smallmatrix} 4_P \\ 3 \end{smallmatrix}, \begin{smallmatrix} 2_D \\ 1 \end{smallmatrix} \right)$		
Coulomb (Diagonal Matrix Elements)		
F^0	+ 3.0	+ 3.0
F^2	+ 0.18367344	- 0.30612241
F^4	- 0.19727889	- 0.16326529
		+ 0.06122448i
		0.0
		+ 3.0
		+ 0.14285712
		- 0.333333329
		+ 0.14285712
Off-Diagonal Coulomb Elements		
$\left(\begin{smallmatrix} 2_D \\ 3 \end{smallmatrix} H_c \begin{smallmatrix} 2_D \\ 1 \end{smallmatrix} \right)$		
F^0	0.0	
F^2	+ 0.28056582	
F^4	- 0.15586990	

TABLE II. (continued)

Orbit-Orbit (Diagonal Matrix Elements)

$$M^0 +12.0 \quad +12.0 \quad +24.0 \quad +32.0 \quad +24.0$$

$$M^2 - 1.4693878 ; + 5.8775511 ; - 2.9387755 ; + 3.4285714 ; + 6.8571428$$

Spin-Orbit

$$+ 0.33333325 \quad - 0.52704614 \quad - 0.33333325 \quad 0.0 \quad - 1.5275249$$

$$- 0.52704614 \quad - 1.1666666 \quad - 1.0540923 \quad 0.0 \quad + 0.96609156$$

$$- 0.33333325 \quad - 1.0540923 \quad - 0.16666663 \quad 0.0 \quad - 0.76376247$$

$$0.0 \quad 0.0 \quad 0.9 \quad +0.50 \quad + 1.5491930$$

$$- 1.5275249 \quad + 0.96609156 \quad - 0.76376247 \quad + 1.5491930 \quad + 0.5$$

Spin-Other-Orbit

$$M^0 +11.714281 \quad - 1.3552610 \quad + 3.0 \quad 0.0 \quad + 3.2732681$$

$$M^2 +10.795914 \quad - 4.7434143 \quad +11.265301 \quad 0.0 \quad + 3.1173968$$

$$M^0 - 1.3552610 \quad +19.0 \quad + 1.3552621 \quad 0.0 \quad - 1.2421183$$

$$M^2 - 4.7434143 \quad + 0.42857143 \quad + 4.0012474 \quad 0.0 \quad + 2.4053705$$

$$M^0 + 3.0 \quad + 1.3552621 \quad - 4.7857124 \quad 0.0 \quad + 2.4053705$$

$$M^2 +11.265301 \quad + 4.0012474 \quad - 3.6122432 \quad - 8.6930116 \quad - 1.9016123$$

$$M^0 0.0 \quad 0.0 \quad 0.0 \quad - 6.0 \quad - 3.0983867$$

$$M^2 0.0 \quad 0.0 \quad - 8.6930116 \quad +11.142852 \quad - 1.9918190$$

TABLE II. (continued)

M^0	+	3.2732680	-	1.2421182	-	0.98198076	-	3.0983867	-	4.5
M^2	-	3.1173970	+	2.4053704	-	1.9016123	-	1.9918190	+	0.14285709

Spin-Spin

M^0	0.0	+	1.8973657	0.0	+	1.3522461	0.0
M^2	0.0	-	1.0067654	0.0	+	6.1816965	0.0
M^0	+	1.8973657	+	0.3428570	-	3.4209421	0.0
M^2	-	1.0067653	+	0.34285702	+	2.6878831	0.0
M^0	0.0	-	1.0842010	0.0	+	0.67612309	0.0
M^0	0.0	+	7.4345754	0.0	+	0.1931780	0.0
M^0	+	1.3522461	-	3.4209421	+	0.80	0.0
M^2	+	6.1816967	+	2.6878829	+	0.19317802	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

 $J = 1.5 \left({}^4_3F, {}^2_3P, {}^4_3P, {}^2_3D, {}^2_1D \right)$

Coulomb (Diagonal Matrix Elements)

F^0	+	3.0	+	3.0	+	3.0	+	3.0		
F^2	-	0.30612241	-	0.12244896	0.0	+	0.061224481	+	0.14285712	
F^4	+	0.16326529;	-	0.027210876;	-	0.33333329;	-	0.12925168;	+	0.14285713

TABLE II. (continued)

Off-Diagonal Coulomb Elements

$$({}_3^2D|H_c|{}_1^2D)$$

$$\begin{aligned} F^0 & 0.0 \\ F^2 & + 0.2805582 \\ F^4 & - 0.15586990 \end{aligned}$$

Orbit-Orbit (Diagonal Matrix Elements)

$$\begin{aligned} M^0 & +12.0 & +32.0 & +24.0 & +24.0 \\ M^2 & + 5.8775511 ; & - 3.9183674 ; & + 3.4285714 ; & - 2.9387755 ; & + 6.8571428 \end{aligned}$$

Spin-Orbit

$$\begin{aligned} & - 2.0 & 0.0 & 0.0 & - 1.5811384 & + 1.4491374 \\ & 0.0 & + 0.33333327 & - 1.9720262 & - 1.8371169 & + 0.93541415 \\ & 0.0 & - 1.9720262 & - 0.33333327 & 0.0 & + 0.63245539 \\ & - 1.5811384 & - 1.8371169 & 0.0 & + 0.25 & + 1.1456437 \\ & + 1.4491374 & + 0.93541415 & + 0.63245539 & + 1.1456437 & - 0.75 \end{aligned}$$

Spin-Other-Orbit

$$\begin{aligned} M^0 & +32.571416 & 0.0 & 0.0 & + 2.0328932 & - 1.8631774 \\ M^2 & + 0.73469391 & 0.0 & 0.0 & + 7.0018713 & + 3.6080557 \end{aligned}$$

TABLE II. (continued)

M^0	0.0	- 2.9285707	+ 3.3806171	+ 3.4117694	- 0.66815373
M^2	0.0	+ 5.5918345	+ 2.7769341	+ 7.7233879	+ 5.1543216
M^0	0.0	+ 3.3806171	+ 4.0	0.0	- 1.2649111
M^2	0.0	+ 2.7769338	- 7.4285682	- 3.5489071	- 0.81315669
M^0	+ 2.0328933	+ 3.4117895	0.0	+ 7.1785686	- 1.4729712
M^2	+ 6.0018711	+ 7.7233881	- 3.5489071	+ 5.4183649	+ 2.8524185
M^0	- 1.8631773	- 0.66815360	- 1.2649111	- 1.4729711	+ 6.75
M^2	+ 3.6080557	+ 5.1543219	- 0.81315669	+ 2.8524185	- 0.21428563

Spin-Spin

M^0	- 1.3714280	- 2.4344453	- 2.0948906	+ 1.0842090	0.0
M^2	- 1.3714281	- 1.6440411	+ 1.6459855	- 7.4345756	0.0
M^0	- 2.4344455	0.0	- 0.33806156	0.0	0.0
M^2	- 1.6440409	0.0	+ 0.86930119	0.0	0.0
M^0	- 2.0948906	- 0.33806155	- 3.1999984	- 2.4842348	0.0
M^2	+ 1.6459855	+ 0.86930107	+ 8.2285672	- 7.0978140	0.0
M^0	+ 1.0842090	0.0	- 2.4842349	0.0	0.0
M^2	- 7.4345754	0.0	- 0.70978136	0.0	0.0
M^0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0

J = .5 ($\frac{2}{3}P$, $\frac{4}{3}P$)

TABLE II. (continued)

Coulomb (Diagonal Matrix Elements)	
F^0	+ 3.0 + 3.0
F^2	- 0.12244896 0.0
F^4	- 0.027210876; - 0.33333329
Orbit-Orbit (Diagonal Matrix Elements)	
M^0	+32.0 +32.0
M^2	- 3.9183674 ; + 3.4285714
Spin-Orbit	
	- 0.66666654 - 1.2472188
	- 1.2472188 - 0.83333319
Spin-Other-Orbit	
M^0	+ 5.8571415 + 2.1380900
M^2	-11.183669 + 1.7562873
$\bar{M}^0$	+ 2.1380900 +10.0
M^2	+ 1.7562872 -18.571420

TABLE II. (continued)

Spin-Spin		
M^0	0.0	+ 1.0690445
M^2	0.0	- 2.7489717
M^0	+ 1.0690445	+ 4.0
M^2	- 2.7489714	-10.285709

TABLE III. MATRIX ELEMENTS FOR d^4 CONFIGURATIONS

$J = 6.0 \left(\frac{1}{4}I, \frac{3}{4}H \right)$	
Coulomb (Diagonal Matrix Elements)	
F^0	$+ 6.0$
F^2	$- 0.30612239$
F^4	$- 0.020408159$
	$+ 6.0$
	$- 0.34693872$
	$- 0.15646256$
Orbit-Orbit (Diagonal Matrix Elements)	
M^0	-36.0
M^2	$+ 4.4081632$
	-12.0
	$+ 6.3673470$
Spin-Orbit	
	0.0
	$+ 1.2247446$
	$+ 0.5$
Spin-Spin	
M^0	0.0
M^2	0.0
	0.0

TABLE III. (continued)

M^0 0.0 - 0.85714237
 M^2 0.0 + 0.97959132

Spin-Other-Orbit

M^0 0.0 - 3.8491978
 M^2 0.0 + 2.6494469
 M^0 - 3.8491978
 M^2 + 2.6494469
 M^0 - 28.571416
 M^2 - 0.51020374

$J = 5.0$ ($\frac{3}{4}H, \frac{3}{4}G$)

Coulomb (Diagonal Matrix Elements)

F^0 + 6.0 + 6.0
 F^2 - 0.34693872 - 0.24489792
 F^4 - 0.15646256 ; - 0.21315189

Orbit-Orbit (Diagonal Matrix Elements)

M^0 -12.0 + 8.0
 M^2 + 6.3673470 ; + 3.9183674

TABLE III. (continued)

Spin-Orbit	
- 0.1	- 0.2
- 1.2	+ 0.6
Spin-Spin	
$M^0 + 2.2285701$	- 0.68571393
$M^2 - 2.5469374$	+ 3.2326513
$M^0 - 0.68571393$	- 0.22857129
$M^2 + 3.2326511$	+ 1.8938765
Spin-Other-Orbit	
$M^0 + 5.7142833$	+ 4.2857138
$M^2 + 0.10204075$	+ 0.61224438
$M^0 + 4.2857137$	-22.142847
$M^2 + 0.61224459$	- 1.1224482

$$J = 4 \left(\frac{1}{2}^G, \frac{1}{4}^G, \frac{3}{4}^H, \frac{3}{4}^G, \frac{3}{2}^F, \frac{3}{4}^F, \frac{5}{4}^D \right)$$

Coulomb (Diagonal Matrix Elements)													
F^0	+ 6.0		+ 6.0		+ 6.0		+ 6.0		+ 6.0		+ 6.0		+ 6.0
F^2	- 0.12244896		- 0.081632641		- 0.34693872		- 0.24489792		- 0.040816319		- 0.163226528		- 0.42857137
F^4	+ 0.11564625	;	- 0.14512469	;	- 0.15646256	;	- 0.21515189	;	- 0.088435356	;	- 0.25850336	;	- 0.42857136

(Off-Diagonal Coulomb Elements)

$\frac{1}{2}\text{G} \text{H}_c \frac{1}{4}\text{G}$	$(\frac{3}{2}\text{F} \text{H}_c \frac{3}{4}\text{F})$
$\frac{0}{\text{F}}$	0.0
$\frac{2}{\text{F}}$	$+ 0.27074484$
$\frac{4}{\text{F}}$	$+ 0.24489792$
	$- 0.13605440$

Orbit-Orbit (Diagonal Matrix Elements)

M^0	+ 8.0	+ 8.0	-12.0	+ 8.0	+24.0	+36.0
M^2	+ 6.3673470	; - 0.97959197	; + 6.3673470	; + 3.9183674	; + 9.3061226	; + 1.9591837 ; +10.285714

Spin-Orbit

0.0	+ 1.5634715	+ 0.57735014	+ 0.33333327	- 1.66666663	0.0
0.0	- 0.94280881	+ 0.95742691	- 1.1055413	+ 0.55277070	0.0

TABLE III. (continued)

+ 1.5634716	- 0.94280882	- 0.59999982	- 1.0832049	0.0	0.0	0.0
+ 0.57735014	+ 0.95742691	- 1.0832049	- 0.150	- 1.4433754	+ 0.72168770	0.0
+ 0.133333327	- 1.1055414	0.0	- 1.4433754	+ 0.5	- 0.5	+ 1.4142132
- 1.66666663	+ 0.55277070	0.0	+ 0.72168769	- 0.5	- 0.25	- 1.4142132
0.0	0.0	0.0	0.0	+ 1.4142132	- 1.4142132	+ 1.0

Spin-Other-Orbit

M^0	0.0	0.0	- 6.4772399	- 1.5670935	+ 1.3333323	+ 7.1904754	0.0
M^2	0.0	0.0	+ 2.6164214	+ 5.3257594	+ 4.1904747	- 1.2789111	0.0
M^0	0.0	0.0	+ 1.4815578	- 0.13677666	+ 5.5277070	- 1.8162469	0.0
M^2	0.0	0.0	- 1.4045926	+ 14.517715	+ 3.1586889	+ 5.9676657	0.0
M^0	- 6.4772401	+ 1.4815575	+ 34.285699	+ 3.8685893	0.0	0.0	0.0
M^2	+ 2.6164212	- 1.4045926	+ 0.61224449	+ 0.55265521	0.0	0.0	0.0
M^0	- 1.5670936	- 0.13677657	+ 3.8685893	+ 5.5357121	+ 6.3920914	- 1.9588672	0.0
M^2	+ 5.3257595	+ 14.517715	+ 0.55265540	+ 0.28061206	- 0.23565314	- 0.63331747	0.0
M^0	+ 1.3333323	+ 5.5277070	0.0	+ 6.3920915	- 15.428566	+ 2.7857137	- 6.6670057
M^2	+ 4.1904742	+ 3.1586888	0.0	- 0.23565318	+ 2.0204076	+ 2.9387742	- 1.9048581
M^0	+ 7.1904752	- 1.8162470	0.0	- 1.9588672	+ 2.7857137	- 12.535709	+ 4.2426406
M^2	- 1.2789113	+ 5.9676658	0.0	- 0.63331761	+ 2.9387742	+ 10.270403	- 7.0133416
M^0	0.0	0.0	0.0	0.0	- 6.6670058	+ 4.2426405	- 23.999991
M^2	0.0	0.0	0.0	0.0	- 1.9048584	- 7.0133419	+ 1.7142853

TABLE III. (continued)

Spin-Spin									
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 5.7433631
M^0	0.0	0.0	- 1.4857135	+ 0.92846105	0.0	0.0	+ 2.6802361	0.0	0.0
M^2	0.0	0.0	+ 1.6979583	- 4.3770304	0.0	0.0	+ 2.6802360	0.0	0.0
M^0	0.0	0.0	+ 0.92846106	+ 0.62857106	0.0	0.0	+ 0.98974279	+ 3.4992694	0.0
M^2	0.0	0.0	- 4.3770304	- 5.2081604	0.0	0.0	- 2.5450529	- 1.4996869	0.0
M^0	0.0	0.0	0.0	0.0	0.0	+ 0.28571416	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	- 1.5510197	0.0	0.0	0.0
M^0	0.0	0.0	+ 2.6802362	+ 0.98974281	0.0	0.0	- 0.28571414	- 1.2121824	0.0
M^2	0.0	0.0	+ 2.6802360	- 2.5450528	0.0	0.0	- 0.89795868	+ 3.9828851	0.0
M^0	0.0	0.0	0.0	+ 3.4992694	0.0	0.0	- 1.2121824	- 1.7142850	0.0
M^2	0.0	+ 5.7433634	0.0	- 1.4996867	0.0	0.0	+ 3.9828851	+ 1.9591827	0.0

TABLE III. (continued)

$J = 3 \left(\frac{1}{4}F, \frac{3}{4}G, \frac{3}{2}F, \frac{3}{4}D, \frac{5}{4}D \right)$					
Coulomb (Diagonal Matrix Elements)					
F^0	+ 6.0	+ 6.0	+ 6.0	+ 6.0	+ 6.0
F^2	0.0	- 0.24489792	- 0.040816319	- 0.16326528	- 0.42857137
F^4	- 0.19047616	- 0.21315189	- 0.088435356	- 0.25850336	- 0.42857136
Off-Diagonal Coulomb Elements					
$\left(\frac{3}{2}F H_c \frac{3}{4}F \right)$					
F^0	0.0				
F^2	+ 0.24489792				
F^4	- 0.13605440				
Orbit-Orbit (Diagonal Matrix Elements)					
M^0	+23.999999	+ 8.0	+23.999999	+36.0	+36.0
M^2	- 2.9387758	+ 3.9183674	+ 9.3061226	+ 1.9591837	+ 0.48979592 ; +10.285714
Spin-Orbit					
0.0	+ 0.98198029	+ 1.2909941	+ 0.64549707	+ 0.97589985	0.0
+ 0.98198031	- 0.74999987	- 1.2677311	+ 0.63386557	0.0	0.0
+ 1.2909941	- 1.2677311	- 0.16666663	+ 0.16666663	- 1.2598813	+ 0.81649640

TABLE III. (continued)

	+ 0.64549709	+ 0.63386554	+ 0.16666663	+ 0.083333316	- 0.25197625	- 0.81649638
	+ 0.97589986	0.0	- 1.2598813	- 0.25197625	- 0.16666664	+ 1.0801232
	0.0	0.0	+ 0.81649640	- 0.81649639	+ 1.0801232	0.0
Spin-Other-Orbit						
M^0	0.0	- 6.5932960	- 4.9795494	- 4.1496239	- 4.6006710	0.0
M^2	0.0	-10.400973	+ 4.1101032	+ 4.1496229	-11.173055	0.0
M^0	- 6.5932961	+27.678560	+ 5.6142382	- 1.7204928	0.0	0.0
M^2	-10.400972	+ 1.4030603	- 0.20697653	- 0.55624910	0.0	0.0
M^0	- 4.9795494	+ 5.6142382	+ 5.1428553	- 0.92857120	+ 5.0755222	- 3.8491976
M^2	+ 4.1101030	- 0.20697656	- 0.67346919	- 0.97959138	- 2.8694434	- 1.0997704
M^0	- 4.1496240	- 1.7204928	- 0.92857122	+ 4.1785694	- 1.8358263	+ 2.4494897
M^2	+ 4.1496233	- 0.55624922	- .97959138	- 3.4234678	- 8.7780281	- 4.0491547
M^0	- 4.6006709	0.0	+ 5.0755221	- 1.8358262	- 8.5714249	- 3.7032802
M^2	-11.173054	0.0	- 2.8694434	- 8.7780277	+ 2.6530601	- 3.7032784
M^0	0.0	0.0	- 3.8491976	+ 2.4494896	- 3.7032803	0.0
M^2	0.0	0.0	- 1.0997705	- 4.0491547	- 3.7032788	0.0

TABLE III. (continued)

Spin-Spin									
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	- 3.8721743	0.0
M^0	0.0	- 0.44897933	0.0	0.0	- 1.4488351	+ 0.54760818	+ 1.7744535		
M^2	0.0	+ 3.7201147	0.0	0.0	+ 3.7255760	- 7.2753657	- 0.76048006		
M^0	0.0	0.0	- 0.85714247	0.0	0.0	0.0	0.0		
M^2	0.0	0.0	+ 4.6530589	0.0	0.0	0.0	0.0		
M^0	0.0	- 1.4488351	0.0	+ 0.85714243	- 1.9438163	+ 2.0995615			
M^2	0.0	+ 3.7255759	0.0	+ 2.6938760	+ 1.7586908	- 6.8985595			
M^0	0.0	+ 0.54760824	0.0	- 1.9438163	- 0.12244892	+ 2.3806790			
M^2	0.0	- 7.2753663	0.0	+ 1.7586908	+ 2.2390658	- 4.9880892			
M^0	0.0	+ 1.7744535	0.0	+ 2.0995615	+ 2.3806790	+ 3.4285698			
M^2	- 3.8721746	- 0.76047996	0.0	- 6.8985595	- 4.9880895	- 3.9183653			

TABLE III. (continued)

- 1.0327953	+ 1.4605931	+ 0.66666651	+ 0.33333326	- 0.21081845	0.0	0.0	- 0.36514827
+ 1.6329928	- 0.57735015	- 1.0540923	- 0.21081846	+ 0.083333322	0.0	- 1.4230246	+ 1.0103627
+ 0.48304581	- 1.3662598	0.0	0.0	0.0	+ 0.16666663	- 1.2472188	+ 1.3662598
- 0.51639767	- 0.18257416	0.0	0.0	- 1.4230247	- 1.2472188	+ 0.33333326	- 0.63900953
0.0	0.0	+ 0.36514828	- 0.36514828	+ 1.0103627	+ 1.3662598	- 0.63900953	- 0.74999984

Spin-Other-Orbit

M^0	0.0	0.0	+ 1.5491934	+ 4.8688924	- 7.6983951	- 1.1041052	+ 3.1721570	0.0
M^2	0.0	0.0	+ 8.1885896	+ 1.3911116	- 2.1995407	+ 3.0362871	+ 4.5948844	0.0
M^0	0.0	0.0	+ 1.0954450	- 6.2596853	+ 2.9692294	+ 6.0505796	+ 3.3966622	0.0
M^2	0.0	0.0	- 2.8168575	+ 1.7884812	+ 1.5553103	- 0.22306295	+13.003748	0.0
M^0	+ 1.5491932	+ 1.0954450	+20.571421	- 3.7142848	+ 4.2464865	0.0	0.0	- 1.7214135
M^2	+ 8.1885897	- 2.8168575	- 2.6938767	- 3.9183655	- 2.4007485	0.0	0.0	- 0.49183225
M^0	+ 4.8688924	- 6.2596853	- 3.7142849	+16.714277	- 1.5359625	0.0	0.0	+ 1.0954451
M^2	+ 1.3911116	+ 1.7884810	- 3.9183655	-13.693871	- 7.3442253	0.0	0.0	- 1.8108370
M^0	- 7.6983952	+ 2.9692294	+ 4.2464865	- 1.5359625	+ 4.2857124	- 1.0141846	+ 5.5565731	- 3.4641015
M^2	- 2.1995407	+ 1.5553102	- 2.4007486	- 7.3442249	- 1.3265301	- 5.3606905	- 8.9640850	- 3.4640997
M^0	- 1.1041051	+ 6.0505797	0.0	0.0	- 1.0141847	- 6.3333311	+ 5.1670499	- 5.4650400
M^2	+ 3.0362872	- .22306287	0.0	0.0	- 5.3606904	- 5.6190453	- 2.0871823	+ 3.3180589
M^0	+ 3.1721570	+ 3.3906623	0.0	0.0	+ 5.5565731	+ 5.1670499	- 6.3809503	+ 4.1992054
M^2	+ 4.5948843	+13.003748	0.0	0.0	- 8.9640854	- 2.0871823	- 3.6258488	+ 4.9816652

TABLE III. (continued)

M^0	0.0	0.0	- 1.7214135	+ 1.0954451	- 3.4641015	- 5.4650398	+ 4.1992053	+17.999993
M^2	0.0	0.0	- 0.49183230	- 1.8108370	- 3.4641001	+ 3.3180589	+ 4.9816651	- 1.2857139
Spin-Spin								
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 7.3469350
M^0	0.0	0.0	+ 0.68571397	0.0	0.0	+ 2.5657066	0.0	0.0
M^2	0.0	0.0	- 3.7224471	0.0	0.0	- 4.7648835	0.0	0.0
M^0	0.0	0.0	0.0	- 0.68571394	+ 3.2526268	0.0	+ 1.3714278	+ 1.8779049
M^2	0.0	0.0	0.0	- 2.1551008	- 2.9428526	0.0	- 5.4857112	- 6.1702591
M^0	0.0	0.0	0.0	+ 3.2526267	+ 0.42857122	0.0	+ 0.27105223	- 2.2269213
M^2	0.0	0.0	0.0	- 2.9428525	- 7.8367306	0.0	+ 0.077443551	4.6659302
M^0	0.0	0.0	+ 2.5657067	0.0	0.0	- 0.39999981	0.0	0.0
M^2	0.0	0.0	- 4.7648835	0.0	0.0	- 0.68571396	0.0	0.0
M^0	0.0	0.0	0.0	+ 1.3714278	+ 0.27105222	0.0	+ 0.11428565	+ 3.2863337
M^2	0.0	0.0	0.0	- 5.4857112	+ 0.077443473	0.0	- 1.2734687	+ 0.93895244
M^0	0.0	0.0	0.0	+ 1.8779050	- 2.2269213	0.0	+ 3.2863337	+ 1.2857137
M^2	0.0	0.0	0.0	- 6.1702591	+ 4.6659304	0.0	+ 0.93895244	- 1.4693870

TABLE III. (continued)

 $J = 1 \left(\begin{smallmatrix} 3 \\ 4 \end{smallmatrix} P, \begin{smallmatrix} 3 \\ 2 \end{smallmatrix} P, \begin{smallmatrix} 3 \\ 4 \end{smallmatrix} P, \begin{smallmatrix} 5 \\ 4 \end{smallmatrix} D \right)$

F^0	+ 6.0	+ 6.0	+ 6.0	+ 6.0
F^2	- 0.10204080	- 0.14285712	- 0.061224483	- 0.142857137
F^4	- 0.29251695	- 0.031746022	- 0.31519269	- 0.42857136

Off-Diagonal Coulomb Elements

 $\left(\begin{smallmatrix} 3 \\ 2 \end{smallmatrix} P | H_c | \begin{smallmatrix} 3 \\ 4 \end{smallmatrix} P \right)$

F^0	0.0
F^2	+ 0.30544137
F^4	- 0.16968965

Orbit-Orbit

M^0	+36.0	+44.0	+44.0	+36.0
M^2	+ 0.48979592	+ 6.8571429	- 0.48979592	+10.285714

Spin-Orbit

	+ 0.24999996	0.0	- 1.0606599	+ 0.66143768
	0.0	- 0.16666663	+ 1.2472188	+ 1.9999996
	- 1.0606599	+ 1.2472188	- 0.33333326	- 0.93541417
	+ 0.66143768	+ 1.9999996	- 0.93541417	- 1.2499997

TABLE III. (continued)

Spin-Other-Orbit			
M^0	+12.857137	- 0.75592853	+ 4.1416251
M^2	- 3.9795902	- 3.9956228	- 6.6814344
			- 2.2677867
			- 2.2677855
M^0	- 0.75592861	+ 6.3333310	- 5.1670498
M^2	- 3.9956226	+ 5.6190453	+ 2.0871823
			+ 4.8571409
M^0	+ 4.1416250	- 5.1670498	+ 6.3809502
M^2	- 6.6814346	+ 2.0871823	+ 3.6258487
			+ 7.2924112
M^0	- 2.2677867	- 7.9999991	+ 6.1470071
M^2	- 2.2677858	+ 4.8571409	+ 7.2924109
			+29.999989
			- 2.1428566
Spin-Spin			
	- 0.42857122	0.0	- 0.60609121
	+ 7.8367306	0.0	- 0.17316905
			+ 7.1273262
	0.0	+ 1.9999991	0.0
	0.0	+ 3.4285698	0.0
			0.0
	- 0.60609119	0.0	- 0.57142827
	- 0.17316887	0.0	+ 6.3673435
			- 1.6035667
			- 0.45816188
	- 3.4016786	0.0	- 1.6035667
	+ 7.1273266	0.0	- 2.9999986
			+ 3.4285697

TABLE III. (continued)

$J = 0 \left(\begin{smallmatrix} 1s \\ 0 \end{smallmatrix}, \begin{smallmatrix} 1s \\ 4 \end{smallmatrix}, \begin{smallmatrix} 3p \\ 2 \end{smallmatrix}, \begin{smallmatrix} 3p \\ 4 \end{smallmatrix}, \begin{smallmatrix} 5p \\ 4 \end{smallmatrix} \right)$				
Coulomb (Diagonal Matrix Elements)				
F^0	+ 6.0	+ 6.0	+ 6.0	+ 6.0
F^2	+ 0.28571425	+ 0.12244896	- 0.14285712	- 0.061224483
F^4	+ 0.28571425	- 0.25850336	- 0.031746022	- 0.31519269
Off-Diagonal Coulomb Elements				
$\left(\begin{smallmatrix} 1s \\ 0 \end{smallmatrix} \middle \begin{smallmatrix} 1s \\ 4 \end{smallmatrix} \right) \left(\begin{smallmatrix} 3p \\ 2 \end{smallmatrix} \middle \begin{smallmatrix} 3p \\ 4 \end{smallmatrix} \right)$				
F^0	0.0	0.0		
F^2	+ 0.56113164	+ 0.30544137		
F^4	- 0.31173980	- 0.16968965		
Orbit-Orbit				
M^0	+48.0	+48.0	+44.0	+36.0
M^2	+13.714286	- 5.8775511	+ 6.8571429	- 0.48979592
Spin-Orbit				
	0.0	0.0	- 2.9999994	0.0
	0.0	0.0	+ 1.5275249	- 1.6329929

TABLE III. (continued)

- 2.9999995 + 1.5275250 - 0.33333328 + 2.4944377 + 2.3094006
 0.0 - 1.6329929 + 2.4944377 - 0.66666653 - 1.0801232
 0.0 0.0 + 2.3094006 - 1.0801232 - 1.4999997

Spin-Other-Orbit

M^0	0.0	0.0	+12.999999	+ 2.1380890	0.0
M^2	0.0	0.0	- 1.9999997	+11.301328	0.0
M^0	0.0	0.0	- 5.4554471	+10.031242	0.0
M^2	0.0	0.0	+ 7.1700138	+27.027692	0.0
M^0	+12.999999	- 5.4554470	+12.666662	-10.334100	- 9.2376035
M^2	- 1.9999996	+ 7.1700136	+11.238091	+ 4.1743646	+ 5.6085433
M^0	+ 2.1380891	+10.031242	-10.334100	+12.761901	+ 7.0979526
M^2	+11.301328	+27.027692	+ 4.1743646	+ 7.2516976	+ 8.4205510
M^0	0.0	0.0	- 9.2376033	+ 7.0979525	+35.999987
M^2	0.0	0.0	+ 5.6085433	+ 8.4205508	- 2.5714278

Spin-Spin

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-12.958776

TABLE III. (continued)

0.0	0.0	- 3.9999981	0.0	0.0
0.0	0.0	- 6.8571396	0.0	0.0
0.0	0.0	0.0	+ 1.1428565	- 5.5549179
0.0	0.0	0.0	-12.734687	- 1.5871193
0.0	0.0	0.0	- 5.5549179	- 5.9999973
0.0	-12.958776	0.0	- 1.5871194	+ 6.8571394

TABLE IV. MATRIX ELEMENTS OF THE α^5 CONFIGURATION

$\bar{J} = 6.5 \left(\begin{smallmatrix} 2 \\ 5 \end{smallmatrix} I \right)$	
Coulomb	
F^0	+10.0
F^2	- 0.48979582
F^4	- 0.20408159
Orbit-Orbit	
M^0	-24.0
M^2	+ 7.8367345
Spin-Orbit	
	0.0
Spin-Other-Orbit	
M^0	-16.714279
M^2	- 4.1632637
Spin-Spin	

TABLE IV. (continued)

M^0 0.0
 M^2 0.0

$J = 5.5 \left(\frac{2}{5}I, \frac{2}{3}H, \frac{4}{5}G \right)$

Coulomb (Diagonal Matrix Elements)

F^0 +10.0 +10.0 +10.0
 F^2 - 0.48979582 - 0.44897950 - 0.51020399
 F^4 - 0.20408159; - 0.068027195; - 0.43083893

Orbit-Orbit

M^0 -24.0 0.0 +20.0
 M^2 + 7.8367345; + 9.7959185; + 9.7959185

Spin-Orbit

0.0 + 1.8027752 0.0
 + 1.8027752 0.0 + 1.7320504
 0.0 + 1.7320503 0.0

Spin-Other-Orbit

M^0 +19.499991 -12.619427 0.0
 M^2 + 4.8571409 + 1.5452358 0.0
 M^0 -12.619427 -13.071423 -12.124353
 M^2 + 1.5452358 - 1.5918360 + 1.484614

TABLE IV (continued)

M^0	0.0	-12.124353	-31.142843
M^2	0.0	+ 1.4846145	+ 2.1224481

Spin-Spin

M^0	0.0	0.0	- 1.7842842
M^2	0.0	0.0	- 3.0587729

M^0	0.0	0.0	0.0
M^2	0.0	0.0	0.0

M^0	- 1.7842842	0.0	- 2.2857129
M^2	- 3.0587725	0.0	+ 4.2448954

$$J = 4.5 \left(\begin{smallmatrix} 2 \\ 3 \end{smallmatrix} H, \begin{smallmatrix} 2 \\ 5 \end{smallmatrix} G, \begin{smallmatrix} 2 \\ 3 \end{smallmatrix} G, \begin{smallmatrix} 4 \\ 5 \end{smallmatrix} G, \begin{smallmatrix} 4 \\ 3 \end{smallmatrix} F \right)$$

Coulomb (Diagonal Matrix Elements)

F^0	+10.0	+10.0	+10.0	+10.0
F^2	- 0.44897950	- 0.26530607	+ 0.061224481	- 0.51020399
F^4	- 0.068027195	;- 0.32879812	;- 0.35147385	;- 0.43083893
				;- 0.40816319

Off-Diagonal Coulomb Elements

$$\left(\begin{smallmatrix} 2 \\ 5 \end{smallmatrix} G | H_c | \begin{smallmatrix} 2 \\ 3 \end{smallmatrix} G \right)$$

F^0	- - 0.0
F^2	0.0
F^4	0.0

TABLE IV. (continued)

Orbit-Orbit				
M^0	0.0	+20.0	+20.0	+36.0
M^2	+ 9.7959185	+ 2.4489793	+ 7.3469388	+ 9.7959185 ; +12.734694
Spin-Orbit				
	0.0	+ 1.2649108	0.0	+ 0.89442695 0.0
	+ 1.2649108	0.0	- 0.85634866	0.0 + 1.3540061
	0.0	- 0.85634866	0.0	- 0.60552993 0.0
	+ 0.89442695	0.0	- 0.60552993	0.0 + 0.95742688
	0.0	+ 1.3540061	0.0	+ 0.95742688 0.0
Spin-Other-Orbit				
M^0	+15.685708	- 8.8543757	- 2.7853835	- 6.2609891 0.0
M^2	+ 1.9102031	+ 1.0842092	+ 0.53054907	+ 0.76665164 0.0
M^0	- 8.8543757	- 7.4761876	+ 5.9944408	+ 0.37038913 - 9.4780426
M^2	+ 1.0842091	+ 6.1292488	- 0.73401307	+ 7.2490437 + 1.1605765
M^0	- 2.7853833	+ 5.9944408	- 7.9714252	+ 4.2387096 + 3.3881532
M^2	+ 0.53054926	- 0.73401307	+ 7.9469351	- 0.51902561 + 8.8737344
M^0	- 6.2609891	+ 0.37038916	+ 4.2387096	- 2.5952369 - 6.7019883
M^2	+ 0.76665164	+ 7.2490440	- 0.51902561	+ 0.17687067 + 0.82065154
M^0	0.0	- 9.4780429	+ 3.3881532	- 6.7019883 -21.642847
M^2	0.0	+ 1.1605766	+ 8.8737347	+ 0.82065154 + 0.24489775

TABLE IV (continued)

Spin-Spin							
M^0	0.0	0.0	0.0	0.0	0.0	0.0	+ 1.4680259
M^2	0.0	0.0	0.0	0.0	0.0	0.0	- 1.6777438
M^0	0.0	0.0	0.0	0.0	0.0	- 0.20203040	0.0
M^2	0.0	0.0	0.0	0.0	0.0	- 3.5211010	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	+ 0.81315674
M^2	0.0	0.0	0.0	0.0	0.0	0.0	- 2.8654093
M^0	0.0	- 0.20203038	0.0	0.0	0.0	+ 3.9999976	0.0
M^2	0.0	- 3.5211013	0.0	0.0	0.0	- 7.4285671	0.0
M^0	+ 1.4680258	0.0	0.0	+ 0.81315669	0.0	0.0	- 0.57142829
M^2	- 1.6777440	0.0	0.0	- 2.8654093	0.0	0.0	- 0.57142827

TABLE IV. (continued)

$J = 3.5 \left(\begin{smallmatrix} 2G \\ 5 \end{smallmatrix}, \begin{smallmatrix} 2G \\ 3 \end{smallmatrix}, \begin{smallmatrix} 2F \\ 5 \end{smallmatrix}, \begin{smallmatrix} 2F \\ 3 \end{smallmatrix}, \begin{smallmatrix} 4G \\ 5 \end{smallmatrix}, \begin{smallmatrix} 4F \\ 3 \end{smallmatrix}, \begin{smallmatrix} 4F \\ 5 \end{smallmatrix}, \begin{smallmatrix} 4D \\ 5 \end{smallmatrix} \right)$									
Coulomb (Diagonal Matrix Elements)									
F^0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0
F^2	- 0.26530607	- 0.061224481	- 0.18367343	- 0.51020397	- 0.51020399	- 0.26530609	- 0.36734688		
F^4	- 0.32879812	- 0.35147385	- 0.37414958	- 0.034013594	- 0.43083893	- 0.40816319	- 0.51020399		
Off-Diagonal Coulomb Elements									
$\left(\begin{smallmatrix} 2G \\ 5 \end{smallmatrix} H_c \begin{smallmatrix} 2G \\ 3 \end{smallmatrix} \right) \quad \left(\begin{smallmatrix} 2F \\ 5 \end{smallmatrix} H_c \begin{smallmatrix} 2F \\ 3 \end{smallmatrix} \right)$									
F^0	0.0	0.0							
F^2	0.0	0.0							
F^4	0.0	0.0							
Orbit-Orbit									
M^0	+20.0	+20.0	+36.0	+36.0	+20.0	+36.0	+46.0		
M^2	+ 2.4489793	+ 7.3469388	+ 0.48979568	+ 5.3877552	+ 9.7959185	+ 12.734694	+ 6.3673470		
Spin-Orbit									
0.0	+ 1.0704358	0.0	+ 0.82915602	0.0	+ 0.67700305	0.0			
+ 1.0704358	0.0	- 1.2990378	0.0	- 0.54006161	0.0				

TABLE IV (continued)

0.0	- 1.2990378	0.0	- 0.55901689	0.0	- 1.3693061	0.0
+ 0.82915603	0.0	- 0.55901689	0.0	- 1.4940355	0.0	- 1.0690447
0.0	- 0.54006161	0.0	- 1.4940354	0.0	+ 0.97589985	0.0
+ 0.67700306	0.0	- 1.3693061	0.0	+ 0.97589985	0.0	+ 1.3093070
0.0	0.0	0.0	- 1.0690447	0.0	+ 1.309370	0.0

Spin-Other-Orbit

$M^0 + 9.3452348$	- 7.4930511	- 2.3837771	- 5.8040924	+ 0.033034362	- 4.7390214	0.0
$M^2 - 7.6615612$	+ 0.91751635	-14.870228	+ 0.71070510	+ 6.4652958	+ 0.58028827	0.0
$M^0 - 7.4930511$	+ 9.9642817	+ 9.0932649	- 1.2448869	+ 3.7804313	+ 1.6940766	0.0
$M^2 + 0.91751635$	+ 9.9336692	- 1.1134609	- 4.9993081	- 0.46290991	+ 4.4368672	0.0
$M^0 - 2.3837771$	+ 9.0932652	- 8.5357115	+ 3.9131184	- 2.5771610	+ 9.5851429	- 1.3659750
$M^2 -14.870229$	- 1.1134609	+ 1.5663257	- 0.47915730	- 4.6225267	- 1.1736908	-13.074332
$M^0 - 5.8040924$	- 1.2448870	+ 3.9131184	- 8.3928540	+10.458249	- 1.6621530	+ 7.4833134
$M^2 + 0.71070511$	- 4.9993081	- 0.47915731	- 3.6989780	- 1.2806017	- 0.28743987	- 0.91632399
$M^0 + 0.33034364$	+ 3.7804314	- 2.5771610	+10.458248	+20.761895	- 6.8312991	0.0
$M^2 + 6.4652961$	- 0.46290991	- 4.6225268	- 1.2806017	+ 1.4149654	+ 0.83648551	0.0
$M^0 - 4.7390215$	+ 1.6940766	+ 9.5851429	- 1.6621531	- 6.8312991	0.0	- 9.1551495
$M^2 + 0.58028828$	+ 4.4368674	- 1.1736908	- 0.28744006	+ 0.83648551	0.0	+ 1.1222631
M^0	0.0	- 1.3659750	+ 7.4833134	0.0	- 9.1651495	-13.571423
M^2	0.0	-13.074332	- 0.91632398	0.0	+ 1.1222631	+ 0.20408164

TABLE IV (continued)

Spin-Spin									
M^0	0.0	0.0	0.0	0.0	0.0	+ 0.28315162	0.0	0.0	+ 3.0391024
M^2	0.0	0.0	0.0	0.0	0.0	+ 4.9349279	0.0	0.0	- 7.8148342
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	- 2.0328918	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 7.1635233	0.0
M^0	0.0	0.0	0.0	0.0	0.0	- 2.4053501	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	+ 3.2398590	0.0	0.0	- 2.9270890
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	- 1.2247443	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 0.64986419	0.0
M^0	0.0	0.0	0.0	0.0	0.0	+ 1.7959173	0.0	0.0	- 2.1904328
M^2	0.0	0.0	0.0	0.0	0.0	- 3.3352751	0.0	0.0	- 1.4081355
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 1.1428566	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 1.1428566	0.0
M^0	0.0	0.0	0.0	0.0	0.0	- 2.1904328	0.0	0.0	+ 0.48979568
M^2	0.0	0.0	0.0	0.0	0.0	- 1.4081356	0.0	0.0	+ 1.5393578

$J = 2.5 \left(\frac{2}{5}F, \frac{2}{3}F, \frac{2}{5}D, \frac{2}{3}D, \frac{2}{5}D, \frac{2}{3}D, \frac{4}{5}G, \frac{4}{5}D, \frac{4}{5}D, \frac{4}{3}P, \frac{6}{5}S \right)$

Coulomb (Diagonal Matrix Elements)

TABLE IV
(continued)

	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0
F ⁰	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0
F ²	- 0.18367343	- 0.51020397	- 0.12244896	- 0.081632636	0.0	- 0.51020399	- 0.26530609	- 0.36734688	- 0.57142847	-
F ⁴	- 0.37414958;	- 0.034013594	; - 0.40816318;	- 0.27210878 ;	0.0	- 0.43083893;	- 0.40816319;	- 0.51020399;	- 0.23809519	-

Off-Diagonal Coulomb Elements

	$(\frac{2}{5}F H_c \frac{2}{3}F)$	$(\frac{2}{5}D H_c \frac{2}{3}D)$	$(\frac{2}{5}D H_c \frac{2}{1}D)$	$(\frac{2}{3}D H_c \frac{2}{1}D)$
0_F	0.0	0.0	0.0	0.0
2_F	0.0	0.0	- 0.45816205	0.0
4_F	0.0	0.0	+ 0.25453448	0.0

Orbit-Orbit

M^0	+36.0	+48.0	+48.0	+20.0	+36.0	+48.0	+56.0
M^2	+0.48979568;	+5.3877552 ;	- 0.97959208;	+ 3.9183674 ;	+13.714286 ;	+ 9.7959125 ;	+12.734694 ;
							+ 6.3673470 ;
							+10.285714 ;

Spin-Orbit

0.0	+ 0.74535585	0.0	+ 1.4907117	0.0	0.0	- 1.1785110	0.0	0.0
+ 0.74535585	0.0	- 1.8856176	0.0	- 1.7638338	- 2.3145497	0.0	- 0.50395251	0.0
0.0	- 1.8856176	0.0	+ 0.47140443	0.0	0.0	+ 0.29814232	0.0	+ 1.6733197
+ 1.4907116	0.0	+ 0.47140443	0.0	- 0.88191693	0.0	0.0	- 1.7638339	0.0
0.0	- 1.7638338	0.0	- 0.88191693	0.0	0.0	+ 1.1155464	0.0	+ 1.788540
0.0	- 2.3145497	0.0	0.0	0.0	0.0	+ 0.73192490	0.0	0.0
- 1.1785110	0.0	+ 0.29814231	0.0	+ 1.1155465	+ 0.73192490	0.0	+ 1.2749102	0.0
0.0	- 0.50395252	0.0	- 1.7638339	0.0	0.0	+ 1.2749102	0.0	+ 1.5652472

TABLE IV (continued)

0.0	0.0	+ 1.6733197	0.0	+ 1.7888540	0.0	0.0	+ 1.5652473	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	- 2.2360675

Spin-Other-Orbit

M^0	-11.380949	- 5.2174912	+ 1.2046768	-10.434982	+ 1.1268719	- 3.9925206	+ 8.2495774	- 0.64392679	0.0
M^2	- 2.0884342	+ 0.63887639	- 6.5396737	+ 1.2777527	+ 5.9563226	- 7.1611875	- 1.0101522	- 6.1632992	0.0
M^0	- 5.2174912	+11.190472	+13.199324	+ 2.0952371	+12.346837	+16.201849	- 1.4305535	+ 3.5276677	0.0
M^2	+ 0.63887640	+ 4.9319706	- 1.6162435	+ 9.5782270	- 1.51118574	- 1.9838997	- 0.24738885	- 0.43195926	0.0
M^0	+ 1.2046767	+13.199324	- 2.9047609	- 3.2998311	- 0.71269635	0.0	- 2.0869963	+ 3.3853076	-11.713238
M^2	- 6.5396732	- 1.6162436	+12.707478	+ 0.40406090	- 3.7671092	0.0	+ 0.25555054	+16.366562	+ 1.4342739
M^0	-10.434982	+ 2.0952371	- 3.2998311	- 5.9523787	+ 6.1734187	0.0	+ 0.48187064	+12.345837	+ 1.0141847
M^2	+ 1.2777527	+ 9.5732268	+ 0.40406090	- 8.2312888	- 0.75592873	0.0	+ 9.1727521	- 1.5118575	- 3.3323207
M^0	+ 1.1268718	+12.346837	- 0.71269631	+ 6.1734188	- 3.6666652	0.0	- 7.8088255	- 1.3333328	-12.521978
M^2	+ 5.9563227	- 1.5118574	- 3.7671093	- 0.75592873	- 9.5238134	0.0	+ 0.95618261	- 7.0476161	+ 1.53333033
M^0	- 3.9925206	+16.201849	0.0	0.0	0.0	+38.928554	- 5.1234744	0.0	0.0
M^2	- 7.1611877	- 1.9838997	0.0	0.0	0.0	- 2.6530601	+ 0.62736414	0.0	0.0
M^0	+ 8.2495774	- 1.4305536	- 2.0869963	+ 0.48187070	- 7.8088257	- 5.1234744	+16.533325	- 8.9243717	0.0
M^2	- 1.0101522	- 0.24738901	+ 0.25555053	+ 9.1727525	+ 0.95618261	+ 0.62736414	- 0.19047602	+ 1.0927801	0.0
M^0	- 0.64392678	+ 3.5276677	+ 3.3853076	+12.346837	- 1.3333329	0.0	- 8.9243717	+ 2.2619037	-10.956731
M^2	- 6.1632991	- 0.43195927	+16.366562	- 1.51118574	- 7.0476164	0.0	+ 1.0927801	- .03401355	+ 1.3416404

TABLE IV (continued)

M^0	0.0	0.0	-11.713238	+ 1.0141849	-12.521978	0.0	0.0	-10.956731	- 6.4999976
M^2	0.0	0.0	+ 1.4342739	- 3.3323211	+ 1.53333033	0.0	0.0	+ 1.3416404	+ 3.8571412
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+15.652473
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	- 1.9166291
Spin-Spin									
M^0	0.0	0.0	0.0	0.0	0.0	2.0701957	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	- 2.7884267	0.0	+ 8.2790577	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	+ 1.8973657	0.0	+ 1.3522462
M^2	0.0	0.0	0.0	0.0	0.0	0.0	- 1.0067653	0.0	+ 6.1816961
M^0	0.0	0.0	0.0	0.0	0.0	- 1.8704382	0.0	+ 1.3744857	0.0
M^2	0.0	0.0	0.0	0.0	0.0	- 6.4129306	0.0	- 3.5343916	0.0
M^0	0.0	0.0	0.0	0.0	0.0	0.0	- 1.0842090	0.0	+ 0.67612310
M^2	0.0	0.0	0.0	0.0	0.0	0.0	+ 7.4345753	0.0	+ 0.19317799
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M^0	+ 2.0701955	0.0	- 1.8704381	0.0	0.0	- 4.4897933	0.0	- 1.5996659	0.0
M^2	- 2.7884269	0.0	- 6.4129306	0.0	0.0	+ 8.3381879	0.0	- 1.0283568	0.0
M^0	0.0	+ 1.8973656	0.0	- 1.0842089	0.0	0.0	+ 0.34285697	0.0	- 3.4209419
M^2	0.0	- 1.0067655	0.0	+ 7.4345753	0.0	0.0	+ 0.34285696	0.0	+ 2.6878829

TABLE IV (continued)

M^0	0.0	0.0	+ 1.3744857	0.0	0.0	- 1.5996660	0.0	- 1.2244892	0.0
M^2	+ 8.2790580	0.0	- 3.5343917	0.0	0.0	- 1.0283569	0.0	- 3.8483945	0.0
M^0	0.0	+ 1.3522461	0.0	+ 0.67612306	0.0	0.0	- 3.4209421	0.0	+ 0.79999959
M^2	0.0	+ 6.1816967	0.0	+ 0.19317794	0.0	0.0	+ 2.6878832	0.0	- 2.0571417
M^0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+ 5.9999971	0.0
M^2	0.0	0.0	+ 9.1632383	0.0	0.0	0.0	0.0	- 6.8571395	0.0

$J = 1.5$ (${}^2D$, ${}^2D$, ${}^2D$, ${}^2P$, ${}^4F$, ${}^4D$, ${}^4P$)

Coulomb (Diagonal Matrix Elements)

F^0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0	+10.0
F^2	- 0.12244896	- 0.081632636	0.0	+ 0.40816319	- 0.26530609	- 0.36734688	- 0.57142847
F^4	- 0.40816318	- 0.27210878	0.0	- 0.54421758	- 0.40816319	- 0.51020399	- 0.23809519

Off-Diagonal Coulomb Elements

$({}^2D H_c {}^2D)$	$({}^2D H_c {}^2D)$	$({}^2D H_c {}^2D)$
F^0	0.0	0.0
F^2	0.0	- 0.45816205
F^4	0.0	+ 0.25453448

Orbit-Orbit

TABLE IV (continued)

$M^0 + 48.0$ $+48.0$ $+56.0$ $+36.0$ $+48.0$ $+56.0$;
 $M^2 - 0.97959208; + 3.9183674 ; +13.714286 ; + 2.9387755 ; +12.734694 ; + 6.3673470 ; +10.285714 ;$

Spin-Orbit

0.0	- 0.70710664	0.0	- 0.28867508	+ 0.44721349	0.0	+ 0.68312991
- 0.70710664	0.0	+ 1.3228754	0.0	0.0	- 1.4142133	0.0
0.0	+ 1.3228754	0.0	+ 1.0801232	+ 1.6733197	0.0	+ 0.73029658
- 0.28867508	0.0	+ 1.0801232	0.0	0.0	- 0.57735015	0.0
+ 0.44721348	0.0	+ 1.6733197	0.0	0.0	+ 0.89442699	0.0
0.0	- 1.4142133	0.0	- 0.57735014	+ 0.8942699	0.0	+ 1.3662598
+ 0.68312991	0.0	+ 0.73029659	0.0	0.0	+ 1.3662598	0.0

Spin-Other-Orbit

$M^0 + 4.3571413$	$+ 4.9497467$	$+ 1.0690445$	$+ 2.0207256$	$- 3.1304946$	$+ 2.7142846$	$- 4.7819095$
$M^2 - 19.061216$	$- 0.60609136$	$+ 5.6506638$	$- 0.24743576$	$+ 0.38332582$	$+13.122444$	$+ 0.58553988$
$M^0 + 4.9497467$	$+ 8.9285680$	$- 9.2601281$	$- 0.69985398$	$+ 0.72280597$	$+ 9.8994934$	$+ 0.41403917$
$M^2 - 0.60609136$	$+12.346933$	$+ 1.1338931$	$+ 3.0493637$	$+13.759128$	$- 1.2121827$	$- 1.3604142$
$M^0 + 1.0690445$	$- 9.2601281$	$+ 5.4999979$	$- 7.5608631$	-11.713239	$- 1.0690445$	$- 5.1120762$
$M^2 + 5.6506639$	$+ 1.1338931$	$+ 0.14285720$	$+ 0.92581986$	$+ 1.4342739$	$- 5.6506640$	$- 0.62596845$
$M^0 + 2.0207256$	$- 0.69985412$	$- 7.5608630$	$- 1.5476187$	0.0	$+ 4.0414510$	$+ 0.28171797$
$M^2 - 0.24743576$	$+ 3.0493639$	$+ 0.92581985$	$+ 9.7959142$	0.0	$- 0.49487150$	$+ 4.7087146$
$M^0 - 3.1304944$	$+ 0.72280606$	-11.713239	0.0	$+28.857130$	$- 6.2609891$	0.0
$M^2 + 0.38332581$	$+13.759129$	$+ 1.4342739$	0.0	$+ 0.32653033$	$+ 0.76665163$	0.0

TABLE IV (continued)

$M^0 + 2.7142846 + 9.8994932$	$- 1.0690446 + 4.0414510$	$- 6.2609891$	$+13.571423$	$- 9.5638192$
$M^2 +13.122444 - 1.2121827$	$- 5.6506641 - 0.49487150$	$+ 0.76665163$	$+ 0.20408164$	$+ 1.1710798$
$M^0 - 4.7819095 + 0.41403925$	$- 5.1120762 + 0.28171790$	0.0	$- 9.5638191$	$+ 4.3333317$
$M^2 + 0.58553988 - 1.3604144$	$+ 0.62596846 + 4.7087146$	0.0	$+ 1.1710798$	$- 2.5714274$

Spin-Spin

M^0	0.0	0.0	0.0	$- 2.5714274$	0.0
M^2	0.0	0.0	0.0	$+ 6.6122414$	0.0
M^0	0.0	0.0	0.0	$+ 1.0842090$	$- 2.4842349$
M^2	0.0	0.0	0.0	$- 7.4345753$	$- 0.70978128$
M^0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0
M^0	0.0	0.0	0.0	$- 2.4344455$	$- 0.33806157$
M^2	0.0	0.0	0.0	$- 1.6440408$	$+ 0.86930112$
M^0	0.0	0.0	0.0	$- 1.3714279$	$- 2.0948905$
M^2	0.0	0.0	0.0	$- 1.3714278$	$+ 1.6459854$
M^0	0.0	0.0	0.0	0.0	0.0
M^2	0.0	0.0	0.0	0.0	0.0
M^0	0.0	0.0	0.0	$- 0.33806153$	$- 3.1999984$
M^2	0.0	0.0	0.0	$+ 0.86930104$	$+ 8.2285670$

TABLE IV (continued)

 $J = 0.5 \left(\begin{smallmatrix} 2 \\ 3 \end{smallmatrix} P, \begin{smallmatrix} 2 \\ 5 \end{smallmatrix} S, \begin{smallmatrix} 4 \\ 5 \end{smallmatrix} D, \begin{smallmatrix} 4 \\ 3 \end{smallmatrix} P \right)$

Coulomb (Diagonal Matrix Elements)

 $F^0 + 10.0 \quad +10.0 \quad +10.0 \quad +10.0$
 $F^2 + 0.40816319 - 0.061224476 - 0.36734688 - 0.57142847$
 $F^4 - 0.54421758; - 0.44217678; - 0.51020399; - 0.23809519$

Orbit-Orbit

 $M^0 + 56.0 \quad +60.0 \quad +48.0 \quad +56.0$
 $M^2 + 2.9387755; - 2.4489796; + 6.3673470; +10.285714$

Spin-Orbit

 $0.0 \quad + 1.6329928 \quad - 0.81649640 \quad 0.0$
 $+ 1.6329928 \quad 0.0 \quad 0.0 \quad - 1.5275249$
 $- 0.81649639 \quad 0.0 \quad 0.0 \quad + 0.76376246$
 $0.0 \quad - 1.5275249 \quad + 0.76376247 \quad 0.0$

Spin-Other-Orbit

 $M^0 + 3.0952372 \quad -11.430950 \quad + 5.7154749 \quad + 0.17817409$
 $M^2 -19.591828 \quad + 1.3997080 \quad - 0.69985400 \quad + 2.9780526$
 $M^0 -11.430950 \quad 0.0 \quad 0.0 \quad +10.692675$
 $M^2 + 1.3997080 \quad 0.0 \quad 0.0 \quad - 1.3993070$

TABLE IV (continued)

$M^0 + 5.7154749$	0.0	+20.357134	- 5.3463374
$M^2 - 0.69985406$	0.0	- 0.30612246	+ 0.65465349
$M^0 + 0.17817404$	+10.692675	- 5.3463374	+10.833329
$M^2 + 2.9780526$	- 1.3093070	+ 0.65465349	- 6.4285687

Spin-Spin

M^0	0.0	0.0	+ 1.0690446
M^2	0.0	0.0	- 2.7489715
M^0	0.0	0.0	- 2.5714275
M^2	0.0	0.0	+12.734688
M^0	0.0	- 2.5714273	+ 1.7142849
M^2	0.0	+12.734688	+ 5.3877524
$M^0 + 1.0690445$	0.0	0.0	+ 3.9999979
$M^2 - 2.7489713$	0.0	0.0	-10.285709