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# Collisional excitation energy transfer in the mixture of mercury and thallium atoms and the calculation of atomic oscillator strengths, transition probabilities and lifetimes in thallium(1) and cesium(1).

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# COLLISIONAL EXCITATION ENERGY TRANSFER IN THE MIXTURE OF MERCURY AND THALLIUM ATOMS AND THE CALCULATION OF ATOMIC OSCILLATOR STRENGTHS, TRANSITION PROBABILITIES, AND LIFETIMES IN THALLIUM I AND CESIUM I

by

Murray K. Wade

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## ABSTRACT

The method of sensitized fluorescence was used to determine the cross sections for excitation transfer from excited $Hg(6^3P_1)$ atoms to close-lying states in thallium. A vapour mixture of mercury and thallium was irradiated with Hg 2537Å resonance radiation and the intensities of the sensitized thallium spectral components resulting from the decay of the collisionally-populated levels were measured. No thallium spectral components originating from levels above the $Hg(6^3P_1)$ state were observed in the fluorescence. The mercury vapour pressure was kept low (about $10^{-5}$ torr) to avoid imprisonment of resonance radiation. The observed cross sections were corrected for cascade transitions where necessary. The calculated cross sections ranged from $0.05Å^2$ to $3.0Å^2$ corresponding to a range in the energy defect $\Delta E$, between the energy of the $Hg(6^3P_1)$ state and the excited thallium state, of -1.58eV to -0.083eV. A pronounced resonance was observed between the $Hg(6^3P_1)$ state and the close-lying thallium states. The results obtained in this investigation for Hg*-Tl collisions compare favourable with those obtained previously for Hg*-Na, Hg*-Cd, Hg*-Zn, Rb*-Cs, and K*-Rb systems.

The behavior of the sensitized fluorescent spectrum of thallium, produced by irradiating a Hg-Tl-$N_2$ vapour-gas system with Hg 2537Å resonance radiation, was studied in relation to $N_2$ pressure. In this tertiary system, the thallium atoms become excited by collisional transfer from $Hg(6^3P_1)$ atoms and also from $Hg(6^3P_0)$ atoms which are formed in $Hg(6^3P_1)$-$N_2$ collisions. The spontaneous decay of the collisionally-populated thallium states gives rise to the fluorescent spectrum and their radiationless decay (quenching), caused by collisions with $N_2$ molecules, manifests itself in a

decrease of the fluorescent intensities as $N_2$ pressure is increased. The quenching cross sections, obtained by analyzing the variation of the fluorescent intensities with $N_2$ pressure, appear to exhibit a resonance property with respect to upward vibrational transitions in $N_2$.

The relativistic oscillator strengths, transition probabilities, and lifetimes involving the first 25 $Thallium_I$ excited states and the first 64 excited states of $Cesium_I$ were calculated and compared to the corresponding non-relativistic Bates-Damgaard and Hydrogenic values commonly employed in the experimental determinations of energy transfer and quenching cross sections. The wave functions that were used were calculated by employing a relativistic Hartree-Fock-Slater method in which the core orbitals were allowed to readjust their radial distributions for each excited state configuration. The resulting non-orthogonality amongst states with the same total angular momentum was removed by applying a Gram-Schmidt orthogonalization process to the radial wave functions. Very good agreement with the most reliable experimental and theoretical data was achieved in the case of $Cesium_I$. In the case of $Thallium_I$ the results were not as good although considerable improvement should be expected upon improving the representation of the exchange potential.

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# INTRODUCTION

When a pure metal vapour is irradiated with light of the appropriate wavelength, ground state atoms become excited to the resonance state from which they may undergo spontaneous decay back to the ground state, emitting resonance fluorescence.

In many binary metal vapour mixtures, consisting of atoms of two different species, A and B, in which atoms of species A have been excited to the resonance state by radiation of the appropriate frequency, the fluorescent spectrum may include not only the resonance radiation from atoms of species A but also several spectral components characteristic of the atoms B. Mercury and thallium form such a system. When this metal-vapour mixture is irradiated with Hg 2537Å resonance radiation, the resulting fluorescence includes the mercury resonance frequency and several components arising from the decay of various excited states of thallium. The observed thallium emissions, which are indicated in figure (1) and are usually referred to as sensitized fluorescence, arise from collisions of the second kind, in which the optically excited $Hg(6^3P_1)$ atoms transfer their excitation energy to the $Tl(6^2P_{1/2})$ ground state atoms.

In the presence of foreign gas molecules, such as nitrogen, it is observed that the intensity of the resonance radiation is reduced in proportion to the density of the foreign gas molecules. This is due to collisions of the second kind between the excited metallic atoms and the foreign gas molecules in the v=0 vibrational state. Such a collision process, in which the excited atomic level is depopulated by a radiationless energy transfer to the foreign gas molecule, is called a quenching

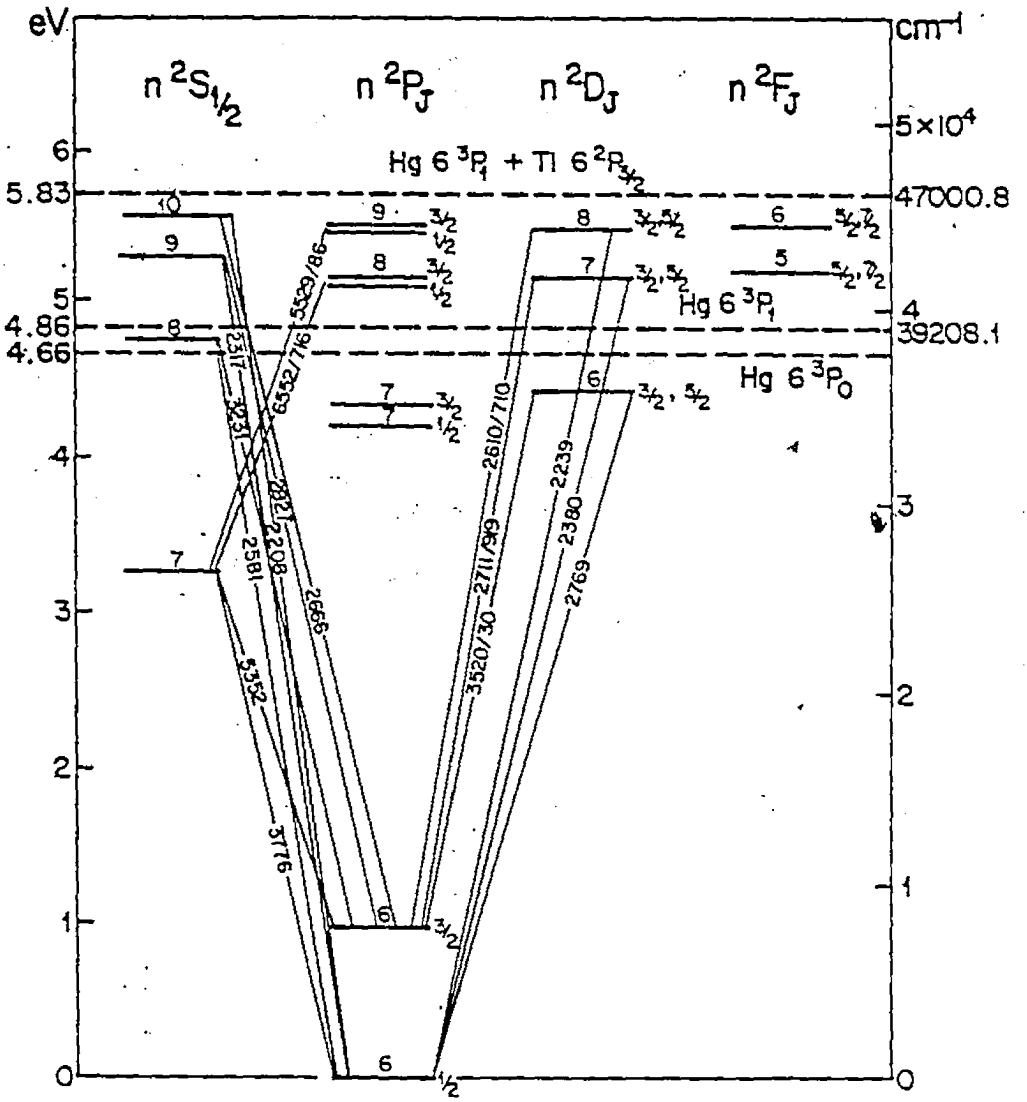


Fig. 1: Energy levels of thallium

collision. An excited atomic state is quenched most efficiently by molecular species, such as nitrogen, but generally atomic gases are almost totally ineffective as quenching agents since quenching collisions between atomic species require the conversion of internal energy into kinetic energy. This represents a very inefficient process in thermal energy collisions. An exception to this general scheme has been found in the case of boron which has been shown to be effectively quenched by argon[1].

The theory of collisions of the second kind was first postulated by Klein and Rosseland[2] on the basis of the principle of microscopic reversibility. This principle states that, in order to preserve thermodynamic equilibrium, each microscopic process must be accompanied by a reverse process. In light of the results of the Franck-Hertz experiments of 1913, where it was found that a collision of a fast electron with a slow atom resulted in the formation of an excited atom and a slow electron, Klein and Rosseland concluded that excited atoms could collide with slow electrons and produce unexcited atoms and fast electrons, the process being unaccompanied by the emission of a photon.

Franck[3] later extended this postulate to a system of excited atoms of one species and unexcited atoms of a second species. He suggested that mercury atoms excited by the Hg 2537Å resonance radiation could, in a collision of the second kind, transfer their excitation energy to unexcited atoms of another species which did not absorb the mercury resonance radiation. The atoms of the second type, if they had energy states close to that of $Hg(6^3P_1)$ at 4.86eV, could become excited and subsequently emit a portion of their characteristic spectrum. This is the essential meaning of the term sensitized fluorescence. Franck and Cario[4] performed such an experiment using a mercury-thallium mixture in

which the mercury vapour was excited by mercury resonance radiation and the $Tl(6^2P_{1/2})$ ground state atoms served as the second element. In the fluorescent spectrum, they observed several components arising from thallium states with excitation energies above the 4.86eV level of the $Hg(6^3P_1)$ resonance state, and suggested that the additional energy required was converted from the available thermal kinetic energy of the colliding partners.

Franck[5] later formulated the empirical rule that, for a most efficient collisional excitation transfer, the energy defect $\Delta E$ between the two atomic states of the two colliding partners should be as small as possible. The formulation of this rule hinges on the principle that collisional excitation transfer occurs with the highest probability when the least amount of excitation energy is transformed into translational energy. On the basis of this empirical rule one would expect that cross sections for atomic excitation transfer decrease with increasing energy defects, $\Delta E$. In general, the term "cross section" denotes a measure of the probability for a particular process to take place. Hence, the cross section for atomic excitation energy transfer is a measure of the probability that, during a collision of the second kind, an atom will transfer some, or all, of its excitation energy to the collision partner.

During the past two decades much effort has been devoted to the study of this resonance effect in inelastic collision processes (Krause[6,7]; Czajkowski et.al.[8]; Hrycyshyn and Krause[9]; Stacy and Zare[10]; Dashevskaya et.al.[11]; Frish and Kraulinya[12]; Kraulinya[13,14,15,16]; Hudson and Curnutte[17]; Czajkowski and Krause[18,19]). Various atomic systems have been examined although the range of the energy defects, $\Delta E$,

has been quite narrow (less than 1.0eV). The cross section for energy transfer in metal-metal collisions are also known to depend on the relative velocity of the colliding partners. Recently, beam experiments have been performed to investigate the dependence of the energy transfer cross sections on the relative velocity of the colliding partners in the Na-Ar and Na-Xe systems[20] and in the K-He system[21]. Similar experiments have been performed on the K-Rare Gas and some K-Diatomic molecule systems as well[22]. Since experimental data for the velocity dependence of the energy transfer cross sections in the mercury-thallium system is unavailable and since this dependence cannot be calculated satisfactorily, the energy transfer cross sections are treated as a function of the energy defect $\Delta E$ with the velocity dependence being treated as an average over the thermal velocity distribution.

The purpose of this investigation was to study the interactions between excited $Hg(6^3P_1)$ atoms and ground state thallium atoms, and to supply additional quantitative data pertinent to the study of the resonance effect in excitation transfer. The quenching of thallium by collisions with $N_2$ molecules was also investigated.

The evaluation of the various cross sections requires the knowledge of thallium lifetimes and transition probabilities for the various states. There is a general lack of experimentally determined values for these parameters and, although several past investigations[17,23] have used the Bates-Damgaard approximation[24] to generate the required information, such an approach may be entirely inadequate for the higher thallium states. It was felt that more rigorous calculations should be carried out to improve the estimates of the cross sections. A relativistic Hartree-Fock-Slater approach was used to determine the radial wave functions required to calculate the $Thallium_1$ transition probabilities and lifetimes.

Anticipating future work of a similar nature on the binary Cd*-Cs system, calculations of the Cesium$_{I}$ transition probabilities and lifetimes were also performed.

## THEORY

### Part A: Sensitized Fluorescence

If a mercury-thallium mixture is continuously irradiated with the Hg 2537Å resonance radiation then, as the first step,

$$Hg(6^1S_o) + h\nu_{2537Å} \rightarrow Hg(6^3P_1)$$

As a consequence of inelastic collisions between excited mercury atoms and ground state thallium atoms in the mixture, part of the excitation energy is transferred from mercury to the ground state thallium atoms, causing them to be raised to the excited state. This process is governed by the mechanism

$$Hg(6^3P_1) + Tl(6^2P_{1/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E$$

A second possible process involves the excitation energy transfer from excited mercury atoms to the metastable thallium atoms, which have been created by the decay of excited thallium atoms formed during collisions between the $Hg(6^3P_1)$ and $Tl(6^2P_{1/2})$ atoms. This second process involving the metastable $Tl(6^2P_{3/2})$ atoms may be expressed by the mechanism

$$Hg(6^3P_1) + Tl(6^2P_{3/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E$$

At temperatures used in this investigation (of the order of 500°C) the available thermal energy amounts to only about 0.1eV which is considerably less than the 0.97eV necessary to populate the metastable $Tl(6^2P_{3/2})$ level directly. Consequently, the energy transfer mechanism involving the thallium metastable state may be considered as a second

order effect. Kraulinya[16] attributes the observed sensitized fluorescent spectra originating from the $Tl(8^2D_{3/2,5/2})$, $Tl(9^2S_{1/2})$ and $Tl(7^2D_{3/2,5/2})$ states to this second order process. She further points out that at thallium pressures corresponding to a temperature of 900°C the metastable state has a population density three orders of magnitude lower than that of the $Tl(6^3P_{1/2})$ ground state.

The probability of depopulating some upper thallium level, j, by a radiative transition to some lower state, i, is given by

$$P_{em} = A_{ij} + B_{ij}\,\rho(\nu_{ij}) \qquad (1)$$

where $A_{ij}$ is the spontaneous emission probability; $B_{ij}$ is the induced emission coefficient for the particular transition of frequency $\nu_{ij}$ between levels j and i; and $\rho(\nu_{ij})$ is the energy density per unit frequency range of the radiation. The absolute intensity* of the spectral component corresponding to the transition j→i is

$$I_{ij} = N_j A_{ij} h\nu_{ij} + N_j B_{ij} h\nu_{ij} \rho(\nu_{ij}) \qquad (2)$$

where $N_j$ is the population density of the upper state, j.

The energy density $\rho(\nu_{ij})$ is small and the contribution to the intensity from induced emission may be neglected; equation (2) therefore reduces to

$$I_{ij} = N_j A_{ij} h\nu_{ij} \qquad (3)$$

For inelastic collisions the number of exciting collisions per unit time per unit volume between mercury and thallium is governed by the equation

$$\Delta N(Tl^*) = N_o(Tl)\, N(Hg^*)\, Q_{oj} \langle v_{rel} \rangle \qquad (4)$$

* more precisely this is the total power emitted per unit volume of the fluorescing vapour. However, since the geometry of the experiment remains fixed, the volume factor will cancel out in formulae for the energy transfer cross sections which follow.

where N(Tl*) is the density of excited thallium atoms; $N_o(Tl)$ is the density of ground state thallium atoms and N(Hg*) is the density of mercury atoms in the $Hg(6^3P_1)$ state; $Q_{oj}$ is the effective inelastic collision cross section for the excitation of a thallium atom from the ground state to the $j^{th}$ excited state; $\langle v_{rel} \rangle$ is the relative velocity of the colliding partners in the vapour mixture assumed to be in thermal equilibrium, and is given by

$$\langle v_{rel} \rangle = \sqrt{\frac{8kT}{\pi \mu}} \tag{5}$$

where k is the Boltzmann constant, T is the temperature in degrees Kelvin and $\mu$ is the reduced mass of the colliding partners. Since the vapour mixture will have a Maxwellian velocity distribution, the use of $\langle v_{rel} \rangle$ is justified.

A general approach to the situation may be developed using the $j^{th}$ thallium level as an example. On collision with a mercury atom in the $Hg(6^3P_1)$ state, some thallium states above the $j^{th}$ state may also become excited. These higher states then become sources for the population of the $j^{th}$ state. The depopulation of the $j^{th}$ state is determined by direct transition to the lowest allowed energy level; by cascade transitions; and by collisions of the second kind with $Hg(6^1S_o)$ and $Tl(6^2P_{1/2})$ atoms. At equilibrium the population rate of the $j^{th}$ thallium level must be exactly balanced by its rate of depopulation. Equivalently, one can express the equilibrium condition for the $j^{th}$ thallium state as

$$N_o(Tl)\, N(Hg^*)\, Q_{oj} \langle v_{rel} \rangle + \sum_{k=j+1}^{\infty} N_k(Tl^*) A_{jk} =$$

$$N_o(Hg)\, N_j(Tl^*)\, Q_{jo} \langle v_{rel} \rangle + N_j(Tl^*) \sum_{l=j-1}^{o} A_{lj} \tag{6}$$

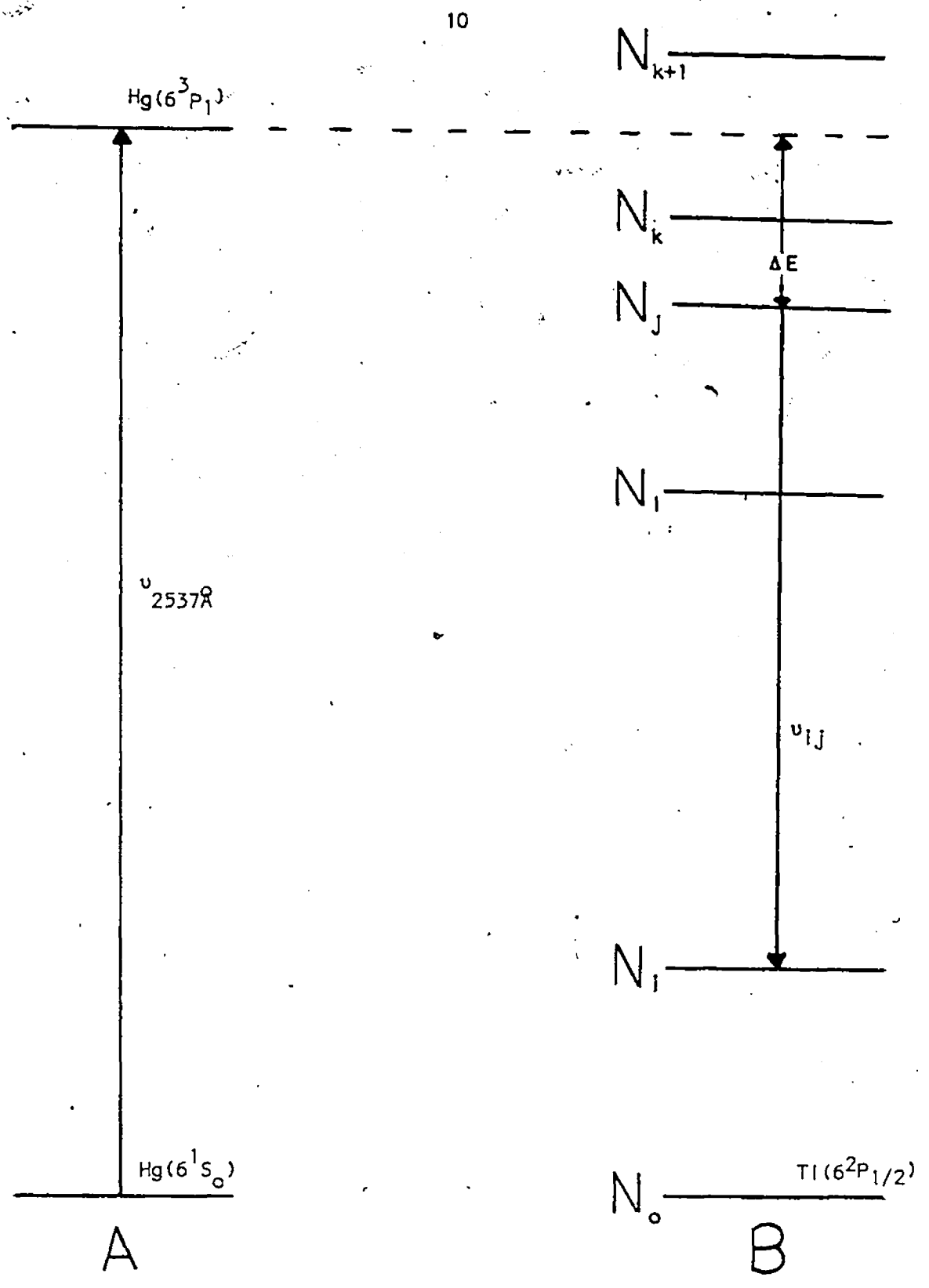


Fig. 2 : Atomic energy level labelling scheme for excitation energy transfer between excited mercury atoms (A) and ground state thallium atoms(B)

where $N_o(Tl)$ is the density of ground state thallium; $\sum_{k=j+1}^{\infty} N_k(Tl^*)A_{jk}$ is the population rate of the $j^{th}$ state by transitions from all excited states, k, above the $j^{th}$ state; $N_o(Hg)$ is the density of ground state mercury atoms; $N_j(Tl^*)$ is the density of thallium atoms in the $j^{th}$ excited state; $N_j(Tl^*) \sum_{i=j-1}^{o} A_{ij}$ is the depopulation rate of the $j^{th}$ excited state by transitions to all thallium levels below the $j^{th}$ state; the $A_{ij}$ are the thallium transition probabilites for the transition $j \to i$; $Q_{oj}$ is the effective cross section for the inelastic collision with $Hg(6^3P_1)$ atoms; $Q_{jo}$ is the effective cross section for the reverse inelastic collision process. The principle of detailed balancing[25] relates $Q_{oj}$ and $Q_{jo}$ by the relation

$$g_o\, p^2\, Q_{oj} = g_j\, p'^2\, Q_{jo} \qquad (7)$$

where $g_o$ and $g_j$ are the statistical weights and p and p' are the momenta of mercury atoms in the $Hg(6^3P_1)$ state and thallium atoms in the $j^{th}$ excited state respectively.

Substitution of equation (7) into equation (6) gives

$$Q_{oj} = \frac{N_j(Tl^*) \sum_{i=j-1}^{o} A_{ij} - \sum_{k=j+1}^{\infty} N_k(Tl^*)A_{jk}}{N_o(Tl)\, N(Hg^*)\langle v_{rel}\rangle - N_o(Hg)N_j(Tl^*)\frac{g_o p^2}{g_j p'^2}\langle v_{rel}\rangle} \qquad (8)$$

When the pressure of mercury vapour is low, as was the case in this investigation, the time between mercury-thallium collisions is much longer than the lifetimes of the excited thallium states. Thus, the thallium atoms will have lost their excitation energy long before they collide with ground state mercury atoms. Also, the density of excited thallium atoms in the $j^{th}$ state is much smaller than both the density of excited

mercury atoms in the $Hg(6^3P_1)$ state and ground state thallium atoms. Therefore, the second term in the denominator of equation (8) may be neglected with respect to the first term. The effective energy transfer cross section then reduces to the form

$$Q_{oj} = \frac{N_j(Tl^*) \sum_{l=j-1}^{o} A_{lj} - \sum_{k=j-1}^{\infty} N_k(Tl^*)A_{jk}}{N_o(Tl)N(Hg^*)\langle v_{rel}\rangle} \qquad (9)$$

To put equation (9) into a form that is experimentally realizable, we make use of equation (12) which relates the intensity per unit volume, $I_{ij}$, to the density of the $j^{th}$ excited state. From equation (9) the density, $N_j(Tl^*)$, may be written as

$$N_j(Tl^*) = \frac{I_{ij}}{A_{ij}h\nu_{ij}} \qquad (10)$$

where $\nu_{ij}$ is the frequency of the spectral component.

Substitution of equation (10) into equation (9) gives

$$Q_{oj} = \left[\frac{I_{ij}}{A_{ij}h\nu_{ij}} \sum_{l=j-1}^{o} A_{lj} - \sum_{k=j+1}^{\infty} N_k(Tl^*)A_{jk}\right] \frac{1}{N_o(Tl)N(Hg^*)\langle v_{rel}\rangle} \qquad (11)$$

In the term $1/(N_o(Tl)N(Hg^*)\langle v_{rel}\rangle)$, the density of the ground state thallium atoms is a constant parameter and is completely controlled by the temperature at the thallium side arm. The density of mercury atoms in the $Hg(6^3P_1)$ state is controlled by the intensity of the Hg 2537Å radiation emitted by the r-f source and may be considered constant since the spectral intensity of the source was essentially constant throughout the investigation and the density of mercury in the reaction region was kept low to avoid the effects of radiation trapping, scattering of incident

light, and formation of the $Hg(6^3P_0)$ metastable atoms. The relative velocity depends only on the temperature at the reaction site in the cell and, by careful control of the oven temperature, this parameter could be maintained constatn. Hence, under controlled temperature conditions the term $1/(N_0(Tl)N(Hg^*)\langle v_{rel}\rangle)$ remains constant.

The first term in the square brackets of equation (11) encompasses all stepwise transitions and direct transitions from the $j^{th}$ thallium state to all lower levels. The remaining term allows for cascade transitions which populate the $j^{th}$ energy level. In the temperature range used in this investigation, the number of significant cascade transitions from thallium states above the $Hg(6^3P_1)$ level would be expected to be very small. The infinite sum accounts for the fact that, in any collision process where energy is exchanged between the colliding partners, there exists a finite probability that the recipient atom may be excited to any higher excited state and even to ionization. In this case, with a thermal energy contribution only of the order of 0.1eV, the probability of exciting thallium atoms to states with energies greater than 5.0eV is very small.

Equation (11) applies to energy transfer from the $Hg(6^3P_1)$ state to thallium states lying below the 4.86eV energy level. For excited thallium states above the $Hg(6^3P_1)$ level, a portion of the translational energy of the colliding partners is converted into excitation energy. Assuming a Maxwell-Boltzmann energy distribution in the mixture, only a fraction, $\delta$, of the inelastic collisions for which the relative energy of the colliding partners is greater than the energy defect, $\Delta E$, can contribute to the energy exchange. This fraction of inelastic collisions populating thallium levels above the energy of the $Hg(6^3P_1)$ state is given by[26]

$$\delta = \frac{2}{\sqrt{\pi}(kT)^{3/2}} \int_{\Delta E}^{\infty} \exp\left[-E/kT\right] \sqrt{E}\, dE$$
$$= \exp(-E/kT)\left[E/kT + 1\right] \qquad (12)$$

where $\Delta E$ is the energy defect between the $Hg(6^3P_1)$ level and the particular thallium level. Thus one can write equation (11) in a form applicable to all thallium excited states as

$$Q_{oj} = \frac{1}{\delta N_o(Tl) N(Hg^*) \langle v_{rel} \rangle} \left[ \frac{I_{ij}}{A_{ij}\, h\nu_{ij}} \sum_{i=j-1}^{o} A_{ij} - \sum_{k=j+1}^{\infty} N_k(Tl^*) A_{jk} \right] \qquad (13)$$

where

$$\delta \begin{cases} = 1 \text{ if state } j \text{ lies below the } Hg(6^3P_1) \text{ level} \\ = \exp(-E/kT)\left[E/kT+1\right] \text{ if state } j \text{ lies above the } Hg(6^3P_1) \text{ level} \end{cases} \qquad (13a)$$

Part B: Quenching

When the effects of radiation diffusion and collision broadening are negligible, the quenching cross section for a particular state may be determined by using the Stern-Volmer formula[27].

Consider a resonance cell in which there are $n_1$ excited atoms and $n_2$ foreign gas molecules per $cm^3$ of the emitting layer. If the lifetime of the excited atomic state is $\tau$, then the number of quenching collisions per second per unit volume is

$$Z = 2n_1\, n_2\, Q \left[\frac{2kT}{\pi}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)\right]^{1/2} . \qquad (14)$$

where Q is the quenching cross section in $\mathring{A}^2$, and $m_1$ and $m_2$ are the masses of the atom and of the foreign gas molecule, respectively. The

number of quenching collisions per second per unit volume of the emitting layer per atom is

$$Z_Q = Z/n_1 \qquad (15)$$

At equilibrium, the rate at which the excited state is depopulated equals the rate at which it is repopulated. Define the rate of formation of the excited state as $s_1$. In the absence of foreign gas, the rate of depopulation by spontaneous decay is $n_1/\tau$. The rate of depopulation by quenching collisions with foreign gas molecules is $Z_Q$. Thus, the rate of depopulation of the excited state is a constant fraction, a, of the total energy emitted by the $n_1$ excited atoms. At equilibrium,

$$n_1 = \frac{s_1}{1/\tau + Z_Q} \qquad (16)$$

The intensity of the emitted radiation in the absence of foreign gas is

$$a \frac{n_1}{\tau} h\nu = a\, s_1\, h\nu \qquad (17)$$

and the intensity of the emitted radiation in the presence of the foreign gas is

$$a \frac{n_1}{\tau} h\nu = \frac{a\, s_1\, h\nu}{1 + \tau Z_Q} \qquad (18)$$

The quenching is defined as

$$\frac{I}{I_o} = \frac{\text{Intensity of emitted radiation with foreign gas present}}{\text{Intensity of emitted radiation in the absence of foreign gas}} \qquad (19)$$

Thus,

$$\frac{I}{I_o} = \frac{1}{1 + \tau Z_Q} \qquad (20)$$

A plot of $I_o/I$ against the number density, $n_2$, of the foreign gas molecules yields the quenching cross section, Q, for the state:

$$\frac{I_o}{I} = 1 + \tau\, Q\, n_2 \left[\frac{8kT}{\pi}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)\right]^{1/2}$$

$$= 1 + \tau\, Q\, n_2 \langle v_{rel} \rangle \qquad (21)$$

from which

$$Q = \frac{I_o/I - 1}{\tau\, n_2 \langle v_{rel} \rangle} \qquad (22)$$

A plot of $I_o/I$ against the number density of the foreign gas molecules is a straight line passing through (0,1) as origin, with a slope given by $Q\,\tau\,\langle v_{rel} \rangle$. From this slope, knowing the lifetime, $\tau$, of the excited state, and calculating the relative velocity, $\langle v_{rel} \rangle$, of the colliding pair, it is possible to determine the quenching cross section, Q, for the excited atomic state.

Part C: Radiative and Collisional Excitation Energy Transfer Mechanisms

Several of the most important radiative and collisional processes that may take place in the mercury-thallium vapour mixture irradiated with Hg 2537Å resonance radiation can be described by the following equations:

$$Hg(6^1S_o) + h\nu_{2537Å} \rightarrow Hg(6^3P_1) \qquad (23)$$

$$Hg(6^3P_1) \rightarrow Hg(6^1S_o) + h\nu_{2537Å} \qquad (24)$$

$$Hg(6^3P_1) + Tl(6^2P_{1/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E \quad (25)$$

$$Hg(6^3P_1) + Tl(6^2P_{3/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E \quad (26)$$

In the presence of nitrogen molecules the following additional processes may also occur:

$$Hg(6^3P_1) + N_2(v=0) \rightarrow Hg(6^3P_o) + N_2(v=1) + \Delta E \quad (27)$$

$$Hg(6^3P_o) + Tl(6^2P_{1/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E \quad (28)$$

$$Hg(6^3P_o) + Tl(6^2P_{3/2}) \rightarrow Hg(6^1S_o) + Tl^* + \Delta E \quad (29)$$

$$Tl^* + N_2(v=0) \rightarrow Tl + N_2^* + \Delta E \quad (30)$$

Equations (23) and (24) represent the optical excitation of the mercury atom and its decay resulting in the emission of the Hg 2537Å resonance fluorescence. Equation (25) indicates the collisional excitation transfer between $Hg(6^3P_1)$ and ground state thallium atoms. The process described by equation (26) is unlikely in the absence of a buffer gas, since the lifetime of the thallium metastable state is effectively limited by the transit time between the fluorescing region in the vapour and the cell wall, which is about $10^{-5}$ seconds at thallium pressures of the order of $10^{-4}$ torr. Equation (27) represents the formation of the mercury metastable state by collisions with nitrogen molecules in the ground vibrational state. Equations (28) and (29) indicate the collisional excitation transfer between the metastable mercury atoms and thallium atoms in the ground and metastable states, respectively. In the presence of buffer gases, such as nitrogen, equation (29) may play a significant role. Addition of nitrogen to the metal vapour system has the effect of increasing

the effective lifetime of the metastable $Tl(6^2P_{3/2})$ state, by reducing the number of quenching collisions with the cell walls. Also, the $Tl(6^2P_{3/2})$ state lies 0.97eV above the $Tl(6^2P_{1/2})$ ground state and consequently, it becomes possible to excite the thallium states in the vicinity of the 5.83eV level, (indicated in figure(1)), in collisions with metastable $Hg(6^3P_o)$ atoms. The intensities of the spectral components arising from these higher excited states and the subsequent influence of the latter on the cross sections for excitation transfer to lower thallium levels (through cascade effects), will depend strongly on the population density of the $Tl(6^2P_{3/2})$ metastable state. Finally, equation (30) expresses the quenching action of nitrogen molecules on the excited thallium states.

It should be noted that no provision has been made for the formation of mercury molecules and their subsequent interactions with thallium atoms. At low mercury vapour and buffer gas pressures, the probability of forming $Hg_2$ molecules is vanishingly small[28]. This was further verified by Winas et.al.[29], who worked with a mercury-thallium mixture, and found that the mercury molecular band structures at 3250Å and 4350Å appeared only above 100 torr of mercury pressure and at very high thallium pressures. These observations indicate that one may safely omit the $Hg_2$ molecules from consideration under conditions employed in this present investigation.

PART D: Calculation of Relativistic Atomic Oscillator Strengths, Transition Probabilities and Lifetimes for Thallium$_I$ and Cesium$_I$

For the sake of completeness, the discussion of this section will begin with a review of the non-relativistic Hartree-Fock theory and its simplification by the use of the averaged exchange potential introduced by Slater[30]. The extension to the relativistic case is then presented along with the theoretical calculations for Thallium$_I$ and Cesium$_I$ using the relativistic Hartree-Fock-Slater method. Unless otherwise specified we work in atomic units (a.u.) where the electronic charge, e, and $\hbar$, Planck's constant divided by $2\pi$, are set equal to unity. The velocity of light is then equal to $\alpha^{-1}$ where $\alpha$ is the fine structure constant. The speed of light has the numerical value of 137.03602 a.u..

(1.0) Non-Relativistic Hartree-Fock Theory

The foundation of the Hartree-Fock (HF) theory rests on the Self-Consistent-Field (SCF) method devised by Hartree[31] in which it is assumed that each electron moves in a central or spherically symmetric force field produced by the nucleus and the other N-1 electrons of the N electron atomic system. In the SCF procedure the instantaneous action of each electron, j (=1, 2, ..., i-1, i+1, ..., N), on the $i^{th}$ electron is replaced by the averaged charge distribution of each $j^{th}$ electron, averaged by taking the quantity $\psi_j^*\psi_j$ and summing over all electrons in the atom. This resultant charge distribution is very nearly spherically symmetric. The first approximation made is to assume such a spherically averaged charge distribution so that each electron in the atom can be assumed to move in a central potential field which is written in the form

$$V_i(\vec{r}) = \frac{1}{4\pi}\int\left[-\frac{Z}{r} + \sum_{j\neq i}\int d^3\vec{r}_j \frac{|\psi_j(\vec{r}_j)|^2}{|\vec{r} - \vec{r}_j|}\right] d\Omega \qquad (31)$$

Here, $V_i(\vec{r})$ is the potential seen by the $i^{th}$ electron at position $\vec{r}$. The first term in equation (31) describes the nuclear potential seen by the $i^{th}$ electron at a distance r from the nucleus taken as origin. The second term is the potential due to all other electrons at positions $\vec{r}_j$. Integration over angles depicts the spherical averaging of the potential. The use of the central potential, $V_i(\vec{r})$, guarantees that the Hamiltonian is spherically symmetric and hence that the solution, $\psi_i(\vec{r})$, of the Schrodinger equation for the $i^{th}$ electron

$$\left[-\frac{1}{2}\nabla^2 + V_i(\vec{r})\right]\psi_i(\vec{r}) = \epsilon_i\psi_i(\vec{r}) \qquad , \qquad (32)$$

can be written in the form

$$\begin{aligned}\psi_i(\vec{r}) &= \psi_{nlm}(r,\theta,\phi) \\ &= \frac{1}{r}R_{nl}(r)Y_l^m(\theta,\phi) \qquad . \qquad (33)\end{aligned}$$

Substitution of this one-electron orbital into the Schrodinger equation gives

$$\frac{1}{2}\frac{d^2}{dr^2}R_{nl} + \left[\epsilon_{nl} - V_{nl} - \frac{l(l+1)}{2r^2}\right]R_{nl} = 0 \qquad , \qquad (34)$$

where the $R_{nl}$ are the radial wave functions for the one-electron orbitals and are subject to the usual boundary conditions that

$$R_{nl}(r) \to 0 \text{ as } r \to \infty \qquad (34a)$$

and

$$R_{nl}(r) = 0 \text{ at } r = 0 \qquad (34b)$$

The method used in solving the SCF problem is based on that of successive approximations. A trial radial wave function, such as a Thomas-Fermi or Hydrogenic radial function, is chosen for each (nl) orbital of the atom. From this trial function, charge densities and potentials are determined and Schrodinger's equation is solved yielding a final radial function. Using this radial function as a starting function, new charge densities and potentials are recalculated and Schrodinger's equation is again solved. Several such iterations are performed until the condition of self-consistency, which demands that the final potential agree with the initial potential used to solve the Schrodinger equation, is satisfied to within some desired tolerance.

The Hartree SCF method yields one electron orbital wave functions which display the proper n-l-1 nodes, but these functions suffer from two important defects. First, they lack the proper antisymmetry. Second, the $R_{nl}$ functions are not orthogonal since for each (nl) shell there is a different central potential, $V_{nl}$, and hence the Schrodinger equations are not the same for all the orbitals.

These problems are overcome in the HF method in a straightforward manner. The wave function of a many-electron system must change sign when the spatial and spin coordinates of any two electrons are interchanged; that is, the wave function defining a many-electron system must be antisymmetric under the exchange of coordinates between any two electrons in the system. It is intuitively obvious that a total wave function of the form $\Psi(\vec{r}_1,\ldots,\vec{r}_n) = \psi_1(\vec{r}_1)\psi_2(\vec{r}_2)\ldots\psi_n(\vec{r}_n)$, where the $\psi_i(\vec{r}_i)$ are one-electron orbital wave functions, as assumed by the

Hartree method, does not satisfy the required antisymmetry property. However, a total wave function in the form of a determinantal function, or a linear combination of determinantal functions, does satisfy this requirement. Each of the one-electron wave functions, $\psi_i$, are written as a product of an orbital function, $\phi_i(\vec{r}_k)$, and a spin function, $\chi_i(\sigma_k)$, where $\sigma_k = \pm 1$ such that for an electron with spin up ($m_s = +1/2$), $\chi_i(1) = 1$ and $\chi_i(-1) = 0$. Similarly, for electron of opposite spin ($m_s = -1/2$), $\chi_i(1) = 0$ and $\chi_i(-1) = 1$. To simplify the calculations one demands that all spin-orbitals, $\chi_i(\vec{r}_k,\sigma_k)$, be orthonormal. The total wave function for the N electron system is

$$\Psi(\vec{r}_1\sigma_1,\vec{r}_2\sigma_2,\ldots,\vec{r}_N\sigma_N) = \frac{1}{\sqrt{N!}} \begin{vmatrix} \psi_1(\vec{r}_1\sigma_1) & \cdots & \psi_1(\vec{r}_N\sigma_N) \\ \vdots & & \vdots \\ \psi_N(\vec{r}_1\sigma_1) & \cdots & \psi_N(\vec{r}_N\sigma_N) \end{vmatrix} \qquad (35)$$

which is normalized, provided the $\psi_i(\vec{r}_k\sigma_k)$ are normalized, and is automatically antisymmetric under the interchange of electron coordinates, thereby satisfying the Pauli exclusion principle.

The non-relativistic Hamiltonian for the N electron system is

$$H = -\sum_{i=1}^{N} \left(\frac{1}{2}\nabla_i^2 + \frac{Z}{r_i}\right) + \sum_{i>j} \frac{1}{r_{ij}} \qquad (36)$$

where $r_i$ is the distance of the $i^{th}$ electron from the nucleus taken as origin; $r_{ij}$ is the distance between the $i^{th}$ and $j^{th}$ electrons and $\nabla_i^2$ refers to differentiation with respect to the coordinates of the $i^{th}$ electron. The terms in the first sum of the Hamiltonian involve only single electron operators; those in the second sum operate on pairs of electrons. Defining the one electron operator by

$$f_i = -\frac{1}{2}\nabla_i^2 - \frac{Z}{r_i}$$

and the two electron operator by

$$g_{ij} = \frac{1}{r_{ij}}$$

allows the Hamiltonian in equation (36) to be written in the more compact form

$$H = \sum_i f_i + \sum_{i>j} g_{ij} \qquad (37)$$

In the process of calculating atomic structure properties one is concerned with the evaluation of matrix elements involving these one and two electron operators. A detailed analysis of the matrix components is discussed by Slater [32] and by Bethe and Jackiw [33].

The Hartree-Fock equations for the spin-orbitals are derived using a variational procedure in which we demand that the energy remain stationary with respect to variations in each of the spin-orbitals. This derivation has been established in detail in many textbooks [33, 34] hence, only the final form is reproduced here. The spin-orbitals are written as the product of an orbital function and a spin function, namely

$$\psi_i(\vec{r}_j\sigma_j) = \psi_i(\vec{r}_j)\chi_i(\sigma_j)$$

The non-relativistic HF equation is then

$$-\frac{1}{2}\nabla_1^2\psi_i(\vec{r}_1) - \frac{Z}{r_1}\psi_i(\vec{r}_1) + \left[\sum_{j=1}^{N}\int d\tau_2 \frac{1}{r_{12}}|\psi_j(\vec{r}_2)|^2\right]\psi_i(\vec{r}_1)$$
$$-\sum_{j=1}^{N}\delta_{m_{s_i},m_{s_j}}\left[\int d\tau_2 \frac{1}{r_{12}}\psi_j^*(\vec{r}_2)\psi_i(\vec{r}_2)\right]\psi_j(\vec{r}_1) = \varepsilon_i\psi_i(\vec{r}_1) \qquad (38)$$

where the sums over j run over all occupied spin-orbitals and integrations over $d\tau_2$ are only over the spatial coordinates. Implicit use of the result that $\sum_{\sigma_j}\chi_i^*(\sigma_j)\chi_j(\sigma_i) = \delta_{m_{s_i},m_{s_j}}$ has been used in equation (38). By Koopman's theorem[35] $-\varepsilon_i$ represents the energy required to remove the $i^{th}$ electron from the atom under the assumption that the remaining core electron orbitals remain unchanged. The HF equations given by equation (38) have N solutions representing the N occupied spin-orbitals comprising the total determinantal wave function representing the state of the N-electron system. With the spin-orbitals normalized, it can be shown that the N solutions are orthonormal[36]. In addition to the N solutions representing the occupied spin-orbitals there also exist an infinite number of other orthonormal spin-orbitals, $\psi_k(\vec{r}_j\sigma_k)$, which are solutions of the HF equation and correspond to the unoccupied, or excited orbitals that are found in the central field problem[36].

The HF equation differs from that of Hartree's SCF equation (32) only in the terms given by

$$\int d\tau_2 \frac{1}{r_{12}}|\psi_j(\vec{r}_2)|^2\psi_j(\vec{r}_1) - \sum_j \delta_{m_{s_i},m_{s_j}}\left[\int d\tau_2 \frac{1}{r_{12}}\psi_j(\vec{r}_2)\psi_i(\vec{r}_2)\right]\psi_j(\vec{r}_1)$$
$$= -\sum_{j\neq i}\delta_{m_{s_i},m_{s_j}}\left[\int d\tau_2 \frac{1}{r_{12}}\psi_j^*(\vec{r}_2)\psi_i(\vec{r}_2)\right]\psi_j(\vec{r}_1) \qquad (39)$$

The second term on the left-hand side of equation (39) is the exchange integral which corrects for the fact that the electron does not act on itself. That part of the HF equation in agreement with the SCF equation

represents an electron moving in an equivalent local potential generated by the nucleus and the other electrons in the system. The exchange term, represented by the right-hand side of equation (39), is the result of a non-local potential. The HF equation (38) can be written in the form

$$\frac{1}{2}\nabla^2\psi_i(\vec{r}_1) + \left[\varepsilon_i - V(\vec{r}_1)\right]\psi_i(\vec{r}_1) - \int U(\vec{r}_1,\vec{r}_2)\psi_i(\vec{r}_2)d\tau_2 = 0 \qquad (40)$$

where $V(\vec{r}_1)$ is the local potential defined by

$$V(\vec{r}) = -\frac{Z}{r_1} + \sum_{j=1}^{N}\int |\psi_j(\vec{r}_2)|^2 \frac{1}{r_{12}} d\tau_2 \qquad (41)$$

and $U(\vec{r}_1,\vec{r}_2)$ is the non-local potential defined by

$$U(\vec{r}_1,\vec{r}_2) = -\frac{1}{r_{12}} \sum_{j=1}^{N} \psi_j^*(\vec{r}_2)\psi_j(\vec{r}_1)\delta_{m_{s_i},m_{s_j}} \qquad (42)$$

with the condition that $U(\vec{r}_1,\vec{r}_2)$ be hermitian. This guarantees that the eigenvalues, $\varepsilon_i$, of the HF equation (40) are real[36]. Using standard techniques and the hermitian property of the non-local potential $U(\vec{r}_1,\vec{r}_2)$, it can further be shown that the orbital functions, $\psi_i(\vec{r})$, are orthogonal[36]. Since the orbitals, $\psi_i(\vec{r})$, are normalized the general result may be written as

$$\int \psi_k^*(\vec{r}_1)\psi_i(\vec{r}_1)d\tau_1 = \delta_{i,k} \qquad . \qquad (43)$$

(1.1) Discussion of the Exchange Term

The exchange term given by the second term on the left-hand side of equation (39) may be regarded as representing the potential energy, at position $\vec{r}_1$ for the $i^{th}$ electron, of a charge distribution at position $\vec{r}_2$ of magnitude

$$\sum_j \delta_{m_{s_i},m_{s_j}} \psi_j^*(\vec{r}_2)\psi_i(\vec{r}_2) \qquad (44)$$

Multiplying the top and bottom by $\psi_i^*(\vec{r}_1)\psi_i(\vec{r}_1)$ gives

$$\sum_j \frac{\delta_{m_{s_i},m_{s_j}} \psi_i^*(\vec{r}_1)\psi_j^*(\vec{r}_2)\psi_j(\vec{r}_1)\psi_i(\vec{r}_1)}{\psi_i^*(\vec{r}_1)\psi_i(\vec{r}_1)} \qquad (45)$$

This term is called the exchange charge density and has a total magnitude equal to one electronic charge ($e = 1$ in a.u.) provided $\psi_i$ is one of the occupied orbitals, but is zero if $\psi_i$ represents an unoccupied orbital. To prove this, integrate equation (45) over $d\tau_2$. By the orthogonality of the $\psi_I$'s and $\psi_J$'s all terms in the summation go out on integration except for the term $j = i$ which integrates to unity, provided $\psi_i$ is an occupied orbital. Since the summation is only over the N occupied orbitals, no term with $j = i$ exists for any $\psi_i$ which is an excited orbital. The inclusion of the Kronecker delta in equation (45) indicates that the electronic charge density is comprised of charges having the same spin as the spin-orbital $\psi_i$ being considered. When the position $\vec{r}_2$ is identical to position $\vec{r}_1$ then equation (45) reduces to

$$\sum_j \delta_{m_{s_i},m_{s_j}} \psi_j^*(\vec{r}_1)\psi_j(\vec{r}_1) \qquad (46)$$

which is the total density of all electrons of the same spin as the $i^{th}$ electron at the position $\vec{r}_1$.

The complete potential energy field in which the electron moves, as given by the HF theory, is composed of the nuclear interaction, the interaction with all electrons of opposite spin to that of the $i^{th}$ electron and an interaction with a charge distribution of electrons of

the same spin as the $i^{th}$ electron. The charge distribution of electrons with the same spin adds up to one less than the total number of electrons in this spin state if an occupied orbital is considered, or in the case of an unoccupied orbital, where the net amount of charge is zero, the charge distribution adds to the total number of electrons with spin the same as that of the $i^{th}$ electron being considered. The net charge density of electrons with the same spin as the spin-orbital, $\psi_i$, is zero in the case where $\vec{r}_2 = \vec{r}_1$ since here the exchange charge density just cancels the total density of all electrons of this spin.

Slater[30] interprets the exchange effects in terms of the Fermi hole theory in which the electron being considered is thought of as carrying with it a hole charge such that for an occupied orbital there is electronic charge with a total magnitude of one unit removed from the immediate vicinity of the electron's position. This Fermi hole is a result of the Pauli Exclusion principle which keeps electrons of the same spin separated. Hence, the effect of the exchange term is to remove electronic charge from the immediate neighbourhood of the $i^{th}$ electron. This tends to reduce the electron-electron Coulomb repulsion and therefore lowers the one-electron energies $\varepsilon_i$ relative to the Hartree SCF values. Slater[37] further points out that the exchange corrections are greatest in the region of large charge density near the nucleus.

The overall effect of exchange is therefore to cause the atom to shrink, with an increased electron density near the nucleus.

(1.2) Simplification of the Exchange Term: The Slater Approximation

Although solutions of the HF equation may be obtained in a straightforward manner similar to the procedure followed in the SCF method, the

occurrence of all the spin-orbitals in each of the equations yields a very complicated system of simultaneous integro-differential equations whose solutions require much effort. Slater[30] has proposed an approximation which involves the formation of an average potential field in which all of the electrons are considered to move. The potential field is found by forming a weighted mean of the exchange charges, weighted and averaged over the various electronic wave funtions at a given point in space. This average exchange charge is then replaced by the corresponding value given by a free-electron gas whose local density is equal to the density of actual charge at the given spatial point.

Slater's exchange correction as described above is obtained by writing the HF exchange operator in the form of an equivalent potential acting on the $i^{th}$ wave function

$$V_{exch}(\vec{r}_1) = -\frac{\sum_{j=1}^{N}\int \psi_i^*(\vec{r}_1)\psi_j^*(\vec{r}_2)\,\frac{1}{r_{12}}\,\psi_j(\vec{r}_1)\psi_i(\vec{r}_2)\,d\tau_2}{\psi_i^*(\vec{r}_1)\psi_i(\vec{r}_1)} \qquad (47)$$

where it is understood that integration over $d\tau_2$ is only over the spatial coordinates and where summation over the spin functions has been carried out implicitly.

The atomic electrons are regarded as a degenerate electron gas with the same electron charge density as that of the exchange density. The electrons are assumed to experience a constant potential and hence the corresponding orbital functions can be written as plane waves

$$\psi_j(\vec{r}_1) = \frac{1}{V^{1/2}}\exp(i\vec{k}_j\cdot\vec{r}_1) \qquad (48)$$

where $\vec{k}_j$ is the wave vector of the $j^{th}$ wave; $\vec{r}_1$ is the radial vector from the origin at the nucleus to the $j^{th}$ electron; V is the volume of the electron gas over which the normalization is carried out. Using the plane wave expression of equation (48) for the orbital wave functions, the numerator of equation (47) becomes

$$\psi_i^*(\vec{r}_1)\psi_j^*(\vec{r}_2)\,\frac{1}{r_{12}}\,\psi_j(\vec{r}_1)\psi_i(\vec{r}_2) = \frac{1}{V^2}\exp\left[i(\vec{k}_j - \vec{k}_i)\cdot(\vec{r}_1 - \vec{r}_2)\right]\frac{1}{r_{12}} \tag{49}$$

and the denominator becomes

$$\psi_i^*(\vec{r}_1)\psi_i(\vec{r}_1) = \frac{1}{V} \tag{50}$$

The exchange potential energy of the interaction of the electron at $\vec{r}_1$ and the electron at $\vec{r}_2$ in the states i and j is found by first computing the integral

$$\int \psi_i^*(\vec{r}_1)\psi_j^*(\vec{r}_2)\,\frac{1}{r_{12}}\,\psi_j(\vec{r}_1)\psi_i(\vec{r}_2)\,d\tau_2 = \frac{1}{V^2}\int \exp\left[i(\vec{k}_j - \vec{k}_i)\cdot(\vec{r}_1 - \vec{r}_2)\right]\frac{1}{r_{12}}\,d\tau_2 \tag{51}$$

The result of the integration is[36]

$$\frac{1}{V^2}\,\frac{4\pi}{|\vec{k}_j - \vec{k}_i|} \tag{52}$$

This result is next summed over the $\vec{k}_j$ which is shown to be equivalent to integration over spherical coordinates in the $\vec{k}_i$ space[36]. The HF exchange potential then takes on the form

$$V_{exch} = -4\left(\frac{3}{8\pi}\frac{N}{V}\right)^{1/3} F(\eta) \quad , \qquad (53)$$

where N is the number of electrons in the volume V of the Fermi gas and $\eta$ is defined by

$$\eta = \frac{|\vec{k}_i|}{k_{max}}$$

where $\vec{k}_i$ is the momentum of the electron (in a.u.) in the orbital $\psi_i$ for which the exchange potential is being evaluated and $k_{max}$ is the Fermi momentum. The value of $k_{max}$ is found by equating the equivalent expressions for the Fermi energy, namely

$$E_f = \frac{h^2}{2m}\left(\frac{3}{8\pi}\frac{N}{V}\right)^{2/3} = \frac{k_{max}^2 \hbar^2}{2m} \qquad \text{(in cgs units)}$$

or

$$E_f = 2\pi^2\left(\frac{3}{8\pi}\frac{N}{V}\right)^{2/3} = \frac{k_{max}^2}{2} \qquad \text{(in a.u.)}$$

from which the Fermi momentum is determined to be

$$k_{max} = \left(3\pi^2 \frac{N}{V}\right)^{1/3} \qquad (54)$$

The function $F(\eta)$ is given by[30]

$$F(\eta) = \frac{1}{2} + \frac{1-\eta^2}{4\eta} \ln\left(\frac{1+\eta}{1-\eta}\right) \qquad (55)$$

which has a range of values in the interval $\left[1/2, 1\right]$ where the extrema occur at $\eta = 0$ for an electron of zero kinetic energy and $\eta = 1$ for an electron with kinetic energy corresponding to that of an electron at the top of the Fermi distribution, respectively.

Equation (53) expresses the HF exchange energy in an electron gas for an electron whose momentum is the fraction, $\eta$, of the maximum Fermi energy. Slater's average exchange potential is found by averaging equation (53) over occupied states. The number of occupied states between $\eta$ and $\eta + d\eta$ is proportional to $\eta^2 d\eta$; hence, the average value of $F(\eta)$ is

$$\bar{F}(\eta) = \frac{\int \eta^2 F(\eta) d\eta}{\int \eta^2 d\eta} = \frac{3}{4} \qquad (56)$$

The averaged exchange potential is thus

$$\bar{V}_{exch} = -\frac{3}{2}\left(\frac{3}{\pi}\frac{N}{V}\right)^{1/3} \qquad (57)$$

With this approximate exchange potential the Hartree-Fock equation becomes

$$-\frac{1}{2}\nabla_1^2\psi_i(\vec{r}_1) - \frac{Z}{r_1}\psi_i(\vec{r}_1) + \left[\sum_{j=1}^{N}\int d\tau_2 \frac{1}{r_{12}}|\psi_j(\vec{r}_2)|^2\right]\psi_i(\vec{r}_1) - \frac{3}{2}\left[\frac{3}{\pi}\sum_{j=1}^{N}\psi_j^*(\vec{r}_1)\psi_j(\vec{r}_1)\delta_{m_{s_i},m_{s_j}}\right]^{1/3}\psi_i(\vec{r}_1) = \epsilon_i\psi_i(\vec{r}_1) \qquad (58)$$

where the term $\frac{N}{V}$ in equation (59) has been interpreted as the local density of electrons given by

$$\frac{N}{V} = \sum_{j=1}^{N}\delta_{m_{s_i},m_{s_j}}\psi_j^*(\vec{r}_1)\psi_j(\vec{r}_1) \qquad (59)$$

which is the exchange charge density of equation (45) for position $\vec{r}_2 = \vec{r}_1$. This Slater exchange approximation is used in the subsequent work.

## (2.0) Extension to the Relativistic Case

In this section we are concerned with the generation of the relativistic formalism of the Hartree-Fock-Slater (HFS) approximation established for the non-relativistic case in the above discussion.

The relativistic single-particle wave function for a central-field potential can be written as

$$\Psi_i = \begin{pmatrix} (G_i/r)\ \chi_\kappa^\mu \\ i(F_i/r)\ \chi_{-\kappa}^\mu \end{pmatrix} \tag{60}$$

where the radial functions multiplied by r, $F(\vec{r})$ and $G(\vec{r})$, are real with $G(\vec{r})$ being the large component. The non-zero integer, $\kappa$, specifies both the total angular momentum

$$j = |\kappa| - 1/2 \tag{61}$$

and the parity of the state, $(-1)^l$, where

$$l = j + \frac{\kappa}{2|\kappa|} \tag{62}$$

The projection of the total angular momentum, j, on the axis of quantization is designated by $\mu$. The spin-angular function, $\chi_\kappa^\mu$, is defined by

$$\chi_\kappa^\mu = \sum_m C(l1/2j;\mu-m,m)\chi_{1/2}^m\ Y_l^{\mu-m} \tag{63}$$

with $\chi_{1/2}^{1/2} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $\chi_{1/2}^{-1/2} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$. In defining the Clebsch-Gordon

coefficient, $C(l1/2j;\mu-m,m)$, we use the notation of Rose[38].

We still seek solutions of the eigenvalue problem

$$H\Psi = E\Psi$$

as in the non-relativistic case, but for the relativistic problem we must replace the non-relativistic Hamiltonian by the Dirac Hamiltonian, namely

$$H \rightarrow H_D \equiv \vec{\alpha}\cdot\vec{p} + \beta + V(r) \qquad (64)$$

Here we define the operators

$$\vec{\alpha} = \begin{pmatrix} 0 & \vec{\sigma} \\ \vec{\sigma} & 0 \end{pmatrix} \text{ and } \beta = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

where 1 is the 2x2 unit matrix and $\vec{\sigma}$ is the 2x2 Pauli matrix.

The eigenvalue problem being considered for the relativistic case is

$$H_D \Psi_i = \varepsilon_i \Psi_i$$

with $E = mc^2 + \varepsilon_i$ and $\varepsilon_i$ is the ionization potential of the $i^{th}$ atomic shell. It can be shown[39] that for $\Psi_i$ to be a solution, the two radial functions $G(\vec{r})$ and $F(\vec{r})$ must satisfy the coupled differential equations

$$\frac{d}{dr_1} G_i(\vec{r}_1) + \frac{\kappa}{r_1} G_i(\vec{r}_1) - \left(2c + \frac{V(\vec{r}_1)}{c} - \frac{\varepsilon_i}{c}\right) F_i(\vec{r}_1) = 0$$

and (65)

$$\frac{d}{dr_1} F_i(\vec{r}_1) - \frac{\kappa}{r_1} F_i(\vec{r}_1) + \left(\frac{V(\vec{r}_1)}{c} - \frac{\varepsilon_i}{c}\right) G_i(\vec{r}_1) = 0$$

in atomic units. $V(r_1)$ is the effective potential producing the field which affects the optical electron. This potential can be written as

$$V(r_1) = -\frac{Z}{r_1} + \sum_j N_j \int d\tau_2 \frac{1}{r_{12}} |\psi_j(\vec{r}_2)|^2 + V_{exch}(\vec{r}_1)$$
$$= -\frac{Z}{r_1} + \int d\tau_2 \frac{1}{r_{12}} \rho(\vec{r}_2) + V_{exch}(\vec{r}_1) \qquad (66)$$

where the charge density has the form

$$\rho(\vec{r}_2) = \sum_j N_j \left[ G_j^2(\vec{r}_2) + F_j^2(\vec{r}_2) \right] \qquad (67)$$

and $N_j$ is the occupation number of the $j^{th}$ shell. The expansion of $\frac{1}{r_{12}}$ in terms of Legendre polynomials gives[40]

$$\frac{1}{r_{12}} = \frac{1}{|\vec{r}_2 - \vec{r}_1|} = \sum_{l=0}^{\infty} \frac{r_<^l}{r_>^{1+l}} P_l(\cos\theta_{12}) \qquad (68)$$

where $r_<$ is the smaller of $\vec{r}_1$ and $\vec{r}_2$. Under the central-field approximation where an averaging over angles is performed, only the $l = 0$ term survives. Using equation (68) in equation (66) under the assumption of a central-field, the potential assumes the form

$$V(\vec{r}_1) = -\frac{Z}{r_1} + \frac{1}{r_1} \int_0^{r_1} r_2^2 \rho(\vec{r}_2)\, d\tau_2 + \int_{r_1}^{\infty} r_2 \rho(\vec{r}_2)\, d\tau_2 + V'_{exch}(\vec{r}_1) \qquad (69)$$

The solutions of equations (65) must satisfy the boundary conditions

$$\lim_{r\to 0} G(\vec{r}) = \lim_{r\to 0} F(\vec{r}) = \lim_{r\to\infty} G(\vec{r}) = \lim_{r\to\infty} F(\vec{r}) = 0 \qquad (70)$$

Since, in general, the experimental ionization energy of the $i^{th}$ shell is not the true eigenvalue of equations (65), there is no solution of this system of equations that can simultaneously satisfy the boundary conditions of equation (70) at the origin and at infinity. The procedure to solve equations (65) such that the boundary conditions are satisfied, as outlined by Rose[41], is to establish solutions that are regular at $r = 0$. Such solutions satisfying this condition are given as truncated power series expansions in the form

$$G(r) = r^{\gamma} \sum_{m=0}^{m_{max}} \alpha_m r^m$$

and

$$F(r) = r^{\gamma} \sum_{m=0}^{m_{max}} \beta_m r^m \qquad (71)$$

where $\gamma = +(\kappa^2 - (Z/c)^2)^{1/2}$. These expansions are valid only for small r. In the asymptotic region, the solutions are of the form

$$G(r) = a\, e^{-\mu r}$$

and

$$F(r) = b\, e^{-\mu r} \qquad (72)$$

where $\mu = \left[2\varepsilon - (\varepsilon/c)^2\right]^{1/2}$ and $a/b = \left[(2c^2 - \varepsilon)/\varepsilon\right]^{1/2}$. The numerical solution of equations (65) is begun from the region of small r values using the power series form of equations (71); a similar numerical solution is begun from the region of large r values using the asymptotic form of equations (72) appropriate for the region. By adjusting the coefficients in equations (71) and (72) it is possible to match the solutions for the two regions at some point $r_1$ to within any desired degree of accuracy. If the solutions in the two regions match at the predetermined point, $r_1$, (usually taken in the neighbourhood of the

classical turning point) then they coincide at all values of r and the solution obtained is an eigensolution[41].

A relativistic HFS program, based on the general procedure outlined above, was used to generate the one-electron wave functions required for the calculations of this section.

As an initial estimate of the eigenvalues for each (nl) shell the Dirac hydrogenic energies

$$E_{(nl)} = \frac{-2Z^2}{N^2 + N(n - |\kappa| + \gamma)} \qquad (73)$$

were used. N is the apparent principal quantum number for the particular (nl) shell defined by

$$N = n^2 - 2(n - |\kappa|)(|\kappa| - \gamma) \quad ; \qquad (74)$$

$\gamma = (|\kappa|^2 - (\alpha Z)^2)^{1/2}$ and n is the principal quantum number.

In principle, the wave function describing a given atomic (nl) shell has an infinite radial extent. The numerical representation of these wave functions make it impossible to depict this feature since the radial wave function must be terminated at some sufficiently large radial displacement from the nucleus. The error introduced by neglecting the tail of the wave function can be made negligible by choosing a sufficiently large termination point. The choice of such a suitable termination point for each (nl) shell can be made by considering the asymptotic radial function[42]

$$R(r) = e^{-\lambda r} f(r) \qquad (75)$$

where f(r) is a function which varies slowly at large r and $\lambda$ is related

to the approximate eigenenergy, $\varepsilon(nl)$, being used at a given stage in the solution through the relation

$$\lambda = + \sqrt{-\varepsilon_{(nl)}} \qquad (76)$$

In our program, the radial wave function was cut off at the point $r_{max}$ determined by the requirement that the asymptotic form of the radial function in equation (75), with $\varepsilon_{(nl)}$ being the approximate eigenenergy, agree with the asymptotic form in which $\varepsilon_{(nl)}$ is replaced with the Coulomb energy for that shell to within one part in $10^9$ in the region of large radial displacements. This condition is satisfied at some sufficiently large radial displacement, $r_{max}$, determined by the relation

$$\exp\left[\left(-\varepsilon_{(nl)} + \frac{Z}{r_{max}}\right)^{1/2} r_{max}\right] \leq 10^{-9} \qquad (77)$$

The numerical solution of equations (65) was begun in the region of large r values for which the asymptotic form of equations (72) is valid. The inward solution began at $r_{max}$ and was continued up to the classical turning point. Here, the inward solution was terminated and replaced by the outward solution beginning at the origin. The asymptotic form given by equations (71) was used in this region with the solution being carried out to the classical turning point. The ratio formed by comparing the large component values at the position of the classical turning point for the outward and inward integration was used to force the inward solution for the large and small components to match those for the outward solution. The number of nodes appearing in the large component, G(r), of this approximate wave function were counted and

compared to the correct number of nodes, $n_r$, given by[43]

$$n_r = (n - |\kappa|)$$
$$= (n - l - 1) \quad , \qquad (78)$$

where n is the principal quantum number for the (nl) shell. There will be more than $n_r$ nodes in G(r) if the approximate eigenvalue, $\varepsilon_{(nl)}$, is too small and fewer than $n_r$ nodes if $\varepsilon_{(nl)}$ is too large. This technique provides a useful method for bounding the correct eigenvalue. The energy parameter, $\varepsilon_{(nl)}$, so bounded can then be adjusted and the process repeated until the correct number of nodes appear.

Upon securing the proper nodal structure, the initial approximation to the wave function was normalized according to the requirement

$$\int (G(r)^2 + F(r)^2)\, dr = 1 \quad . \qquad (79)$$

New charge densities and potentials, which include the exchange effects through the Slater potential, were calculated from this initial approximate wave function. A new approximate eigenenergy was calculated from these new charge densities and potentials and the entire process repeated until the inward and outward integrations matched to within at least one part in $10^7$. This procedure was performed for each occupied (nl) shell of the atomic configuration under study. The final radial wave functions for the configuration were separately normalized and the predicted eigenvalue for each shell was calculated. Note that since the core is allowed to readjust for each excited state configuration, no guarantee is made that the outer shell radial wave functions between different excited states with the same total angular momentum are orthogonal even though each outer shell is orthogonal to all core shells in the configuration. More discussion of this point will appear later.

The numerical solutions of the first order differential equations (65) were accomplished using the fifth order Adams predictor-corrector method[44]. Equations (65) were solved at points $r_i$ determined by the relation

$$r_i = r_0 \left[ \exp(h(i - 1)) - 1 \right] \tag{80}$$

where i had a maximum value of 384 and the scaling factor, $r_0$, was chosen in such a manner that the wave function cut off point determined by equation (77) was less than, but close to the radial displacement given by $r_{384}$ from equation (80). In general, $r_0$ was on the order of $10^{-3}$ a.u. when the step size h was taken to be 1/32.

(3.0) Calculations of Transition Probabilities

The transition probabilities and oscillator strengths may be obtained from the formulae rigorously derived by Bhalla[45] using the relativistic single-configuration wave functions from the HFS calculations.

The spontaneous emission probability per unit time ($\tau_0 = \hbar^3/me^4 = 2.4189 \times 10^{-17}$sec) for the EL transition $\beta \to \alpha$ is given by Grant[46] to be

$$A_{\beta\to\alpha} = \left[ J_\beta \right]^{-1} \sum_{m_\beta} \sum_{m_\alpha} 2\pi |M^e_{\alpha\beta}|^2 \tag{81}$$

with $M^e_{\alpha\beta}$ defined by the following relation involving "3-j" symbols:

$$M^e_{\alpha\beta} = \left(\frac{\omega}{\pi c}\right)^{1/2} (-1)^{j_\alpha - m_\alpha} \begin{pmatrix} j_\alpha & L & j_\beta \\ -m_\alpha & M & m_\beta \end{pmatrix} \times (-1)^{j_\alpha - 1/2} \left[ J_\alpha, J_\beta \right]^{1/2} \begin{pmatrix} j_\alpha & L & j_\beta \\ 1/2 & 0 & -1/2 \end{pmatrix} \bar{M}^e_{\alpha\beta} \tag{82}$$

where $\bar{M}^e_{\alpha\beta}$ is given as

$$\tilde{M}^{e}_{\alpha\beta} = i^{L}\left[\left(\frac{L}{L+1}\right)^{1/2}\left[(k_\alpha - k_\beta)I^{+}_{L+1} + (L+1)\bar{I}_{L+1}\right]\right.$$
$$\left.-\left(\frac{L+1}{L}\right)^{1/2}\left[(k_\alpha - k_\beta)I^{+}_{L-1} - L\bar{I}_{L-1}\right]\right] \qquad (83)$$

in the velocity form and by

$$\tilde{M}^{e}_{\alpha\beta} = i^{L}\left[(2L+1)J^{(L)}\left(\frac{\omega r}{c}\right) + (k_\alpha - k_\beta)(I^{+}_{L+1} + I^{+}_{L-1})\right.$$
$$\left. - L\bar{I}_{L-1} + (L+1)\bar{I}_{L+1}\right] \qquad (84)$$

in the length form. In equations (82) and (84) the transition frequency, $\omega$, is the energy difference between the upper and lower states expressed in a.u. and L is the order of the electric multipole which in our present case for dipole transitions has the value L=1. Also, the notation[47]

$$\left[j_\alpha, j_\beta, \ldots\right] = (2j_\alpha + 1)(2j_\beta + 1)\ldots \qquad (85)$$

is used. The values of k for the upper and lower states are as defined in equation (62). The radial integrals $I^{+}_{\lambda}$, $\bar{I}_{\lambda}$ and $J^{(L)}\left(\frac{\omega r}{c}\right)$ are given by Bhalla[45] to be

$$I^{+}_{\lambda} \equiv \int j_\lambda\left(\frac{\omega r}{c}\right)(G_\alpha F_\beta + F_\alpha G_\beta)dr \qquad (86a)$$

$$\bar{I}_{\lambda} \equiv \int j_\lambda\left(\frac{\omega r}{c}\right)(G_\alpha F_\beta - F_\alpha G_\beta)dr \qquad (86b)$$

and

$$J^{(L)}\left(\frac{\omega r}{c}\right) \equiv \int j_L\left(\frac{\omega r}{c}\right)(G_\alpha G_\beta + F_\alpha F_\beta)dr \qquad (86c)$$

where $j_\lambda\left(\frac{\omega r}{c}\right)$ is the spherical Bessel function of order $\lambda$ and $G_{\alpha(\beta)}F_{\alpha(\beta)}$

are the large and small components of the relativistic HFS wave function for the lower (upper) state.

Performing the summation over initial states and averaging over final states in the expression for the spontaneous emission transition probability per unit time reduces equation (81) to the form

$$A_{\beta\to\alpha} = 2\alpha\omega \frac{[J_\alpha]}{[L]} \begin{pmatrix} J_\beta & L & J_\alpha \\ 1/2 & 0 & -1/2 \end{pmatrix}^2 |\bar{M}^e_{\alpha\beta}|^2 \qquad (87)$$

with $\bar{M}^e_{\alpha\beta}$ being of the appropriate form for either the velocity or length matrix element given by equations (83) and (84) respectively. Grant[46] proves that for all pairs of states $\alpha$ and $\beta$ which are exact eigensolutions of the same Dirac Hamiltonian, the length and velocity forms yield identical results. Hence, the comparison of matrix element calculations using the two formulations provides a check on the accuracy of the subsequent calculations of the atomic transition parameters and indirectly yields an estimate of the quality of the approximation method used to generate the wave functions for the particular system under study.

The absorption oscillator strength is defined in terms of the spontaneous emission transition probability per unit time for the transition $\beta\to\alpha$ by

$$f_{\alpha\beta} = \frac{[J_\beta]}{[J_\alpha]} \frac{A_{\beta\to\alpha}}{2\alpha^3\omega^2} \qquad (88)$$

The numerical values of $\omega$ are computed from the C.E. Moore tables[48]. (A misprint occurs in Grants equation (5.2) where $\alpha$ appears in the denominator instead of the correct $\alpha^3$.)

Considerable controversy exists concerning which form of the matrix

element, $\bar{M}^{e}_{\alpha\beta}$, should be used to obtain the most accurate representation of the atomic oscillator strengths. Starace[49] argues that the length form should be preferred over the velocity form if the wave functions are exact eigenfunctions of an approximate non-local Hamiltonian such as is the case in the HF approximation. On the other hand, Grant[46] considers the guage invariance of the transition matrices and infers that for electric dipole transitions the dipole velocity form should be given priority. In this investigation all calculations are presented in both forms for the sake of comparison.

(3.1) The Bates-Damgaard Approximation

Several past investigations[17,23] related to sensitized fluorescence studies in mercury-thallium vapour mixtures have relied on the results of the Bates-Damgaard[24] (BD) approximation for determining the necessary transition probabilities required in the calculations of various cross sections. In the evaluation of such experimental data it becomes necessary to distinguish between trends that are of a physical nature and those introduced through the theoretical calculations of the transition probabilities and lifetimes. As we have mentioned previously, only a few reliable experimental values of transition probabilities and lifetimes exist in the literature, particularly in the case of thallium, and hence the necessity for the theoretical calculation of such parameters. However, because of the inherent dependence of the cross sections on such calculations it is important to choose a theoretical approximation method that not only yields results that agree closely with those found by experiment, but also displays consistent behavior in regions not investigated experimentally. The Bates-Damgaard approximation scheme is introduced here in order to facilitate the comparison of our

experimental cross sections, in which the theoretical relativistic transition probabilities and lifetimes are used, with those of the other authors who have employed the BD results.

Assuming coulombic behavior of the potential outside the core region, Bates and Damgaard proposed to use a solution of the hydrogenic Schrodinger equation,

$$\frac{d^2R_{nl}(r)}{dr^2} + \left( \frac{2\,Z_{eff}}{r} - \frac{l(l+1)}{r^2} - \varepsilon_{nl} \right) R_{nl}(r) = 0 \,, \qquad (89)$$

where $Z_{eff}$, the effective charge, is the excess charge on the nucleus when the active electron is removed and the energy parameter, $\varepsilon_{nl}$, is taken to be the experimental energy for the particular (nl) orbital. Solutions of equation (89) are subject to the boundary condition

$$R_{nl}(r) \to 0 \text{ as } r \to \infty \qquad (89a)$$

and are expressed in the form

$$R_{nl}(r) = \left[ \frac{n^{*2}\,\Gamma(n^*+l+1)\Gamma(n^*-l)}{Z_{eff}} \right]^{-1/2} \times \left( \frac{2rZ_{eff}}{n^*} \right)^{n^*} \exp\left( \frac{-rZ_{eff}}{n^*} \right) F\left(-n^*+l+1, 2l+2; \frac{2rZ_{eff}}{n^*}\right)$$

where $n^*$ is the effective principal quantum number given by

$$n^* = Z_{eff} / \varepsilon_{nl}^{1/2} \qquad (90a)$$

and $F\left(-n^*+l+1, 2l+2; \frac{2rZ_{eff}}{n^*}\right)$ is the confluent hypergeometric function.

The asymptotic expansion of F(a,b;x) is

$$F(a,b;x) = x^{-a}\left[\sum_{n=0}^{R-1} \frac{(a)_n(1+a-b)_n(-x)^{-n}}{n!} + O(x^{-R})\right] \qquad (91)$$

Thus equation (90) can be written in the more compact form

$$R_{nl}(r) = \left[\frac{n^{*2}\,\Gamma(n^*+l+1)\,\Gamma(n^*-l)}{Z_{eff}}\right]^{-1/2} \times \left(\frac{2rZ_{eff}}{n^*}\right)^{n^*} \exp\left(\frac{-rZ_{eff}}{n^*}\right)\left[1+\sum_{\nu=1}^{\nu_{max}} \frac{a_\nu}{r^\nu}\right] \qquad (92)$$

where

$$a_1 = \frac{n^*}{2Z_{eff}}\left[\,l(l+1) - n^*(n^*-1)\,\right] \qquad (92a)$$

and

$$a_\nu = a_{\nu-1}\left[\frac{n^*}{2\nu Z_{eff}}\left[\,l(l+1) - (n^*-\nu)(n^*-\nu+1)\,\right]\right] \qquad (92b)$$

The asymptotic series in equation (92) diverges for any r. In practice the series is terminated at some value of $\nu_{max}$ in such a way that the dipole transition integrals are convergent.

The validity of the Coulomb approximation depends critically on the assumption that the true potential can be adequately represented by the $\frac{2Z_{eff}}{r}$ Coulomb potential. For complex systems, where the outer electrons overlap significantly with the core electrons, the Coulomb approximation would be expected to be less reliable. Generally, the BD approximation gives the best results for the highly excited states in these complex systems. In particular, good results are expected in the calculation of oscillator strengths when the principal maxima of both the upper and lower states occur in the outer region where the Coulomb potential is a good approximation.

Choosing $\nu_{max}$ in equation (92) such that the transition integrals

converge does not avoid divergence of the wave function as $r \to 0$, nor does it guarantee the proper (n-l-1) number of nodes. In certain types of calculations, such as in the evaluation of the electric dipole transition matrix elements, these latter two deficiencies in themselves may not introduce serious error. This is because the main contribution to such calculations comes from the region of large radial displacements and the improper behavior of the radial function near the origin will often not seriously affect the matrix elements.

The absorption oscillator strength for E1 transitions between the states $\beta$ and $\alpha$ is given by [50]

$$f_{\alpha\beta} = \frac{2}{3}|\Delta E|(2j_\beta+1)W^2(l_\alpha j_\alpha l_\beta j_\beta;\tfrac{1}{2}\,1)l_{max}|R_{\alpha\beta}|^2 \qquad (93)$$

where $\Delta E$ is the energy difference between the states, W is the Racah coefficient, $l_{max} = \max(l_\alpha, l_\beta)$ and the radial integral for the transition $\beta \to \alpha$ is

$$R_{\alpha\beta} = \int R_\alpha R_\beta r\, dr \qquad (94)$$

where $R_\alpha$ and $R_\beta$ are of the form given by equation (92) appropriate for the lower and upper state respectively. The transition probabilities (in units of $sec^{-1}$) are determined according to the relation[51]

$$A_{\beta\to\alpha} = 0.6669|\Delta E|^2 f_{\alpha\beta} \quad , \qquad (95)$$

where $\Delta E$ is in $cm^{-1}$.

(4.0) Results and Discussion

Numerous regularities and systematic trends among oscillator strengths have been studied in recent years. Such regularities are of great practical importance since they may be used to obtain additional

oscillator strengths by simple extrapolation procedures as well as to evaluate the reliability of existing data by the degree of fit with respect to established systematic trends. Regular variations in spectral line intensities were noted by Trumphy[52] as early as 1925 in the principal series (3s-np) of sodium. It was observed that the oscillator strengths decrease with increasing principal quantum number, n, in a regular fashion which could be approximated by the general expression

$$\text{constant } x(n^*)^{-3} \tag{96}$$

where $n^*$ is the effective principal quantum number. Similar trends have been observed in numerous other elements.

Appendix (2) indicates the behavior of the relativistic HFS oscillator strengths, taken from Appendix (1), as a function of the effective principal quantum number of the upper state for several of the Thallium I series. Also indicated are the curves generated by the combined experimental data of Norton and Gallagher[53] and Penkin and Shabanova[54]. Similar plots for the corresponding series in Cesium I, formed from the data taken from Appendix (3), along with curves resulting from the experimental values of Agnew[55] are shown in Appendix (4).

From the plots in Appendices (2) and (4), the oscillator strengths can be seen to exhibit the well known hydrogenlike "constant $x(n^*)^{-3}$" behavior in the region of large $n^*$ values. However, for the $7^2S_{1/2} - n^2P_{1/2}$ series in thallium and all series shown in the case of cesium with the exception of the $6^2P_J - n^2S_{1/2}$ series, marked departures from the hydrogenic behavior in the form of pronounced minima are indicated in the theoretical curves at intermediate or low $n^*$ values. These minima are absent from the corresponding experimental curves. The

appearance of the "Cooper minima"[56,57] are associated with sign reversals in the transition matrix elements along a given series and reflect the non-hydrogenic character of the atomic potentials V(r). These minima, which commonly occur in the continuum, are related to the structure of the lower state wave function. If the wave function for the lower state in the transition series has a node then the transition integrals for a spectral series involving this lower level will change sign somewhere along the series and the oscillator strengths, which are related to the square of the transition matrix elements, will pass through a minimum. There is no general way to fix the n* value for which this minimum will occur in a given series. In other elements, where the Cooper minima occur in the discrete spectra, such as in the case of $Li_I$[58] and $Mg_{II}$,[59] one observes the minima at $n^* \simeq 3$ and $n^* \simeq 4$ respectively.

Comparison of the relativistic HFS curves with those generated from the experimental results show a general lack of agreement in both thallium and cesium with the exception of the first members of each series. This divergence between the theoretical and experimental oscillator strengths with increasing energy separation between the upper and lower states involved in the transitions is further manifested over the entire range of oscillator strengths shown in Appendices (1) and (3) when a comparison is made between the radial matrix elements, $\bar{M}^e_{ij}$, in the length and velocity forms. In this case there is a definite correlation between the relative percentage difference in the two forms of the transition matrix elements and the energy separation of the states involved in the transition. The relative percentage difference, $\eta$, between the two formulations is calculated according to the relation

$$\eta = \left| \frac{|\bar{M}^e_{ij}|_{velocity} - |\bar{M}^e_{ij}|_{length}}{\left[\frac{|\bar{M}^e_{ij}|_{velocity} + |\bar{M}^e_{ij}|_{length}}{2}\right]} \right| \times 100\% \quad . \qquad (97)$$

In order to distinguish between accidentally small energy differences between low lying states and systematically small energy differences occuring between pairs of higher excited states, we introduce a scaling factor, $\bar{n}^2$, defined by

$$\bar{n}^2 = \left[\frac{1}{n'^2} - \frac{1}{n^2}\right]$$

for $nl - n'l'$ transitions. It is found for both Thallium$_I$ and Cesium$_I$ that the relative percentage difference, $\eta$, tends to decrease as the scaled energy separation, $\bar{n}^2 \Delta E$, between the participating levels becomes smaller. Such a feature is completely consistent with the divergence between the theoretical and experimental plots in Appendices (2) and (4).

Careful testing of the various computer programmes and subroutines used to generate both the wave functions and oscillator strengths did not indicate the presence of any accumulating error that might explain the observed behavior. It was noticed however, that although the wave functions for the excited states were normalized to at least 1 part in $10^9$, states with the same total angular momentum were generally orthogonal to only a few parts in ten. States with different total angular momentum are necessarily orthogonal through the spin-angular portion of the wave functions.

The entire problem of orthogonality amongst the simplified Hartree-Fock solutions stems from the replacement of the HF exchange potential by the averaged approximate potential. What has been done up to this

point is to solve the simplified HF equations for each excited state configuration in such a manner that the core orbitals are allowed to readjust their radial distributions from that of the ground state configuration. Due to this readjustment of the core, and hence the potential, each configuration is defined by a slightly different Hamiltonian. Therefore, radial wave functions for excited states with the same total angular momentum can not be expected to remain orthogonal as they do in the case of full Hartree-Fock calculations for which all configurations are solved using a consistent Hamiltonian.

What is commonly done to avoid complications arising from the non-orthogonality amongst simplified HF wave functions is to make the physically unrealistic approximation that the core wave functions remain fixed in the ground state configuration and that only the outer most orbital changes when solving for excited levels. This Frozen-Core approximation allows the ground and excited state configurations to be defined by the same Hamiltonian and hence guarantees the orthogonality of all radial wave functions amongst states with the same total angular momentum. Noticable increases in the binding energies of the inner most orbitals occur as one proceeds from the ground state configuration to higher excited state configurations. Within a given configuration the relative change in the orbital binding energy decreases as one proceeds from inner to outer core orbitals with the inner core orbitals of thallium being less affected than those of cesium. The variation in binding energy of the core orbitals is linked to the radial redistribution of the core wave functions with changing configurations. This leads one to suspect that the Frozen Core approximation should be more valid for systems with higher atomic number.

In an attempt to remove the non-orthogonality amongst the relativistic HFS radial wave functions, we initiated a Gram-Schmidt orthogonalization process on each series of states with the same total angular momentum. A priori, one would expect wave functions with the lowest symmetry in each such series to be more accurately represented by the HFS approximation than those with a higher degree of symmetry. On this basis we chose such states to begin the inductive orthogonalization process for each series. The resulting radial wave functions, orthogonal to at least 1 part in $10^{15}$, were then used to re-evaluate the oscillator strengths.

(4.b) Cesium$_I$ Oscillator Strengths, Transition Probabilities and Lifetimes

We compare the oscillator strengths calculated using the orthogonalized Cesium$_I$ wave functions with the experimental data of Agnew and the Model Potential calculations of Stone[60] in Appendix (5). Immediately obvious from this comparison is the generally good agreement between our calculated values and those of experiment over the entire range of data. The behavior of these oscillator strengths as a function of the effective principal quantum number $n^*$, as indicated by the plots of Appendix (6), show that the deviation of the calculated values from the experimental data with increasing $n^*$ values has been almost totally eliminated by the orthogonalization process. The theoretical curves follow closely the shape of the experimental curves generated by Agnew's data with the exception of the $6^2S_{1/2} - n^2P_{1/2}$ series for which the theoretical data predicts the appearance of a large Cooper minimum in the vicinity of $n^* = 8$ which is absent from Agnew's data. Further, the experimental results predict a crossing of the $6^2P_{1/2} - n^2D_{3/2}$ and $6^2P_{3/2} - n^2D_{5/2}$ curves near $n^* = 7$ while the

theoretical data does not show this feature. The relatively large scatter of the experimental values in this region makes it difficult to form the curves accurately and hence the crossing of the two curves may be due to this uncertainty.

In Stone's Model Potential calculations, the one-electron solutions of the non-relativistic Schrodinger equation, including the spin-orbit interaction, were used as radial wave functions. His solutions are obtained using a central symmetric potential that includes the nucleus and the closed shell electrons and is chosen so that the binding energies of the lowest 40 levels agree closely with experimental results. The agreement between these Model Potential calculations and those obtained here is generally good although in many cases our results, in the velocity formulation, give somewhat closer agreement with experiment. In general, it appears that the dipole velocity form yields results superior to those found in the length form when compared to experimental data and theoretical calculations done using other approximation schemes.

Lifetimes calculated using the length and velocity forms of the transition probabilities determined from the orthogonalized relativistic HFS wave functions are shown in Appendix (7) and are compared with those determined by using the non-orthogonal wave functions and the Bates-Damgaard approximation. Also shown in Appendix (7) are the available experimental lifetimes.

In the case where the orthogonalized wave functions have been used, the agreement between the velocity form and available experimental lifetimes for the $n^2S_{1/2}$ states is within about 10 percent. The calculated lifetimes of the $n^2P_J$ levels agree with experiment to within 20 percent while those for the $n^2D_J$ states lie within 30 percent of the

corresponding experimental values.

The Bates-Damgaard approximation is generally considered to give good results for the alkali metals. However, comparison between these lifetimes and those found from experiment indicates that the BD approximation yields results that are generally too high and that tend to diverge from the accepted values for the higher excited states.

The effects of the orthogonalization procedure are very evident in the comparison of the lifetimes obtained from the orthogonalized and non-orthogonalized wave functions. The orthogonalization of the wave functions reduces the overall magnitudes of the lifetimes and severely decreases the rate of divergence between theoretical and experimental values.

(4.2) Thallium, Oscillator Strengths, Transition Probabilities and Lifetimes

Oscillator strengths calculated using the orthogonalized Thallium, wave functions are compared with the combined experimental data of Norton and Gallagher[53] and Penkin and Sabanova[54] and with the theoretical calculations performed by Migdalek[61] in Appendix (8). Corresponding plots of our theoretical oscillator strengths as a function of the effective principal quantum number are shown is Appendix (9) along with those generated from the experimental data. In the case of the $6^2P_{1/2} - n^2S_{1/2}$ and $6^2P_{3/2} - n^2S_{1/2}$ series, the experimental data indicates minima occuring around $n^* = 4.7$ and $n^* = 4.3$ respectively. These minima are absent in our theoretical curves. However, the proximity of the $6s6p^2\ ^4P_{1/2}$ levels to the $6s^2(^1S)10s^2S_{1/2}$ level could account for the appearance of the anomaly in the experimental data through configuration interactions. Perturbations due to the presence of this singly core excited level would be expected to affect most strongly the $10^2S_{1/2}$ levels. Since the HFS program used here to generate the relativistic wave

functions does not take into account the existence of such configuration interactions, one might not expect the minima to manifest themselves in the theoretical curves. The overall agreement between the relativistic HFS oscillator strengths and those obtained experimentally is a bit difficult to assess since the number of data points available for comparison is small, but generally the agreement is not as good as in the case of $Cesium_I$ with the exception of the $6^2P_J - n^2S_{1/2}$ series in $Cesium_I$.

Migdalek has calculated oscillator strengths for $Thallium_I$ using the "long wave" approximation with radial wave functions determined by a relativistic semi-empirical method which employs an adjustable central symmetric exchange potential of Slater type. The use of this "long wave" approximation can be justified in the case of $Thallium_I$ by investigating the structure of the dipole length form of the transition matrix elements. The dominant term in the matrix element of equation (84) for E1 transitions is

$$3J^{(1)}\left(\frac{\omega r}{c}\right) = 3\int (G_\alpha G_\beta + F_\alpha F_\beta) j_1\left(\frac{\omega r}{c}\right) dr \quad . \qquad (98)$$

It follows from the power series expansion of the spherical Bessel function[40] that in the limit of small arguments

$$j_1\left(\frac{\omega r}{c}\right) = \frac{1}{3}\left(\frac{\omega r}{c}\right) + 0\left[\left(\frac{\omega r}{c}\right)^3\right] \quad . \qquad (99)$$

When only this lowest order term in $\omega r/c$ is retained, then equation (88) reduces to the "long wave" approximation for the absorption oscillator strength for E1 transitions given by

$$f_{\alpha\beta} = \frac{2}{3}|\Delta E|(2J_\beta + 1)W^2(l_\alpha J_\alpha l_\beta j_\beta; 1/2\ 1)I_{max}|R_{\alpha\beta}|^2 \qquad (100)$$

where the radial integral for the transition $\beta \rightarrow \alpha$ is

$$R_{\alpha\beta} = \int (G_\alpha G_\beta + F_\alpha F_\beta) r dr \qquad . \qquad (101)$$

Since the $J^{(1)}$ term in the dipole length matrix element dominates the contributions from the terms involving the $I_2^+$ and $I_2^-$ radial integrals by at least 5 orders of magnitude and since $(\omega r/c)^2 \leq 10^{-5}$ for r values up to an atomic radius, the use of the "long wave" approximation yields oscillator strengths that agree with those obtained using the length formulation of the relativistic HFS method to within about 1 part in $10^5$. However, since we find that the velocity formulation appears to give results more consistent with the experimental data, the velocity form of the "long wave" approximation should be used. In Migdalek's calculations, use of the adjustable parameter in the exchange potential reduces the dependence of the oscillator strengths on the length or velocity formulation of the transition matrix elements.

Lifetimes calculated using the length and velocity forms of the transistion probabilities determined from the orthogonalized relativistic HFS wave functions are shown in Appendix (10) and are compared with those found by using the non-orthogonal wave functions and the Bates-Damgaard approximation. Also listed in Appendix (10) are the few existing lifetimes measured experimentally.

A general comparison between the theoretical results and those of experiment is difficult because of the lack of experimental results. The velocity form of the orthogonalized HFS lifetimes agree well with the experimental data for the $8^2S_{1/2}$ and $6^2D_{3/2,5/2}$ states. However,

the calculated resonance state lifetime is about 40 percent too high and the remaining $n^2D_J$ states have predicted lifetimes that are between 60 and 75 percent too low.

Lifetimes calculated using the BD approximation are about a factor of 2 too large for the $7^2S_{1/2}$ and $8^2S_{1/2}$ states while for the $6^2D_J$ and $7^2D_J$ states values are obtained which lie within the experimental range of uncertainty. The behavior of the BD lifetimes with respect to the experimental values indicates that, for the $n^2S_{1/2}$ and $n^2P_J$ states, the approximation of the potential by a coulombic potential is generally not valid in complex systems like Thallium$_I$ since in these cases the optically active electron is expected to interact strongly with the core. However, in the cases of $n^2D_J$ and $n^2F_J$ states core penetration would be essentially absent. This allows the inner core electrons to be treated as a point charge to a first approximation and such a situation may then be treated adequately by the BD approximation. Caution must be exercised in using the BD treatment for complex systems for which correlation effects and configuration interactions may be of significance. This is indicated by the poor agreement between the BD and experimental lifetime for the $8^2D_{5/2}$ state.

(4.3) Suggestions for Improving the Orthogonalized Free-Core Simplified Hartree-Fock Procedure

Examination of the theoretical data obtained by using the orthogonalized HFS wave functions still indicates the diverging trends with increasing scaled energy separations between the states involved in the transitions. However, this divergence has been considerably reduced by the orthogonalization process. The theoretical data supplied by Migdalek in the "long wave" approximation for Thallium$_I$ indicates a similar trend when compared with the existing experimental data although the magnitude of the deviations are slightly less than found in our

data. The difference between these two sets of theoretical data is partially accounted for by the different forms of the Slater exchange potential used in the two sets of theoretical results. Kohn and Sham[62] have indicated that the strict Slater exchange potential used in our case generally leads to an over estimation of the exchange by at least a factor of 3/2. Migdalek found that his adjustable multiplying parameter always assumed values less that 2/3. Such a semi-empirical potential as used by Migdalek, although still not physically correct in form for reasons to be discussed below, might be expected to yield a slightly better approximation to the correct exchange potential which may account for the better fit of Migdalek's data to that of experiment. We found, by using the Kohn-Sham exchange potential in which the Slater exchange potential is multiplied by a factor of 2/3, that corrections to the oscillator strengths generally amount to at most a few parts in $10^2$.

We reconsider the Hartree-Fock exchange potential for a electron in the $i^{th}$ spin-orbital given by equation (47). The value of this potential may vary by as much as a factor of 2 for various spin-orbitals, $\psi_i$, at a fixed value of r. This has been quantitatively shown for the $Cu^+$ ion by Hartree[63]. Hence, the replacement of the exchange potential in equation (47) by an averaged exchange potential is a very crude approximation which may lead to serious error. For a given spin-orbital, the averaged Slater exchange potential yields results that are too large at some r values and too small at others. Another serious deficiency of the averaged Slater potential is its incorrect behavior at large r values. In the full HF method the exchange potential of equation (47) can be seen to have the property that

$$rV_{exch}(r) \to -1 \text{ as } r \to \infty \tag{102}$$

To see this, write the exchange potential as

$$V_{exch}(r) = V_{self}(r) + V_{ex}(r) \tag{103}$$

where the self-interaction potential, $V_{self}(r)$, is written as

$$V_{self}(r) = -\int \psi_i^*(\vec{r}_2)\psi_i(\vec{r}_2)\frac{1}{r_{12}}\,d\tau_2 \tag{104}$$

and the true exchange potential, $V_{ex}(r)$, has the form

$$V_{ex}(r) = -\sum_{j\neq i}\frac{\int \psi_i^*(\vec{r}_1)\psi_j^*(\vec{r}_2)\frac{1}{r_{12}}\psi_j(\vec{r}_1)\psi_i(\vec{r}_2)\,d\tau_2}{\psi_i^*(\vec{r}_1)\psi_i(\vec{r}_1)} \tag{105}$$

Then, in the limit as $r \to \infty$,

$$rV_{self}(r) \to -1 \tag{106}$$

and

$$rV_{ex}(r) \to 0 \tag{107}$$

However, the averaged Slater exchange potential multiplied by r tends to zero as r tends to infinity and thus the Slater exchange potential fails to correct for the electron self-interaction at large values of r.

What is often done to compensate for this defect is to apply the empirical correction due to Latter[64] to the total potential; that is, one makes the replacement

$$rV(r) = -(Z-N+1) \text{ for } r \geq r_c \tag{108}$$

where $r_c$ is determined by the condition

$$r_c V(r_c) = -(Z-N+1) \qquad (109)$$

and where N is the total number of electrons in the system. Coulson and Sharma[65] have pointed out several defects in such an empirical correction. First, the Latter potential yields a discontinuous slope at $r_c$ and consequently gives rise to the non-physical result of a non-vanishing surface charge density on the sphere separating the two regions $r \geq r_c$ and $r < r_c$. Wilson, Wood and Slater[66] further point out that the Latter potential is not variationally derivable from the expression for the total energy of the system. Gopinathan[67] demonstrates that the HFS potential underestimates the self-interaction at both large and intermediate values of r. Hence, the potential is generally smaller than the correct potential and the Latter correction to the potential leads to a non-physical shrinkage of the atom.

To remove the discrepancies between the theoretical calculations and the experimental data, it is necessary to use a better approximation of the exchange potential. Recently, Gopinathan[67] has developed an approximate exchange potential which may prove to be extremely useful in atomic structure calculations. His method of treating the exchange potential is based on the separation of the potential into an electron self-interaction term and a true exchange term. The self-interaction term is evaluated exactly while the true exchange potential is approximated in a manner similar to the $\rho^{1/3}$ approximation of Dirac and Slater. In the Gopinathan scheme, electrons in different spin-orbitals have different exchange potentials thus avoiding the major defects that arise from the use of a single averaged potential for all electrons as is employed in the Slater approximation. In Gopinathan's approach, the

self-interaction is accounted for correctly and the exchange potential is shown to have the proper asymptotic behavior at large r values. One additional feature of this treatment is that the simplicity of the computations featured by the HFS method is retained and computations of exchange potentials, one-electron eigenvalues and spin density distributions, as determined in the cases of $Cu^{+}$ and $Mn^{+2}$, yields results that compare favourably with those obtained by the more elaborate and time consuming full Hartree-Fock procedure.

Using the diagonalization procedure presented in this investigation, together with a more accurate exchange potential such as the one derived by Gopinathan, one might expect to perform atomic structure calculations with an accuracy approaching that of a full Hartree-Fock calculation. Such a procedure would allow the rapid and inexpensive computation of atomic structure data.

# EXPERIMENTAL

## PART A: Description of the Apparatus

The arrangement of the apparatus is shown in figure (3). Mercury resonance radiation emitted by a radio-frequency mercury vapour lamp was passed through an interference filter with a peak transmission of 10 percent at 2537Å, and was focussed in the fluorescence cell, which contained the mercury-thallium vapour mixture and which was located in an oven whose temperature could be accurately controlled. The resulting fluorescence, observed at right angles to the direction of excitation, was resolved with a grating spectrometer, and was brought to a focus at the photocathode of the photomultiplier tube. The signal produced by the photomultiplier tube was registered with a Keithley model 417 picoammeter and a Hewlett-Packard strip-chart recorder.

The fluorescence cell was connected to a vacuum system and could be filled with controlled amounts of nitrogen. The cell was fitted with two sidearms, one for thallium and one for mercury. Both sidearms could be heated independently to produce the required vapour pressures of thallium and mercury.

### (1.0) Light Sources

The Hg 2537Å exciting radiation was produced by an electrodeless discharge in mercury vapour, which was contained in a quartz bulb. The discharge was driven by a radio-frequency oscillator, powered by a Fluke model 407DR power supply. The r-f oscillator is drawn schematically in figure (4). This type of lamp, which has been used previously in this laboratory, provides an intense source of Hg 2537Å resonance radiation. The resonance line is narrow and relatively free of self-reversal.

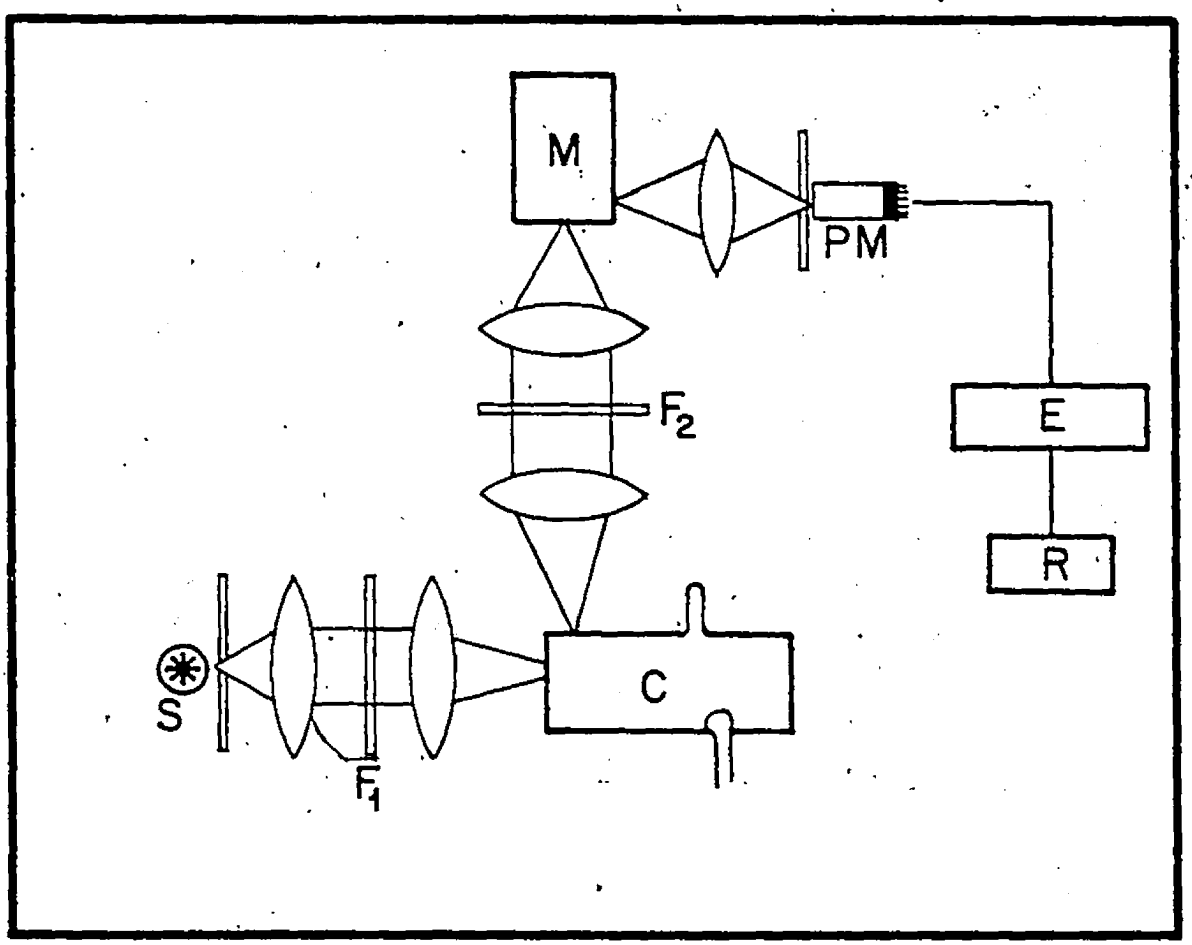


Fig. 3: Arrangement of the apparatus

S - source
C - fluorescence cell
M - monochromator
PM - photomultiplier tube
E - Keithley picoammeter
R - strip-chart recorder
$F_1$ - filter

$F_2$ - filter

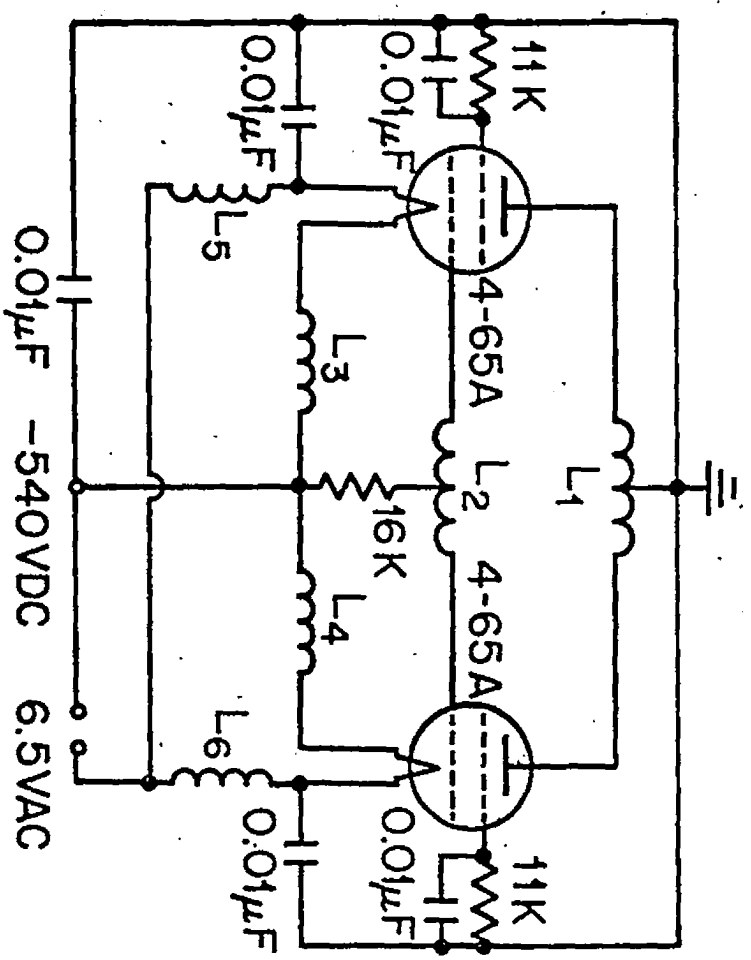


Fig. 4 : R-F oscillator circuit

$L_1$ - RF coil, 5½ turns with Hg bulb enclosed

$L_2$ - RF coil, 4½ turns

$L_3$, $L_4$, $L_5$, $L_6$ - RF coils, 20 turns

The bulbs were constructed of high-quality non-fluorescing quartz tubing with an outside diameter of 1.4cm and a wall thickness of 2mm. Several ampoules were connected to a distillation manifold and small amounts of mercury (previously distilled several times) were distilled under vacuum into each bulb. Argon* at various pressures in the range 0.2 - 1.8 torr was admitted into the ampoules which were then sealed and removed from the manifold. Subsequent tests of the mercury lamps indicated that argon pressures in the range 0.8 - 1.1 torr gave greatest stability and highest output of the Hg 2537Å resonance component. It was also found that slight cooling, by an even flow of air about the bulb, resulted in greater stability and a moderate increase in the intensity of the Hg 2537Å radiation emitted from the lamps.

When studying the quenching of the $Tl(7^2S_{1/2})$ state in the $Tl-N_2$ mixture, the thallium atoms were excited directly with the Tl 3776Å resonance radiation emitted from an air-cooled Osram lamp. The lamp operated at a current of 0.8 amperes which was supplied by an Ealing Universal Spectral Lamp power supply. It was found that at a current of 0.9amperes, (as recommended by the manufacture), the intensity of the resonance radiation emitted from the lamp fluctuated rather noticeably. By reducing the current to 0.8 amperes the intensity fluctuations could be rendered insignificant.

(2.0) The Fluorescence Cell and Oven

The whole cell, which is depicted in figure (5), was constructed of high optical quality-non-fluorescing quartz†. Ordinary (optical quality) quartz, when irradiated with ultraviolet light, fluoresces

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* research grade, supplied by the Linde Corporation

† Suprasil W1 supplied by the Amersil Corporation

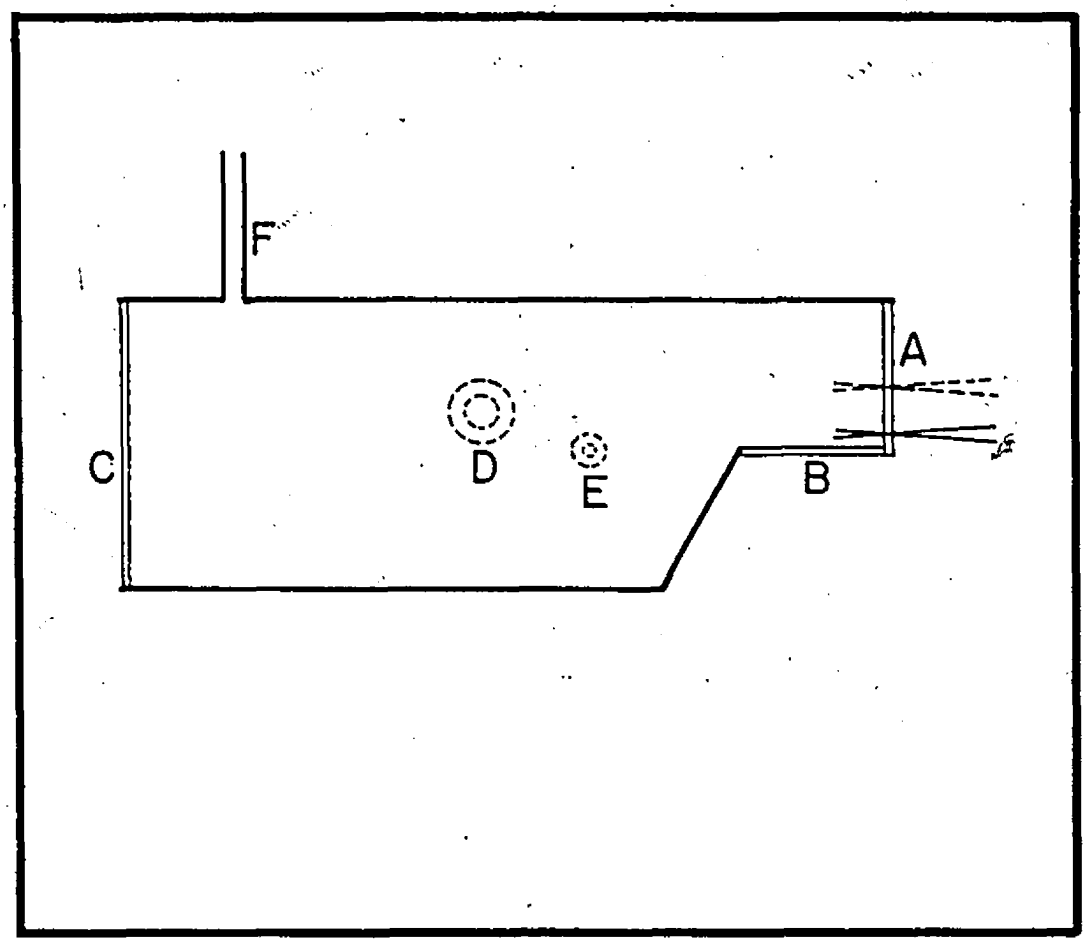



Fig. 5: The fluorescence cell

A - entrance window
B - observation window
C - rear observation window
D - thallium sidearm
E - mercury sidearm
F - capillary to vacuum system

strongly in the spectral region from 3500Å to 4800Å. This quartz fluorescence would completely mask all atomic fluorescence emitted from the metal vapour mixture in the cell. The cell had an overall length of 10cm, an outside diameter of 35mm, and a wall thickness of 3mm. The entrance and exit windows were cut from 1.5mm quartz plates and fused to the "D" shaped portion of the cell. The observation window at the rear of the cell was 3mm thick. This design of the fluorescence cell permitted the exciting beam of the Hg 2537Å light to be focused just inside the rectangular corner formed by the entrance and observation windows, keeping the optical paths through the cell to less than 1mm and thus reducing the reabsorption of the mercury resonance radiation.

The cell was enclosed in a series of stainless steel shields to reduce the intensity of black body radiation reaching the spectrometer from the heating elements. Aquadag, commonly employed to reduce the stray light, could not be used since, at high temperatures, it vapourizes from the cell surface. The steel shield covering the observation window had in it a rectangular aperture in the form of a slit to provide a well-defined geometry required for fluorescent intensity measurements.

The window at the rear of the cell was provided to facilitate the optical alignment of the cell and to monitor the strong corrosive action which took place on prolonged exposure of the quartz to thallium vapour at temperatures in the range 500°C - 600°C. At these temperatures the corrosive action of thallium on the inner surfaces of the windows and cell body was strong enough to cause sufficient erosion of the window surfaces so that the transmission of the fluorescent light was severely reduced. After each experimental run the windows had to be replaced or repolished in order to maintain optimal transmission.

The cell was fitted with two sidearms one of which, containing metallic thallium, was approximately 9cm long and had an inside bore of 15mm to allow efficient transport of thallium vapour to the cell. The second sidearm, which contained mercury, extended below the cell and protruded out of the oven, and terminated in a reservoir which could be heated separately by means of a "Chromel A" heater wrapped along the whole of the sidearm. Current to this heater was delivered through a Variac autotransformer which allowed the temperature of the sidearm to be accurately controlled. The mercury reservoir was connected to the cell by a capillary approximately 50cm in length and having a bore of 2mm. The reservoir heater was necessary to produce and maintain the proper density of mercury vapour in the cell. Without it, a very long time was required for the mercury to migrate through the capillary against the high thermal gradient, and the mercury density in the cell was difficult to stabilize.

The fluorescence cell was mounted inside a stainless steel oven which was heated by means of nine G.E. strip-heaters fastened to the exterior surfaces of the box in series-parallel combinations. Current to these heaters was supplied by a Variac rated at 1800 watts. Using these heaters only, a cell temperature of about 350°C could be produced. To reach the required temperatures, several coils of "Chromel A" resistance wire were wound and mounted on 6mm thick asbestos fibre boards. These additional heater units were connected in series-parallel configurations and attached to the inner surfaces of the oven. The resistance of each component in the heater circuit was established by a trial and error method so as to provide a thermal gradient along the cell. The front windows were kept at about 10°C above the temperature of the

thallium sidearm, to prevent condensation of thallium metal on the window surfaces. Current to the inner heater elements was supplied by a 2800 watt Variac. With this arrangement it was possible to maintain the oven temperature within $\pm 2^{\circ}C$, in the range $450^{\circ}C - 580^{\circ}C$. The temperatures were measured by chromel-alumel thermocouples placed at various positions on the cell sidearms and connected to a Hewlett-Packard digital multimeter.

The oven was placed in a transite box covered with a water-cooled copper jacket. The space between the two boxes was filled with mica chips to reduce heat loss from the oven.

Non-fluorescent quartz plate windows covered the appropriately placed apertures in the inner and outer boxes. These windows served to reduce the heat lost through the apertures.

(3.0) The Vacuum System

The fluorescence cell was connected to an external vacuum system by means of a capillary tube approximately 40cm in length and 2mm inside diameter. Although the capillary severely reduced the pumping efficiency, it did effectively prevent the migration of afomic vapours from the cell into the vacuum system. The system was evacuated by an Edwards E02 diffusion pump, backed by an Edwards rotary pump which had a pumping rate of 50 litres per minute. The pressure in the vacuum system was of the order of $10^{-8}$ torr, and was monitored by a CVC type GIC-110B ionization guage.

(4.0) The Monochromator and Photomultiplier Tube

The fluorescent spectra emitted from the fluorescence cell was resolved by a Jarrel-Ash model 82-000 spectrometer equipped with an 1800 grooves/mm diffraction grating blazed at 3000Å in first order. The monochromator had an aperture of f/8.6 and a focal length of 0.5 meter with a reciprocal dispersion of 16Å/mm in first order.

The resolved fluorescence from the monochromator was focused on the photocathode of a 13 dynode EMI D260/9865QAM photomultiplier tube. The tube, mounted in a cryostat cooled to liquid nitrogen temperatures, had a tri-alkali photocathode with an S-20 spectral response. The nominal cathode diameter was 10mm. The tube was operated at a potential of -1000V which produced a gain of $10^6$. The cathode potential was maintained by a Fluke model 412B power supply. The dark current at liquid nitrogen temperature was measured to be $1.5 \times 10^{-11}$ amperes. For comparative purposes, an EMR type 514N-03-14-03900 photomultiplier tube, equipped with a tri-alkali photocathode having an S-20 spectral response and a 14 stage venetian blind dynode chain, was used. This tube was operated at -1660V which produced a gain of $10^6$. The dark current, at room temperature, was found to be $6 \times 10^{-11}$ amperes, and was depressed to $5 \times 10^{-13}$ amperes at liquid nitrogen temperature.

(5.0) Calibration of the Monochromator and Photomultiplier Tube

Although the quenching cross sections are independent of the spectral response characteristics of the optical support equipment, the determination of the energy transfer cross sections, depending on the intensities of the spectral components, demand complete knowledge of the spectral response features of the monochromator and photomultiplier tube, and of the absorption characteristics of the quartz optics.

The spectral response of the monochromator was obtained using the experimental arrangement shown in figure (6). The first Jarrel-Ash spectrometer served to isolate a particular line from the Osram lamp source. This line was focused onto the entrance slit, (with a 0.5mm slit-width), of the second Jarrel-Ash monochromator which was to be calibrated. A vacuum photodiode (ITT F4000), with an effective photocathode 4cm in diameter, was placed behind the entrance slit and detected

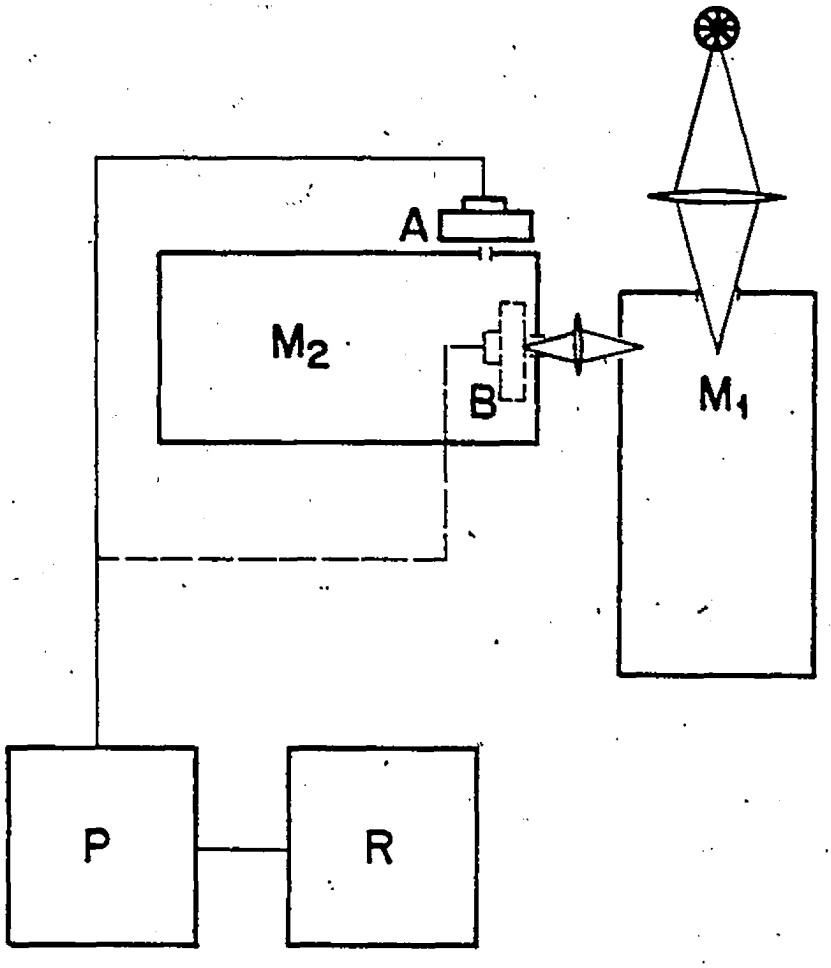



Fig. 6: Experimental arrangement used to calibrate the Jarrel-Ash monochromator

A - photodiode set to receive light emerging from monochromator $M_2$
B - photodiode set to receive light incident on monochromator $M_2$
P - Keithley picoammeter
R - strip-chart recorder
$M_1$ - Jarrel-Ash monochromator

$M_2$ - Jarrel-Ash monochromator to be calibrated

all the light entering the monochromator. The exit slit was also set at 0.5mm and the emergent light from the monochromator was detected by the same photodiode placed against the outside of the exit slit so as to receive all the emergent light. Several light sources, consisting of Hg, K, Cs, Na, and Zn Osram lamps, were used to produce the spectral response curve (shown in figure(7)) for the Jarrel-Ash monochromator. Several complete runs were made to determine the reproducibility of the curve.

Spectral response characteristics at -40°C had been supplied by the manufacturer for the EMI photomultiplier tube, but previous experience with other photomultipliers indicated that the spectral response may be altered somewhat by depressing the operating temperature to that of liquid nitrogen.

Calibration of the EMI photomultiplier at liquid nitrogen temperature was accomplished by allowing light of the same energy flux to be incident on the photocathode of the photomultiplier as was incident on the window of a calibrated RBL-500 thermopile (supplied by the C.M.Reader company). The thermopile sensitivity was quoted to be 12.27 $\frac{\mu V}{\mu W}$ . Several spectral components emitted by Hg, Zn, and K Osram lamps were used as light sources. The thermopile, which was equipped with a quartz window having rectangular dimensions of 3mm by 0.5mm, was mounted to the holder shown in figure (8). The holder,which could be placed in either of two positions, had a light baffle with an aperture of the same dimensions as the thermopile window. The light baffle aperture and the thermopile window coexisted in the same optical plane situated perpendicular to the light path from the monochromator. In the first position, the thermopile was allowed to detect the light flux emerging from the monochromator. The

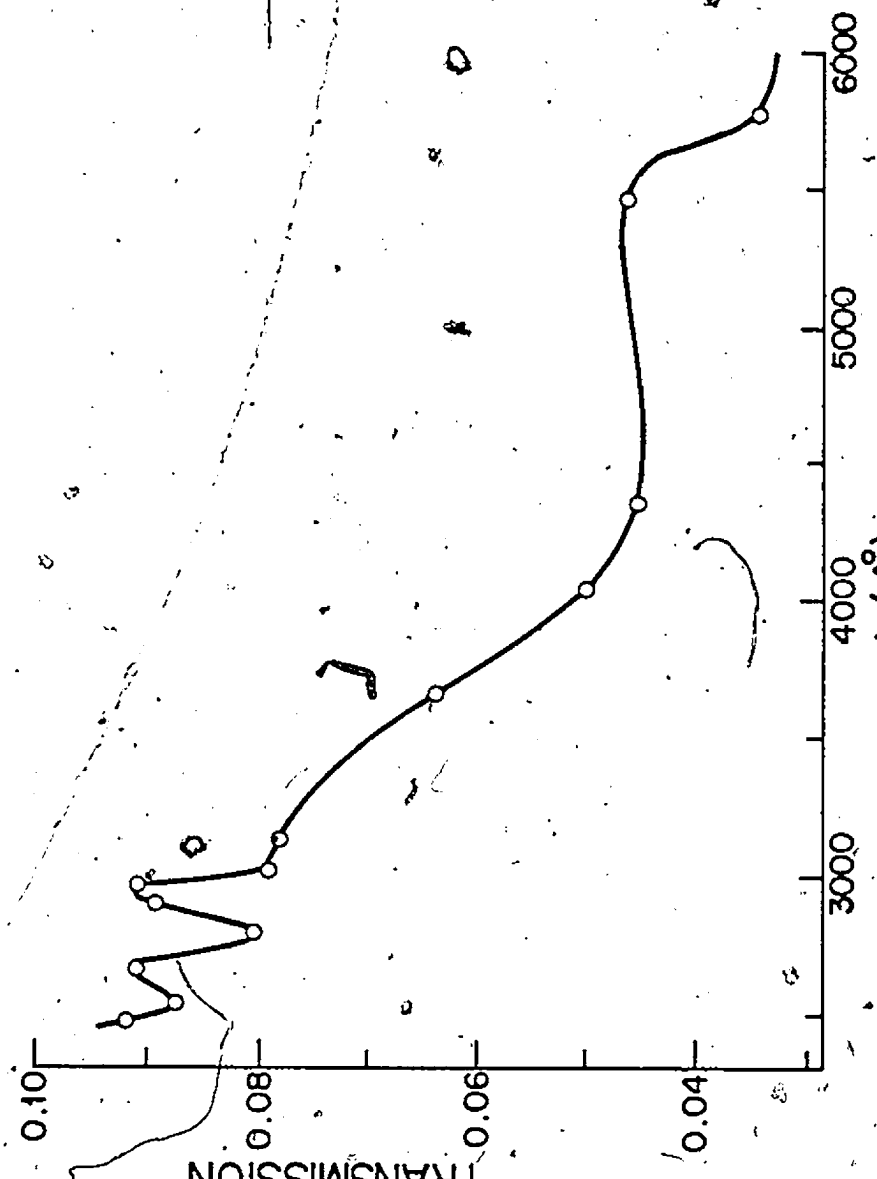



Fig. 7: Transmission of Jarrel-Ash monochromator

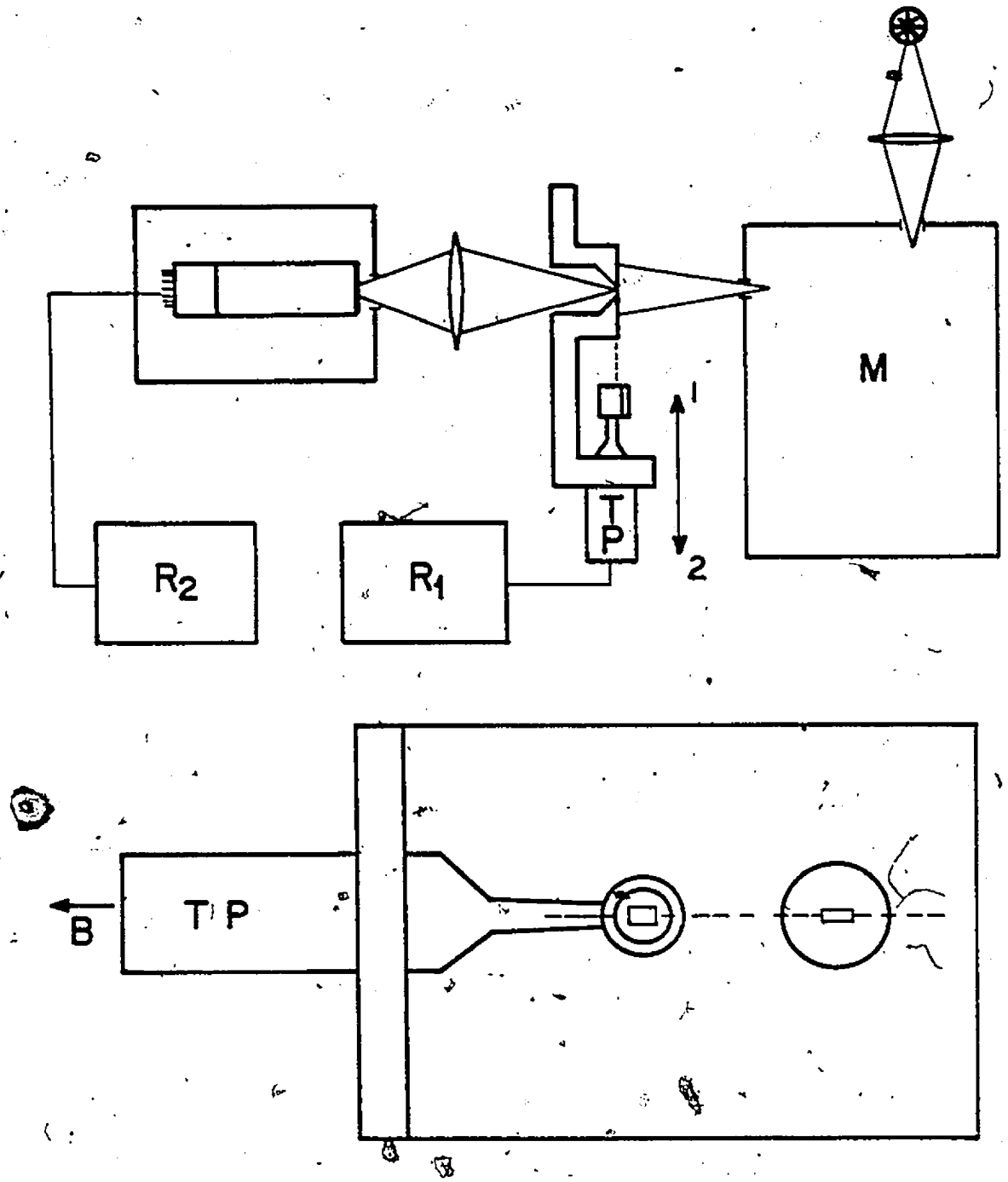


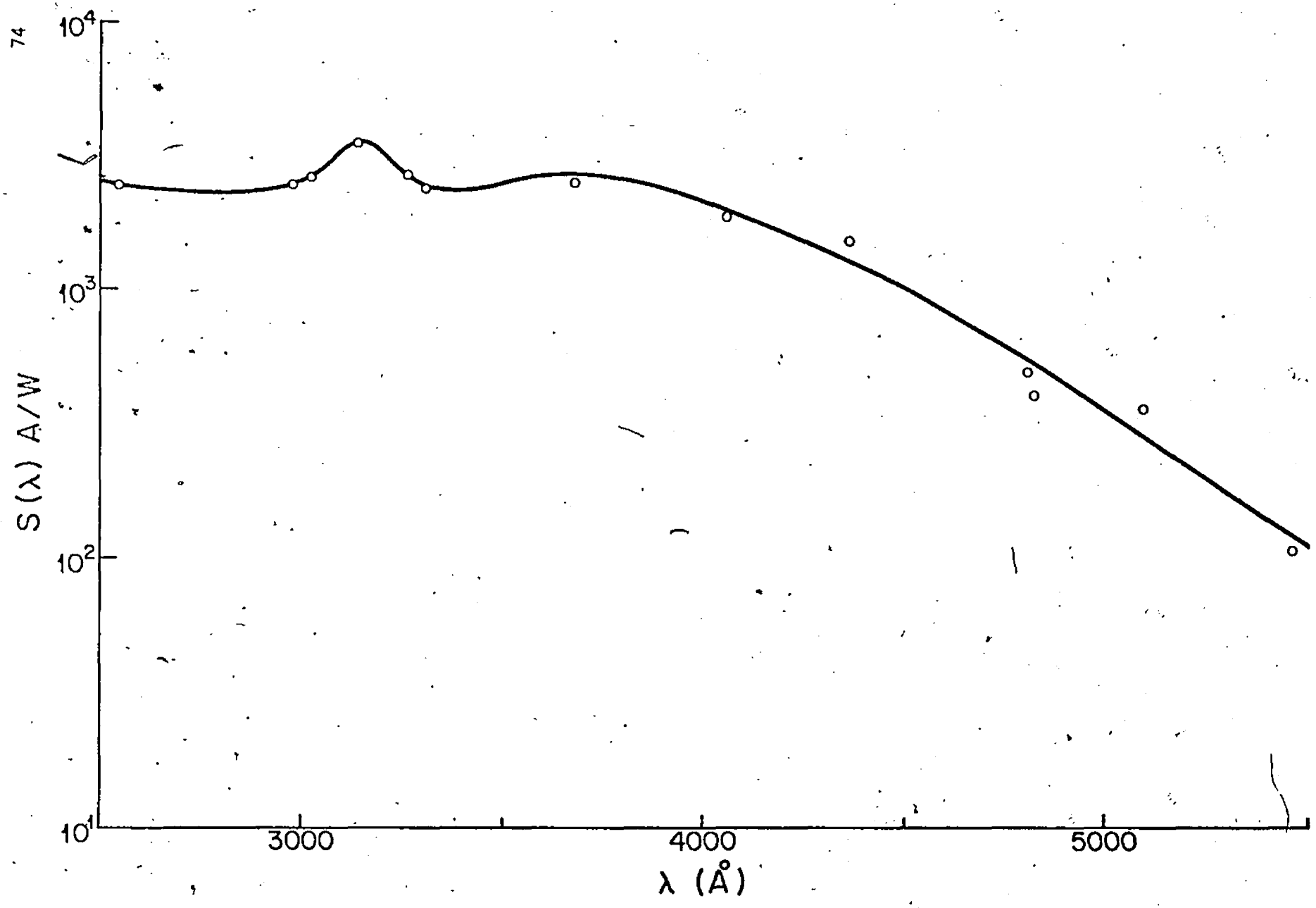

Fig. 8: Apparatus for measuring spectral response of photomultiplier showing enlarged front view of slide-holder.

M - monochromator
TP - thermopile
$R_1$ - milli-microvoltmeter
$R_2$ - Keithley picoammeter
B - milli-microvoltmeter

resulting response, in microvolts, was registered by a Keithley model 149 milli-microvoltmeter. In the second position, the same light flux was transmitted through the aperture and was brought to focus at the photocathode of the photomultiplier tube. The photomultiplier response, corresponding to this energy flux, was measured by the Keithley model 417 electrometer-amplifier. The results of this calibration are shown in figure (9).

The EMR photomultiplier, which was to be used to check the intensity measurements obtained by the EMI photomultiplier tube, was calibrated by the manufacturer.

Fig. 9 : Spectral response of EMI photomultiplier tube



## EXPERIMENTAL PROCEDURE

The fluorescence cell was thoroughly cleaned with an acid solution composed of four parts HCl and one part $HNO_3$. The cell was flushed several times with distilled water and finally rinsed with alcohol. The thallium metal (about 2gm) was sealed into the appropriate sidearm of the cell. Mercury was prepared using the distillation manifold shown in figure (10). The manifold was attached to the vacuum system and baked under vacuum at 180°C for several days. A charge of triply distilled mercury* was introduced into the lowest ampoule through the fill tube which was then sealed. The mercury was distilled under vacuum from ampoule to ampoule, each time leaving behind a small amount of residue which was sealed off and removed from the manifold before continuing the distillation process. The final ampoule containing the clean mercury was transferred to the mercury reservoir at the base of the second sidearm. The mercury was prevented from entering the cell, until required, by a break-seal at the head of the reservoir, which could be opened under vacuum. The cell was then inserted into the oven, aligned, and connected to the vacuum system. To remove water vapour and other contaminants, the oven temperature was raised to about 250°C and the cell was baked under vacuum for several days until a final pressure of the order of $10^{-8}$ torr was attained. Thermocouples were secured to the cell body close to the front windows and near the rear window. Additional thermocouples were placed along the length of the thallium sidearm.

The temperature of the oven was brought up slowly and allowed to

* supplied by A.D. MacKay Co.

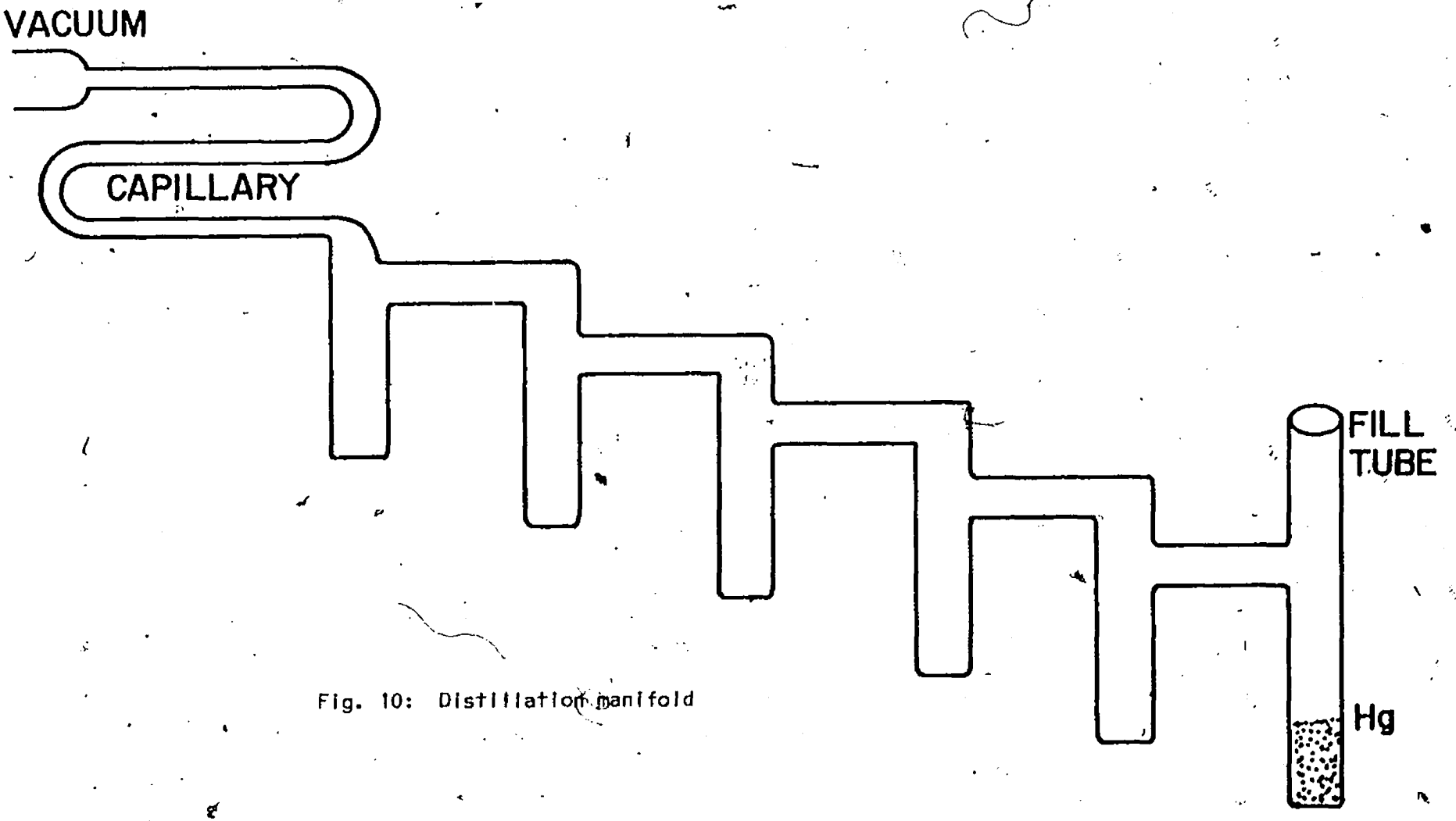



Fig. 10: Distillation manifold

stabilize with the thallium sidearm temperature in the range 430°C - 580°C. The corresponding pressure of the thallium vapour in the cell was determined by this sidearm temperature and was calculated from the formula given by Nesmeyanov[68]. The exciting beam from the mercury r-f electrodless discharge lamp was first passed through a mercury interference filter with a peak transmission of 10 percent at 2537Å, and then brought to a focus just inside the entrance window of the cell at a point about 1mm from the observation window. The mercury reservoir was opened and a small amount of mercury vapour was admitted into the cell by heating the reservoir to about 40°C - 50°C. The intensity of the Hg 2537Å resonance radiation emitted from the cell was continuously monitored during the admission of the mercury vapour. The density of mercury in the cell was stabilized when the intensity of the Hg 2537Å fluorescence reached a maximum.

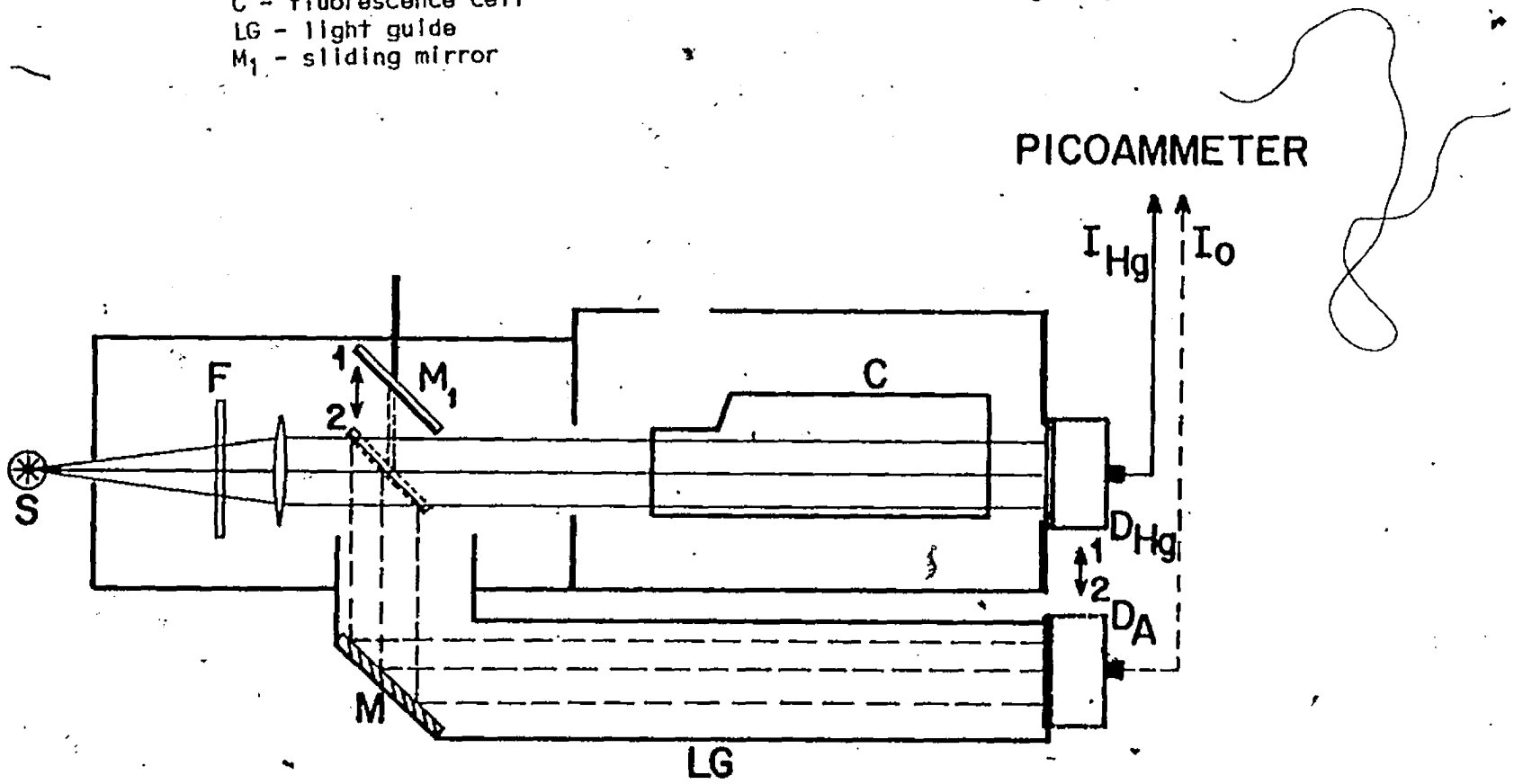
The fluorescent radiation emitted from the cell was focused onto the entrance slit of the monochromator which automatically scanned the thallium fluorescent spectrum at a rate of 10Å/min . A typical run lasted for several hours, and although the intensity of the mercury resonance radiation remained relatively stable throughout each run, it was monitored frequently to avoid the introduction of experimental uncertainty into the evaluation of the energy transfer cross sections. All intensities were detected by the photomultiplier (cooled to liquid nitrogen temperature) and were recorded by the Hewlett-Packard strip-chart recorder.

Since the mercury admitted to the fluorescence cell had to pass through a long capillary, and since there was a large thermal gradient between the reservoir and the cell, the pressure-temperature formula given by Nesmeyanov could not be used to determine the pressure of

mercury in the cell. An auxiliary experiment was performed which allowed the pressure of mercury in the fluorescence cell to be determined. The experimental arrangement is shown in figure (11). A two position sliding mirror assembly was mounted between the lens and the cell. In the first position the Hg 2537Å radiation was allowed to enter the cell which was void of any mercury vapour in the initial case. In the second position the beam was reflected down the length of a light guide. The intensities (and their ratio) corresponding to these two positions were recorded by the same photodiode (ITT F4000) attached to a sliding assembly at the rear of the oven. Mercury was next placed in the sidearm normally used for the thallium charge, and was frozen to liquid nitrogen temperature. At this temperature the vapour pressure of mercury was essentially zero. The cell was pumped continuously until all mercury vapour that had escaped into the cell body during the admission of the mercury into the sidearm was removed, as indicated by the ratio of light intensities through the cell and through the light guide. By stabilizing the temperature of the mercury sidearm at various temperatures in the range -20°C - +60°C, various mercury pressures in the cell could be obtained. To obtain temperatures in the range -20°C - 0°C several anhydrous salts were used in an eutectic mixture with ice (see Appendix (14)). Since the sidearm bore was large (14mm) and the distance from the reservoir to the cell body was short (8mm), the flow of mercury to the cell was unrestricted and the pressure-temperature formula of Nesmeyanov could be used. For each sidearm temperature employed, the intensity, $I_{Hg}$, of light transmitted through the cell and the intensity, $I_o$, of light through the light guide was determined. A plot of the ratio $I_o/I_{Hg}$ as a function of the mercury density is shown in figure (12). The curve was formed over several runs and was found to be reproducible within 10 percent. During the sensitized fluorescence experiments,

Fig. 11: Experimental arrangement used to determine mercury density in the fluorescence cell

S - source of Hg 2537Å resonance radiation
F - 2537Å filter
M - mirror
C - fluorescence cell
LG - light guide
$M_1$ - sliding mirror
$D_{Hg}$ - photodiode detecting light through cell
$D_A$ - photodiode detecting light through light guide



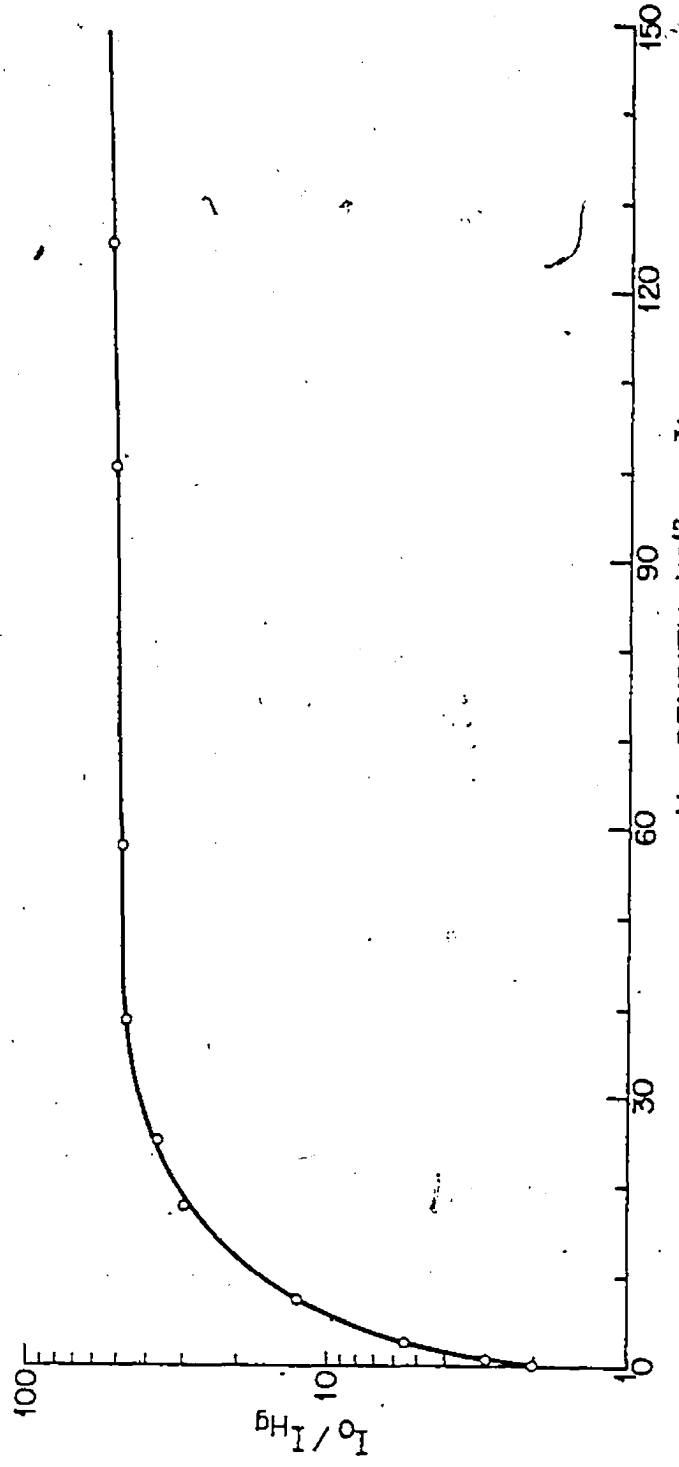



Fig. 12: Intensity variation of mercury 2537Å resonance radiation transmitted through the cell as a function of the mercury vapour density

the density of mercury in the cell at any given time could be determined by comparing the intensity of the Hg 2537Å light being transmitted through the vapour to that being transmitted down the light guide. This calibration curve should remain valid when thallium vapour is also present, since there was no indication that amalgams of mercury and thallium were formed, under the experimental conditions employed, which could alter the shape of the curve.

The reabsorption of the mercury and thallium resonance fluorescence by the vapour mixture must be taken into account when determining the collisional excitation energy transfer cross sections. It has been found previously[69] that, for partial pressures of mercury of the order of $10^{-5}$ torr and the experimental arrangement employed here, the reabsoption of mercury resonance radiation can be disregarded. It remained to find the extent of reabsorption for the thallium resonance fluorescence. Pure thallium vapour, contained in the cell and stabilized at a pressure corresponding to that employed in the actual experiment (of the order of $10^{-5}$ torr), was radiated with Tl 3776Å resonance radiation emitted from the filtered Osram lamp source. The exciting beam was passed through a narrow slit (0.1mm wide) and was focused by means of an adjustable lens assembly just inside the cell at a distance $d_o$, (a distance of about 0.5mm), from the observation window. The intensity, $I_o$, of the resonance radiation was measured for focusing at this point. At such a focal point the optical path through the vapour was restricted to about 1mm. By means of the calibrated adjustment on the lens assembly, the distance from the observation window could be stepwise increased. The intensity, I, of the resonance radiation emitted from the vapour was measured for each such increment. The ratio $I/I_o$ was determined and plotted as a function of the distance

from the observation window. This plot is depicted in figure (13). By extrapolating this curve to the $I/I_o$ axis one can determine the intensity of the resonance line in the absence of reabsorption. Comparing this value to that of the intensity found at a distance of 0.5mm and 1mm, which represent the distances used in the actual experiment, it is evident that the reabsorption of the thallium resonance fluorescence amounts to only about 7 percent and 13 percent for the two positions, respectively.

In studying the quenching effects of $N_2$ molecules on the thallium sensitized fluorescence the same experimental arrangement was used. The exciting mercury resonance radiation was made incident on the tertiary system Hg-Tl-$N_2$, at nitrogen pressures between 0.2 torr and 8 torr. The intensity of each thallium fluorescent component being emitted from the cell was first measured in the absence of nitrogen. Controlled quantities of nitrogen were admitted into the cell and the system was allowed to return to equilibrium. Several scans of the thallium fluorescence were made and the intensity of each spectral component was recorded on the strip-chart recorder for each nitrogen pressure used. Several complete experimental runs, using different cells, were carried out for a range of thallium densities between about $10^{11}cm^{-3}$ and $10^{13}cm^{-3}$. The mercury density was kept constant at about $10^{11}cm^{-3}$. The stability of the mercury density was frequently checked by monitoring the intensity of the Hg 2537Å resonance fluorescence emitted from the cell.

The partial pressure of nitrogen being admitted into the cell was found by first measuring the pressure in mm of #704 diffusion pump oil contained in the manometer attached to the vacuum station. This reading was then converted to a pressure in torr by means of the hydrostatic equation

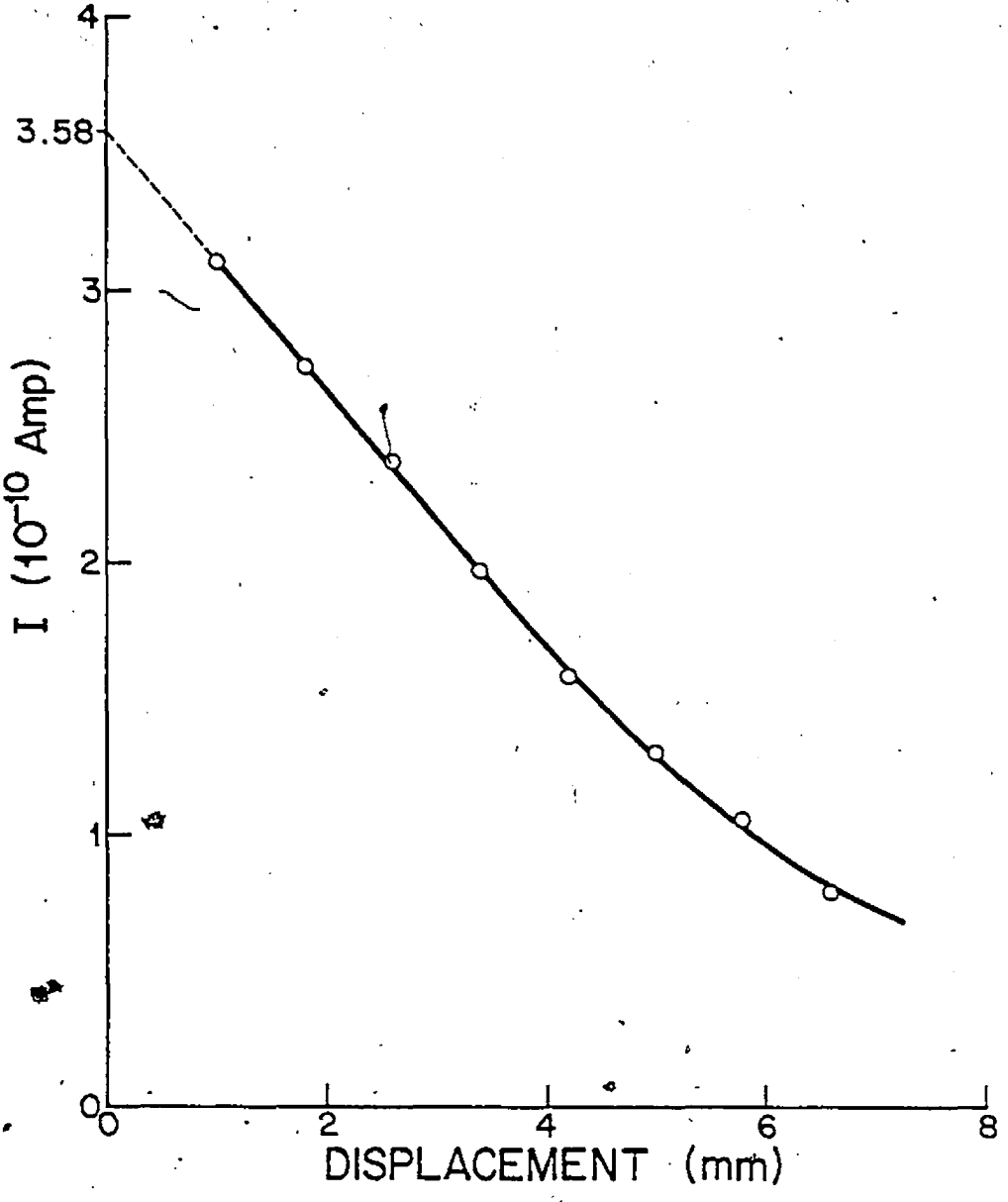



Fig. 13: Intensity of the Tl 3776Å resonance fluorescence as a function of the displacement of the slit image from the observation window

$$P_{Hg} = \frac{d_{oil}}{d_{Hg}} P_{oil}$$

where $d_{oil}$ is the density of #704 pump oil (1.05gm/cm$^3$) and $d_{Hg}$ is the density of mercury (13.54gm/cm$^3$). $P_{oil}$ is the height of the #704 pump oil in the manometer and $P_{Hg}$ is the corresponding height of an equivalent mercury column at room temperature. The nitrogen partial pressure must be corrected for thermal transpiration effects between the cell and the vacuum system since the thermal gradient between these two regions is very large (about500$^{\circ}$C) and the two regions are connected by a long capillary. The pressure in the cell is related to the pressure in the manometer, (at room temperature), by the equation

$$P_{cell} = \sqrt{\frac{T_{cell}}{T_{room}}} P_{man}$$

where $T_{cell}$ is the temperature of the cell in degrees Kelvin and $T_{room}$ is the room temperature in degrees Kelvin (see Appendix 15).

In order to verify that the observed quenching cross sections for the thallium states are due completely to the presence of the nitrogen molecules, and that no other apparent quenching processes related to the metal-metal collisional excitation energy transfer phenomenon were influencing the cross sections, the effect of $N_2$ molecules on the fluorescence emitted from the Tl-$N_2$ vapour was investigated. We investigated the quenching action of $N_2$ molecules on the Tl($7^2S_{1/2}$) resonance state which could be directly populated by irradiating the Tl-$N_2$ mixture with the Tl 3776Å resonance radiation. Light emitted from the thallium Osram lamp source was first passed through an interference filter with a peak transmission of 21 percent at 3776Å and, as before, was

focused inside a new clean cell containing only pure thallium in its sidearm. The oven temperature was brought up slowly and allowed to stabilize with a sidearm temperature of about 530°C, which corresponds to a thallium density of about $6 \times 10^{12} cm^{-3}$ . The resonance fluorescence emitted by the Tl-$N_2$ mixture was focused onto the entrance slit of the monochromator which alternately scanned the two resonance components at 3776Å and 5352Å . The intensities of these spectral components were first measured in the absence of $N_2$ molecules. Successive amounts of nitrogen, in the range 0.2 torr - 8 torr, were admitted into the cell and the intensities of the resonance fluorescent components were recorded for each nitrogen pressure used. The quenching cross section for the $Tl(7^2S_{1/2})$ resonance state obtained in this manner could be directly compared with the cross section obtained for the resonance state populated by the collisional excitation energy transfer from excited mercury atoms.

## EXPERIMENTAL RESULTS AND DISCUSSION

### (1.0) Energy Transfer Cross Sections

Before proceeding with a detailed discussion of the results, we first point out one major source of disagreement between our findings and those of several other authors working with the binary metal vapour system comprised of excited mercury atoms and ground state thallium atoms. Kraulinya and Lezdin[16] and Anderson[23], working at temperatures between 650°C and 850°C, report the appearance of sensitized fluorescent components originating from the Tl($8^2D_{3/2,5/2}$, $7^2D_{3/2,5/2}$, $9^2S_{1/2}$) states. In this investigation, where the sensitivity of the detection equipment was superior to that employed by Anderson, we were unable to detect radiative transitions from these levels which lie above the Hg($6^3P_1$) state. If these components were present in the thallium sensitized fluorescence, their intensities were well below those which our instruments were able to detect. Using the current supression device on the Keithley pico-ammeter, it was possible to detect intensity ratios down to about $10^{-7}$. We were able to detect the spectral components originating from the Tl($7^2S_{1/2}$, $8^2S_{1/2}$, $6^2D_{3/2,5/2}$) states although it was not possible to completely resolve the Tl 3520Å and Tl 3530Å spectral components resulting from the $6^2P_{3/2} - 6^2D_{3/2}$ and $6^2P_{3/2} - 6^2D_{5/2}$ transitions, respectively. The spectral components corresponding to transitions from the Tl($6^2D_{3/2,5/2}$) states to the Tl($7^2P_{1/2,3/2}$) states and from the Tl($7^2P_{1/2,3/2}$) states to the Tl($7^2S_{1/2}$) state could not be detected by our equipment since these spectral components are in the infrared region which is beyond the spectral response range of the photomultipliers used in this investigation, both having S-20 photocathodes. The sensitized fluorescent components observed here are in agreement with those detected by Hudson and Curnutte[17], who also were unable to detect

radiative emissions from thallium states above the $Hg(6^3P_1)$ level at thallium densities comparable to those used by the other authors.

Absolute intensities of the thallium fluorescent spectral components and the mercury resonance radiation at 2537Å were used to obtain the excitation energy transfer cross sections shown in table (1) which are compared to those values obtained by Kraulinya and Lezdin, and by Hudson and Curnutte. In determining these cross sections, corrections to the absolute intensity measurements were made to account for the reabsorption of the thallium resonance fluorescence, (which was determined to be less than 10 percent), and for variations in the spectral response characteristics of the monochromator and photomultiplier tubes at the different wave lengths encountered in the fluorescent spectrum. Further corrections were made for the absorption characteristics of the quartz optical system at the various wave lengths. In this latter correction we have also accounted for variations in the quartz absorption features that occur at higher temperatures as found by Eckstein and Selvart[70]. Both photomultiplier tubes were used to determine the cross sections. The results from both tubes were completely consisfent, indicating that the calibration of the tubes with respect to absolute intensity measurements was reliable.

In general, the energy transfer cross section $Q_{oj}$ associated with the $j^{th}$ excited thallium state is related to the intensity of radiative emissions, $I_{ij}$, from the thallium state j to some lower state i, and to the population density, N(Hg*), of the $Hg(6^3P_1)$ state as indicated by equation (13). However, in a fashion similar to equation (10), the density of excited mercury atoms may be expressed in terms of the observed absolute intensity of the Hg 2537Å resonance radiation re-emitted from the cell as

TABLE 1: Cross Sections for $Hg(6^3P_1)$→Tl Excitation Energy Transfer

| Collision Process | ΔE (eV) | ΔE ($cm^{-1}$) | COLLISION CROSS SECTION: This Investigation Q(Å²) | This Investigation T(°C) | Kraulinya and Lezdin Q(Å²) | Kraulinya and Lezdin T(°C) | Hudson and Curnutte Q(Å²) | Hudson and Curnutte T(°C) |
|---|---|---|---|---|---|---|---|---|
| $Hg(6^3P_1)$→$Tl(8^2S_{1/2})$ | -0.083 | - 666 | 3.0±0.6 | 437 | 33 | 660 | 2.2 | 800 |
| | | | 3.0±0.6 | 542 | 1.5 | 800 | 1.3 | 900 |
| $Hg(6^3P_1)$→$Tl(6^2D_{5/2})$ | -0.40 | - 3212 | 0.3±0.06 | 437 | 55 | 660 | 9.4 | 800 |
| | | | 0.3±0.06 | 542 | 33 | 800 | 8.5 | 900 |
| $Hg(6^3P_1)$→$Tl(7^2P_{3/2})$ | -0.50 | - 4251 | | | | | 17.6 | 800 |
| | | | | | | | 23.3 | 900 |
| $Hg(6^3P_1)$→$Tl(7^2P_{1/2})$ | -0.63 | - 5352 | | | | | | |
| $Hg(6^3P_1)$→$Tl(7^2S_{1/2})$ | -1.58 | -12935 | 0.05±0.03 | 542 | 155 | 660 | | |
| | | | | | 150 | 800 | | |
| $Hg(6^3P_1)$→$Tl(7^2D_{3/2})$ | +0.32 | + 2599 | | | 6.8 | 660 | | |
| | | | | | 3.3 | 800 | | |
| $Hg(6^3P_1)$→$Tl(7^2D_{5/2})$ | +0.33 | + 2637 | | | 1.5 | 660 | | |
| | | | | | 2.3 | 800 | | |

TABLE 1: Cross Sections for $Hg(6^3P_1) \rightarrow Tl$ Excitation Energy Transfer

| Collision Process | ΔE (eV) | ΔE ($cm^{-1}$) | COLLISION CROSS SECTION: This Investigation Q($Å^2$) | This Investigation T(°C) | Kraulinya and Lezdin Q($Å^2$) | Kraulinya and Lezdin T(°C) | Hudson and Curnutte Q($Å^2$) | Hudson and Curnutte T(°C) |
|---|---|---|---|---|---|---|---|---|
| $Hg(6^3P_1)$ $Tl(9^2S_{1/2})$ | +0.45 | + 3754 | | | 9<br>0.27 | 660<br>800 | | |
| $Hg(6^3P_1)$ $Tl(8^2D_{3/2,5/2})$ | +0.66 | + 5280 | | | 44<br>1.7 | 660<br>800 | | |

$$N(Hg^*) = \frac{I_{2537\text{Å}}^{\circ}}{A_{Hg}\, h\nu_{2537\text{Å}}^{\circ}}$$

where $I_{2537\text{Å}}^{\circ}$ is the absolute intensity of the mercury resonance line, $A_{Hg}$ is the transition probability for the mercury transition $6^1S_o - 6^3P_1$, and $\nu_{2537\text{Å}}^{\circ}$ is the corresponding transition frequency. Hence, the general quenching cross section of the $j^{th}$ excited thallium state may be rewritten in terms of the observable fluorescent intensities as

$$Q_{oj} = \frac{1}{\delta}\left[\frac{I_{ij}\, A_{Hg}\, h\nu_{2537\text{Å}}^{\circ}}{I_{2537\text{Å}}^{\circ}\, A_{ij}\, h\nu_{ij}} \sum_{i=j-1}^{\circ} A_{ij} - \sum_{k=j+1}^{\infty} \frac{N_k(Tl^*)A_{jk}A_{Hg}\, h\nu_{2537\text{Å}}^{\circ}}{I_{2537\text{Å}}^{\circ}}\right] \times \frac{1}{N_o(Tl)\langle v_{rel}\rangle} \qquad (110)$$

where $\delta$ is as defined in equation (13a). The thallium transition probabilities are derived from the orthogonalized relativistic HFS wave functions in the velocity formulation as quoted in Appendix (8). The transition probability, $A_{Hg}$, for the mercury resonance transition is taken to be $8.55 \times 10^6 sec^{-1}$, as determined from the mean radiative lifetime of the $Hg(6^3P_1)$ state calculated by Deech and Baylis[71].

In our present investigation, equation (110) may be greatly simplified. Since we are unable to observe any spectral components originating from thallium states above the $Hg(6^3P_1)$ level, we may assume that the population of the $Tl(8^2S_{1/2})$ and $Tl(6^2D_{3/2,5/2})$ states by cascade transitions from higher thallium levels may be neglected, and the second term in the square brackets of equation (110) may be ignored for these states. The $Tl(7^2S_{1/2})$ state will be affected by cascading from the $Tl(7^2P_{1/2,3/2})$ states which, in turn, are pumped by cascade transitions from the $Tl(8^2S_{1/2})$ and $Tl(6^2D_{3/2,5/2})$ states. Since all these transitions are in the infrared region, no direct measurement of their spectral intensities could be made to correct

the energy trannsfer cross section of the $Tl(7^2S_{1/2})$ state for these cascade effects . However, since the intensity ratio between any two spectral components is directly related to the ratio of the corresponding transition probabilities, it becomes possible to obtain a good estimate of the contribution to the energy transfer cross section of the $Tl(7^2S_{1/2})$ state due to the cascade transitions from the $Tl(7^2P_{1/2,3/2})$ states.

In order to obtain the cross section for the $Tl(7^2S_{1/2})$ state it is necessary to first determine the total population density of the $Tl(7^2P_{1/2,3/2})$ states. These latter states are populated both by direct collisional transfer from the $Hg(6^3P_1)$ atoms and by cascade transitions from the $Tl(8^2S_{1/2})$ and $Tl(6^2D_{3/2,5/2})$ states. According to Franck's empirical rule, which is well supported by recent studies in numerous binary metal vapour systems,[8,9,10,18,19,7] the probability that, during an inelastic collision between an excited and unexcited atom, the second collisional partner will become excited to some higher excited state decreases as the energy defect $\Delta E$ between the excited states of the collison partners increases. Hence, on the basis of these results and since the transition probabilities linking the $Tl(8^2S_{1/2})$ and $Tl(6^2D_{3/2,5/2})$ states with the $Tl(7^2P_{1/2,3/2})$ states are large, we assume that the contribution to the total population density of the $Tl(7^2P_{1/2,3/2})$ states,(which lie relatively far below the $Hg(6^3P_1)$ level),due to the direct collisional energy transfer will be negligible with respect to the pumping of these states by cascading from the $Tl(8^2S_{1/2})$ and $Tl(6^2D_{3/2,5/2})$ states. To determine the contributions to the total population density of the $Tl(7^2P_{1/2,3/2})$ states, we must know the intensities of the transitions from the higher excited states. If we know the intensities corresponding to other observable transitions originating from these higher excited states we can determine the unobservable intensities of the infrared spectral components.

The intensity I' of the infrared component resulting from the transition from one of the upper excited states to the $Tl(7^2P_{1/2(3/2)})$ state is related to the observable intensity I, corresponding to a transition from the same upper state, according to the relation

$$I' = I\frac{\nu' A'}{\nu A} \qquad (111)$$

where use has been made of equation (10) and where $\nu'$ is the transition frequency of the infrared component and A' is its corresponding transition probability, $\nu$ is the frequency of the observable transition of intensity I and A is the associated transition probability. The transition probabilities are taken from Appendix (8). Using these intensities I', the population densities of the $Tl(7^2P_{1/2,3/2})$ states can be determined and finally the cross section of the $Tl(7^2S_{1/2})$ state can be calculated, using equation (110).

It is evident from table (1) that the experimental results of Kraulinya and Lezdin give no indication of a resonance effect between the energy transfer cross sections and the corresponding energy defects $\Delta E$ between the $Hg(6^3P_1)$ state and the excited thallium levels. For $\Delta E = -0.083eV$, (corresponding to the $Tl(8^2S_{1/2})$ state), our cross section compares favourably with their value of $1.5 \times 10^{-16} cm^2$ obtained at a temperature of 800°C. However, their value of $33 \times 10^{-16} cm^2$ obtained at a temperature of 660°C is in total disagreement with our value of $3.0 \times 10^{-16} cm^2$ obtained at temperatures of 542°C and 437°C. The cross section for the $Tl(6^2D_{5/2})$ state obtained in this investigation, with $\Delta E = -0.40eV$ is 2 orders of magnitude lower than that obtained by Kraulinya and Lezdin. Their cross section for the $Tl(6^2D_{5/2})$ state is considerably larger than their cross section for the $Tl(8^2S_{1/2})$ state, a result which is in violation of Franck's empirical rule.

In order to explain the appearance of the sensitized fluorescent components originating from thallium states above the $Hg(6^3P_1)$ level, Kraulinya

and Lezdin anticipate the participation of the $Tl(6^2P_{3/2})$ metastable atoms in a process governed by equation (26). They further indicate the participation of some unspecified molecular formation, (most probably taken to mean the mercury-thallium excimer), in populating the excited thallium states which lie above the $Hg(6^3P_1)$ level.

Recently, mercury-thallium excimers have been observed by Drummond and Schlie[72] with molecular bands at 4600Å and 6500Å, but this was at Hg-Tl amalgam densities on the order of $1.5 \times 10^{19} cm^{-3}$ which exceeds the densities used in this investigation by 7 - 8 orders of magnitude. No such molecular bands could be detected in our investigation, and it seems likely that the participation of such a molecular species, as suggested by Kraulinya, is improbable.

Pickett and Anderson[73] have reported lifetimes and self-quenching cross sections for the $Tl(6^2P_{3/2})$ metastable state. Their measurements, performed at 550°C, indicate a lifetime of the order of $10^{-4}$ seconds. However, such a lifetime gives rise to a large diffusion cross section (of the order of $10^{-14} cm^2$) for quenching collisions with the cell walls. A crude order of magnitude estimate based on the value of $\langle v_{rel} \rangle$ characteristic of our experimental conditions gives rise to a mean time of about $10^{-6}$ seconds required for the $Tl(6^2P_{3/2})$ atoms to migrate across the 1mm distance between the fluorescing region and the cell walls. This time is considerably less than the lifetime of the thallium metastable state and hence the participation of these metastables in the energy transfer process, as defined by equation (26), may be neglected.

The results of Hudson and Curnutte are difficult to assess in relation to our cross sections since they have failed to define the meaning of $\Delta E$. In their paper they determine cross sections for a total energy transfer

from combined $Hg(6^3P_1)$ and $Hg(6^3P_0)$ states to the thallium atom.

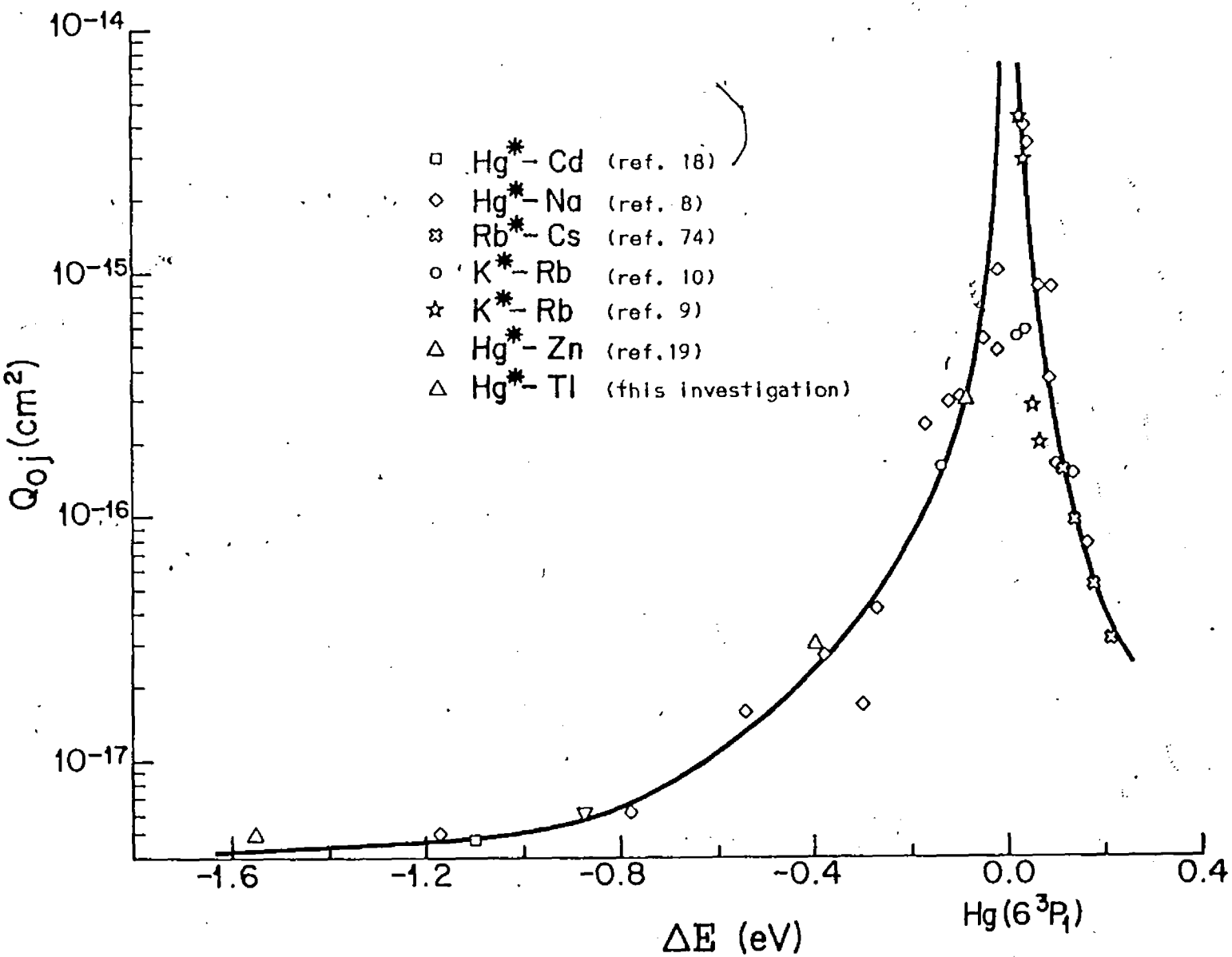
The energy transfer cross sections, as determined by the methods of this investigation, are plotted on the general resonance curve (shown in figure (14)) that has been generated from cross sections measured in several experiments using various metal-metal systems at this University[8,9,18,19,74]. It can be seen that the thallium values fit well to the established trends. Since the energy transfer cross sections are also dependent on the relative velocity of the colliding partners, one might question the validity of comparing the cross sections from the different binary metal vapour systems on the same resonance curve. However, the mean relative thermal velocities for all experimental data are of the same order of magnitude, hence a comparison of the respective cross sections on a common resonance curve is not unjustified.

The fact that all cross sections for the various systems studied exhibit a common dependence of $\Delta E$ may be regarded as a significant indication that excitation energy transfer in binary metal vapour systems proceeds by a single mechanism. In particular, the results of this investigation indicate that the energy transfer from excited mercury atoms to ground state thallium atoms proceeds by way of pure binary collisions as defined by equation (25), and does not require the participation of HgTl excimers, mercury molecular formations, or the metastable $Tl(6^2P_{3/2})$ atoms at the temperatures used here. However, it may be possible that at higher mercury and thallium densities some of these other mechanisms leading to the population of higher quantum states in thallium may become significantly prevalent so as to influence the now apparent trends.

(2.0) Quenching Cross Sections

As we have mentioned previously, it is necessary to verify that

Fig. 14: General "resonance curve" showing dependence of excitation transfer cross sections between dissimilar atoms on ΔE



measured quenching cross sections obtained under sensitized fluorescence remain independent of the metal-metal collisional excitation transfer process. In confirming this independence we compare the quenching cross section of the resonance state found under the conditions of sensitized fluorescence with that determined from the direct optical excitation of the $Tl(7^2S_{1/2})$ state in the $Tl-N_2$ mixture.

Direct optical excitation of the $Tl(7^2S_{1/2})$ resonance state was accomplished by radiating the $Tl-N_2$ mixture with the Tl 3776Å resonance radiation emitted from the filtered Osram lamp source. The subsequent depopulation of this resonance state via the transitions $6^2P_{1/2} - 7^2S_{1/2}$ and $6^2P_{3/2} - 7^2S_{1/2}$, which give rise to the emission of the Tl 3776Å and Tl 5352Å resonance fluorescence, could be monitored as a function of increasing nitrogen density. The results of the quenching action of nitrogen molecules on the thallium resonance state are shown in tables (2) and (3) as obtained by monitoring the Tl 5352Å and Tl 3776Å emissions, respectively. In these and subsequent tables, we use $I_o$ to denote the fluorescent intensity at zero nitrogen density and $I_{N_2}$ to denote the fluorescent intensities at higher nitrogen densities. Corresponding Stern-Volmer plots are depicted in figures (15) and (16). The slope of such curves is given as $(Q\ \tau_{7^2S_{1/2}} \langle v_{rel} \rangle)$, where Q is the quenching cross section to be determined, $\langle v_{rel} \rangle$ is the relative thermal velocity of the colliding thallium atoms and nitrogen molecules, and $\tau_{7^2S_{1/2}}$ is the lifetime of the resonance state. As before we use our theoretical values for this lifetime. We calculate the quenching cross section of the thallium resonance state from the slopes of the Stern-Volmer plots in figures (15) and (16) to be $11.4Å^2$ and $10.3Å^2$, respectively.

In the binary metal vapour system comprised of excited mercury atoms

TABLE 2: Quenching of the $Tl(7^2S_{1/2})$ state as determined by monitoring the Tl 5352Å resonance radiation emitted from the Tl-$N_2$ mixture.

$\langle v_{rel} \rangle = 8.45 \times 10^4 cm/sec$

| $N_2$ Pressure (torr) | $N_2$ Density ($10^{16} cm^{-3}$) | $I_o/I_{N_2}$ |
|---|---|---|
| 0.00 | 0.00 | 1.000 |
| 0.24 | 0.48 | 1.015 |
| 0.64 | 1.27 | 1.029 |
| 0.72 | 1.42 | 1.032 |
| 0.88 | 1.74 | 1.038 |
| 0.96 | 1.90 | 1.046 |
| 1.20 | 2.30 | 1.016 |
| 1.24 | 2.37 | 1.017 |
| 1.36 | 2.69 | 1.026 |
| 1.52 | 2.91 | 1.032 |
| 1.60 | 3.16 | 1.051 |
| 1.68 | 3.32 | 1.052 |
| 1.88 | 3.60 | 1.033 |
| 1.92 | 3.80 | 1.052 |
| 2.12 | 4.06 | 1.039 |
| 2.40 | 4.75 | 1.061 |
| 2.56 | 4.90 | 1.046 |
| 3.12 | 5.97 | 1.060 |
| 3.32 | 6.57 | 1.078 |
| 5.00 | 9.89 | 1.110 |

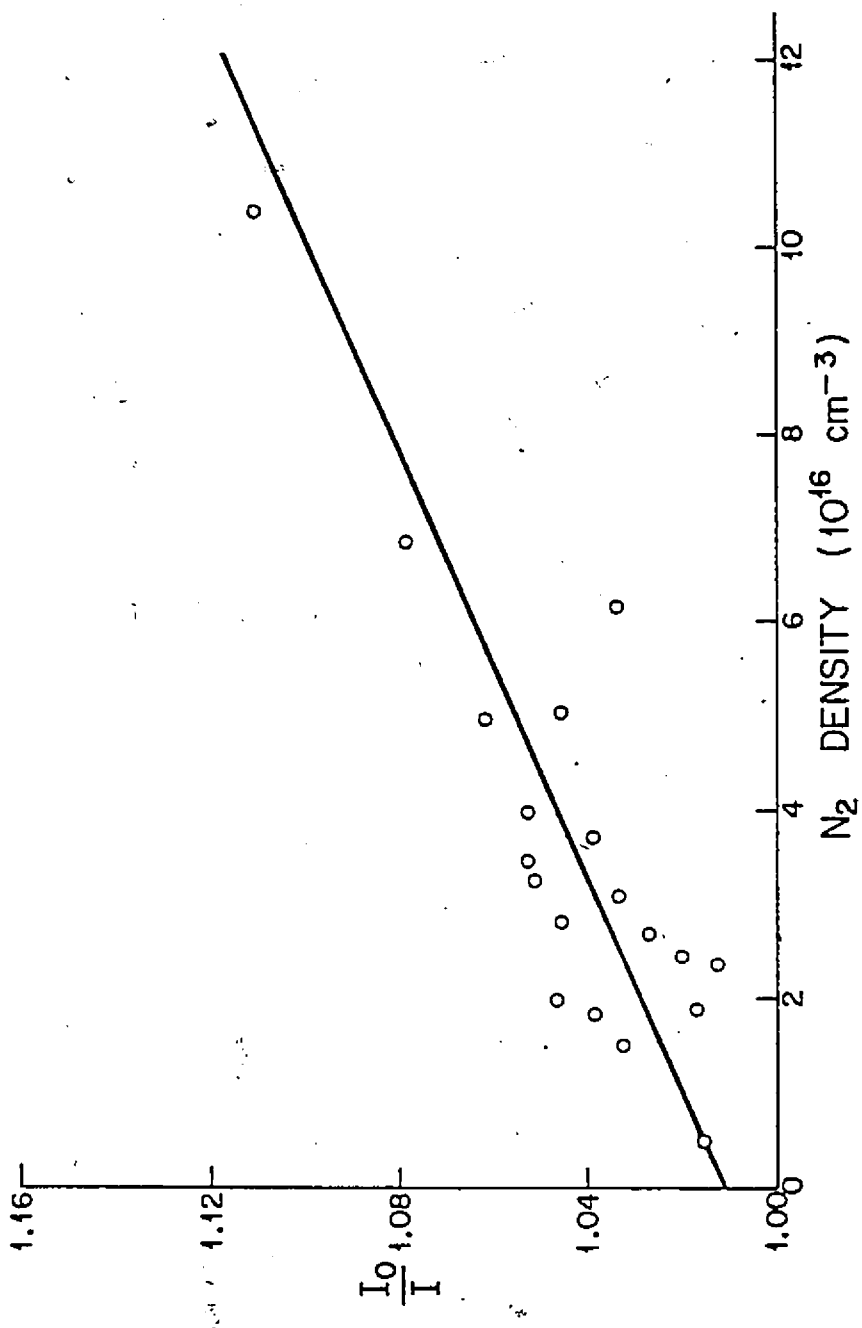



Fig. 15: Stern-Volmer plot for data obtained by monitoring the TI 5352Å resonance radiation emitted from the TI-$N_2$ mixture

TABLE 3: Quenching of the $Tl(7^2S_{1/2})$ state as determined by monitoring the Tl3776Å resonance radiation emitted from the $Tl-N_2$ mixture.

$\langle v_{rel} \rangle = 8.28 \times 10^4 cm/sec$

| $N_2$ Pressure (torr) | $N_2$ Density ($10^{16} cm^{-3}$) | $I_o/I_{N_2}$ |
|---|---|---|
| 0.0 | 0.0 | 1.000 |
| 0.24 | 0.48 | 1.025 |
| 0.64 | 1.27 | 1.035 |
| 0.80 | 1.59 | 1.038 |
| 1.28 | 2.55 | 1.028 |
| 1.32 | 2.63 | 1.031 |
| 1.36 | 2.69 | 1.039 |
| 1.52 | 3.01 | 1.040 |
| 1.60 | 3.17 | 1.048 |
| 1.76 | 3.51 | 1.035 |
| 1.92 | 3.83 | 1.042 |
| 2.12 | 4.20 | 1.056 |
| 2.16 | 4.28 | 1.058 |
| 2.80 | 5.55 | 1.060 |
| 2.84 | 5.66 | 1.060 |
| 3.28 | 6.54 | 1.061 |
| 4.28 | 8.48 | 1.109 |
| 4.36 | 8.69 | 1.079 |
| 5.68 | 11.30 | 1.111 |

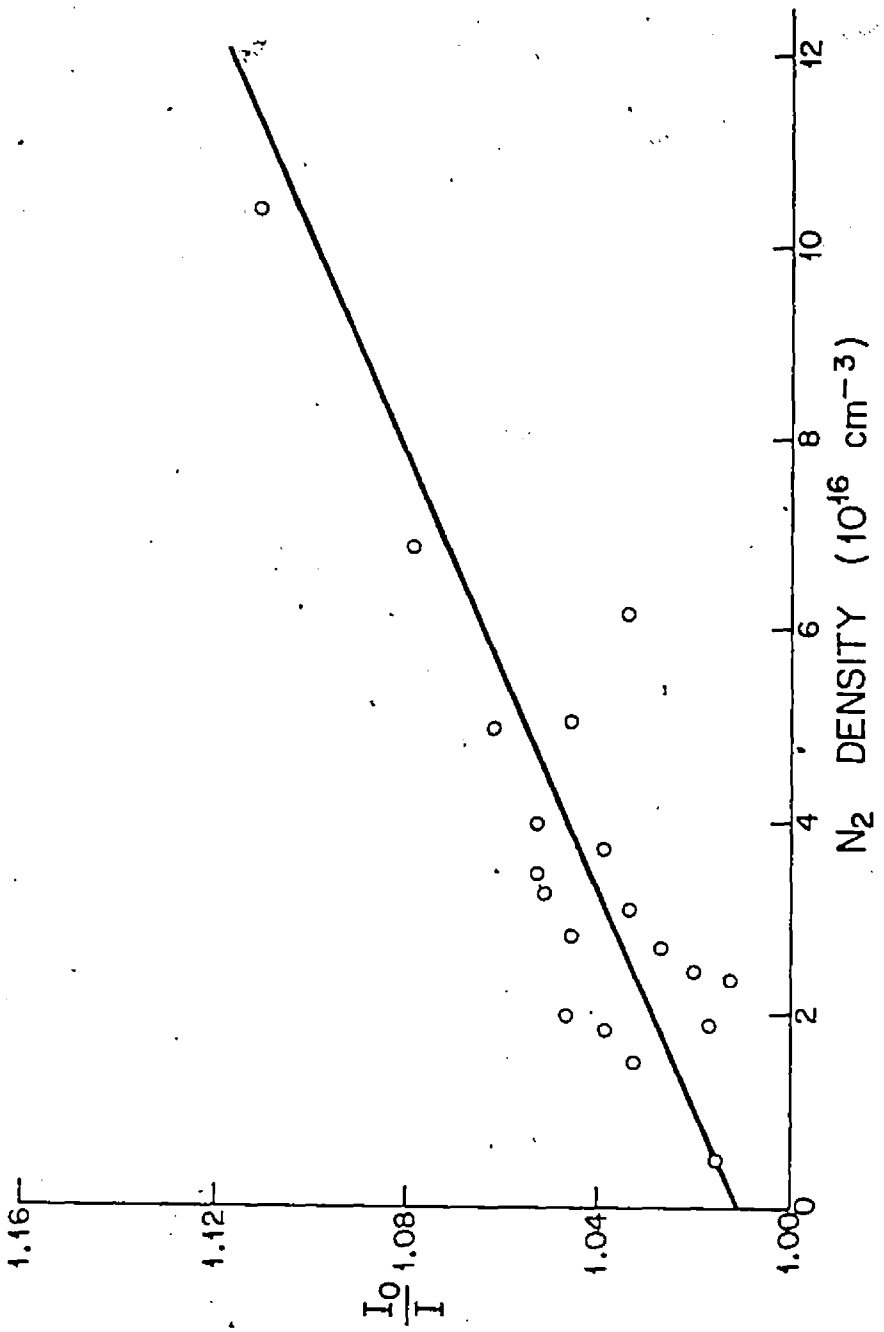



Fig. 16: Stern-Volmer plot for data obtained by monitoring the TI 3776Å resonance radiation emitted from the TI-$N_2$ mixture

and ground state thallium atoms the thallium resonance state is populated by the transfer of the mercury excitation energy to the ground state thallium atoms. As indicated previously, this process may by defined by the equation

$$Hg(6^3P_1) + Tl(6^2P_{1/2,3/2}) \rightarrow Hg(6^1S_o) + Tl(7^2S_{1/2}) + \Delta E$$

and in the presence of nitrogen molecules the additional process

$$Hg(6^3P_o) + Tl(6^2P_{1/2,3/2}) \rightarrow Hg(6^1S_o) + Tl(7^2S_{1/2}) + \Delta E$$

is also of significance. As in the case of direct optical excitation, the quenching cross section of the thallium resonance state may be determined by monitoring the variations in the intensity of either of the two resonance components as a function of nitrogen density in the tertiary Hg-Tl-$N_2$ system. Data indicating the quenching action of nitrogen molecules on the thallium resonance state, under the conditions of sensitized fluorescence, is displayed in tables (4) and (5) as obtained by monitoring the Tl 5352Å and Tl 3776Å resonance lines, respectively. The corresponding Stern-Volmer plots are shown in figures (17) and (18). In forming these plots from tables (4) and (5) we are concerned only with that portion of the data which reflects the quenching process. Hence, ratios $I^o_{N_2}/I_{N_2}$ are formed, where $I^o_{N_2}$ is the intensity of the thallium fluorescence corresponding to that for which, at a certain nitrogen density, the onset of quenching appears. As before, $I_{N_2}$ is the intensity of the fluorescence at higher nitrogen pressures. We determine the quenching cross section of the thallium resonance state from the slopes of these two plots to be $10.2Å^2$ and $11.1Å^2$, respectively.

Since the cross section for the $Tl(7^2S_{1/2})$ resonance state obtained under direct optical excitation of the Tl-N2 mixture agrees closely with

TABLE 4: Quenching of the $Tl(7^2S_{1/2})$ state as determined by monitoring the Tl 5352Å resonance radiation emitted from the Hg-Tl-$N_2$ mixture.

$\langle v_{rel} \rangle = 8.57 \times 10^4$ cm/sec

| $N_2$ Pressure (torr) | $N_2$ Density ($10^{16}$ $cm^{-3}$) | $I_{N_2}/I_o$ | $I_{N_2}/I_{N_2}$ |
|---|---|---|---|
| 0.0 | 0.0 | 1.000 | |
| 0.80 | 1.54 | 2.000 | |
| 1.52 | 2.92 | 2.427 | |
| 2.64 | 5.07 | 2.571 | 1.000 |
| 3.48 | 6.68 | 2.538 | 1.014 |
| 4.16 | 7.99 | 2.500 | 1.029 |
| 5.60 | 10.80 | 2.445 | 1.053 |
| 6.64 | 12.80 | 2.392 | 1.075 |
| 7.60 | 14.60 | 2.358 | 1.091 |

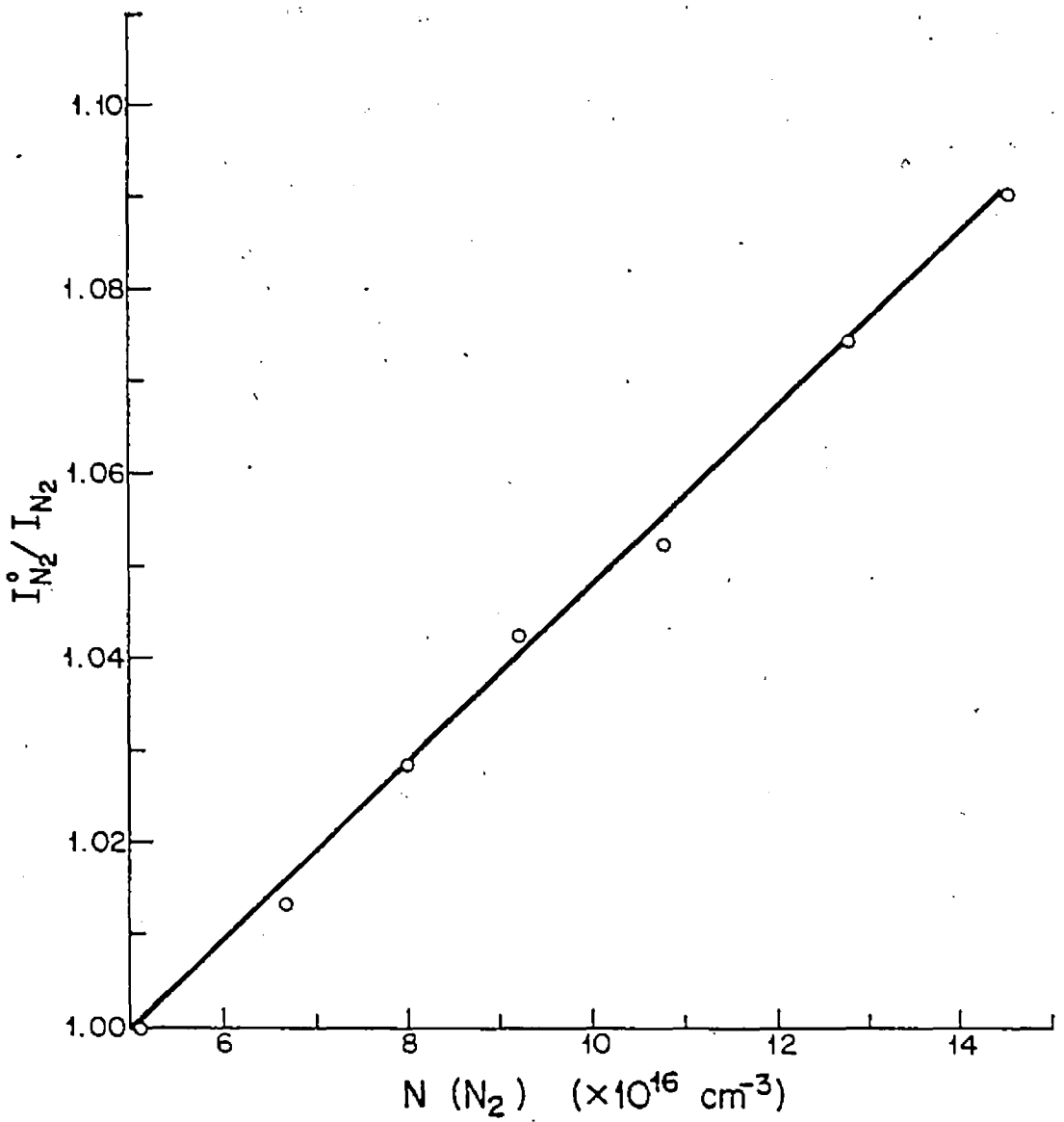



Fig. 17: Stern-Volmer plot for data obtained by monitoring the Tl 5352Å resonance radiation emitted from the Hg-Tl-$N_2$ mixture.

TABLE 5: Quenching of the Tl($7^2S_{1/2}$) state as determined by monitoring the Tl 3776Å resonance radiation emitted from the Hg-Tl-$N_2$ mixture.

$\langle v_{rel} \rangle = 8.57 \times 10^4$ cm/sec

| $N_2$ Pressure (torr) | $N_2$ Density ($10^{16}$ cm$^{-3}$) | $I_{N_2}/I_o$ | $I^o_{N_2}/I_{N_2}$ |
|---|---|---|---|
| 0.0 | 0.0 | 1.00 | |
| 0.80 | 1.54 | 3.571 | |
| 1.52 | 2.92 | 5.556 | |
| 2.64 | 5.07 | 6.667 | 1.000 |
| 3.48 | 6.68 | 6.579 | 1.014 |
| 4.16 | 7.99 | 6.536 | 1.022 |
| 4.80 | 9.22 | 6.410 | 1.037 |
| 5.60 | 10.80 | 6.329 | 1.057 |
| 6.64 | 12.80 | 6.173 | 1.077 |
| 7.60 | 14.60 | 6.061 | 1.098 |

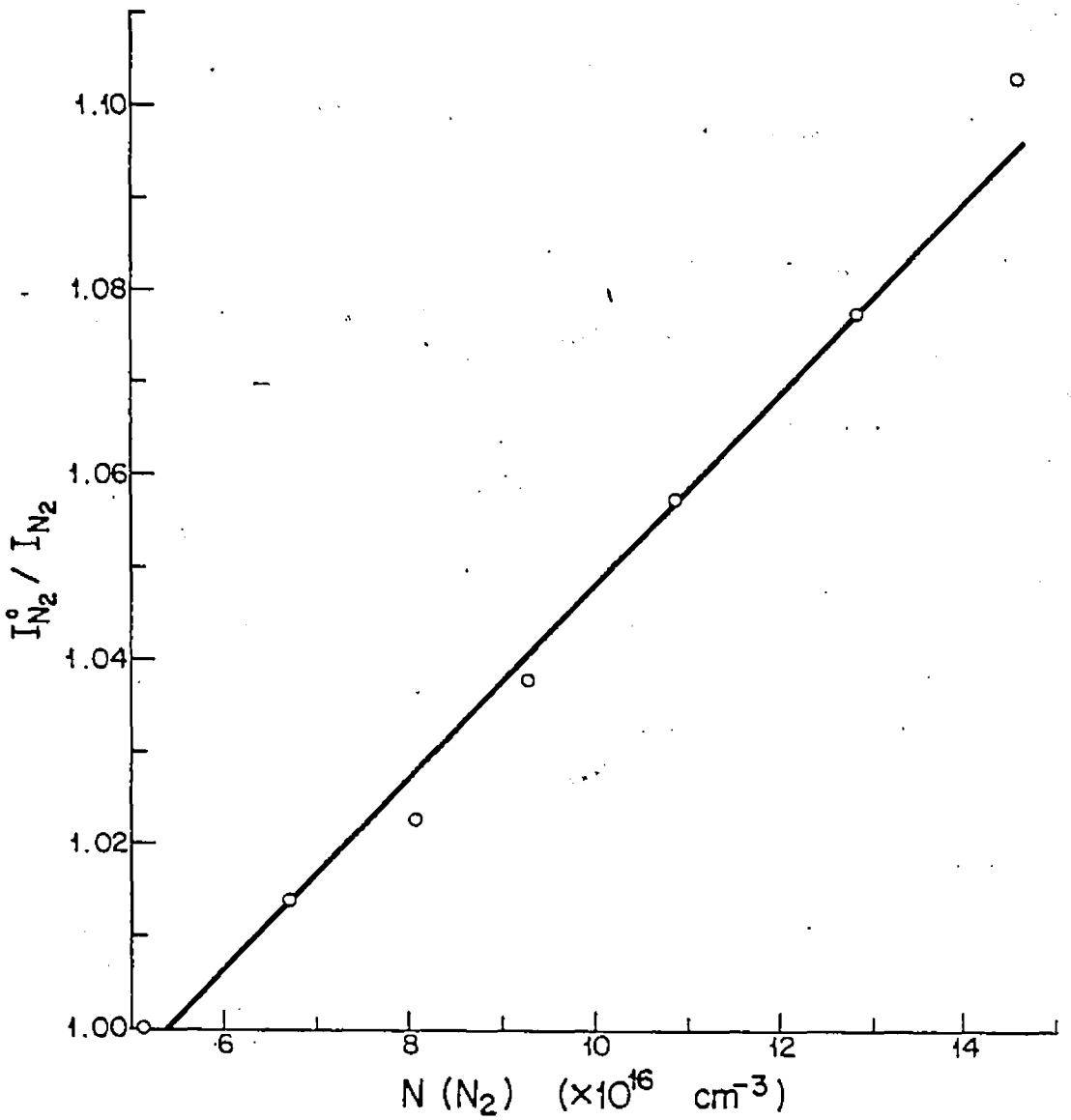



Fig. 18: Stern-Volmer plot for data obtained by monitoring the Tl 3776Å resonance radiation emitted from the Hg-Tl-$N_2$ mixture

that found for the Hg-Tl-$N_2$ system under sensitized fluorescence, one may be assured that the quenching cross section measurements obtained under sensitized fluorescence are not coupled to the inelastic collision process occuring between the excited mercury atoms and the unexcited thallium atoms. In light of this agreement, we may safely proceed to determine the quenching cross sections for other excited thallium states contributing to the sensitized fluorescent spectrum with confidence that the observed reductions in the emitted intensities of the thallium spectral components with increasing nitrogen pressures (up to about 8 torr) are due solely to the pure quenching action of nitrogen molecules present in the mixture.

Figure (19) shows plots of the experimentally determined ratios of sensitized fluorescent intensities $I_{N_2}/I_o$ as a function of the nitrogen density for the Tl 3776Å, Tl 5352Å, Tl 3231Å and Tl 3520Å fluorescent components arising from the transitions $6^2P_{1/2} - 7^2S_{1/2}$, $6^2P_{3/2} - 7^2S_{1/2}$, $6^2P_{3/2} - 8^2S_{1/2}$, $6^2P_{3/2} - 6^2D_{5/2}$, respectively. The relavent data for the intensity ratios $I_{N_2}/I_o$ has been extracted from tables (4), (5), (6), and (7).

Under the experimental conditions employed in this investigation, the atomic densities of both thallium and mercury remain constant during a given experimental run as does their relative thermal velocity. Hence, the variations in the intensity ratios $I_{N_2}/I_o$ with $N_2$ density provide direct information about the variations in the population densities of the excited thallium states resulting both directly and indirectly from inelastic collisions with nitrogen molecules.

From equation (27) it is evident that the effect of $Hg(6^3P_1) - N_2$ collisions is to populate the $Hg(6^3P_o)$ metastable state from which, in turn, this excitation energy can be transferred collisionally to $Tl(6^2P_{1/2})$

Fig. 19: Variations in the intensities of the sensitized flurescent spectral components of thallium as a function of $N_2$ density . Also shown is the absorption curve obtained by Gatzke for the Hg 4047Å spectral component indicating the dependence of the population density of the Hg($6^3P_0$) metastable atoms as a function of nitrogen density. A-Tl 3776Å;B-Tl 5352Å; C-Tl 3520Å; D-Tl 3231Å

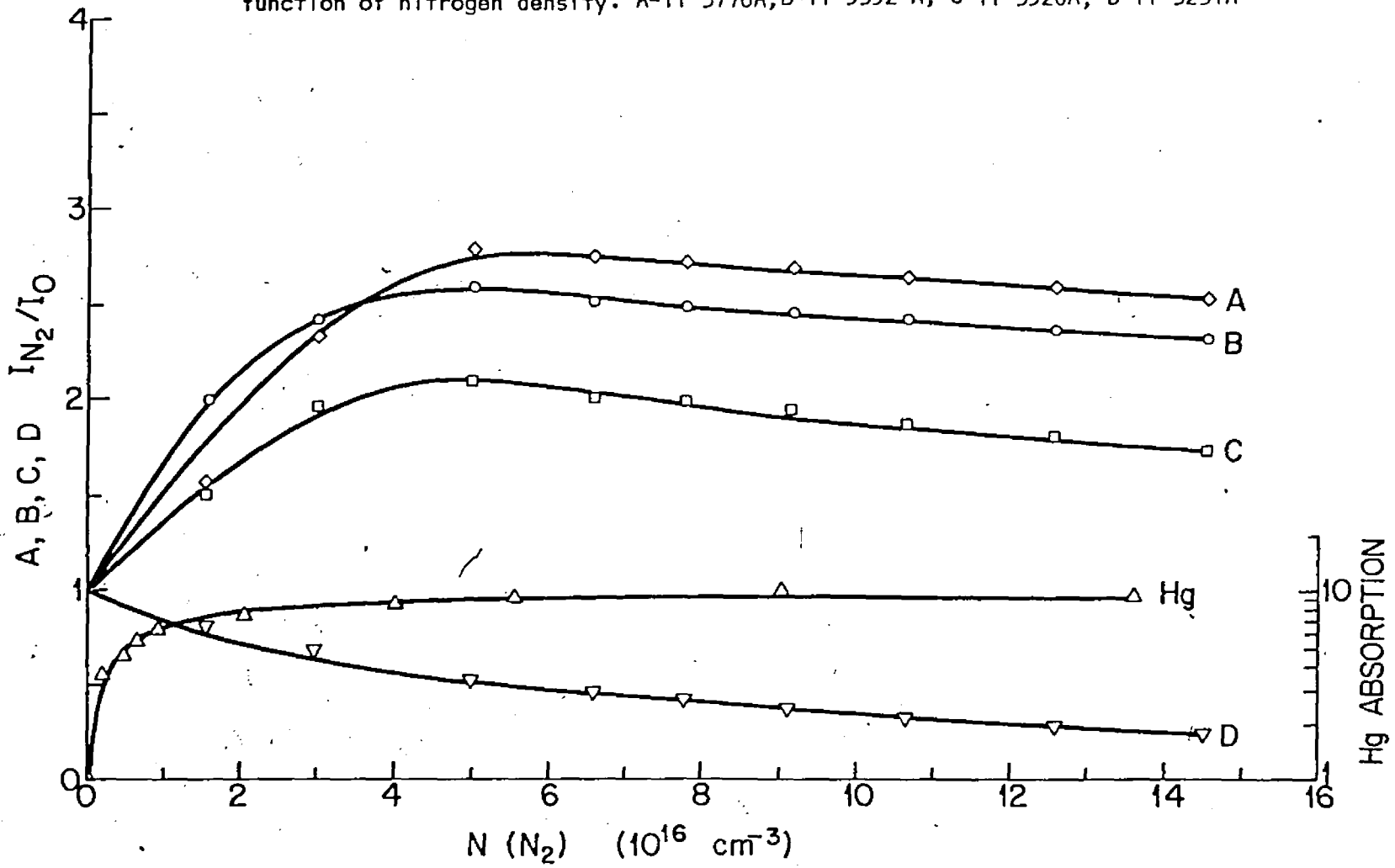


TABLE 6: Quenching of the $Tl(8^2S_{1/2})$ state as determined by monitoring the Tl 3231Å radiation emitted from the Hg-Tl-$N_2$ mixture.

$\langle v_{rel} \rangle = 8.57 \times 10^4$ cm/sec

| $N_2$ Pressure (torr) | $N_2$ Density ($10^{16}$ cm$^{-3}$) | $I_{N_2}/I_o$ | $I^o_{N_2}/I_{N_2}$ |
|---|---|---|---|
| 0.0 | 0.0 | 1.000 | 1.000 |
| 0.80 | 1.54 | 0.800 | 1.250 |
| 1.52 | 2.92 | 0.680 | 1.471 |
| 2.64 | 5.07 | 0.504 | 1.984 |
| 3.48 | 6.68 | 0.468 | 2.137 |
| 4.16 | 7.99 | 0.440 | 2.273 |
| 4.80 | 9.22 | 0.360 | 2.778 |
| 5.60 | 10.80 | 0.320 | 3.125 |
| 6.64 | 12.80 | 0.280 | 3.571 |
| 7.60 | 14.60 | 0.240 | 4.167 |

TABLE 7: Quenching of the $Tl(6^2D_{5/2})$ state as determined by monitoring the Tl 3520Å radiation emitted from the Hg-Tl-$N_2$ mixture.

$\langle v_{rel} \rangle = 8.37 \times 10^4 cm/sec$

$N_2$

| Pressure (torr) | Density ($10^{16} cm^{-3}$) | $I_{N_2}/I_o$ | $I^o_{N_2}/I_{N_2}$ |
|---|---|---|---|
| 0.0 | 0.0 | 1.000 | |
| 0.80 | 1.54 | 1.522 | |
| 1.52 | 2.92 | 1.957 | |
| 2.64 | 5.07 | 2.101 | 1.000 |
| 3.48 | 6.68 | 2.045 | 1.028 |
| 4.16 | 7.99 | 1.992 | 1.055 |
| 4.80 | 9.22 | 1.957 | 1.074 |
| 5.60 | 10.80 | 1.883 | 1.115 |
| 6.64 | 12.80 | 1.812 | 1.160 |
| 7.60 | 14.60 | 1.739 | 1.208 |

ground state atoms and $Tl(6^2P_{3/2})$ metastable state atoms resulting in the population of higher excited thallium states as indicated in equations (28) and (29). The population densities of such excited thallium states depend critically on the concentration of $Hg(6^3P_o)$ atoms and hence indirectly depend on the density of $N_2$ molecules as well as on the magnitude of the resonance defect $\Delta E$ between the particular thallium state and the mercury metastable state. In the case of close energy resonance, (that is, $\Delta E$ is small), one would expect that in the presence of $N_2$ molecules the intensity ratio $I_{N_2}/I_o$ should show an initial enhancement with increasing nitrogen pressures. The competing quenching process defined by equation (30), which results from a direct interaction between the excited thallium atom and a ground-state nitrogen molecule, causes radiationless transitions from the higher excited states to the ground state directly, or indirectly in a series of cascade transitions, with the simultaneous excitation of the nitrogen molecule to higher vibrational states from its ground electronic configuration. Such a process would manifest itself by reducing the ratio $I_{N_2}/I_o$ with increasing nitrogen pressures.

The presence of these two competing processes together are responsible for the variations in $I_{N_2}/I_o$ with $N_2$ pressure as indicated by the curves in figure (19). Also shown in figure (19) is the absorption curve obtained by Gatzke[76] for the Hg 4047Å spectral component arising from the mercury transition $6^3P_o \rightarrow 7^3S_1$ which indicates the dependence of the concentration of metastable $Hg(6^3P_o)$ atoms on the nitrogen density at mercury vapour pressures similar to those employed in this experiment. It is of significance that the $I_{N_2}/I_o$ curves corresponding to the $Tl(7^2S_{1/2})$ and the $Tl(6^2D_{5/2})$ states, reach their maxima in the near vicinity of the saturation point of the absorption curve which occurs at about 1 torr. At pressures above this saturation point the

density of $Hg(6^3P_o)$ metastable atoms remains constant and the only factor affecting the shapes of the $I_{N_2}/I_o$ curves is the quenching process. In the case of the $Tl(8^2S_{1/2})$ state the quenching effect is much stronger as indicated by the immediate decrease in the $I_{N_2}/I_o$ curve with increasing nitrogen density.

A basis for rationalizing these results is afforded by considering the relative levels of the various excited thallium states connected with the $I_{N_2}/I_o$ curves with respect to the $Hg(6^3P_o)$ state which becomes populated with the introduction of $N_2$ molecules into the Hg-Tl system. The $Tl(7^2S_{1/2})$ and $Tl(6^2D_{5/2})$ states are brought into a closer resonance with the $Hg(6^3P_o)$ level ($\Delta E = -1.38eV$ and $\Delta E = -0.20eV$, respectively) than exists for the $Hg(6^3P_1)$ level and the thallium states ($\Delta E = -1.58eV$ and $\Delta E = -0.40eV$, respectively). One would expect that this closer resonance, combined with the relatively long lifetime of the $Hg(6^3P_o)$ state, would lead to an efficient energy transfer from the $Hg(6^3P_o)$ atoms to the $Tl(7^2S_{1/2})$ and $Tl(6^2D_{5/2})$ atoms. Since the population density of the $Hg(6^3P_o)$ state increases with $N_2$ density the $I_{N_2}/I_o$ curves would be expected to rise with increasing $N_2$ density up to about $5 \times 10^{16} cm^{-3}$. With further increases in the $N_2$ density, the density of the $Hg(6^3P_o)$ atoms remains constant and the only remaining process is that of the quenching of the excited $Tl(7^2S_{1/2})$ and $Tl(6^2D_{5/2})$ states which is reflected by the decreasing $I_{N_2}/I_o$ ratios. In the case of the $Tl(8^2S_{1/2})$ state, which lies above the $Hg(6^3P_o)$ level, the energy defect between the $Hg(6^3P_o)$ level and the $Tl(8^2S_{1/2})$ level ($\Delta E = +0.12eV$) is larger than that for the $Hg(6^3P_1)$ state and the $Tl(8^2S_{1/2})$ state ($\Delta E = -0.083eV$). In addition, a Boltzmann factor must be introduced[26] when considering the energy transfer from the $Hg(6^3P_o)$ state to the $Tl(8^2S_{1/2})$ state. Taking these factors into account, we estimate that the $Hg(6^3P_o)$ states populate the $Tl(8^2S_{1/2})$ state to less than one-tenth of the level to which the $Hg(6^3P_1)$

atoms populate this thallium state during inelastic collisions. Hence, one would expect that the dominant process involving the $N_2$ molecules in the case of the $Tl(8^2S_{1/2})$ state would be that of quenching and indeed this is reflected in the $I_{N_2}/I_o$ curve which begins to decrease immediately upon the introduction of nitrogen gas into the Hg-Tl vapour mixture.

The actual quenching cross sections may be obtained from the intensity measurements at various nitrogen pressures in the range 0 torr - 8 torr, as found in tables (4), (5), (6) and (7), by using the Stern-Volmer relation

$$I_{N_2} = I^{\circ}_{N_2}/(1 + \tau Z)$$

where $I^{\circ}_{N_2}$ is the relative intensity of the sensitized fluorescent component at some fixed $N_2$ pressure beyond which the quenching process is dominant and $I_{N_2}$ is the relative intensity of the same spectral component at higher $N_2$ pressures. The lifetime of the appropriate thallium state, $\tau$, is taken from our theoretical calculations which have been done in the velocity formulation using the orthogonalized HFS wave functions. The quenching cross sections are determined from the Stern-Volmer relation by first substituting for the frequency of quenching collisions, Z, in terms of the quenching cross section, Q, according to the relation

$$Z = n_2 \langle v_{rel} \rangle Q$$

where $n_2$ is the density of $N_2$ molecules and $\langle v_{rel} \rangle$ is the mean relative thermal velocity of the colliding partners. The quenching cross section Q is given by equation (9) where, in this case, the intensity ratio $I_{N_2}/I^{\circ}_{N_2}$ is to be used. The Stern-Volmer plots of $I_{N_2}/I^{\circ}_{N_2}$ as a function nitrogen density for the sensitized fluorescent components arising from the thallium transitions $6^2P_{1/2} - 7^2S_{1/2}$, $6^2P_{3/2} - 7^2S_{1/2}$, $6^2P_{3/2} - 6^2D_{5/2}$ and $6^2P_{3/2} - 8^2S_{1/2}$ are

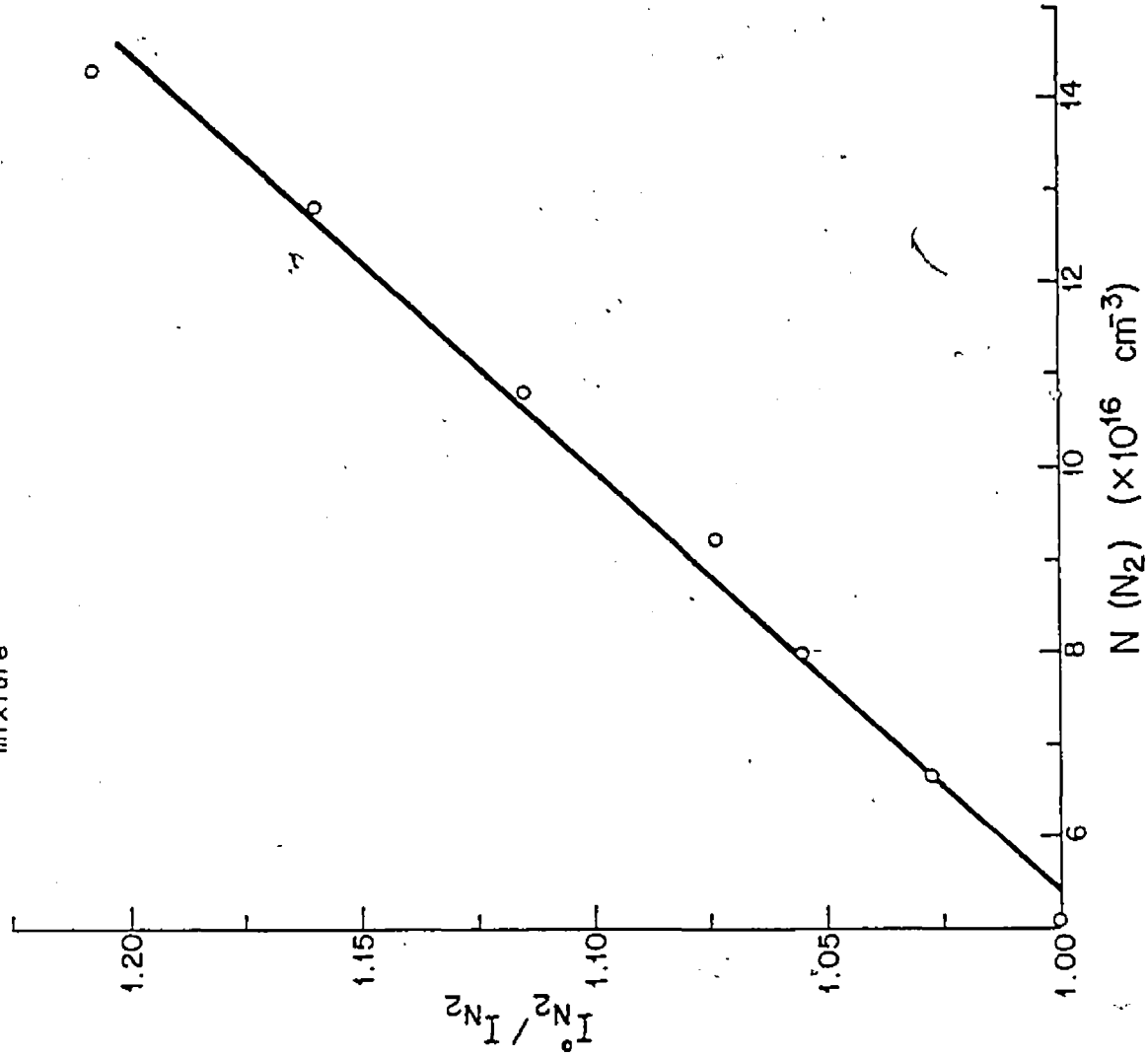



Fig. 20: Stern-Volmer plot for data obtained by monitoring the Tl 3520Å radiation emitted from the Hg-Tl-$N_2$ mixture

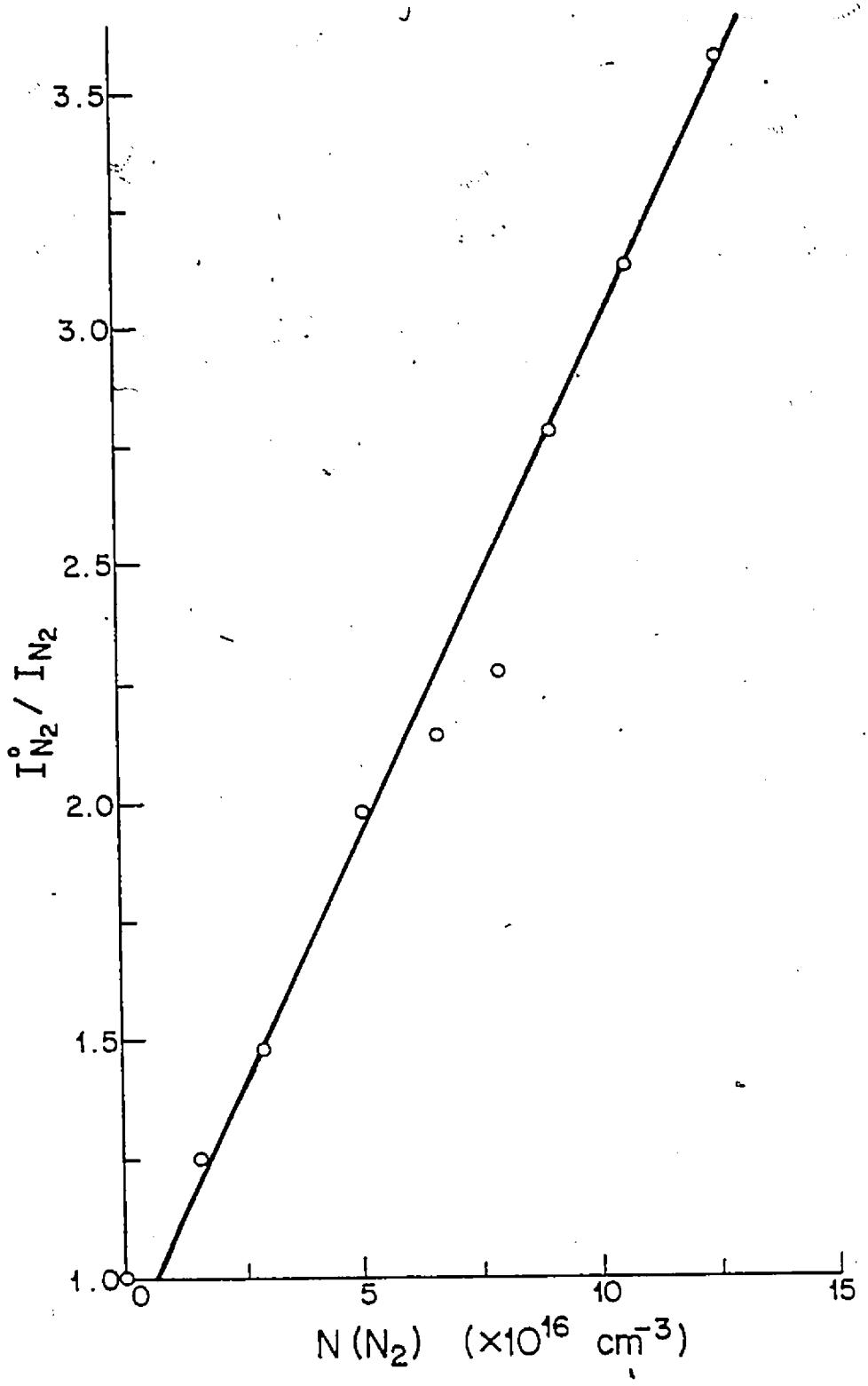



Fig. 21: Stern-Volmer plot for data obtained by monitoring the Tl 3231Å radiation emitted from the Hg-Tl-$N_2$ mixture

TABLE 8: Cross sections for Quenching of thallium states by collisions with $N_2$ molecules.

| Observed Sensitized Fluorescence | | Description of the Quenched States | | | Cross Section |
|---|---|---|---|---|---|
| Transition | $\lambda$(Å) | Tl* State | $\tau^{(a)}$ ($10^{-9}$sec) | $\Delta E$ Hg($6^3P_0$)-Tl* (eV) | $Q(Å^2)\pm 20\%$ |
| $6^2P_{3/2} - 8^2S_{1/2}$ | 3231 | $8^2S_{1/2}$ | 22.4 | +0.12 | 110 |
| $6^2P_{3/2} - 6^2D_{5/2}$ | 3520 | $6^2D_{5/2}$ | 5.1 | -0.20 | 40 |
| $6^2P_{3/2} - 7^2S_{1/2}$ | 5352 | $7^2S_{1/2}$ | 11 | -1.38 | 10.2 |
| $6^2P_{1/2} - 7^2S_{1/2}$ | 3776 | $7^2S_{1/2}$ | 11 | -1.38 | 11.1 |

(a) Taken from theoretical values in the velocity formulation (listed in Appendix (10)) as determined from the orthogonalized HFS wave functions.

shown in figures (17), (18), (20) and (21) respectively. The quenching cross sections, Q, are listed in table (8) along with other pertinent data describing the quenching states.

Quenching of excited atoms by collisions with diatomic molecules is generally agreed to be accomplished by means of the transfer of the atomic excitation energy to specific vibrational states in the molecule[75]. Pitre, Hammond and Krause[76] have shown that such is the case when the $Hg(6^3P_1)$ state is quenched to the $Hg(6^3P_0)$ metastable state by nitrogen molecules which, as a result, become vibrationally excited from the v=0 to the v=1 state. Such a description of the quenching mechanism has been supported by results of quenching experiments with CO, $N_2$, $H_2$ and other diatomic species[75]. It has been generally observed in experiments of this nature that an atomic state is most efficiently quenched by diatomic molecules when the depopulation of the atomic excited state proceeds by way of a radiationless transition to some lower state in such a manner that the corresponding atomic transition frequency lies in close resonance to that of some upward vibrational transition in the quenching molecule. Quantitative investigation of this resonance property has been performed previously in this laboratory[8] in the quenching study of the mercury-sensitized fluorescence in sodium. It was shown explicitly that excited sodium states were quenched most efficiently by $N_2$ molecules when the energy defect, $\Delta E'$, between the energy of a downward radiationless transition in sodium and the energy of the closest upward vibrational transition in the ground electronic state of the $N_2$ molecule was small. This resonance phenomenom also appears to persist here in the case of thallium.

Quenching of the excited thallium states may be accomplished by radiationless transitions to the ground state, or to intermediate states if allowed by the dipole selection rules. In table (9) we list all possible transitions from each of the excited thallium states observed to be populated by the

TABLE 9: Possible radiationless transitions in thallium, resulting from the quenching action of $N_2$ molecules, with the most probable corresponding upward vibrational transitions in $N_2$ from the ground vibration state.

| Quenching Transition in Tl | Vibrational Transition in $N_2$ | $\Delta E'$ -(eV) |
|---|---|---|
| $6^2P_{3/2} - 8^2S_{1/2}$ | v=0 → v=15 | -0.10 |
| $6^2P_{1/2} - 8^2S_{1/2}$ | v=0 → v=19 | -0.05 |
| $7^2P_{3/2} - 8^2S_{1/2}$ | v=0 → v=2 | -0.12 |
| $7^2P_{1/2} - 8^2S_{1/2}$ | v=0 → v=2 | +0.01 |
| $6^2P_{3/2} - 6^2D_{5/2}$ | v=0 → v=13 | +0.04 |
| $7^2P_{3/2} - 6^2D_{5/2}$ | v=0 → v=1 | -0.17 |
| $6^2P_{3/2} - 7^2S_{1/2}$ | v=0 → v=8 | +0.11 |
| $6^2P_{1/2} - 7^2S_{1/2}$ | v=0 → v=12 | +0.06 |

transfer of the mercury excitation energy to the ground state thallium atoms. Also shown there is the most probable corresponding vibrational transition in the nitrogen molecule. We have chosen these possible transitions so as to obtain the closest resonance between the downward radiationless transition in the thallium atom and the accompanying upward vibrational transition in the $N_2$ molecule. The vibrational transition energies in $N_2$ are taken from Gilmore[78].

The resonance condition will be best satisfied when the atomic transition frequency closely matches a vibrational transition frequency in the $N_2$ molecule. In the case of the $Tl(7^2S_{1/2})$ state a quenching collision would only result in a radiationless transition to the $Tl(6^2P_{1/2,3/2})$ states. The $Tl(8^2S_{1/2})$ level would be most likely quenched to the $Tl(7^2P_{1/2,3/2})$ states while the $Tl(6^2D_{5/2})$ state would be quenched to the thallium ground state. With the exception of the $Tl(8^2S_{1/2})$ level, the quenching mechanism requires vibrational transitions in nitrogen of up to 13 vibrational quanta. The appearance of such large quantum jumps in quenching collisions are not uncommon. In the investigation of the quenching of the mercury-sensitized fluorescence of sodium by nitrogen molecules, jumps of up to 10 vibrational quanta were predicted[8] and in similar studies on the quenching of the $Hg(6^3P_1)$ state by collisions with CO molecules[79] jumps of up to 11 vibrational quanta were observed.

The resonance behavior of the quenching cross sections is depicted graphically in figure (22). It should be stressed that the relatively small sampling of data obtained here for thallium does not, in itself, provide sufficient evidence for the resonance effect in quenching; however, combining our findings with those found in the case of sodium[8] strongly suggests that the quenching mechanism, as defined by equation (30), proceeds most efficiently when the downward radiationless atomic transition lies in close resonance to an accompanying upward vibrational transition in the quenching gas molecule.

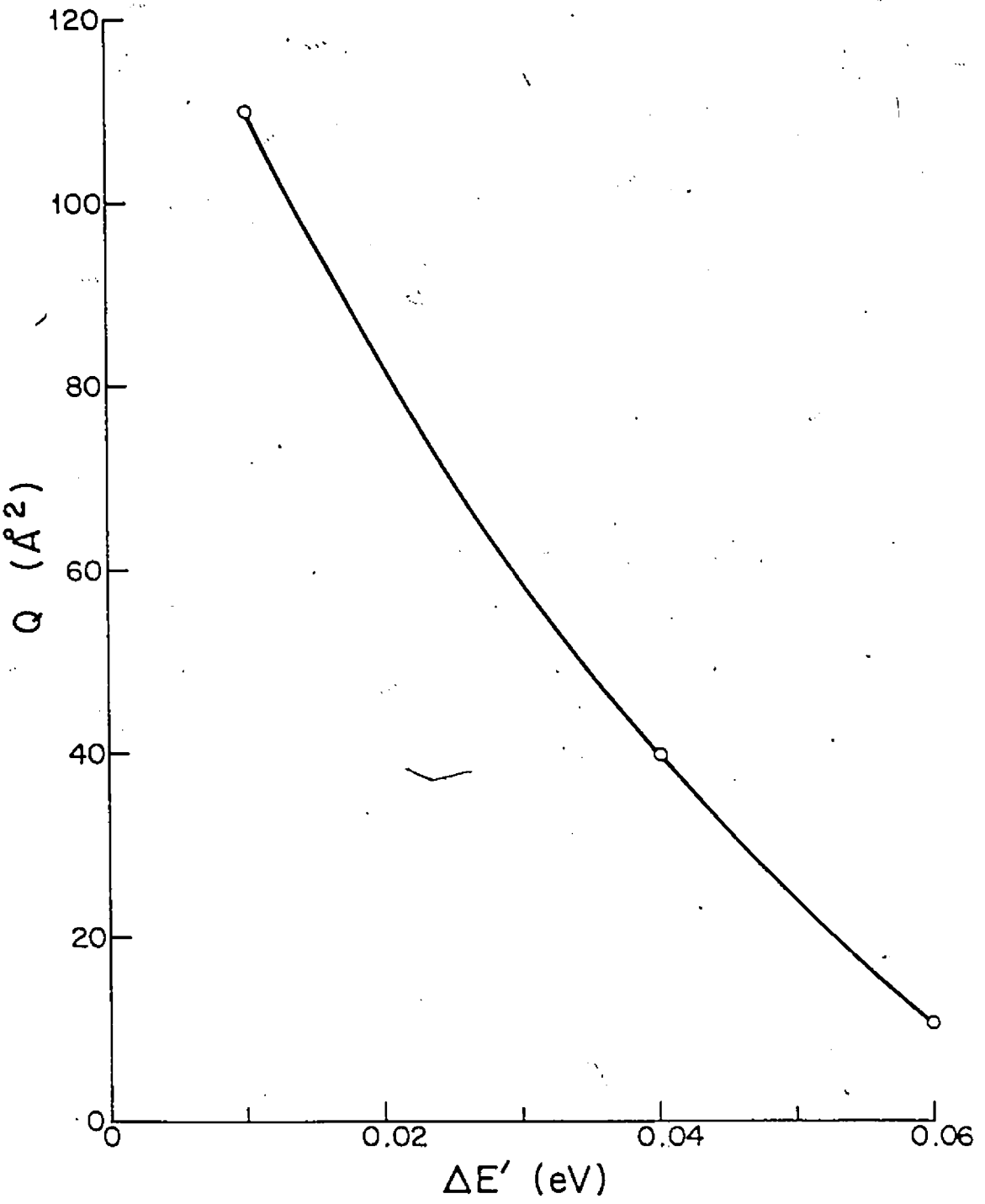



Fig. 22: Plot of quenching cross sections for the thallium states against $\Delta E'$, the energy defect between the energy of the downward radiationless transition in thallium and the accompanying upward vibrational transition in $N_2$

## APPENDIX 1: Thallium, Oscillator Strengths Calculated From Non-Orthogonal Wave Functions

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR THALLIUM. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $\bar{M}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}$ ($sec^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | n | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 7 | 1/2-1/2 | -0.226D-02 | 0.325D-02 | 0.890D-01 | 0.182D 00 | 0.131D 00 | 0.136D 00 | 0.412D 08 | 0.852D 08 |
| | | 3/2-1/2 | -0.208D-02 | 0.315D-02 | 0.106D 00 | 0.243D 00 | 0.176D 00 | 0.154D 00 | 0.495D 08 | 0.113D 09 |
| 6 | 8 | 1/2-1/2 | -0.594D-03 | 0.111D-02 | 0.117D-01 | 0.146D-01 | 0.166D-01 | 0.179D-01 | 0.117D 08 | 0.146D 08 |
| | | 3/2-1/2 | -0.761D-03 | 0.763D-03 | 0.857D-02 | 0.859D-02 | 0.159D-01 | 0.139D-01 | 0.109D 08 | 0.107D 08 |
| 6 | 9 | 1/2-1/2 | -0.603D-03 | 0.532D-03 | 0.386D-02 | 0.300D-02 | 0.579D-02 | 0.630D-02 | 0.480D 07 | 0.373D 07 |
| | | 3/2-1/2 | -0.452D-03 | 0.285D-03 | 0.265D-02 | 0.105D-02 | 0.521D-02 | 0.490D-02 | 0.442D 07 | 0.175D 07 |
| 6 | 10 | 1/2-1/2 | -0.411D-03 | 0.303D-03 | 0.171D-02 | 0.927D-03 | 0.285D-02 | | 0.234D 07 | 0.127D 07 |
| | | 3/2-1/2 | -0.307D-03 | 0.126D-03 | 0.115D-02 | 0.193D-03 | 0.258D-02 | 0.310D-02 | 0.216D 07 | 0.363D 06 |
| 6 | 11 | 1/2-1/2 | -0.302D-03 | 0.194D-03 | 0.900D-03 | 0.371D-03 | 0.156D-02 | 0.220D-02 | 0.130D 07 | 0.534D 06 |
| | | 3/2-1/2 | -0.225D-03 | 0.606D-04 | 0.601D-03 | 0.435D-04 | 0.136D-02 | | 0.120D 07 | 0.868D 05 |
| 7 | 8 | 1/2-1/2 | -0.151D-02 | 0.147D-02 | 0.259D 00 | 0.216D 00 | 0.269D 00 | | 0.363D 07 | 0.303D 07 |
| | | 3/2-1/2 | -0.158D-02 | 0.137D-02 | 0.318D 00 | 0.241D 00 | 0.303D 00 | | 0.545D 07 | 0.413D 07 |
| 7 | 9 | 1/2-1/2 | -0.593D-03 | 0.588D-03 | 0.173D-01 | 0.176D-01 | 0.226D-01 | | 0.935D 06 | 0.952D 06 |
| | | 3/2-1/2 | -0.496D-03 | 0.463D-03 | 0.135D-01 | 0.123D-01 | 0.164D-01 | | 0.115D 07 | 0.105D 07 |
| 7 | 10 | 1/2-1/2 | -0.325D-03 | 0.347D-03 | 0.435D-02 | 0.495D-02 | 0.769D-02 | | 0.360D 06 | 0.410D 06 |
| | | 3/2-1/2 | -0.258D-03 | 0.255D-03 | 0.301D-02 | 0.273D-02 | 0.546D-02 | | 0.412D 06 | 0.402D 06 |
| 7 | 11 | 1/2-1/2 | -0.214D-03 | 0.237D-03 | 0.170D-02 | 0.210D-02 | 0.352D-02 | | 0.172D 06 | 0.212D 06 |
| | | 3/2-1/2 | -0.165D-03 | 0.167D-03 | 0.110D-02 | 0.113D-02 | 0.237D-02 | | 0.167D 06 | 0.192D 06 |
| 8 | 9 | 1/2-1/2 | -0.127D-02 | 0.117D-02 | 0.412D 00 | 0.350D 00 | | | 0.889D 06 | 0.755D 06 |
| | | 3/2-1/2 | -0.120D-02 | 0.108D-02 | 0.459D 00 | 0.377D 00 | | | 0.124D 07 | 0.102D 07 |
| 8 | 10 | 1/2-1/2 | -0.463D-03 | 0.451D-03 | 0.260D-01 | 0.237D-01 | | | 0.257D 06 | 0.244D 06 |
| | | 3/2-1/2 | -0.347D-03 | 0.335D-03 | 0.155D-01 | 0.145D-01 | | | 0.262D 06 | 0.244D 06 |
| 8 | 11 | 1/2-1/2 | -0.274D-03 | 0.274D-03 | 0.674D-02 | 0.673D-02 | | | 0.116D 06 | 0.116D 06 |
| | | 3/2-1/2 | -0.192D-03 | 0.190D-03 | 0.337D-02 | 0.330D-02 | | | 0.106D 06 | 0.104D 06 |
| 9 | 10 | 1/2-1/2 | -0.137D-02 | 0.958D-03 | 0.588D 00 | 0.459D 00 | | | 0.318D 06 | 0.257D 06 |
| | | 3/2-1/2 | -0.993D-03 | 0.695D-03 | 0.615D 00 | 0.500D 00 | | | 0.443D 06 | 0.360D 06 |
| 9 | 11 | 1/2-1/2 | -0.414D-03 | 0.382D-03 | 0.378D-01 | 0.322D-01 | | | 0.109D 06 | 0.926D 05 |
| | | 3/2-1/2 | -0.336D-03 | 0.281D-03 | 0.227D-01 | 0.194D-01 | | | 0.109D 06 | 0.928D 05 |
| 10 | 11 | 1/2-1/2 | -0.909D-03 | 0.794D-03 | 0.731D 00 | 0.557D 00 | | | 0.131D 06 | 0.996D 05 |
| | | 3/2-1/2 | -0.843D-03 | 0.736D-03 | 0.796D 00 | 0.601D 00 | | | 0.181D 06 | 0.137D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - mp^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR THALLIUM. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $\tilde{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 7 | 7 | 1/2-1/2 | 0.241D-02 | -0.284D-02 | 0.346D 00 | 0.481D 00 | 0.463D 00 | | 0.136D 08 | 0.189D 08 |
| | | 1/2-3/2 | 0.269D-02 | -0.312D-02 | 0.761D 00 | 0.103D 01 | 0.937D 00 | | 0.191D 08 | 0.258D 08 |
| 7 | 8 | 1/2-1/2 | 0.166D-03 | -0.996D-04 | 0.847D-03 | 0.305D-03 | 0.118D-01 | | 0.125D 06 | 0.451D 05 |
| | | 1/2-3/2 | 0.524D-03 | -0.511D-03 | 0.165D-01 | 0.157D-01 | 0.547D-01 | | 0.128D 07 | 0.122D 07 |
| 7 | 9 | 1/2-1/2 | -0.342D-04 | 0.167D-03 | 0.300D-04 | 0.712D-03 | 0.255D-02 | | 0.640D 04 | 0.152D 06 |
| | | 1/2-3/2 | 0.215D-03 | -0.123D-03 | 0.235D-02 | 0.760D-03 | 0.154D-01 | | 0.256D 06 | 0.829D 05 |
| 7 | 10 | 1/2-1/2 | -0.687D-04 | 0.204D-03 | 0.111D-03 | 0.975D-03 | 0.940D-03 | | 0.280D 05 | 0.246D 06 |
| | | 1/2-3/2 | 0.111D-03 | -0.162D-05 | 0.577D-03 | 0.122D-06 | 0.674D-02 | | 0.737D 05 | 0.156D 02 |
| 8 | 8 | 1/2-1/2 | 0.177D-02 | -0.181D-02 | 0.544D 00 | 0.571D 00 | | | 0.250D 07 | 0.262D 07 |
| | | 1/2-3/2 | 0.192D-02 | -0.195D-02 | 0.112D 01 | 0.116D 01 | | | 0.336D 07 | 0.348D 07 |
| 8 | 9 | 1/2-1/2 | 0.265D-03 | -0.218D-03 | 0.572D-02 | 0.488D-02 | | | 0.121D 06 | 0.822D 05 |
| | | 1/2-3/2 | 0.529D-03 | -0.486D-03 | 0.441D-01 | 0.372D-01 | | | 0.498D 06 | 0.419D 06 |
| 8 | 10 | 1/2-1/2 | 0.696D-04 | -0.202D-04 | 0.309D-03 | 0.259D-04 | | | 0.106D 05 | 0.894D 03 |
| | | 1/2-3/2 | 0.260D-03 | -0.212D-03 | 0.846D-02 | 0.566D-02 | | | 0.150D 06 | 0.100D 06 |
| 9 | 9 | 1/2-1/2 | 0.137D-02 | -0.135D-02 | 0.708D 00 | 0.689D 00 | | | 0.656D 06 | 0.678D 06 |
| | | 1/2-3/2 | 0.148D-02 | -0.144D-02 | 0.144D 01 | 0.136D 01 | | | 0.933D 06 | 0.883D 06 |
| 9 | 10 | 1/2-1/2 | 0.282D-03 | -0.254D-03 | 0.132D-01 | 0.106D-01 | | | 0.675D 05 | 0.545D 05 |
| | | 1/2-3/2 | 0.478D-03 | -0.441D-03 | 0.726D-01 | 0.620D-01 | | | 0.201D 06 | 0.171D 06 |
| 10 | 10 | 1/2-1/2 | 0.111D-02 | -0.106D-02 | 0.872D 00 | 0.800D 00 | | | 0.240D 05 | 0.220D 06 |
| | | 1/2-3/2 | 0.119D-02 | -0.113D-02 | 0.174D 01 | 0.156D 01 | | | 0.323D 06 | 0.291D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR THALLIUM. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $\bar{r}_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 8 | 3/2-1/2 | 0.862D-03 | -0.111D-02 | 0.649D-01 | 0.107D 00 | | | 0.238D 07 | 0.393D 07 |
| | | 3/2-3/2 | 0.779D-03 | -0.950D-03 | 0.988D-02 | 0.147D-01 | | | 0.208D 06 | 0.310D 06 |
| | | 5/2-3/2 | 0.796D-03 | -0.978D-03 | 0.628D-01 | 0.949D-01 | | | 0.193D 07 | 0.291D 07 |
| 6 | 9 | 3/2-1/2 | 0.339D-03 | -0.452D-03 | 0.635D-02 | 0.113D-01 | | | 0.578D 06 | 0.103D 07 |
| | | 3/2-3/2 | 0.343D-03 | -0.426D-03 | 0.127D-02 | 0.196D-02 | | | 0.605D 05 | 0.934D 05 |
| | | 5/2-3/2 | 0.348D-03 | -0.433D-03 | 0.795D-02 | 0.123D-01 | | | 0.556D 06 | 0.862D 06 |
| 6 | 10 | 3/2-1/2 | 0.156D-03 | -0.280D-03 | 0.162D-02 | 0.366D-02 | | | 0.208D 06 | 0.470D 06 |
| | | 3/2-3/2 | 0.129D-03 | -0.274D-03 | 0.366D-03 | 0.693D-03 | | | 0.241D 05 | 0.455D 05 |
| | | 5/2-3/2 | 0.202D-03 | -0.279D-03 | 0.228D-02 | 0.430D-02 | | | 0.221D 06 | 0.417D 06 |
| 7 | 9 | 3/2-1/2 | 0.729D-03 | -0.764D-03 | 0.103D 00 | 0.113D 00 | | | 0.769D 06 | 0.845D 06 |
| | | 3/2-3/2 | 0.589D-03 | -0.607D-03 | 0.125D-01 | 0.132D-01 | | | 0.540D 05 | 0.574D 05 |
| | | 5/2-3/2 | 0.627D-03 | -0.659D-03 | 0.860D-01 | 0.949D-01 | | | 0.543D 06 | 0.600D 06 |
| 7 | 10 | 3/2-1/2 | 0.357D-03 | -0.382D-03 | 0.148D-01 | 0.170D-01 | | | 0.305D 06 | 0.349D 06 |
| | | 3/2-3/2 | 0.309D-03 | -0.327D-03 | 0.218D-02 | 0.243D-02 | | | 0.236D 05 | 0.263D 05 |
| | | 5/2-3/2 | 0.325D-03 | -0.347D-03 | 0.145D-01 | 0.165D-01 | | | 0.232D 06 | 0.264D 06 |
| 8 | 10 | 3/2-1/2 | 0.592D-03 | -0.545D-03 | 0.127D 00 | 0.138D 00 | | | 0.271D 06 | 0.230D 06 |
| | | 3/2-3/2 | 0.449D-03 | -0.406D-03 | 0.130D-01 | 0.110D-01 | | | 0.162D 05 | 0.138D 05 |
| | | 5/2-3/2 | 0.484D-03 | -0.435D-03 | 0.951D-01 | 0.342D-01 | | | 0.174D 06 | 0.154D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR THALLIUM. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $r^e_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 6 | 1/2-3/2 | 0.3890-02 | -0.4260-02 | 0.3830 00 | 0.4190 00 | 0.4100 00 | 0.2900 00 | 0.1670 09 | 0.2000 09 |
| | | 3/2-3/2 | 0.3950-02 | -0.4500-02 | 0.5050-01 | 0.6550-01 | 0.5500-01 | 0.4000-01 | 0.2700 08 | 0.3510 08 |
| | | 3/2-5/2 | 0.3890-02 | -0.4440-02 | 0.4980 00 | 0.5730 00 | 0.4760 00 | 0.3500 00 | 0.1570 09 | 0.2050 09 |
| 6 | 7 | 1/2-3/2 | 0.2760-02 | -0.2500-02 | 0.1670 00 | 0.1360 00 | 0.1100 00 | 0.7400-01 | 0.9810 08 | 0.8020 08 |
| | | 3/2-3/2 | 0.2450-02 | -0.2220-02 | 0.1610-01 | 0.1320-01 | 0.1300-01 | 0.9100-02 | 0.1260 08 | 0.1030 08 |
| | | 3/2-5/2 | 0.2450-02 | -0.2260-02 | 0.1450 00 | 0.1230 00 | 0.1190 00 | 0.8100-01 | 0.7560 08 | 0.6420 08 |
| 6 | 8 | 1/2-3/2 | 0.1750-02 | -0.1310-02 | 0.6260-01 | 0.3520-01 | 0.4900-01 | 0.2800-01 | 0.4160 08 | 0.2350 08 |
| | | 3/2-3/2 | 0.1430-02 | -0.7870-03 | 0.5080-02 | 0.2420-02 | 0.5200-02 | 0.4000-02 | 0.4610 07 | 0.2190 07 |
| | | 3/2-5/2 | 0.1480-02 | -0.1070-02 | 0.4880-01 | 0.2560-01 | 0.4500-01 | 0.2800-01 | 0.2950 08 | 0.1550 08 |
| 6 | 9 | 1/2-3/2 | 0.1160-02 | -0.7580-03 | 0.2690-01 | 0.1140-01 | 0.2600-01 | 0.1400-01 | 0.1910 08 | 0.8090 07 |
| | | 3/2-3/2 | 0.9070-03 | -0.4900-03 | 0.1970-02 | 0.5740-03 | 0.2600-02 | 0.2000-02 | 0.1920 07 | 0.5620 06 |
| | | 3/2-5/2 | 0.9590-03 | -0.5640-03 | 0.1980-01 | 0.6350-02 | 0.2300-01 | 0.1500-01 | 0.1290 08 | 0.4470 07 |
| 7 | 6 | 1/2-3/2 | -0.1550-02 | 0.9750-03 | 0.1130 01 | 0.3580 00 | | | 0.1440 07 | 0.4580 06 |
| | | 3/2-3/2 | -0.1140-02 | 0.4390-03 | 0.1250 00 | 0.1840-01 | | | 0.7660 05 | 0.1120 05 |
| | | 3/2-5/2 | -0.1190-02 | 0.4810-03 | 0.1130 01 | 0.1830 00 | | | 0.5430 06 | 0.8800 05 |
| 7 | 7 | 1/2-3/2 | 0.1530-02 | -0.1420-02 | 0.2710 00 | 0.2370 00 | | | 0.5590 07 | 0.4870 07 |
| | | 3/2-3/2 | 0.1840-02 | -0.1660-02 | 0.4530-01 | 0.3680-01 | | | 0.1420 07 | 0.1150 07 |
| | | 3/2-5/2 | 0.1750-02 | -0.1570-02 | 0.3650 00 | 0.2940 00 | | | 0.7700 07 | 0.6200 07 |
| 7 | 8 | 1/2-3/2 | 0.1160-02 | -0.1120-02 | 0.1180 00 | 0.1090 00 | | | 0.4340 07 | 0.4030 07 |
| | | 3/2-3/2 | 0.1230-02 | -0.1140-02 | 0.1450-01 | 0.1240-01 | | | 0.8780 06 | 0.7490 06 |
| | | 3/2-5/2 | 0.1210-02 | -0.1120-02 | 0.1270 00 | 0.1080 00 | | | 0.5120 07 | 0.4380 07 |
| 7 | 9 | 1/2-3/2 | 0.8160-03 | -0.7880-03 | 0.5100-01 | 0.4760-01 | | | 0.2430 07 | 0.2260 07 |
| | | 3/2-3/2 | 0.9170-03 | -0.7510-03 | 0.5580-02 | 0.4720-02 | | | 0.4460 06 | 0.3770 06 |
| | | 3/2-5/2 | 0.8220-03 | -0.7580-03 | 0.5080-01 | 0.4330-01 | | | 0.2710 07 | 0.2410 07 |
| 8 | 7 | 1/2-3/2 | -0.7480-03 | 0.5570-03 | 0.7970 00 | 0.4420 00 | | | 0.1100 06 | 0.6110 05 |
| | | 3/2-3/2 | -0.4190-03 | 0.2380-03 | 0.5930-01 | 0.1910-01 | | | 0.2890 04 | 0.9320 03 |
| | | 3/2-5/2 | -0.5020-03 | 0.2740-03 | 0.6740 00 | 0.2310 00 | | | 0.2650 05 | 0.8480 04 |
| 8 | 8 | 1/2-3/2 | 0.1170-02 | -0.1120-02 | 0.3770 00 | 0.3490 00 | | | 0.1370 07 | 0.1270 07 |
| | | 3/2-3/2 | 0.1390-02 | -0.1320-02 | 0.6030-01 | 0.5480-01 | | | 0.3460 06 | 0.3140 06 |
| | | 3/2-5/2 | 0.1310-02 | -0.1240-02 | 0.4930 00 | 0.4310 00 | | | 0.1670 07 | 0.1670 07 |
| 8 | 9 | 1/2-3/2 | 0.3200-03 | -0.7000-03 | 0.1300 00 | 0.1210 00 | | | 0.3710 06 | 0.9010 06 |
| | | 3/2-3/2 | 0.5740-03 | -0.6310-03 | 0.1610-01 | 0.1450-01 | | | 0.2030 06 | 0.1840 06 |
| | | 3/2-5/2 | 0.6570-03 | -0.3130-03 | 0.1390 00 | 0.1250 00 | | | 0.1180 07 | 0.1060 07 |
| 9 | 8 | 1/2-3/2 | -0.4050-03 | 0.4140-03 | 0.5140 00 | 0.5330 00 | | | 0.1460 05 | 0.1530 05 |
| | | 3/2-3/2 | -0.1140-03 | 0.1560-03 | 0.1080-01 | 0.1030-01 | | | 0.8730 02 | 0.1640 03 |
| | | 3/2-5/2 | -0.1940-03 | 0.1880-03 | 0.2370 00 | 0.2230 00 | | | 0.1790 04 | 0.1680 04 |
| 9 | 9 | 1/2-3/2 | 0.9660-03 | -0.9200-03 | 0.4000 00 | 0.3540 00 | | | 0.1930 06 | 0.3520 06 |
| | | 3/2-3/2 | 0.1070-02 | -0.1010-02 | 0.6760-01 | 0.5120-01 | | | 0.1060 06 | 0.9640 05 |
| | | 3/2-5/2 | 0.1010-02 | -0.9460-03 | 0.5390 00 | 0.4770 00 | | | 0.5740 06 | 0.5080 06 |
| 10 | 9 | 1/2-3/2 | -0.2740-03 | 0.3380-03 | 0.4450 00 | 0.6550 00 | | | 0.3760 04 | 0.5540 04 |
| | | 3/2-3/2 | -0.2950-04 | 0.1180-03 | 0.1450-02 | 0.2340-01 | | | 0.2920 01 | 0.4700 02 |
| | | 3/2-5/2 | -0.9770-04 | 0.1430-03 | 0.1180 00 | 0.2530 00 | | | 0.2330 03 | 0.5000 03 |

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| TRANSITION | | | $\bar{M}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}$ (sec$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | N' | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 5 | 3/2-5/2 | -0.257D-02 | 0.274D-02 | 0.875D 00 | 0.997D 00 | | | 0.150D 08 | 0.170D 08 |
| | | 5/2-5/2 | -0.257D-02 | 0.275D-02 | 0.424D-01 | 0.435D-01 | | | 0.106D 07 | 0.121D 07 |
| | | 5/2-7/2 | -0.257D-02 | 0.275D-02 | 0.847D 00 | 0.970D 00 | | | 0.159D 08 | 0.182D 08 |
| 6 | 6 | 3/2-5/2 | -0.132D-02 | 0.136D-02 | 0.164D 00 | 0.175D 00 | | | 0.553D 07 | 0.589D 07 |
| | | 5/2-5/2 | -0.130D-02 | 0.135D-02 | 0.770D-02 | 0.824D-02 | | | 0.382D 06 | 0.409D 06 |
| | | 5/2-7/2 | -0.130D-02 | 0.135D-02 | 0.154D 00 | 0.165D 00 | | | 0.573D 07 | 0.613D 07 |
| 7 | 5 | 3/2-5/2 | 0.561D-03 | -0.233D-03 | 0.845D 00 | 0.153D 00 | | | 0.354D 05 | 0.642D 04 |
| | | 5/2-5/2 | 0.496D-03 | -0.206D-03 | 0.353D-01 | 0.633D-02 | | | 0.171D 04 | 0.309D 03 |
| | | 5/2-7/2 | 0.496D-03 | -0.206D-03 | 0.706D 00 | 0.128D 00 | | | 0.256D 05 | 0.463D 04 |
| 7 | 6 | 3/2-5/2 | -0.130D-02 | 0.114D-02 | 0.496D 00 | 0.383D 00 | | | 0.174D 07 | 0.135D 07 |
| | | 5/2-5/2 | -0.135D-02 | 0.121D-02 | 0.259D-01 | 0.206D-01 | | | 0.133D 06 | 0.106D 06 |
| | | 5/2-7/2 | -0.135D-02 | 0.121D-02 | 0.518D 00 | 0.413D 00 | | | 0.199D 07 | 0.159D 07 |
| 8 | 6 | 3/2-5/2 | 0.776D-03 | -0.314D-03 | 0.329D 01 | 0.250D 00 | | | 0.333D 05 | 0.253D 04 |
| | | 5/2-5/2 | 0.734D-03 | -0.186D-03 | 0.149D 00 | 0.104D-01 | | | 0.170D 04 | 0.119D 03 |
| | | 5/2-7/2 | 0.704D-03 | -0.186D-03 | 0.298D 01 | 0.209D 00 | | | 0.255D 05 | 0.178D 04 |

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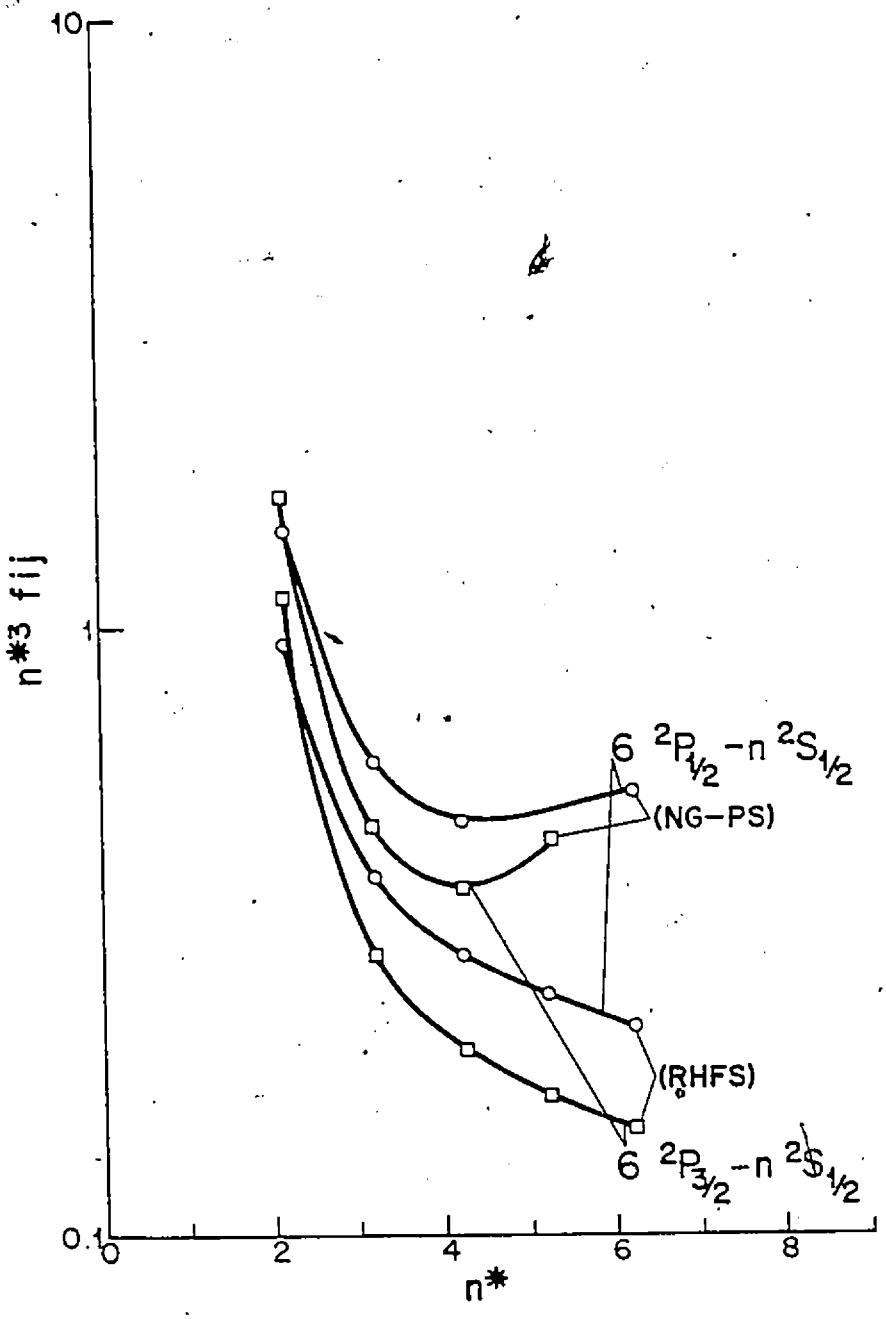
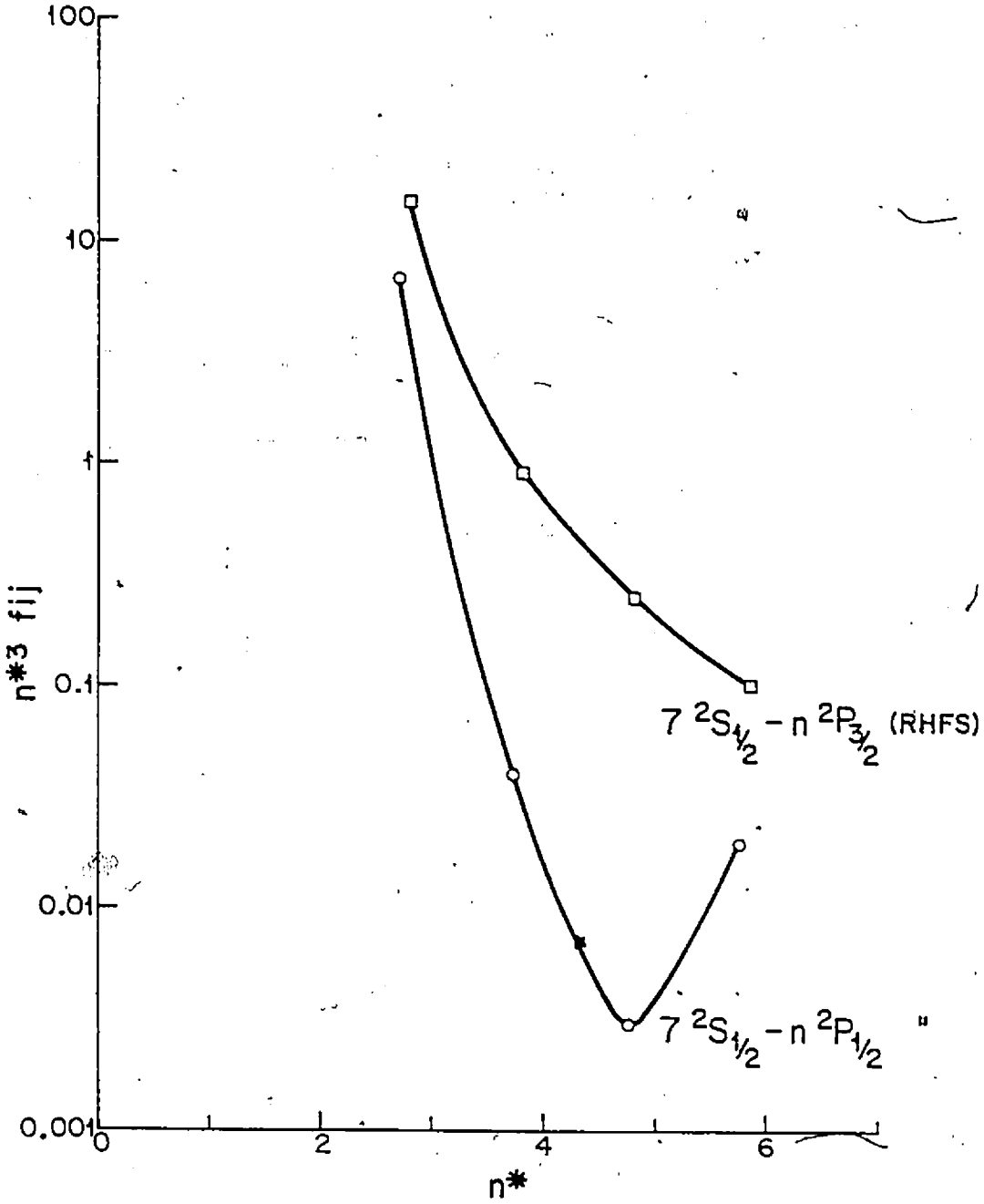
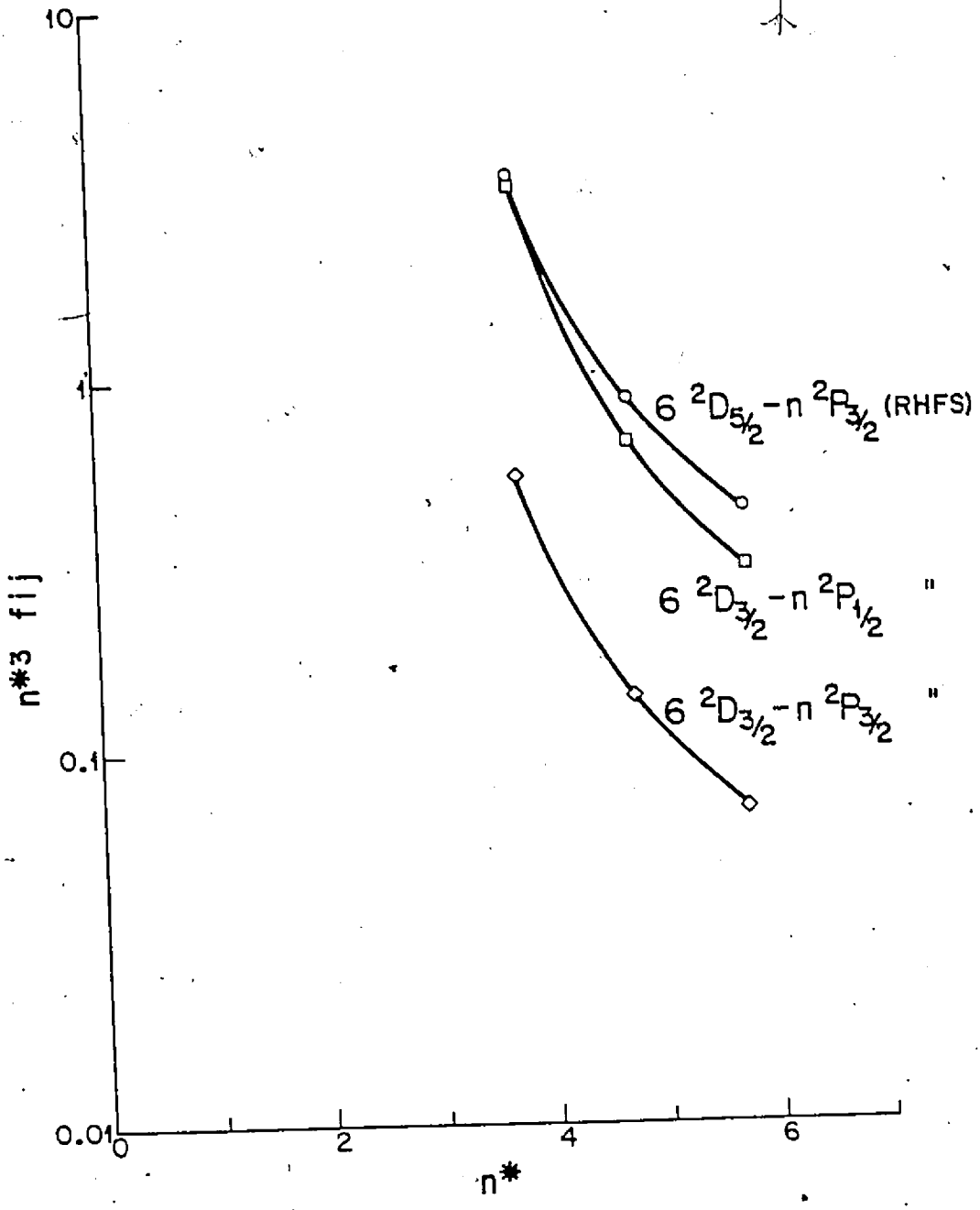
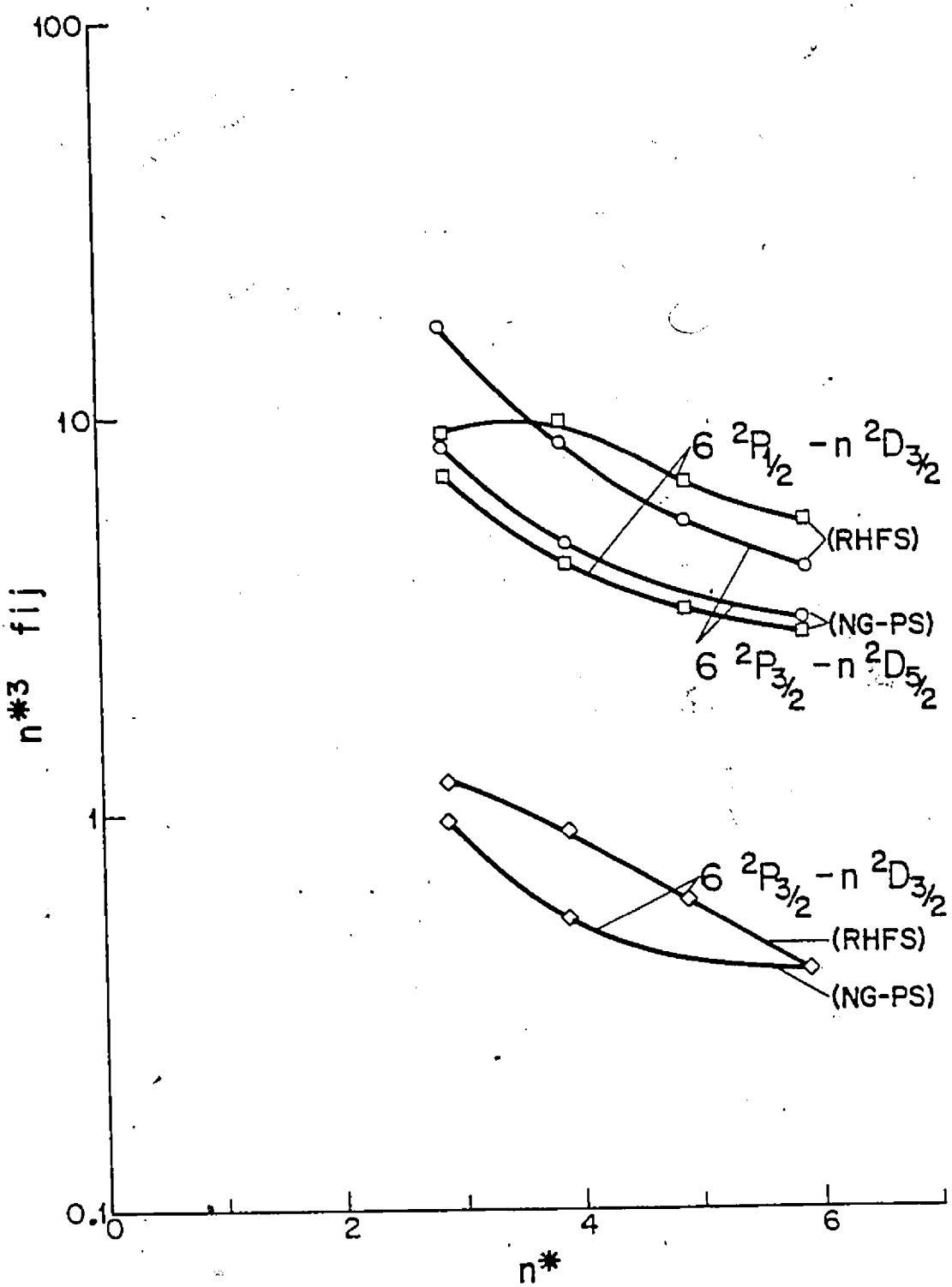
| TRANSITION | | | $R^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 5 | 8 | 5/2-3/2 | -0.536D-03 | 0.646D-03 | 0.671D-01 | 0.975D-01 | | | 0.372D 06 | 0.540D 06 |
| | | 5/2-5/2 | -0.513D-03 | 0.605D-03 | 0.436D-02 | 0.606D-02 | | | 0.164D 05 | 0.228D 05 |
| | | 7/2-5/2 | -0.513D-03 | 0.606D-03 | 0.653D-01 | 0.909D-01 | | | 0.327D 06 | 0.456D 06 |
| 5 | 9 | 5/2-3/2 | -0.253D-03 | 0.277D-03 | 0.101D-01 | 0.112D-01 | | | 0.144D 05 | 0.159D 06 |
| | | 5/2-5/2 | -0.259D-03 | 0.270D-03 | 0.695D-03 | 0.756D-03 | | | 0.667D 04 | 0.725D 04 |
| | | 7/2-5/2 | -0.259D-03 | 0.270D-03 | 0.104D-01 | 0.113D-01 | | | 0.133D 06 | 0.145D 06 |
| 6 | 9 | 5/2-3/2 | -0.609D-03 | 0.780D-03 | 0.160D 00 | 0.263D 00 | | | 0.260D 06 | 0.427D 06 |
| | | 5/2-5/2 | -0.590D-03 | 0.738D-03 | 0.106D-01 | 0.166D-01 | | | 0.117D 05 | 0.183D 05 |
| | | 7/2-5/2 | -0.590D-03 | 0.738D-03 | 0.159D 00 | 0.249D 00 | | | 0.234D 06 | 0.367D 06 |

APPENDIX 2 : Plots of $n^{*3}f_{ij}$ versus $n^*$ indicating the behavior of the relativistic Hartree-Fock-Slater oscillator strengths as a function of the effective principal quantum number for several of the Thallium I series. The oscillator strengths are taken from Appendix (1) and correspond to those derived in the velocity formulation. The theoretical plots are denoted by (RHFS) and the corresponding plots formed from the combined experimental data of Norton and Gallagher, and Penkin and Shabanova are designated by (NG-PS).









## APPENDIX 3 : Cesium, Oscillator Strengths Calculated From Non-Orthogonal HFS Wave Functions

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ns^2S_{1/2}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 7 | 1/2-1/2 | -0.162D-02 | 0.207D-02 | 0.163D 00 | 0.268D 00 | 0.171D 00 | | 0.587D 07 | 0.967D 07 |
| | | 3/2-1/2 | -0.160D-02 | 0.205D-02 | 0.172D 00 | 0.284D 00 | 0.208D 00 | | 0.106D 08 | 0.175D 08 |
| 6 | 8 | 1/2-1/2 | -0.449D-03 | 0.609D-03 | 0.702D-02 | 0.129D-01 | 0.202D-01 | | 0.808D 06 | 0.149D 07 |
| | | 3/2-1/2 | -0.405D-03 | 0.543D-03 | 0.596D-02 | 0.107D-01 | 0.204D-01 | | 0.126D 07 | 0.226D 07 |
| 6 | 9 | 1/2-1/2 | -0.231D-03 | 0.341D-03 | 0.155D-02 | 0.338D-02 | 0.702D-02 | 0.122D-01 | 0.256D 06 | 0.558D 06 |
| | | 3/2-1/2 | -0.202D-03 | 0.296D-03 | 0.123D-02 | 0.264D-02 | 0.687D-02 | | 0.378D 06 | 0.810D 06 |
| 6 | 10 | 1/2-1/2 | -0.148D-03 | 0.201D-03 | 0.589D-03 | 0.108D-02 | 0.326D-02 | 0.433D-02 | 0.115D 06 | 0.212D 06 |
| | | 3/2-1/2 | -0.128D-03 | 0.168D-03 | 0.453D-03 | 0.779D-03 | 0.299D-02 | 0.381D-02 | 0.166D 06 | 0.285D 06 |
| 6 | 11 | 1/2-1/2 | -0.107D-03 | 0.135D-03 | 0.293D-03 | 0.463D-03 | 0.193D-02 | 0.243D-02 | 0.630D 05 | 0.995D 05 |
| | | 3/2-1/2 | -0.918D-04 | 0.109D-03 | 0.222D-03 | 0.313D-03 | 0.166D-02 | 0.261D-02 | 0.896D 05 | 0.126D 06 |
| 6 | 12 | 1/2-1/2 | -0.826D-04 | 0.984D-04 | 0.169D-03 | 0.240D-03 | 0.122D-01 | 0.151D-02 | 0.385D 05 | 0.547D 05 |
| | | 3/2-1/2 | -0.705D-04 | 0.778D-04 | 0.127D-03 | 0.155D-03 | 0.117D-02 | 0.140D-02 | 0.544D 05 | 0.664D 05 |
| 6 | 13 | 1/2-1/2 | -0.664D-04 | 0.761D-04 | 0.108D-03 | 0.141D-03 | 0.820D-03 | 0.121D-02 | 0.253D 05 | 0.332D 05 |
| | | 3/2-1/2 | -0.566D-04 | 0.592D-04 | 0.804D-04 | 0.879D-04 | 0.780D-03 | 0.104D-02 | 0.357D 05 | 0.390D 05 |
| 6 | 14 | 1/2-1/2 | -0.552D-04 | 0.617D-04 | 0.731D-04 | 0.916D-04 | 0.590D-03 | 0.700D-03 | 0.177D 05 | 0.222D 05 |
| | | 3/2-1/2 | -0.469D-04 | 0.475D-04 | 0.544D-04 | 0.557D-04 | 0.560D-03 | 0.690D-03 | 0.249D 05 | 0.255D 05 |
| 6 | 15 | 1/2-1/2 | -0.469D-04 | 0.518D-04 | 0.523D-04 | 0.637D-04 | | 0.380D-03 | 0.130D 05 | 0.158D 05 |
| | | 3/2-1/2 | -0.398D-04 | 0.395D-04 | 0.388D-04 | 0.382D-04 | | | 0.131D 05 | 0.178D 05 |
| 7 | 8 | 1/2-1/2 | -0.137D-02 | 0.138D-02 | 0.335D 00 | 0.340D 00 | 0.297D 00 | | 0.145D 07 | 0.148D 07 |
| | | 3/2-1/2 | -0.133D-02 | 0.139D-02 | 0.343D 00 | 0.371D 00 | 0.333D 00 | | 0.257D 07 | 0.278D 07 |
| 7 | 9 | 1/2-1/2 | -0.499D-03 | 0.501D-03 | 0.222D-01 | 0.223D-01 | 0.305D-01 | | 0.392D 06 | 0.394D 06 |
| | | 3/2-1/2 | -0.444D-03 | 0.451D-03 | 0.182D-01 | 0.188D-01 | 0.256D-01 | | 0.598D 06 | 0.616D 06 |
| 7 | 10 | 1/2-1/2 | -0.289D-03 | 0.294D-03 | 0.585D-02 | 0.606D-02 | 0.964D-02 | | 0.167D 06 | 0.172D 06 |
| | | 3/2-1/2 | -0.250D-03 | 0.255D-03 | 0.449D-02 | 0.468D-02 | 0.842D-02 | | 0.242D 06 | 0.252D 06 |
| 7 | 11 | 1/2-1/2 | -0.198D-03 | 0.202D-03 | 0.243D-02 | 0.255D-02 | 0.501D-02 | | 0.879D 05 | 0.922D 05 |
| | | 3/2-1/2 | -0.168D-03 | 0.172D-03 | 0.181D-02 | 0.188D-02 | 0.455D-02 | | 0.124D 06 | 0.129D 06 |
| 7 | 12 | 1/2-1/2 | -0.148D-03 | 0.152D-03 | 0.127D-02 | 0.134D-02 | 0.287D-02 | | 0.527D 05 | 0.557D 05 |
| | | 3/2-1/2 | -0.125D-03 | 0.127D-03 | 0.925D-03 | 0.959D-03 | 0.259D-02 | | 0.735D 05 | 0.762D 05 |
| 7 | 13 | 1/2-1/2 | -0.117D-03 | 0.119D-03 | 0.761D-03 | 0.795D-03 | 0.183D-02 | | 0.341D 05 | 0.357D 05 |
| | | 3/2-1/2 | -0.981D-04 | 0.990D-04 | 0.550D-03 | 0.560D-03 | 0.164D-02 | | 0.471D 05 | 0.480D 05 |
| 7 | 14 | 1/2-1/2 | -0.958D-04 | 0.983D-04 | 0.495D-03 | 0.522D-03 | 0.126D-02 | | 0.238D 05 | 0.250D 05 |
| | | 3/2-1/2 | -0.802D-04 | 0.812D-04 | 0.355D-03 | 0.363D-03 | 0.113D-02 | | 0.326D 05 | 0.334D 05 |
| 7 | 15 | 1/2-1/2 | -0.808D-04 | 0.832D-04 | 0.344D-03 | 0.365D-03 | | | 0.173D 05 | 0.184D 05 |
| | | 3/2-1/2 | -0.676D-04 | 0.684D-04 | 0.246D-03 | 0.252D-03 | | | 0.237D 05 | 0.243D 05 |
| 8 | 9 | 1/2-1/2 | -0.114D-02 | 0.104D-02 | 0.494D 00 | 0.415D 00 | | | 0.476D 06 | 0.400D 06 |
| | | 3/2-1/2 | -0.112D-02 | 0.105D-02 | 0.511D 00 | 0.455D 00 | | | 0.853D 06 | 0.759D 06 |
| 8 | 10 | 1/2-1/2 | -0.449D-03 | 0.421D-03 | 0.356D-01 | 0.313D-01 | | | 0.159D 06 | 0.140D 06 |
| | | 3/2-1/2 | -0.403D-03 | 0.382D-03 | 0.297D-01 | 0.267D-01 | | | 0.249D 06 | 0.224D 06 |
| 8 | 11 | 1/2-1/2 | -0.277D-03 | 0.263D-03 | 0.103D-01 | 0.927D-02 | | | 0.803D 05 | 0.724D 05 |
| | | 3/2-1/2 | -0.244D-03 | 0.233D-03 | 0.815D-02 | 0.742D-02 | | | 0.121D 06 | 0.110D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{R}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 8 | 12 | 1/2-1/2 | -0.198D-03 | 0.190D-03 | 0.454D-02 | 0.418D-02 | | | 0.474D 05 | 0.436D 05 |
| | | 3/2-1/2 | -0.172D-03 | 0.166D-03 | 0.351D-02 | 0.324D-02 | | | 0.702D 05 | 0.649D 05 |
| 8 | 13 | 1/2-1/2 | -0.152D-03 | 0.145D-03 | 0.250D-02 | 0.226D-02 | | | 0.302D 05 | 0.273D 05 |
| | | 3/2-1/2 | -0.132D-03 | 0.125D-03 | 0.191D-02 | 0.172D-02 | | | 0.443D 05 | 0.400D 05 |
| 8 | 14 | 1/2-1/2 | -0.123D-03 | 0.118D-03 | 0.153D-02 | 0.141D-02 | | | 0.210D 05 | 0.193D 05 |
| | | 3/2-1/2 | -0.106D-03 | 0.102D-03 | 0.116D-02 | 0.106D-02 | | | 0.306D 05 | 0.281D 05 |
| 8 | 15 | 1/2-1/2 | -0.103D-03 | 0.992D-04 | 0.102D-02 | 0.951D-03 | | | 0.153D 05 | 0.143D 05 |
| | | 3/2-1/2 | -0.883D-04 | 0.851D-04 | 0.767D-03 | 0.712D-03 | | | 0.222D 05 | 0.206D 05 |
| 9 | 10 | 1/2-1/2 | -0.559D-03 | 0.874D-03 | 0.636D 00 | 0.528D 00 | | | 0.186D 06 | 0.155D 06 |
| | | 3/2-1/2 | -0.942D-03 | 0.880D-03 | 0.657D 00 | 0.574D 00 | | | 0.335D 06 | 0.292D 06 |
| 9 | 11 | 1/2-1/2 | -0.392D-03 | 0.363D-03 | 0.470D-01 | 0.404D-01 | | | 0.699D 05 | 0.601D 05 |
| | | 3/2-1/2 | -0.354D-03 | 0.331D-03 | 0.396D-01 | 0.347D-01 | | | 0.111D 06 | 0.969D 05 |
| 9 | 12 | 1/2-1/2 | -0.250D-03 | 0.233D-03 | 0.141D-01 | 0.123D-01 | | | 0.387D 05 | 0.337D 05 |
| | | 3/2-1/2 | -0.221D-03 | 0.208D-03 | 0.113D-01 | 0.997D-02 | | | 0.594D 05 | 0.524D 05 |
| 9 | 13 | 1/2-1/2 | -0.183D-03 | 0.168D-03 | 0.656D-02 | 0.555D-02 | | | 0.237D 05 | 0.200D 05 |
| | | 3/2-1/2 | -0.160D-03 | 0.148D-03 | 0.517D-02 | 0.439D-02 | | | 0.359D 05 | 0.305D 05 |
| 9 | 14 | 1/2-1/2 | -0.143D-03 | 0.134D-03 | 0.360D-02 | 0.314D-02 | | | 0.163D 05 | 0.142D 05 |
| | | 3/2-1/2 | -0.125D-03 | 0.117D-03 | 0.280D-02 | 0.245D-02 | | | 0.245D 05 | 0.215D 05 |
| 9 | 15 | 1/2-1/2 | -0.117D-03 | 0.111D-03 | 0.224D-02 | 0.199D-02 | | | 0.118D 05 | 0.105D 05 |
| | | 3/2-1/2 | -0.102D-03 | 0.964D-04 | 0.173D-02 | 0.154D-02 | | | 0.177D 05 | 0.157D 05 |
| 10 | 11 | 1/2-1/2 | -0.827D-03 | 0.753D-03 | 0.778D 00 | 0.644D 00 | | | 0.842D 05 | 0.698D 05 |
| | | 3/2-1/2 | -0.812D-03 | 0.756D-03 | 0.803D 00 | 0.695D 00 | | | 0.151D 06 | 0.131D 06 |
| 10 | 12 | 1/2-1/2 | -0.344D-03 | 0.319D-03 | 0.577D-01 | 0.496D-01 | | | 0.339D 05 | 0.291D 05 |
| | | 3/2-1/2 | -0.312D-03 | 0.291D-03 | 0.487D-01 | 0.425D-01 | | | 0.541D 05 | 0.472D 05 |
| 10 | 13 | 1/2-1/2 | -0.224D-03 | 0.196D-03 | 0.186D-01 | 0.142D-01 | | | 0.190D 05 | 0.146D 05 |
| | | 3/2-1/2 | -0.199D-03 | 0.175D-03 | 0.150D-01 | 0.116D-01 | | | 0.293D 05 | 0.227D 05 |
| 10 | 14 | 1/2-1/2 | -0.166D-03 | 0.152D-03 | 0.829D-02 | 0.697D-02 | | | 0.127D 05 | 0.107D 05 |
| | | 3/2-1/2 | -0.147D-03 | 0.135D-03 | 0.659D-02 | 0.556D-02 | | | 0.196D 05 | 0.165D 05 |
| 10 | 15 | 1/2-1/2 | -0.132D-03 | 0.123D-03 | 0.459D-02 | 0.402D-02 | | | 0.911D 04 | 0.797D 04 |
| | | 3/2-1/2 | -0.116D-03 | 0.108D-03 | 0.362D-02 | 0.316D-02 | | | 0.139D 05 | 0.121D 05 |
| 11 | 12 | 1/2-1/2 | -0.727D-03 | 0.660D-03 | 0.922D 00 | 0.761D 00 | | | 0.423D 05 | 0.349D 05 |
| | | 3/2-1/2 | -0.713D-03 | 0.661D-03 | 0.951D 00 | 0.817D 00 | | | 0.760D 05 | 0.654D 05 |
| 11 | 13 | 1/2-1/2 | -0.305D-03 | 0.254D-03 | 0.760D-01 | 0.527D-01 | | | 0.160D 05 | 0.111D 05 |
| | | 3/2-1/2 | -0.277D-03 | 0.231D-03 | 0.646D-01 | 0.448D-01 | | | 0.255D 05 | 0.177D 05 |
| 11 | 14 | 1/2-1/2 | -0.202D-03 | 0.173D-03 | 0.222D-01 | 0.164D-01 | | | 0.105D 05 | 0.774D 04 |
| | | 3/2-1/2 | -0.179D-03 | 0.157D-03 | 0.179D-01 | 0.136D-01 | | | 0.162D 05 | 0.124D 05 |
| 11 | 15 | 1/2-1/2 | -0.151D-03 | 0.138D-03 | 0.993D-02 | 0.835D-02 | | | 0.727D 04 | 0.612D 04 |
| | | 3/2-1/2 | -0.134D-03 | 0.122D-03 | 0.794D-02 | 0.658D-02 | | | 0.113D 05 | 0.933D 04 |
| 12 | 13 | 1/2-1/2 | -0.648D-03 | 0.364D-03 | 0.172D 01 | 0.543D 00 | | | 0.144D 05 | 0.454D 04 |
| | | 3/2-1/2 | -0.635D-03 | 0.349D-03 | 0.185D 01 | 0.558D 00 | | | 0.247D 05 | 0.746D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 12 | 14 | 1/2-1/2 | -0.274D-03 | 0.230D-03 | 0.874D-01 | 0.615D-01 | | | 0.899D 04 | 0.632D 04 |
| | | 3/2-1/2 | -0.249D-03 | 0.209D-03 | 0.745D-01 | 0.525D-01 | | | 0.144D 05 | 0.102D 05 |
| 12 | 15 | 1/2-1/2 | -0.184D-03 | 0.153D-03 | 0.259D-01 | 0.179D-01 | | | 0.620D 04 | 0.428D 04 |
| | | 3/2-1/2 | -0.163D-03 | 0.137D-03 | 0.207D-01 | 0.146D-01 | | | 0.950D 04 | 0.674D 04 |
| 13 | 14 | 1/2-1/2 | -0.100D-03 | 0.110D-03 | 0.582D-01 | 0.695D-01 | | | 0.245D 03 | 0.293D 03 |
| | | 3/2-1/2 | -0.359D-03 | 0.109D-03 | 0.831D 00 | 0.764D-01 | | | 0.559D 04 | 0.514D 03 |
| 13 | 15 | 1/2-1/2 | -0.684D-04 | 0.344D-03 | 0.749D-02 | 0.190D 00 | | | 0.408D 03 | 0.103D 05 |
| | | 3/2-1/2 | -0.225D-03 | 0.357D-03 | 0.836D-01 | 0.210D 00 | | | 0.858D 04 | 0.215D 05 |
| 14 | 15 | 1/2-1/2 | -0.120D-03 | 0.225D-04 | 0.112D 00 | 0.395D-02 | | | 0.257D 03 | 0.907D 01 |
| | | 3/2-1/2 | -0.485D-03 | 0.327D-04 | 0.206D 01 | 0.935D-02 | | | 0.751D 04 | 0.342D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - mp^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $M^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 6 | 1/2-1/2 | 0.289D-02 | -0.317D-02 | 0.342D 00 | 0.411D 00 | 0.394D 00 | | 0.285D 08 | 0.342D 08 |
| | | 1/2-3/2 | 0.302D-02 | -0.331D-02 | 0.712D 00 | 0.854D 00 | 0.814D 00 | | 0.327D 08 | 0.392D 08 |
| 6 | 7 | 1/2-1/2 | 0.799D-04 | 0.277D-03 | 0.134D-03 | 0.162D-02 | 0.284D-02 | 0.320D-02 | 0.424D 05 | 0.511D 06 |
| | | 1/2-3/2 | 0.310D-03 | 0.488D-06 | 0.401D-02 | 0.993D-08 | 0.174D-01 | 0.133D-01 | 0.644D 06 | 0.160D 01 |
| 6 | 8 | 1/2-1/2 | -0.140D-03 | 0.507D-03 | 0.351D-03 | 0.459D-02 | 0.317D-03 | 0.385D-03 | 0.155D 06 | 0.202D 07 |
| | | 1/2-3/2 | 0.778D-05 | 0.337D-03 | 0.215D-05 | 0.404D-02 | 0.349D-02 | 0.294D-02 | 0.477D 03 | 0.897D 06 |
| 6 | 9 | 1/2-1/2 | -0.151D-03 | 0.456D-03 | 0.376D-03 | 0.345D-02 | 0.725D-04 | 0.830D-04 | 0.191D 06 | 0.176D 07 |
| | | 1/2-3/2 | -0.502D-04 | 0.346D-03 | 0.833D-04 | 0.397D-02 | 0.125D-02 | 0.910D-03 | 0.213D 05 | 0.101D 07 |
| 6 | 10 | 1/2-1/2 | -0.132D-03 | 0.382D-03 | 0.279D-03 | 0.233D-02 | 0.289D-04 | 0.190D-04 | 0.153D 06 | 0.128D 07 |
| | | 1/2-3/2 | -0.594D-04 | 0.305D-03 | 0.112D-03 | 0.297D-02 | 0.620D-03 | 0.417D-03 | 0.310D 05 | 0.818D 06 |
| 6 | 11 | 1/2-1/2 | -0.113D-03 | 0.319D-03 | 0.197D-03 | 0.159D-02 | 0.124D-04 | 0.800D-05 | 0.114D 06 | 0.915D 06 |
| | | 1/2-3/2 | -0.567D-04 | 0.262D-03 | 0.100D-03 | 0.213D-02 | 0.356D-03 | 0.223D-03 | 0.289D 05 | 0.616D 06 |
| 6 | 12 | 1/2-1/2 | -0.558D-04 | 0.269D-03 | 0.141D-03 | 0.111D-02 | 0.620D-05 | 0.430D-05 | 0.838D 05 | 0.661D 06 |
| | | 1/2-3/2 | -0.513D-04 | 0.225D-03 | 0.808D-04 | 0.155D-02 | 0.208D-03 | 0.126D-03 | 0.240D 05 | 0.460D 06 |
| 6 | 13 | 1/2-1/2 | -0.767D-04 | 0.208D-03 | 0.892D-04 | 0.654D-03 | | 0.240D-05 | 0.541D 05 | 0.397D 06 |
| | | 1/2-3/2 | -0.404D-04 | 0.173D-03 | 0.495D-04 | 0.913D-03 | | 0.790D-04 | 0.150D 05 | 0.277D 06 |
| 6 | 14 | 1/2-1/2 | -0.663D-04 | 0.178D-03 | 0.662D-04 | 0.479D-03 | | 0.160D-05 | 0.408D 05 | 0.295D 06 |
| | | 1/2-3/2 | -0.357D-04 | 0.150D-03 | 0.383D-04 | 0.678D-03 | | 0.580D-04 | 0.118D 05 | 0.209D 06 |
| 6 | 15 | 1/2-1/2 | -0.580D-04 | 0.156D-03 | 0.505D-04 | 0.362D-03 | | | 0.314D 05 | 0.226D 06 |
| | | 1/2-3/2 | -0.318D-04 | 0.132D-03 | 0.302D-04 | 0.519D-03 | | | 0.942D 04 | 0.162D 06 |
| 7 | 7 | 1/2-1/2 | 0.203D-02 | -0.181D-02 | 0.583D 00 | 0.462D 00 | 0.556D 00 | | 0.406D 07 | 0.322D 07 |
| | | 1/2-3/2 | 0.212D-02 | -0.186D-02 | 0.121D 01 | 0.929D 00 | 0.112D 01 | | 0.470D 07 | 0.360D 07 |
| 7 | 8 | 1/2-1/2 | 0.255D-03 | -0.175D-03 | 0.416D-02 | 0.195D-02 | 0.516D-02 | | 0.143D 06 | 0.668D 05 |
| | | 1/2-3/2 | 0.413D-03 | -0.321D-03 | 0.215D-01 | 0.130D-01 | 0.256D-02 | | 0.378D 06 | 0.229D 06 |
| 7 | 9 | 1/2-1/2 | 0.359D-04 | 0.278D-04 | 0.648D-04 | 0.388D-04 | 0.620D-03 | | 0.358D 04 | 0.215D 04 |
| | | 1/2-3/2 | 0.143D-03 | -0.731D-04 | 0.206D-02 | 0.535D-03 | 0.502D-02 | | 0.575D 05 | 0.149D 05 |
| 7 | 10 | 1/2-1/2 | -0.175D-04 | 0.692D-04 | 0.138D-04 | 0.215D-03 | 0.170D-03 | | 0.956D 03 | 0.149D 05 |
| | | 1/2-3/2 | 0.599D-04 | -0.320D-05 | 0.322D-03 | 0.920D-06 | 0.167D-02 | | 0.112D 05 | 0.320D 02 |
| 7 | 11 | 1/2-1/2 | -0.321D-04 | 0.749D-04 | 0.435D-04 | 0.236D-03 | 0.620D-04 | | 0.343D 04 | 0.186D 05 |
| | | 1/2-3/2 | 0.268D-04 | 0.200D-04 | 0.602D-04 | 0.337D-04 | 0.911D-03 | | 0.238D 04 | 0.133D 04 |
| 7 | 12 | 1/2-1/2 | -0.350D-04 | 0.710D-04 | 0.495D-04 | 0.204D-03 | 0.270D-04 | | 0.423D 04 | 0.174D 05 |
| | | 1/2-3/2 | 0.117D-04 | 0.276D-04 | 0.111D-04 | 0.616D-04 | 0.486D-03 | | 0.474D 03 | 0.264D 04 |
| 7 | 13 | 1/2-1/2 | -0.389D-04 | 0.934D-04 | 0.596D-04 | 0.344D-03 | | | 0.538D 04 | 0.310D 05 |
| | | 1/2-3/2 | -0.114D-05 | 0.592D-04 | 0.102D-06 | 0.276D-03 | | | 0.463D 01 | 0.125D 05 |
| 7 | 14 | 1/2-1/2 | -0.358D-04 | 0.839D-04 | 0.496D-04 | 0.272D-03 | | | 0.465D 04 | 0.255D 05 |
| | | 1/2-3/2 | -0.419D-05 | 0.554D-04 | 0.135D-05 | 0.237D-03 | | | 0.635D 02 | 0.111D 05 |
| 7 | 15 | 1/2-1/2 | -0.327D-04 | 0.752D-04 | 0.406D-04 | 0.215D-03 | | | 0.392D 04 | 0.207D 05 |
| | | 1/2-3/2 | -0.558D-05 | 0.509D-04 | 0.237D-05 | 0.197D-03 | | | 0.114D 03 | 0.952D 04 |
| 8 | 8 | 1/2-1/2 | 0.147D-02 | -0.134D-02 | 0.715D 00 | 0.588D 00 | | | 0.924D 06 | 0.760D 06 |
| | | 1/2-3/2 | 0.155D-02 | -0.137D-02 | 0.149D 01 | 0.117D 01 | | | 0.108D 07 | 0.849D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - np^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\tilde{M}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | N' | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 8 | 9 | 1/2-1/2 | 0.254D-03 | -0.220D-03 | 0.890D-02 | 0.669D-02 | | | 0.654D 05 | 0.492D 05 |
| | | 1/2-3/2 | 0.365D-03 | -0.321D-03 | 0.362D-01 | 0.280D-01 | | | 0.137D 06 | 0.106D 06 |
| 8 | 10 | 1/2-1/2 | 0.858D-04 | -0.656D-04 | 0.764D-03 | 0.447D-03 | | | 0.991D 04 | 0.580D 04 |
| | | 1/2-3/2 | 0.164D-03 | -0.137D-03 | 0.553D-02 | 0.388D-02 | | | 0.363D 05 | 0.254D 05 |
| 8 | 11 | 1/2-1/2 | 0.337D-04 | -0.191D-04 | 0.102D-03 | 0.328D-04 | | | 0.176D 04 | 0.566D 03 |
| | | 1/2-3/2 | 0.916D-04 | -0.724D-04 | 0.150D-02 | 0.941D-03 | | | 0.131D 05 | 0.818D 04 |
| 8 | 12 | 1/2-1/2 | 0.128D-04 | -0.119D-05 | 0.136D-04 | 0.118D-06 | | | 0.277D 03 | 0.241D 01 |
| | | 1/2-3/2 | 0.581D-04 | -0.430D-04 | 0.557D-03 | 0.305D-03 | | | 0.571D 04 | 0.313D 04 |
| 8 | 13 | 1/2-1/2 | -0.106D-04 | 0.320D-04 | 0.871D-05 | 0.800D-04 | | | 0.199D 03 | 0.183D 04 |
| | | 1/2-3/2 | 0.261D-04 | -0.244D-05 | 0.107D-03 | 0.929D-06 | | | 0.122D 04 | 0.106D 02 |
| 8 | 14 | 1/2-1/2 | -0.133D-04 | 0.323D-04 | 0.133D-04 | 0.784D-04 | | | 0.327D 03 | 0.193D 04 |
| | | 1/2-3/2 | 0.172D-04 | 0.366D-05 | 0.445D-04 | 0.202D-05 | | | 0.549D 03 | 0.249D 02 |
| 8 | 15 | 1/2-1/2 | -0.140D-04 | 0.307D-04 | 0.143D-04 | 0.693D-04 | | | 0.372D 03 | 0.180D 04 |
| | | 1/2-3/2 | 0.120D-04 | 0.644D-05 | 0.210D-04 | 0.607D-05 | | | 0.273D 03 | 0.791D 02 |
| 9 | 9 | 1/2-1/2 | 0.115D-02 | -0.108D-02 | 0.831D 00 | 0.733D 00 | | | 0.293D 06 | 0.258D 06 |
| | | 1/2-3/2 | 0.121D-02 | -0.111D-02 | 0.173D 01 | 0.146D 01 | | | 0.343D 06 | 0.289D 06 |
| 9 | 10 | 1/2-1/2 | 0.226D-03 | -0.206D-03 | 0.129D-01 | 0.107D-01 | | | 0.284D 05 | 0.236D 05 |
| | | 1/2-3/2 | 0.311D-03 | -0.284D-03 | 0.481D-01 | 0.399D-01 | | | 0.545D 05 | 0.452D 05 |
| 9 | 11 | 1/2-1/2 | 0.945D-04 | -0.834D-04 | 0.164D-02 | 0.128D-02 | | | 0.680D 04 | 0.529D 04 |
| | | 1/2-3/2 | 0.155D-03 | -0.139D-03 | 0.878D-02 | 0.707D-02 | | | 0.185D 05 | 0.149D 05 |
| 9 | 12 | 1/2-1/2 | 0.494D-04 | -0.427D-04 | 0.380D-03 | 0.283D-03 | | | 0.220D 04 | 0.164D 04 |
| | | 1/2-3/2 | 0.953D-04 | -0.852D-04 | 0.282D-02 | 0.225D-02 | | | 0.820D 04 | 0.655D 04 |
| 9 | 13 | 1/2-1/2 | 0.108D-04 | 0.706D-06 | 0.163D-04 | 0.701D-07 | | | 0.115D 03 | 0.495D 00 |
| | | 1/2-3/2 | 0.478D-04 | -0.344D-04 | 0.640D-03 | 0.333D-03 | | | 0.227D 04 | 0.118D 04 |
| 9 | 14 | 1/2-1/2 | 0.273D-05 | 0.736D-05 | 0.981D-06 | 0.713D-05 | | | 0.794D 01 | 0.577D 02 |
| | | 1/2-3/2 | 0.331D-04 | -0.215D-04 | 0.287D-03 | 0.121D-03 | | | 0.117D 04 | 0.492D 03 |
| 9 | 15 | 1/2-1/2 | -0.118D-05 | 0.101D-04 | 0.175D-06 | 0.128D-04 | | | 0.155D 01 | 0.114D 03 |
| | | 1/2-3/2 | 0.244D-04 | -0.143D-04 | 0.149D-03 | 0.509D-04 | | | 0.667D 03 | 0.227D 03 |
| 10 | 10 | 1/2-1/2 | 0.958D-03 | -0.893D-03 | 0.984D 00 | 0.856D 00 | | | 0.120D 06 | 0.104D 06 |
| | | 1/2-3/2 | 0.100D-02 | -0.915D-03 | 0.203D 01 | 0.169D 01 | | | 0.139D 06 | 0.116D 06 |
| 10 | 11 | 1/2-1/2 | 0.223D-03 | -0.207D-03 | 0.206D-01 | 0.178D-01 | | | 0.167D 05 | 0.144D 05 |
| | | 1/2-3/2 | 0.289D-03 | -0.267D-03 | 0.684D-01 | 0.583D-01 | | | 0.287D 05 | 0.244D 05 |
| 10 | 12 | 1/2-1/2 | 0.108D-03 | -0.100D-03 | 0.346D-02 | 0.295D-02 | | | 0.556D 04 | 0.475D 04 |
| | | 1/2-3/2 | 0.157D-03 | -0.145D-03 | 0.145D-01 | 0.122D-01 | | | 0.118D 05 | 0.999D 04 |
| 10 | 13 | 1/2-1/2 | 0.440D-04 | -0.370D-04 | 0.476D-03 | 0.336D-03 | | | 0.110D 04 | 0.781D 03 |
| | | 1/2-3/2 | 0.829D-04 | -0.735D-04 | 0.336D-02 | 0.264D-02 | | | 0.353D 04 | 0.309D 04 |
| 10 | 14 | 1/2-1/2 | 0.264D-04 | -0.206D-04 | 0.152D-03 | 0.931D-04 | | | 0.445D 03 | 0.272D 03 |
| | | 1/2-3/2 | 0.576D-04 | -0.501D-04 | 0.145D-02 | 0.109D-02 | | | 0.213D 04 | 0.161D 04 |
| 10 | 15 | 1/2-1/2 | 0.171D-04 | -0.121D-04 | 0.590D-04 | 0.295D-04 | | | 0.202D 03 | 0.101D 03 |
| | | 1/2-3/2 | 0.431D-04 | -0.366D-04 | 0.752D-03 | 0.542D-03 | | | 0.129D 04 | 0.929D 03 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES. FOR THE SERIES $ns^2S_{1/2} - np^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $R^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}$ ($sec^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 11 | 11 | 1/2-1/2 | 0.819D-03 | -0.770D-03 | 0.112D 01 | 0.992D 00 | | | 0.561D 05 | 0.496D 05 |
| | | 1/2-3/2 | 0.856D-03 | -0.789D-03 | 0.230D 01 | 0.196D 01 | | | 0.651D 05 | 0.553D 05 |
| 11 | 12 | 1/2-1/2 | 0.209D-03 | -0.196D-03 | 0.275D-01 | 0.243D-01 | | | 0.960D 04 | 0.848D 04 |
| | | 1/2-3/2 | 0.263D-03 | -0.245D-03 | 0.864D-01 | 0.751D-01 | | | 0.155D 05 | 0.135D 05 |
| 11 | 13 | 1/2-1/2 | 0.835D-04 | -0.746D-04 | 0.308D-02 | 0.246D-02 | | | 0.221D 04 | 0.176D 04 |
| | | 1/2-3/2 | 0.127D-03 | -0.115D-03 | 0.141D-01 | 0.115D-01 | | | 0.511D 04 | 0.419D 04 |
| 11 | 14 | 1/2-1/2 | 0.497D-04 | -0.456D-04 | 0.897D-03 | 0.754D-03 | | | 0.954D 03 | 0.802D 03 |
| | | 1/2-3/2 | 0.827D-04 | -0.767D-04 | 0.493D-02 | 0.424D-02 | | | 0.265D 04 | 0.228D 04 |
| 11 | 15 | 1/2-1/2 | 0.331D-04 | -0.299D-04 | 0.350D-03 | 0.285D-03 | | | 0.479D 03 | 0.390D 03 |
| | | 1/2-3/2 | 0.600D-04 | -0.553D-04 | 0.229D-02 | 0.195D-02 | | | 0.158D 04 | 0.134D 04 |
| 12 | 12 | 1/2-1/2 | 0.715D-03 | -0.681D-03 | 0.125D 01 | 0.114D 01 | | | 0.292D 05 | 0.265D 05 |
| | | 1/2-3/2 | 0.746D-03 | -0.697D-03 | 0.256D 01 | 0.224D 01 | | | 0.337D 05 | 0.295D 05 |
| 12 | 13 | 1/2-1/2 | 0.161D-03 | -0.155D-03 | 0.238D-01 | 0.219D-01 | | | 0.356D 04 | 0.365D 04 |
| | | 1/2-3/2 | 0.211D-03 | -0.201D-03 | 0.799D-01 | 0.730D-01 | | | 0.689D 04 | 0.629D 04 |
| 12 | 14 | 1/2-1/2 | 0.805D-04 | -0.687D-04 | 0.408D-02 | 0.297D-02 | | | 0.144D 04 | 0.105D 04 |
| | | 1/2-3/2 | 0.119D-03 | -0.103D-03 | 0.176D-01 | 0.133D-01 | | | 0.315D 04 | 0.239D 04 |
| 12 | 15 | 1/2-1/2 | 0.514D-04 | -0.496D-04 | 0.135D-02 | 0.126D-02 | | | 0.723D 03 | 0.674D 03 |
| | | 1/2-3/2 | 0.796D-04 | -0.765D-04 | 0.643D-02 | 0.595D-02 | | | 0.174D 04 | 0.161D 04 |
| 13 | 13 | 1/2-1/2 | 0.247D-04 | -0.362D-03 | 0.139D-02 | 0.298D 00 | | | 0.376D 02 | 0.803D 04 |
| | | 1/2-3/2 | 0.479D-04 | -0.382D-03 | 0.100D-01 | 0.637D 00 | | | 0.147D 03 | 0.934D 04 |
| 13 | 14 | 1/2-1/2 | -0.138D-03 | -0.519D-03 | 0.203D-01 | 0.288D 00 | | | 0.249D 04 | 0.353D 05 |
| | | 1/2-3/2 | -0.209D-04 | -0.552D-03 | 0.923D-03 | 0.643D 00 | | | 0.582D 02 | 0.405D 05 |
| 13 | 15 | 1/2-1/2 | -0.207D-03 | -0.516D-03 | 0.329D-01 | 0.204D 00 | | | 0.786D 04 | 0.487D 05 |
| | | 1/2-3/2 | -0.538D-04 | -0.561D-03 | 0.439D-02 | 0.477D 00 | | | 0.533D 03 | 0.579D 05 |
| 14 | 14 | 1/2-1/2 | 0.459D-03 | -0.299D-03 | 0.654D 00 | 0.277D 00 | | | 0.950D 04 | 0.402D 04 |
| | | 1/2-3/2 | 0.203D-03 | -0.289D-03 | 0.245D 00 | 0.496D 00 | | | 0.194D 04 | 0.392D 04 |
| 14 | 15 | 1/2-1/2 | 0.281D-03 | -0.523D-03 | 0.114D 00 | 0.395D 00 | | | 0.766D 04 | 0.266D 05 |
| | | 1/2-3/2 | 0.136D-03 | -0.509D-03 | 0.523D-01 | 0.736D 00 | | | 0.181D 04 | 0.255D 05 |
| 15 | 15 | 1/2-1/2 | 0.596D-03 | -0.126D-03 | 0.146D 01 | 0.656D-01 | | | 0.121D 05 | 0.543D 03 |
| | | 1/2-3/2 | 0.234D-03 | -0.976D-04 | 0.431D 00 | 0.751D-01 | | | 0.194D 04 | 0.338D 03 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - np^2P_J$, CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\tilde{M}^e_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 5 | 7 | 3/2-1/2 | 0.429D-03 | -0.828D-03 | 0.116D-01 | 0.432D-01 | 0.251D 00 | | 0.816D 06 | 0.305D 07 |
| | | 3/2-3/2 | 0.410D-03 | -0.752D-03 | 0.207D-02 | 0.696D-02 | 0.211D-01 | | 0.764D 05 | 0.258D 06 |
| | | 5/2-3/2 | 0.437D-03 | -0.792D-03 | 0.143D-01 | 0.469D-01 | 0.204D 00 | | 0.771D 06 | 0.253D 07 |
| 5 | 8 | 3/2-1/2 | 0.620D-04 | -0.366D-03 | 0.157D-03 | 0.547D-02 | 0.652D 00 | | 0.263D 05 | 0.917D 06 |
| | | 3/2-3/2 | 0.724D-04 | -0.351D-03 | 0.425D-04 | 0.100D-02 | 0.208D 00 | | 0.362D 04 | 0.851D 05 |
| | | 5/2-3/2 | 0.816D-04 | -0.361D-03 | 0.327D-03 | 0.641D-02 | 0.153D 01 | | 0.410D 05 | 0.804D 06 |
| 5 | 9 | 3/2-1/2 | -0.107D-04 | -0.234D-03 | 0.401D-05 | 0.190D-02 | 0.915D-01 | | 0.922D 03 | 0.438D 06 |
| | | 3/2-3/2 | -0.991D-06 | -0.228D-03 | 0.682D-08 | 0.363D-03 | 0.299D-01 | | 0.790D 00 | 0.420D 05 |
| | | 5/2-3/2 | 0.411D-05 | -0.233D-03 | 0.709D-06 | 0.228D-02 | 0.219D 00 | | 0.121D 03 | 0.390D 06 |
| 5 | 10 | 3/2-1/2 | -0.284D-04 | -0.170D-03 | 0.260D-04 | 0.929D-03 | 0.309D-01 | | 0.701D 04 | 0.251D 06 |
| | | 3/2-3/2 | -0.209D-04 | -0.168D-03 | 0.281D-05 | 0.181D-03 | 0.100D-01 | | 0.381D 03 | 0.245D 05 |
| | | 5/2-3/2 | -0.176D-04 | -0.170D-03 | 0.120D-04 | 0.113D-02 | 0.733D-01 | | 0.241D 04 | 0.226D 06 |
| 5 | 11 | 3/2-1/2 | -0.316D-04 | -0.132D-03 | 0.306D-04 | 0.535D-03 | 0.143D-01 | | 0.907D 04 | 0.159D 06 |
| | | 3/2-3/2 | -0.258D-04 | -0.131D-03 | 0.409D-05 | 0.105D-03 | 0.450D-02 | | 0.607D 03 | 0.157D 05 |
| | | 5/2-3/2 | -0.234D-04 | -0.133D-03 | 0.203D-04 | 0.653D-03 | 0.335D-01 | | 0.446D 04 | 0.144D 06 |
| 5 | 12 | 3/2-1/2 | -0.304D-04 | -0.107D-03 | 0.276D-04 | 0.340D-03 | 0.798D-02 | | 0.867D 04 | 0.107D 06 |
| | | 3/2-3/2 | -0.259D-04 | -0.107D-03 | 0.399D-05 | 0.676D-04 | 0.248D-02 | | 0.628D 03 | 0.107D 05 |
| | | 5/2-3/2 | -0.240D-04 | -0.108D-03 | 0.207D-04 | 0.418D-03 | 0.184D-01 | | 0.484D 04 | 0.974D 05 |
| 5 | 13 | 3/2-1/2 | -0.288D-04 | -0.693D-04 | 0.242D-04 | 0.140D-03 | | | 0.792D 04 | 0.460D 05 |
| | | 3/2-3/2 | -0.252D-04 | -0.701D-04 | 0.372D-05 | 0.287D-04 | | | 0.610D 03 | 0.471D 04 |
| | | 5/2-3/2 | -0.237D-04 | -0.705D-04 | 0.197D-04 | 0.176D-03 | | | 0.479D 04 | 0.426D 05 |
| 5 | 14 | 3/2-1/2 | -0.261D-04 | -0.577D-04 | 0.196D-04 | 0.961D-04 | | | 0.661D 04 | 0.324D 05 |
| | | 3/2-3/2 | -0.232D-04 | -0.585D-04 | 0.309D-05 | 0.197D-04 | | | 0.521D 03 | 0.333D 04 |
| | | 5/2-3/2 | -0.218D-04 | -0.588D-04 | 0.166D-04 | 0.120D-03 | | | 0.414D 04 | 0.300D 05 |
| 5 | 15 | 3/2-1/2 | -0.236D-04 | -0.493D-04 | 0.158D-04 | 0.693D-04 | | | 0.545D 04 | 0.239D 05 |
| | | 3/2-3/2 | -0.211D-04 | -0.501D-04 | 0.254D-05 | 0.143D-04 | | | 0.437D 03 | 0.247D 04 |
| | | 5/2-3/2 | -0.200D-04 | -0.503D-04 | 0.137D-04 | 0.871D-04 | | | 0.350D 04 | 0.222D 05 |
| 6 | 8 | 3/2-1/2 | 0.361D-03 | -0.269D-03 | 0.191D-01 | 0.106D-01 | | | 0.248D 06 | 0.138D 06 |
| | | 3/2-3/2 | 0.273D-03 | -0.203D-03 | 0.213D-02 | 0.117D-02 | | | 0.145D 05 | 0.802D 04 |
| | | 5/2-3/2 | 0.290D-03 | -0.217D-03 | 0.146D-01 | 0.818D-02 | | | 0.146D 06 | 0.817D 05 |
| 6 | 9 | 3/2-1/2 | 0.218D-03 | -0.180D-03 | 0.430D-02 | 0.294D-02 | | | 0.146D 06 | 0.100D 06 |
| | | 3/2-3/2 | 0.174D-03 | -0.143D-03 | 0.547D-03 | 0.370D-03 | | | 0.946D 04 | 0.640D 04 |
| | | 5/2-3/2 | 0.182D-03 | -0.152D-03 | 0.362D-02 | 0.251D-02 | | | 0.923D 05 | 0.639D 05 |
| 6 | 10 | 3/2-1/2 | 0.153D-03 | -0.131D-03 | 0.175D-02 | 0.128D-02 | | | 0.880D 05 | 0.645D 05 |
| | | 3/2-3/2 | 0.126D-03 | -0.107D-03 | 0.236D-03 | 0.171D-03 | | | 0.599D 04 | 0.432D 04 |
| | | 5/2-3/2 | 0.131D-03 | -0.113D-03 | 0.154D-02 | 0.114D-02 | | | 0.576D 05 | 0.429D 05 |
| 6 | 11 | 3/2-1/2 | 0.117D-03 | -0.102D-03 | 0.912D-03 | 0.694D-03 | | | 0.565D 05 | 0.430D 05 |
| | | 3/2-3/2 | 0.574D-04 | -0.842D-04 | 0.127D-03 | 0.950D-04 | | | 0.356D 04 | 0.296D 04 |
| | | 5/2-3/2 | 0.101D-03 | -0.884D-04 | 0.820D-03 | 0.633D-03 | | | 0.378D 05 | 0.292D 05 |
| 6 | 12 | 3/2-1/2 | 0.928D-04 | -0.819D-04 | 0.543D-03 | 0.423D-03 | | | 0.382D 05 | 0.298D 05 |
| | | 3/2-3/2 | 0.785D-04 | -0.685D-04 | 0.775D-04 | 0.590D-04 | | | 0.274D 04 | 0.208D 04 |
| | | 5/2-3/2 | 0.809D-04 | -0.718D-04 | 0.497D-03 | 0.392D-03 | | | 0.260D 05 | 0.205D 05 |
| 6 | 13 | 3/2-1/2 | 0.667D-04 | -0.802D-04 | 0.269D-03 | 0.389D-03 | | | 0.206D 05 | 0.298D 05 |
| | | 3/2-3/2 | 0.563D-04 | -0.706D-04 | 0.383D-04 | 0.602D-04 | | | 0.147D 04 | 0.231D 04 |
| | | 5/2-3/2 | 0.580D-04 | -0.730D-04 | 0.245D-03 | 0.389D-03 | | | 0.140D 05 | 0.221D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{M}^e_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 14 | 3/2-1/2 | 0.555D-04 | -0.687D-04 | 0.181D-03 | 0.277D-03 | | | 0.147D 05 | 0.225D 05 |
| | | 3/2-3/2 | 0.470D-04 | -0.608D-04 | 0.259D-04 | 0.433D-04 | | | 0.106D 04 | 0.176D 04 |
| | | 5/2-3/2 | 0.484D-04 | -0.628D-04 | 0.166D-03 | 0.279D-03 | | | 0.100D 05 | 0.168D 05 |
| 6 | 15 | 3/2-1/2 | 0.473D-04 | -0.596D-04 | 0.129D-03 | 0.204D-03 | | | 0.109D 05 | 0.173D 05 |
| | | 3/2-3/2 | 0.402D-04 | -0.530D-04 | 0.186D-04 | 0.322D-04 | | | 0.790D 03 | 0.137D 04 |
| | | 5/2-3/2 | 0.414D-04 | -0.547D-04 | 0.119D-03 | 0.207D-03 | | | 0.747D 04 | 0.130D 05 |
| 7 | 9 | 3/2-1/2 | 0.417D-03 | -0.319D-03 | 0.500D-01 | 0.293D-01 | | | 0.169D 06 | 0.986D 05 |
| | | 3/2-3/2 | 0.336D-03 | -0.254D-03 | 0.631D-02 | 0.363D-02 | | | 0.112D 05 | 0.646D 04 |
| | | 5/2-3/2 | 0.350D-03 | -0.265D-03 | 0.416D-01 | 0.239D-01 | | | 0.108D 06 | 0.622D 05 |
| 7 | 10 | 3/2-1/2 | 0.249D-03 | -0.203D-03 | 0.106D-01 | 0.705D-02 | | | 0.101D 06 | 0.675D 05 |
| | | 3/2-3/2 | 0.208D-03 | -0.168D-03 | 0.147D-02 | 0.961D-03 | | | 0.717D 04 | 0.469D 04 |
| | | 5/2-3/2 | 0.215D-03 | -0.175D-03 | 0.950D-02 | 0.624D-02 | | | 0.685D 05 | 0.450D 05 |
| 7 | 11 | 3/2-1/2 | 0.176D-03 | -0.146D-03 | 0.424D-02 | 0.293D-02 | | | 0.636D 05 | 0.439D 05 |
| | | 3/2-3/2 | 0.150D-03 | -0.123D-03 | 0.612D-03 | 0.413D-03 | | | 0.465D 04 | 0.314D 04 |
| | | 5/2-3/2 | 0.155D-03 | -0.128D-03 | 0.393D-02 | 0.268D-02 | | | 0.441D 05 | 0.301D 05 |
| 7 | 12 | 3/2-1/2 | 0.135D-03 | -0.114D-03 | 0.220D-02 | 0.155D-02 | | | 0.424D 05 | 0.300D 05 |
| | | 3/2-3/2 | 0.116D-03 | -0.965D-04 | 0.325D-03 | 0.224D-03 | | | 0.316D 04 | 0.217D 04 |
| | | 5/2-3/2 | 0.120D-03 | -0.998D-04 | 0.207D-02 | 0.144D-02 | | | 0.299D 05 | 0.208D 05 |
| 7 | 13 | 3/2-1/2 | 0.107D-03 | -0.102D-03 | 0.127D-02 | 0.117D-02 | | | 0.288D 05 | 0.264D 05 |
| | | 3/2-3/2 | 0.940D-04 | -0.901D-04 | 0.196D-03 | 0.180D-03 | | | 0.223D 04 | 0.205D 04 |
| | | 5/2-3/2 | 0.963D-04 | -0.924D-04 | 0.124D-02 | 0.114D-02 | | | 0.209D 05 | 0.193D 05 |
| 7 | 14 | 3/2-1/2 | 0.884D-04 | -0.859D-04 | 0.824D-03 | 0.778D-03 | | | 0.208D 05 | 0.196D 05 |
| | | 3/2-3/2 | 0.779D-04 | -0.759D-04 | 0.128D-03 | 0.121D-03 | | | 0.162D 04 | 0.153D 04 |
| | | 5/2-3/2 | 0.798D-04 | -0.778D-04 | 0.809D-03 | 0.768D-03 | | | 0.152D 05 | 0.144D 05 |
| 7 | 15 | 3/2-1/2 | 0.749D-04 | -0.735D-04 | 0.569D-03 | 0.548D-03 | | | 0.155D 05 | 0.149D 05 |
| | | 3/2-3/2 | 0.663D-04 | -0.652D-04 | 0.890D-04 | 0.861D-04 | | | 0.121D 04 | 0.117D 04 |
| | | 5/2-3/2 | 0.678D-04 | -0.668D-04 | 0.562D-03 | 0.544D-03 | | | 0.114D 05 | 0.110D 05 |
| 8 | 10 | 3/2-1/2 | 0.377D-03 | -0.289D-03 | 0.710D-01 | 0.419D-01 | | | 0.794D 05 | 0.468D 05 |
| | | 3/2-3/2 | 0.304D-03 | -0.232D-03 | 0.899D-02 | 0.525D-02 | | | 0.533D 04 | 0.311D 04 |
| | | 5/2-3/2 | 0.318D-03 | -0.243D-03 | 0.599D-01 | 0.349D-01 | | | 0.519D 05 | 0.302D 05 |
| 8 | 11 | 3/2-1/2 | 0.228D-03 | -0.187D-03 | 0.150D-01 | 0.100D-01 | | | 0.507D 05 | 0.339D 05 |
| | | 3/2-3/2 | 0.190D-03 | -0.155D-03 | 0.206D-02 | 0.137D-02 | | | 0.357D 04 | 0.236D 04 |
| | | 5/2-3/2 | 0.198D-03 | -0.161D-03 | 0.135D-01 | 0.895D-02 | | | 0.345D 05 | 0.229D 05 |
| 8 | 12 | 3/2-1/2 | 0.164D-03 | -0.135D-03 | 0.601D-02 | 0.412D-02 | | | 0.334D 05 | 0.229D 05 |
| | | 3/2-3/2 | 0.139D-03 | -0.114D-03 | 0.856D-03 | 0.578D-03 | | | 0.241D 04 | 0.162D 04 |
| | | 5/2-3/2 | 0.144D-03 | -0.119D-03 | 0.555D-02 | 0.379D-02 | | | 0.231D 05 | 0.158D 05 |
| 8 | 13 | 3/2-1/2 | 0.131D-03 | -0.118D-03 | 0.335D-02 | 0.270D-02 | | | 0.248D 05 | 0.199D 05 |
| | | 3/2-3/2 | 0.114D-03 | -0.102D-03 | 0.503D-03 | 0.405D-03 | | | 0.187D 04 | 0.151D 04 |
| | | 5/2-3/2 | 0.118D-03 | -0.105D-03 | 0.323D-02 | 0.260D-02 | | | 0.179D 05 | 0.144D 05 |
| 8 | 14 | 3/2-1/2 | 0.106D-03 | -0.966D-04 | 0.200D-02 | 0.166D-02 | | | 0.177D 05 | 0.147D 05 |
| | | 3/2-3/2 | 0.925D-04 | -0.843D-04 | 0.303D-03 | 0.252D-03 | | | 0.135D 04 | 0.112D 04 |
| | | 5/2-3/2 | 0.954D-04 | -0.868D-04 | 0.194D-02 | 0.161D-02 | | | 0.129D 05 | 0.107D 05 |
| 8 | 15 | 3/2-1/2 | 0.885D-04 | -0.813D-04 | 0.130D-02 | 0.110D-02 | | | 0.132D 05 | 0.111D 05 |
| | | 3/2-3/2 | 0.775D-04 | -0.713D-04 | 0.200D-03 | 0.169D-03 | | | 0.101D 04 | 0.856D 03 |
| | | 5/2-3/2 | 0.799D-04 | -0.733D-04 | 0.128D-02 | 0.108D-02 | | | 0.964D 04 | 0.811D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\tilde{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 11 | 3/2-1/2 | 0.329D-03 | -0.252D-03 | 0.861D-01 | 0.505D-01 | | | 0.379D 05 | 0.223D 05 |
| | | 3/2-3/2 | 0.264D-03 | -0.202D-03 | 0.108D-01 | 0.629D-02 | | | 0.253D 04 | 0.147D 04 |
| | | 5/2-3/2 | 0.277D-03 | -0.211D-03 | 0.721D-01 | 0.419D-01 | | | 0.247D 05 | 0.144D 05 |
| 9 | 12 | 3/2-1/2 | 0.203D-03 | -0.167D-03 | 0.184D-01 | 0.124D-01 | | | 0.257D 05 | 0.174D 05 |
| | | 3/2-3/2 | 0.168D-03 | -0.138D-03 | 0.249D-02 | 0.168D-02 | | | 0.178D 04 | 0.120D 04 |
| | | 5/2-3/2 | 0.175D-03 | -0.143D-03 | 0.164D-01 | 0.110D-01 | | | 0.174D 05 | 0.116D 05 |
| 9 | 13 | 3/2-1/2 | 0.157D-03 | -0.135D-03 | 0.844D-02 | 0.623D-02 | | | 0.201D 05 | 0.149D 05 |
| | | 3/2-3/2 | 0.135D-03 | -0.115D-03 | 0.124D-02 | 0.905D-03 | | | 0.150D 04 | 0.109D 04 |
| | | 5/2-3/2 | 0.139D-03 | -0.120D-03 | 0.793D-02 | 0.592D-02 | | | 0.142D 05 | 0.106D 05 |
| 9 | 14 | 3/2-1/2 | 0.122D-03 | -0.108D-03 | 0.437D-02 | 0.340D-02 | | | 0.143D 05 | 0.111D 05 |
| | | 3/2-3/2 | 0.105D-03 | -0.927D-04 | 0.648D-03 | 0.501D-03 | | | 0.107D 04 | 0.825D 03 |
| | | 5/2-3/2 | 0.109D-03 | -0.960D-04 | 0.417D-02 | 0.324D-02 | | | 0.102D 05 | 0.792D 04 |
| 9 | 15 | 3/2-1/2 | 0.995D-04 | -0.893D-04 | 0.261D-02 | 0.210D-02 | | | 0.105D 05 | 0.844D 04 |
| | | 3/2-3/2 | 0.861D-04 | -0.773D-04 | 0.390D-03 | 0.315D-03 | | | 0.787D 03 | 0.635D 03 |
| | | 5/2-3/2 | 0.891D-04 | -0.796D-04 | 0.252D-02 | 0.201D-02 | | | 0.756D 04 | 0.603D 04 |
| 10 | 12 | 3/2-1/2 | 0.295D-03 | -0.228D-03 | 0.104D 00 | 0.619D-01 | | | 0.205D 05 | 0.122D 05 |
| | | 3/2-3/2 | 0.238D-03 | -0.183D-03 | 0.131D-01 | 0.775D-02 | | | 0.137D 04 | 0.811D 03 |
| | | 5/2-3/2 | 0.250D-03 | -0.192D-03 | 0.876D-01 | 0.517D-01 | | | 0.134D 05 | 0.793D 04 |
| 10 | 13 | 3/2-1/2 | 0.200D-03 | -0.174D-03 | 0.263D-01 | 0.198D-01 | | | 0.171D 05 | 0.128D 05 |
| | | 3/2-3/2 | 0.170D-03 | -0.148D-03 | 0.373D-02 | 0.283D-02 | | | 0.124D 04 | 0.940D 03 |
| | | 5/2-3/2 | 0.177D-03 | -0.152D-03 | 0.245D-01 | 0.181D-01 | | | 0.120D 05 | 0.890D 04 |
| 10 | 14 | 3/2-1/2 | 0.146D-03 | -0.124D-03 | 0.106D-01 | 0.762D-02 | | | 0.121D 05 | 0.869D 04 |
| | | 3/2-3/2 | 0.126D-03 | -0.106D-03 | 0.157D-02 | 0.110D-02 | | | 0.908D 03 | 0.638D 03 |
| | | 5/2-3/2 | 0.130D-03 | -0.111D-03 | 0.995D-02 | 0.730D-02 | | | 0.854D 04 | 0.627D 04 |
| 10 | 15 | 3/2-1/2 | 0.115D-03 | -0.100D-03 | 0.549D-02 | 0.419D-02 | | | 0.878D 04 | 0.669D 04 |
| | | 3/2-3/2 | 0.991D-04 | -0.860D-04 | 0.819D-03 | 0.616D-03 | | | 0.660D 03 | 0.496D 03 |
| | | 5/2-3/2 | 0.102D-03 | -0.895D-04 | 0.524D-02 | 0.403D-02 | | | 0.628D 04 | 0.483D 04 |
| 11 | 13 | 3/2-1/2 | 0.301D-03 | -0.242D-03 | 0.154D 00 | 0.998D-01 | | | 0.149D 05 | 0.966D 04 |
| | | 3/2-3/2 | 0.250D-03 | -0.200D-03 | 0.207D-01 | 0.132D-01 | | | 0.106D 04 | 0.682D 03 |
| | | 5/2-3/2 | 0.260D-03 | -0.209D-03 | 0.136D 00 | 0.872D-01 | | | 0.102D 05 | 0.658D 04 |
| 11 | 14 | 3/2-1/2 | 0.186D-03 | -0.165D-03 | 0.319D-01 | 0.252D-01 | | | 0.105D 05 | 0.830D 04 |
| | | 3/2-3/2 | 0.158D-03 | -0.142D-03 | 0.453D-02 | 0.366D-02 | | | 0.764D 03 | 0.618D 03 |
| | | 5/2-3/2 | 0.165D-03 | -0.145D-03 | 0.300D-01 | 0.231D-01 | | | 0.748D 04 | 0.577D 04 |
| 11 | 15 | 3/2-1/2 | 0.137D-03 | -0.114D-03 | 0.130D-01 | 0.886D-02 | | | 0.769D 04 | 0.525D 04 |
| | | 3/2-3/2 | 0.120D-03 | -0.971D-04 | 0.197D-02 | 0.129D-02 | | | 0.591D 03 | 0.386D 03 |
| | | 5/2-3/2 | 0.122D-03 | -0.103D-03 | 0.122D-01 | 0.866D-02 | | | 0.544D 04 | 0.387D 04 |
| 12 | 14 | 3/2-1/2 | 0.297D-03 | 0.971D-04 | 0.205D 00 | 0.220D-01 | | | 0.105D 05 | 0.113D 04 |
| | | 3/2-3/2 | -0.146D-03 | 0.135D-03 | 0.970D-02 | 0.821D-02 | | | 0.265D 03 | 0.224D 03 |
| | | 5/2-3/2 | 0.575D-03 | 0.129D-03 | 0.907D 00 | 0.459D-01 | | | 0.363D 05 | 0.184D 04 |
| 12 | 15 | 3/2-1/2 | 0.265D-03 | 0.680D-04 | 0.878D-01 | 0.578D-02 | | | 0.157D 05 | 0.103D 04 |
| | | 3/2-3/2 | -0.132D-03 | 0.122D-03 | 0.430D-02 | 0.369D-02 | | | 0.395D 03 | 0.339D 03 |
| | | 5/2-3/2 | 0.522D-03 | 0.115D-03 | 0.406D 00 | 0.197D-01 | | | 0.551D 05 | 0.267D 04 |
| 13 | 15 | 3/2-1/2 | 0.148D-03 | 0.236D-03 | 0.684D-01 | 0.173D 00 | | | 0.198D 04 | 0.500D 04 |
| | | 3/2-3/2 | -0.671D-04 | 0.258D-03 | 0.272D-02 | 0.400D-01 | | | 0.418D 02 | 0.616D 03 |
| | | 5/2-3/2 | 0.258D-03 | 0.254D-03 | 0.244D 00 | 0.236D 00 | | | 0.550D 04 | 0.533D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_J$, CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $M^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 5 | 1/2-3/2 | -0.960D-03 | 0.961D-03 | 0.254D 00 | 0.254D 00 | 0.251D 00 | | 0.935D 06 | 0.936D 06 |
| | | 3/2-3/2 | -0.829D-03 | 0.805D-03 | 0.227D-01 | 0.214D-01 | | | 0.116D 06 | 0.109D 06 |
| | | 3/2-5/2 | -0.900D-03 | 0.848D-03 | 0.233D 00 | 0.207D 00 | | | 0.850D 06 | 0.755D 06 |
| 6 | 6 | 1/2-3/2 | 0.299D-02 | -0.364D-02 | 0.717D 00 | 0.106D 01 | 0.298D 00 | | 0.311D 08 | 0.461D 08 |
| | | 3/2-3/2 | 0.299D-02 | -0.366D-02 | 0.756D-01 | 0.113D 00 | 0.397D-01 | | 0.594D 07 | 0.888D 07 |
| | | 3/2-5/2 | 0.298D-02 | -0.363D-02 | 0.670D 00 | 0.999D 00 | 0.332D 00 | | 0.354D 08 | 0.527D 08 |
| 6 | 7 | 1/2-3/2 | 0.132D-02 | -0.142D-02 | 0.107D 00 | 0.125D 00 | 0.927D-01 | 0.123D 00 | 0.786D 07 | 0.918D 07 |
| | | 3/2-3/2 | 0.125D-02 | -0.135D-02 | 0.101D-01 | 0.117D-01 | 0.110D-01 | 0.130D-01 | 0.138D 07 | 0.160D 07 |
| | | 3/2-5/2 | 0.126D-02 | -0.137D-02 | 0.920D-01 | 0.107D 00 | 0.951D-01 | 0.111D 00 | 0.840D 07 | 0.980D 07 |
| 6 | 8 | 1/2-3/2 | 0.800D-03 | -0.780D-03 | 0.353D-01 | 0.335D-01 | 0.419D-01 | 0.419D-01 | 0.325D 07 | 0.309D 07 |
| | | 3/2-3/2 | 0.745D-03 | -0.718D-03 | 0.317D-02 | 0.294D-02 | 0.480D-02 | 0.561D-02 | 0.546D 06 | 0.507D 06 |
| | | 3/2-5/2 | 0.756D-03 | -0.735D-03 | 0.293D-01 | 0.277D-01 | 0.418D-01 | 0.439D-01 | 0.337D 07 | 0.319D 07 |
| 6 | 9 | 1/2-3/2 | 0.548D-03 | -0.480D-03 | 0.156D-01 | 0.120D-01 | 0.228D-01 | 0.251D-01 | 0.162D 07 | 0.124D 07 |
| | | 3/2-3/2 | 0.502D-03 | -0.430D-03 | 0.135D-02 | 0.991D-03 | 0.250D-02 | 0.300D-02 | 0.263D 06 | 0.193D 06 |
| | | 3/2-5/2 | 0.511D-03 | -0.444D-03 | 0.126D-01 | 0.950D-02 | 0.223D-01 | 0.237D-01 | 0.164D 07 | 0.124D 07 |
| 6 | 10 | 1/2-3/2 | 0.406D-03 | -0.331D-03 | 0.827D-02 | 0.550D-02 | 0.139D-01 | 0.152D-01 | 0.923D 06 | 0.614D 06 |
| | | 3/2-3/2 | 0.369D-03 | -0.291D-03 | 0.703D-03 | 0.436D-03 | 0.150D-02 | 0.200D-02 | 0.147D 06 | 0.915D 05 |
| | | 3/2-5/2 | 0.377D-03 | -0.302D-03 | 0.659D-02 | 0.423D-02 | 0.135D-01 | 0.153D-01 | 0.922D 06 | 0.592D 06 |
| 6 | 11 | 1/2-3/2 | 0.319D-03 | -0.247D-03 | 0.497D-02 | 0.299D-02 | 0.920D-02 | 0.108D-01 | 0.581D 06 | 0.350D 06 |
| | | 3/2-3/2 | 0.288D-03 | -0.214D-03 | 0.417D-03 | 0.230D-03 | 0.100D-02 | 0.810D-03 | 0.918D 05 | 0.506D 05 |
| | | 3/2-5/2 | 0.294D-03 | -0.223D-03 | 0.393D-02 | 0.226D-02 | 0.880D-02 | 0.893D-02 | 0.576D 06 | 0.331D 06 |
| 6 | 12 | 1/2-3/2 | 0.260D-03 | -0.195D-03 | 0.326D-02 | 0.183D-02 | | 0.869D-02 | 0.393D 06 | 0.220D 06 |
| | | 3/2-3/2 | 0.234D-03 | -0.166D-03 | 0.270D-03 | 0.137D-03 | | 0.837D-02 | 0.615D 05 | 0.312D 05 |
| | | 3/2-5/2 | 0.239D-03 | -0.174D-03 | 0.255D-02 | 0.136D-02 | | 0.837D-02 | 0.387D 06 | 0.206D 06 |
| 6 | 13 | 1/2-3/2 | 0.218D-03 | -0.159D-03 | 0.226D-02 | 0.121D-02 | | 0.470D-02 | 0.279D 06 | 0.149D 06 |
| | | 3/2-3/2 | 0.195D-03 | -0.135D-03 | 0.187D-03 | 0.895D-04 | | 0.530D-02 | 0.485D 05 | 0.208D 05 |
| | | 3/2-5/2 | 0.200D-03 | -0.142D-03 | 0.177D-02 | 0.890D-03 | | 0.530D-02 | 0.274D 06 | 0.138D 06 |
| 6 | 14 | 1/2-3/2 | 0.187D-03 | -0.135D-03 | 0.165D-02 | 0.854D-03 | | 0.380D-02 | 0.207D 06 | 0.107D 06 |
| | | 3/2-3/2 | 0.167D-03 | -0.113D-03 | 0.136D-03 | 0.624D-04 | | 0.396D-02 | 0.321D 05 | 0.148D 05 |
| | | 3/2-5/2 | 0.171D-03 | -0.119D-03 | 0.128D-02 | 0.623D-03 | | 0.396D-02 | 0.203D 06 | 0.985D 05 |
| 7 | 6 | 1/2-3/2 | 0.140D-03 | 0.490D-03 | 0.217D-01 | 0.267D 00 | 0.327D 00 | | 0.491D 04 | 0.604D 05 |
| | | 3/2-3/2 | 0.291D-03 | 0.376D-03 | 0.120D-01 | 0.202D-01 | 0.320D-01 | | 0.331D 04 | 0.556D 04 |
| | | 3/2-5/2 | 0.259D-03 | 0.406D-03 | 0.807D-01 | 0.198D 00 | 0.309D 00 | | 0.168D 05 | 0.414D 05 |
| 7 | 7 | 1/2-3/2 | 0.181D-02 | -0.189D-02 | 0.701D 00 | 0.761D 00 | 0.237D 00 | | 0.429D 07 | 0.465D 07 |
| | | 3/2-3/2 | 0.188D-02 | -0.200D-02 | 0.788D-01 | 0.893D-01 | 0.340D-01 | | 0.883D 06 | 0.100D 07 |
| | | 3/2-5/2 | 0.186D-02 | -0.198D-02 | 0.693D 00 | 0.785D 00 | 0.282D 00 | | 0.523D 07 | 0.593D 07 |
| 7 | 8 | 1/2-3/2 | 0.103D-02 | -0.990D-03 | 0.159D 00 | 0.148D 00 | 0.822D-01 | | 0.194D 07 | 0.181D 07 |
| | | 3/2-3/2 | 0.101D-02 | -0.984D-03 | 0.159D-01 | 0.151D-01 | 0.105D-01 | | 0.366D 06 | 0.347D 06 |
| | | 3/2-5/2 | 0.101D-02 | -0.986D-03 | 0.143D 00 | 0.136D 00 | 0.890D-01 | | 0.220D 07 | 0.210D 07 |
| 7 | 9 | 1/2-3/2 | 0.690D-03 | -0.644D-03 | 0.617D-01 | 0.537D-01 | 0.391D-01 | | 0.103D 07 | 0.894D 06 |
| | | 3/2-3/2 | 0.664D-03 | -0.621D-03 | 0.586D-02 | 0.513D-02 | 0.470D-02 | | 0.165D 06 | 0.162D 06 |
| | | 3/2-5/2 | 0.667D-03 | -0.626D-03 | 0.533D-01 | 0.469D-01 | 0.410D-01 | | 0.112D 07 | 0.990D 06 |
| 7 | 10 | 1/2-3/2 | 0.507D-03 | -0.464D-03 | 0.306D-01 | 0.256D-01 | 0.221D-01 | | 0.606D 06 | 0.506D 06 |
| | | 3/2-3/2 | 0.482D-03 | -0.440D-03 | 0.283D-02 | 0.235D-02 | 0.260D-02 | | 0.107D 06 | 0.888D 05 |
| | | 3/2-5/2 | 0.486D-03 | -0.445D-03 | 0.258D-01 | 0.217D-01 | 0.228D-01 | | 0.651D 06 | 0.546D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns\,^2S_{1/2} - md\,^2D_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 7 | 11 | 1/2-3/2 | 0.396D-03 | -0.357D-03 | 0.176D-01 | 0.144D-01 | 0.139D-01 | | 0.389D 06 | 0.317D 06 |
| | | 3/2-3/2 | 0.373D-03 | -0.335D-03 | 0.160D-02 | 0.129D-02 | 0.160D-02 | | 0.674D 05 | 0.544D 05 |
| | | 3/2-5/2 | 0.376D-03 | -0.340D-03 | 0.147D-01 | 0.120D-01 | 0.142D-01 | | 0.413D 06 | 0.336D 06 |
| 7 | 12 | 1/2-3/2 | 0.321D-03 | -0.287D-03 | 0.112D-01 | 0.897D-02 | | | 0.266D 06 | 0.213D 06 |
| | | 3/2-3/2 | 0.301D-03 | -0.267D-03 | 0.101D-02 | 0.793D-03 | | | 0.456D 05 | 0.360D 05 |
| | | 3/2-5/2 | 0.304D-03 | -0.272D-03 | 0.924D-02 | 0.738D-02 | | | 0.280D 06 | 0.223D 06 |
| 7 | 13 | 1/2-3/2 | 0.268D-03 | -0.239D-03 | 0.762D-02 | 0.603D-02 | | | 0.190D 06 | 0.150D 06 |
| | | 3/2-3/2 | 0.251D-03 | -0.221D-03 | 0.679D-03 | 0.528D-03 | | | 0.325D 05 | 0.252D 05 |
| | | 3/2-5/2 | 0.254D-03 | -0.225D-03 | 0.625D-02 | 0.492D-02 | | | 0.200D 06 | 0.157D 06 |
| 7 | 14 | 1/2-3/2 | 0.229D-03 | -0.203D-03 | 0.547D-02 | 0.429D-02 | | | 0.142D 06 | 0.111D 06 |
| | | 3/2-3/2 | 0.214D-03 | -0.187D-03 | 0.485D-03 | 0.372D-03 | | | 0.241D 05 | 0.185D 05 |
| | | 3/2-5/2 | 0.216D-03 | -0.191D-03 | 0.447D-02 | 0.347D-02 | | | 0.148D 06 | 0.115D 06 |
| 8 | 7 | 1/2-3/2 | -0.255D-04 | 0.383D-03 | 0.175D-02 | 0.397D 00 | | | 0.670D 02 | 0.152D 05 |
| | | 3/2-3/2 | 0.115D-03 | 0.287D-03 | 0.471D-02 | 0.294D-01 | | | 0.206D 03 | 0.129D 04 |
| | | 3/2-5/2 | 0.909D-04 | 0.312D-03 | 0.246D-01 | 0.290D 00 | | | 0.838D 03 | 0.990D 04 |
| 8 | 8 | 1/2-3/2 | 0.124D-02 | -0.124D-02 | 0.670D 00 | 0.672D 00 | | | 0.987D 06 | 0.991D 06 |
| | | 3/2-3/2 | 0.132D-02 | -0.135D-02 | 0.789D-01 | 0.825D-01 | | | 0.215D 06 | 0.224D 06 |
| | | 3/2-5/2 | 0.130D-02 | -0.133D-02 | 0.687D 00 | 0.718D 00 | | | 0.126D 07 | 0.132D 07 |
| 8 | 9 | 1/2-3/2 | 0.767D-03 | -0.730D-03 | 0.173D 00 | 0.156D 00 | | | 0.561D 06 | 0.507D 06 |
| | | 3/2-3/2 | 0.777D-03 | -0.746D-03 | 0.182D-01 | 0.168D-01 | | | 0.112D 06 | 0.103D 06 |
| | | 3/2-5/2 | 0.774D-03 | -0.744D-03 | 0.162D 00 | 0.150D 00 | | | 0.669D 06 | 0.617D 06 |
| 8 | 10 | 1/2-3/2 | 0.544D-03 | -0.508D-03 | 0.721D-01 | 0.628D-01 | | | 0.340D 06 | 0.296D 06 |
| | | 3/2-3/2 | 0.540D-03 | -0.507D-03 | 0.727D-02 | 0.639D-02 | | | 0.655D 05 | 0.576D 05 |
| | | 3/2-5/2 | 0.540D-03 | -0.507D-03 | 0.654D-01 | 0.577D-01 | | | 0.394D 06 | 0.347D 06 |
| 8 | 11 | 1/2-3/2 | 0.416D-03 | -0.385D-03 | 0.378D-01 | 0.324D-01 | | | 0.221D 06 | 0.189D 06 |
| | | 3/2-3/2 | 0.408D-03 | -0.379D-03 | 0.372D-02 | 0.320D-02 | | | 0.418D 05 | 0.360D 05 |
| | | 3/2-5/2 | 0.409D-03 | -0.380D-03 | 0.336D-01 | 0.290D-01 | | | 0.252D 06 | 0.218D 06 |
| 8 | 12 | 1/2-3/2 | 0.333D-03 | -0.307D-03 | 0.227D-01 | 0.192D-01 | | | 0.152D 06 | 0.129D 06 |
| | | 3/2-3/2 | 0.325D-03 | -0.300D-03 | 0.220D-02 | 0.187D-02 | | | 0.284D 05 | 0.241D 05 |
| | | 3/2-5/2 | 0.326D-03 | -0.301D-03 | 0.199D-01 | 0.170D-01 | | | 0.172D 06 | 0.147D 06 |
| 8 | 13 | 1/2-3/2 | 0.276D-03 | -0.253D-03 | 0.148D-01 | 0.125D-01 | | | 0.110D 06 | 0.924D 05 |
| | | 3/2-3/2 | 0.268D-03 | -0.246D-03 | 0.142D-02 | 0.120D-02 | | | 0.203D 05 | 0.171D 05 |
| | | 3/2-5/2 | 0.269D-03 | -0.248D-03 | 0.129D-01 | 0.109D-01 | | | 0.123D 06 | 0.104D 06 |
| 8 | 14 | 1/2-3/2 | 0.235D-03 | -0.215D-03 | 0.103D-01 | 0.868D-02 | | | 0.819D 05 | 0.687D 05 |
| | | 3/2-3/2 | 0.227D-03 | -0.208D-03 | 0.987D-03 | 0.825D-03 | | | 0.151D 05 | 0.126D 05 |
| | | 3/2-5/2 | 0.228D-03 | -0.209D-03 | 0.897D-02 | 0.754D-02 | | | 0.915D 05 | 0.769D 05 |
| 9 | 8 | 1/2-3/2 | -0.217D-04 | 0.310D-03 | 0.249D-02 | 0.506D 00 | | | 0.251D 02 | 0.510D 04 |
| | | 3/2-3/2 | 0.974D-04 | 0.229D-03 | 0.672D-02 | 0.370D-01 | | | 0.749D 02 | 0.413D 03 |
| | | 3/2-5/2 | 0.745D-04 | 0.251D-03 | 0.324D-01 | 0.367D 00 | | | 0.286D 03 | 0.325D 04 |
| 9 | 9 | 1/2-3/2 | 0.943D-03 | -0.950D-03 | 0.683D 00 | 0.694D 00 | | | 0.323D 06 | 0.328D 06 |
| | | 3/2-3/2 | 0.101D-02 | -0.104D-02 | 0.822D-01 | 0.865D-01 | | | 0.721D 05 | 0.759D 05 |
| | | 3/2-5/2 | 0.999D-03 | -0.102D-02 | 0.713D 00 | 0.750D 00 | | | 0.422D 06 | 0.444D 06 |
| 9 | 10 | 1/2-3/2 | 0.598D-03 | -0.573D-03 | 0.179D 00 | 0.164D 00 | | | 0.200D 06 | 0.184D 06 |
| | | 3/2-3/2 | 0.617D-03 | -0.595D-03 | 0.195D-01 | 0.181D-01 | | | 0.415D 05 | 0.386D 05 |
| | | 3/2-5/2 | 0.613D-03 | -0.591D-03 | 0.173D 00 | 0.161D 00 | | | 0.246D 06 | 0.230D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{M}^e_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 11 | 1/2-3/2 | 0.436D-03 | -0.410D-03 | 0.771D-01 | 0.682D-01 | | | 0.131D 06 | 0.116D 06 |
| | | 3/2-3/2 | 0.441D-03 | -0.415D-03 | 0.805D-02 | 0.719D-02 | | | 0.263D 05 | 0.235D 05 |
| | | 3/2-5/2 | 0.440D-03 | -0.416D-03 | 0.720D-01 | 0.644D-01 | | | 0.158D 06 | 0.141D 06 |
| 9 | 12 | 1/2-3/2 | 0.341D-03 | -0.319D-03 | 0.415D-01 | 0.363D-01 | | | 0.907D 05 | 0.794D 05 |
| | | 3/2-3/2 | 0.341D-03 | -0.320D-03 | 0.424D-02 | 0.374D-02 | | | 0.179D 05 | 0.158D 05 |
| | | 3/2-5/2 | 0.341D-03 | -0.320D-03 | 0.381D-01 | 0.336D-01 | | | 0.107D 06 | 0.947D 05 |
| 9 | 13 | 1/2-3/2 | 0.278D-03 | -0.259D-03 | 0.254D-01 | 0.221D-01 | | | 0.654D 05 | 0.570D 05 |
| | | 3/2-3/2 | 0.277D-03 | -0.258D-03 | 0.256D-02 | 0.224D-02 | | | 0.128D 05 | 0.112D 05 |
| | | 3/2-5/2 | 0.277D-03 | -0.259D-03 | 0.230D-01 | 0.202D-01 | | | 0.767D 05 | 0.672D 05 |
| 9 | 14 | 1/2-3/2 | 0.233D-03 | -0.217D-03 | 0.169D-01 | 0.147D-01 | | | 0.489D 05 | 0.425D 05 |
| | | 3/2-3/2 | 0.231D-03 | -0.216D-03 | 0.169D-02 | 0.147D-02 | | | 0.948D 04 | 0.824D 04 |
| | | 3/2-5/2 | 0.232D-03 | -0.216D-03 | 0.152D-01 | 0.133D-01 | | | 0.570D 05 | 0.497D 05 |
| 10 | 9 | 1/2-3/2 | 0.417D-05 | 0.261D-03 | 0.156D-03 | 0.613D 00 | | | 0.541D 00 | 0.212D 04 |
| | | 3/2-3/2 | 0.105D-03 | 0.191D-03 | 0.134D-01 | 0.444D-01 | | | 0.501D 02 | 0.167D 03 |
| | | 3/2-5/2 | 0.849D-04 | 0.210D-03 | 0.723D-01 | 0.443D 00 | | | 0.217D 03 | 0.133D 04 |
| 10 | 10 | 1/2-3/2 | 0.755D-03 | -0.769D-03 | 0.704D 00 | 0.730D 00 | | | 0.129D 06 | 0.134D 06 |
| | | 3/2-3/2 | 0.818D-03 | -0.847D-03 | 0.858D-01 | 0.918D-01 | | | 0.292D 05 | 0.313D 05 |
| | | 3/2-5/2 | 0.805D-03 | -0.832D-03 | 0.743D 00 | 0.794D 00 | | | 0.171D 06 | 0.183D 06 |
| 10 | 11 | 1/2-3/2 | 0.487D-03 | -0.471D-03 | 0.186D 00 | 0.174D 00 | | | 0.847D 05 | 0.793D 05 |
| | | 3/2-3/2 | 0.507D-03 | -0.494D-03 | 0.206D-01 | 0.195D-01 | | | 0.179D 05 | 0.170D 05 |
| | | 3/2-5/2 | 0.503D-03 | -0.490D-03 | 0.182D 00 | 0.173D 00 | | | 0.106D 06 | 0.101D 06 |
| 10 | 12 | 1/2-3/2 | 0.361D-03 | -0.341D-03 | 0.811D-01 | 0.723D-01 | | | 0.584D 05 | 0.521D 05 |
| | | 3/2-3/2 | 0.369D-03 | -0.351D-03 | 0.865D-02 | 0.781D-02 | | | 0.120D 05 | 0.109D 05 |
| | | 3/2-5/2 | 0.368D-03 | -0.349D-03 | 0.771D-01 | 0.696D-01 | | | 0.717D 05 | 0.646D 05 |
| 10 | 13 | 1/2-3/2 | 0.286D-03 | -0.270D-03 | 0.443D-01 | 0.394D-01 | | | 0.421D 05 | 0.375D 05 |
| | | 3/2-3/2 | 0.290D-03 | -0.275D-03 | 0.464D-02 | 0.415D-02 | | | 0.854D 04 | 0.765D 04 |
| | | 3/2-5/2 | 0.289D-03 | -0.274D-03 | 0.414D-01 | 0.371D-01 | | | 0.509D 05 | 0.457D 05 |
| 10 | 14 | 1/2-3/2 | 0.236D-03 | -0.223D-03 | 0.275D-01 | 0.245D-01 | | | 0.315D 05 | 0.280D 05 |
| | | 3/2-3/2 | 0.238D-03 | -0.225D-03 | 0.284D-02 | 0.254D-02 | | | 0.632D 04 | 0.564D 04 |
| | | 3/2-5/2 | 0.237D-03 | -0.225D-03 | 0.254D-01 | 0.227D-01 | | | 0.377D 05 | 0.338D 05 |
| 11 | 10 | 1/2-3/2 | 0.131D-04 | 0.227D-03 | 0.242D-02 | 0.725D 00 | | | 0.340D 01 | 0.102D 04 |
| | | 3/2-3/2 | 0.993D-04 | 0.165D-03 | 0.191D-01 | 0.524D-01 | | | 0.286D 02 | 0.786D 02 |
| | | 3/2-5/2 | 0.820D-04 | 0.182D-03 | 0.106D 00 | 0.521D 00 | | | 0.128D 03 | 0.629D 03 |
| 11 | 11 | 1/2-3/2 | 0.628D-03 | -0.644D-03 | 0.732D 00 | 0.771D 00 | | | 0.593D 05 | 0.625D 05 |
| | | 3/2-3/2 | 0.683D-03 | -0.712D-03 | 0.899D-01 | 0.978D-01 | | | 0.136D 05 | 0.147D 05 |
| | | 3/2-5/2 | 0.672D-03 | -0.700D-03 | 0.776D 00 | 0.843D 00 | | | 0.791D 05 | 0.859D 05 |
| 11 | 12 | 1/2-3/2 | 0.409D-03 | -0.401D-03 | 0.193D 00 | 0.186D 00 | | | 0.406D 05 | 0.390D 05 |
| | | 3/2-3/2 | 0.429D-03 | -0.421D-03 | 0.217D-01 | 0.210D-01 | | | 0.873D 04 | 0.842D 04 |
| | | 3/2-5/2 | 0.425D-03 | -0.418D-03 | 0.191D 00 | 0.185D 00 | | | 0.514D 05 | 0.497D 05 |
| 11 | 13 | 1/2-3/2 | 0.306D-03 | -0.289D-03 | 0.849D-01 | 0.756D-01 | | | 0.290D 05 | 0.258D 05 |
| | | 3/2-3/2 | 0.316D-03 | -0.302D-03 | 0.918D-02 | 0.839D-02 | | | 0.606D 04 | 0.554D 04 |
| | | 3/2-5/2 | 0.315D-03 | -0.300D-03 | 0.819D-01 | 0.745D-01 | | | 0.362D 05 | 0.329D 05 |
| 11 | 14 | 1/2-3/2 | 0.245D-03 | -0.232D-03 | 0.469D-01 | 0.420D-01 | | | 0.216D 05 | 0.194D 05 |
| | | 3/2-3/2 | 0.252D-03 | -0.238D-03 | 0.500D-02 | 0.447D-02 | | | 0.449D 04 | 0.401D 04 |
| | | 3/2-5/2 | 0.250D-03 | -0.237D-03 | 0.443D-01 | 0.398D-01 | | | 0.265D 05 | 0.238D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np\,^2P_J - md\,^2D_J$, CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $r^e_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 12 | 11 | 1/2-3/2 | 0.157D-04 | 0.200D-03 | 0.514D-02 | 0.837D 00 | | | 0.329D 01 | 0.535D 03 |
| | | 3/2-3/2 | 0.914D-04 | 0.146D-03 | 0.240D-01 | 0.613D-01 | | | 0.163D 02 | 0.416D 02 |
| | | 3/2-5/2 | 0.755D-04 | 0.160D-03 | 0.134D 00 | 0.600D 00 | | | 0.735D 02 | 0.330D 03 |
| 12 | 12 | 1/2-3/2 | 0.536D-03 | -0.553D-03 | 0.764D 00 | 0.814D 00 | | | 0.302D 05 | 0.322D 05 |
| | | 3/2-3/2 | 0.585D-03 | -0.613D-03 | 0.944D-01 | 0.104D 00 | | | 0.695D 04 | 0.764D 04 |
| | | 3/2-5/2 | 0.575D-03 | -0.602D-03 | 0.815D 00 | 0.893D 00 | | | 0.406D 05 | 0.444D 05 |
| 12 | 13 | 1/2-3/2 | 0.352D-03 | -0.351D-03 | 0.202D 00 | 0.200D 00 | | | 0.213D 05 | 0.212D 05 |
| | | 3/2-3/2 | 0.372D-03 | -0.371D-03 | 0.230D-01 | 0.229D-01 | | | 0.466D 04 | 0.464D 04 |
| | | 3/2-5/2 | 0.366D-03 | -0.367D-03 | 0.200D 00 | 0.201D 00 | | | 0.272D 05 | 0.274D 05 |
| 12 | 14 | 1/2-3/2 | 0.266D-03 | -0.248D-03 | 0.890D-01 | 0.776D-01 | | | 0.157D 05 | 0.137D 05 |
| | | 3/2-3/2 | 0.275D-03 | -0.260D-03 | 0.966D-02 | 0.866D-02 | | | 0.330D 04 | 0.296D 04 |
| | | 3/2-5/2 | 0.275D-03 | -0.258D-03 | 0.869D-01 | 0.766D-01 | | | 0.199D 05 | 0.175D 05 |
| 13 | 12 | 1/2-3/2 | 0.510D-03 | 0.158D-04 | 0.769D 01 | 0.734D-02 | | | 0.247D 04 | 0.235D 01 |
| | | 3/2-3/2 | 0.557D-03 | 0.705D-05 | 0.373D 01 | 0.202D-03 | | | 0.126D 04 | 0.683D-01 |
| | | 3/2-5/2 | 0.266D-03 | 0.883D-05 | 0.235D 01 | 0.259D-02 | | | 0.646D 03 | 0.709D 00 |
| 13 | 13 | 1/2-3/2 | 0.508D-03 | -0.339D-04 | 0.946D 00 | 0.421D-02 | | | 0.197D 05 | 0.878D 02 |
| | | 3/2-3/2 | 0.923D-03 | -0.714D-04 | 0.323D 00 | 0.193D-02 | | | 0.126D 05 | 0.752D 02 |
| | | 3/2-5/2 | 0.259D-03 | -0.610D-04 | 0.228D 00 | 0.126D-01 | | | 0.599D 04 | 0.332D 03 |
| 13 | 14 | 1/2-3/2 | 0.460D-03 | -0.148D-03 | 0.468D 00 | 0.487D-01 | | | 0.268D 05 | 0.279D 04 |
| | | 3/2-3/2 | 0.819D-03 | -0.197D-03 | 0.151D 00 | 0.879D-02 | | | 0.166D 05 | 0.966D 03 |
| | | 3/2-5/2 | 0.232D-03 | -0.184D-03 | 0.109D 00 | 0.684D-01 | | | 0.802D 04 | 0.504D 04 |
| 14 | 13 | 1/2-3/2 | 0.106D-03 | 0.524D-04 | 0.446D 00 | 0.110D 00 | | | 0.780D 02 | 0.192D 02 |
| | | 3/2-3/2 | 0.272D-03 | 0.362D-04 | 0.409D 00 | 0.723D-02 | | | 0.748D 02 | 0.132D 01 |
| | | 3/2-5/2 | 0.700D-04 | 0.399D-04 | 0.221D 00 | 0.717D-01 | | | 0.328D 02 | 0.106D 02 |
| 14 | 14 | 1/2-3/2 | 0.221D-03 | 0.238D-03 | 0.239D 00 | 0.277D 00 | | | 0.280D 04 | 0.324D 04 |
| | | 3/2-3/2 | 0.457D-03 | 0.204D-03 | 0.106D 00 | 0.211D-01 | | | 0.230D 04 | 0.461D 03 |
| | | 3/2-5/2 | 0.122D-03 | 0.213D-03 | 0.675D-01 | 0.206D 00 | | | 0.998D 03 | 0.304D 04 |
| 15 | 14 | 1/2-3/2 | -0.246D-03 | 0.558D-04 | 0.321D 01 | 0.166D 00 | | | 0.317D 03 | 0.164D 02 |
| | | 3/2-3/2 | -0.365D-03 | 0.411D-04 | 0.977D 00 | 0.124D-01 | | | 0.101D 03 | 0.129D 01 |
| | | 3/2-5/2 | -0.105D-03 | 0.456D-04 | 0.664D 00 | 0.124D 00 | | | 0.563D 02 | 0.105D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 4 | 7 | 5/2-3/2 | -0.487D-03 | 0.953D-03 | 0.828D-01 | 0.317D 00 | | | 0.206D 06 | 0.786D 06 |
| | | 5/2-5/2 | -0.497D-03 | 0.958D-03 | 0.607D-02 | 0.226D-01 | | | 0.103D 05 | 0.383D 05 |
| | | 7/2-5/2 | -0.496D-03 | 0.962D-03 | 0.906D-01 | 0.341D 00 | | | 0.205D 06 | 0.774D 06 |
| 4 | 8 | 5/2-3/2 | -0.580D-04 | 0.806D-04 | 0.554D-03 | 0.107D-02 | | | 0.618D 04 | 0.119D 05 |
| | | 5/2-5/2 | -0.667D-04 | 0.899D-04 | 0.521D-04 | 0.946D-04 | | | 0.390D 03 | 0.708D 03 |
| | | 7/2-5/2 | -0.653D-04 | 0.886D-04 | 0.750D-03 | 0.138D-02 | | | 0.749D 04 | 0.138D 05 |
| 4 | 9 | 5/2-3/2 | -0.115D-04 | 0.319D-04 | 0.165D-04 | 0.128D-03 | | | 0.314D 03 | 0.243D 04 |
| | | 5/2-5/2 | -0.167D-04 | 0.372D-04 | 0.251D-05 | 0.125D-04 | | | 0.319D 02 | 0.158D 03 |
| | | 7/2-5/2 | -0.159D-04 | 0.365D-04 | 0.341D-04 | 0.180D-03 | | | 0.577D 03 | 0.305D 04 |
| 4 | 10 | 5/2-3/2 | 0.863D-06 | 0.184D-04 | 0.819D-07 | 0.372D-04 | | | 0.205D 01 | 0.930D 03 |
| | | 5/2-5/2 | -0.275D-05 | 0.221D-04 | 0.592D-07 | 0.382D-05 | | | 0.987D 00 | 0.638D 02 |
| | | 7/2-5/2 | -0.223D-05 | 0.215D-04 | 0.584D-06 | 0.542D-04 | | | 0.130D 02 | 0.121D 04 |
| 4 | 11 | 5/2-3/2 | 0.457D-05 | 0.126D-04 | 0.212D-05 | 0.160D-04 | | | 0.623D 02 | 0.470D 03 |
| | | 5/2-5/2 | 0.179D-05 | 0.153D-04 | 0.230D-07 | 0.170D-05 | | | 0.453D 00 | 0.334D 02 |
| | | 7/2-5/2 | 0.220D-05 | 0.149D-04 | 0.524D-06 | 0.241D-04 | | | 0.137D 02 | 0.632D 03 |
| 4 | 12 | 5/2-3/2 | 0.553D-05 | 0.947D-05 | 0.293D-05 | 0.861D-05 | | | 0.962D 02 | 0.282D 03 |
| | | 5/2-5/2 | 0.331D-05 | 0.117D-04 | 0.753D-07 | 0.936D-06 | | | 0.165D 01 | 0.205D 02 |
| | | 7/2-5/2 | 0.365D-05 | 0.114D-04 | 0.137D-05 | 0.133D-04 | | | 0.400D 02 | 0.389D 03 |
| 4 | 13 | 5/2-3/2 | 0.554D-05 | 0.760D-05 | 0.284D-05 | 0.534D-05 | | | 0.100D 03 | 0.189D 03 |
| | | 5/2-5/2 | 0.368D-05 | 0.944D-05 | 0.895D-07 | 0.588D-06 | | | 0.211D 01 | 0.139D 02 |
| | | 7/2-5/2 | 0.396D-05 | 0.921D-05 | 0.156D-05 | 0.840D-05 | | | 0.489D 02 | 0.264D 03 |
| 4 | 14 | 5/2-3/2 | 0.519D-05 | 0.636D-05 | 0.243D-05 | 0.364D-05 | | | 0.906D 02 | 0.136D 03 |
| | | 5/2-5/2 | 0.360D-05 | 0.792D-05 | 0.832D-07 | 0.403D-06 | | | 0.207D 01 | 0.100D 02 |
| | | 7/2-5/2 | 0.384D-05 | 0.773D-05 | 0.142D-05 | 0.576D-05 | | | 0.471D 02 | 0.191D 03 |
| 5 | 8 | 5/2-3/2 | -0.518D-03 | 0.905D-03 | 0.176D 00 | 0.537D 00 | | | 0.124D 06 | 0.378D 06 |
| | | 5/2-5/2 | -0.528D-03 | 0.910D-03 | 0.129D-01 | 0.382D-01 | | | 0.622D 04 | 0.185D 05 |
| | | 7/2-5/2 | -0.524D-03 | 0.923D-03 | 0.190D 00 | 0.589D 00 | | | 0.122D 06 | 0.380D 06 |
| 5 | 9 | 5/2-3/2 | -0.823D-04 | 0.110D-03 | 0.200D-02 | 0.358D-02 | | | 0.691D 04 | 0.123D 05 |
| | | 5/2-5/2 | -0.910D-04 | 0.119D-03 | 0.174D-03 | 0.299D-03 | | | 0.404D 03 | 0.693D 03 |
| | | 7/2-5/2 | -0.857D-04 | 0.114D-03 | 0.232D-02 | 0.412D-02 | | | 0.716D 04 | 0.127D 05 |
| 5 | 10 | 5/2-3/2 | -0.367D-04 | 0.554D-04 | 0.297D-03 | 0.675D-03 | | | 0.185D 04 | 0.421D 04 |
| | | 5/2-5/2 | -0.423D-04 | 0.609D-04 | 0.281D-04 | 0.581D-04 | | | 0.117D 03 | 0.243D 03 |
| | | 7/2-5/2 | -0.388D-04 | 0.579D-04 | 0.355D-03 | 0.789D-03 | | | 0.198D 04 | 0.439D 04 |
| 5 | 11 | 5/2-3/2 | -0.210D-04 | 0.371D-04 | 0.830D-04 | 0.258D-03 | | | 0.710D 03 | 0.221D 04 |
| | | 5/2-5/2 | -0.250D-04 | 0.410D-04 | 0.838D-05 | 0.225D-04 | | | 0.479D 02 | 0.129D 03 |
| | | 7/2-5/2 | -0.226D-04 | 0.385D-04 | 0.103D-03 | 0.299D-03 | | | 0.786D 03 | 0.228D 04 |
| 5 | 12 | 5/2-3/2 | -0.138D-04 | 0.275D-04 | 0.327D-04 | 0.129D-03 | | | 0.340D 03 | 0.134D 04 |
| | | 5/2-5/2 | -0.170D-04 | 0.305D-04 | 0.351D-05 | 0.113D-04 | | | 0.244D 02 | 0.785D 02 |
| | | 7/2-5/2 | -0.151D-04 | 0.287D-04 | 0.416D-04 | 0.150D-03 | | | 0.365D 03 | 0.139D 04 |
| 5 | 13 | 5/2-3/2 | -0.100D-04 | 0.217D-04 | 0.159D-04 | 0.754D-04 | | | 0.189D 03 | 0.895D 03 |
| | | 5/2-5/2 | -0.126D-04 | 0.242D-04 | 0.181D-05 | 0.665D-05 | | | 0.143D 02 | 0.527D 02 |
| | | 7/2-5/2 | -0.110D-04 | 0.228D-04 | 0.208D-04 | 0.891D-04 | | | 0.220D 03 | 0.941D 03 |
| 5 | 14 | 5/2-3/2 | -0.773D-05 | 0.180D-04 | 0.910D-05 | 0.492D-04 | | | 0.119D 03 | 0.641D 03 |
| | | 5/2-5/2 | -0.996D-05 | 0.200D-04 | 0.108D-05 | 0.435D-05 | | | 0.937D 01 | 0.378D 02 |
| | | 7/2-5/2 | -0.862D-05 | 0.189D-04 | 0.121D-04 | 0.585D-04 | | | 0.141D 03 | 0.678D 03 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F^{o}_{J} - md^2D_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $R^{e}_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 9 | 5/2-3/2 | -0.431D-03 | 0.936D-03 | 0.204D 00 | 0.965D 00 | | | 0.510D 05 | 0.241D 06 |
| | | 5/2-5/2 | -0.443D-03 | 0.943D-03 | 0.152D-01 | 0.689D-01 | | | 0.260D 04 | 0.118D 05 |
| | | 7/2-5/2 | -0.476D-03 | 0.902D-03 | 0.264D 00 | 0.946D 00 | | | 0.601D 05 | 0.216D 06 |
| 6 | 10 | 5/2-3/2 | -0.342D-04 | 0.545D-04 | 0.565D-03 | 0.143D-02 | | | 0.734D 03 | 0.186D 04 |
| | | 5/2-5/2 | -0.436D-04 | 0.654D-04 | 0.653D-04 | 0.147D-03 | | | 0.570D 02 | 0.128D 03 |
| | | 7/2-5/2 | -0.733D-04 | 0.975D-04 | 0.277D-02 | 0.489D-02 | | | 0.322D 04 | 0.569D 04 |
| 6 | 11 | 5/2-3/2 | -0.131D-04 | 0.253D-04 | 0.602D-04 | 0.224D-03 | | | 0.148D 03 | 0.550D 03 |
| | | 5/2-5/2 | -0.192D-04 | 0.316D-04 | 0.924D-05 | 0.249D-04 | | | 0.152D 02 | 0.409D 02 |
| | | 7/2-5/2 | -0.376D-04 | 0.513D-04 | 0.529D-03 | 0.988D-03 | | | 0.116D 04 | 0.217D 04 |
| 6 | 12 | 5/2-3/2 | 0.723D-04 | -0.630D-03 | 0.154D-02 | 0.117D 00 | | | 0.537D 04 | 0.407D 06 |
| | | 5/2-5/2 | -0.124D-03 | -0.628D-03 | 0.321D-03 | 0.827D-02 | | | 0.748D 03 | 0.193D 05 |
| | | 7/2-5/2 | -0.249D-04 | 0.359D-04 | 0.190D-03 | 0.405D-03 | | | 0.590D 03 | 0.126D 04 |
| 6 | 13 | 5/2-3/2 | 0.467D-04 | -0.570D-03 | 0.574D-03 | 0.856D-01 | | | 0.250D 04 | 0.373D 06 |
| | | 5/2-5/2 | -0.831D-04 | -0.569D-03 | 0.130D-03 | 0.609D-02 | | | 0.378D 03 | 0.177D 05 |
| | | 7/2-5/2 | -0.180D-04 | 0.273D-04 | 0.914D-04 | 0.210D-03 | | | 0.354D 03 | 0.816D 03 |
| 6 | 14 | 5/2-3/2 | 0.314D-04 | -0.513D-03 | 0.241D-03 | 0.642D-01 | | | 0.122D 04 | 0.326D 06 |
| | | 5/2-5/2 | -0.586D-04 | -0.512D-03 | 0.599D-04 | 0.458D-02 | | | 0.202D 03 | 0.155D 05 |
| | | 7/2-5/2 | -0.142D-04 | 0.221D-04 | 0.525D-04 | 0.127D-03 | | | 0.237D 03 | 0.575D 03 |
| 7 | 10 | 5/2-3/2 | -0.963D-04 | 0.328D-04 | 0.159D-01 | 0.185D-02 | | | 0.163D 04 | 0.190D 03 |
| | | 5/2-5/2 | -0.859D-04 | 0.291D-04 | 0.891D-03 | 0.102D-03 | | | 0.628D 02 | 0.719D 01 |
| | | 7/2-5/2 | -0.450D-03 | 0.824D-03 | 0.367D 00 | 0.123D 01 | | | 0.345D 05 | 0.115D 06 |
| 7 | 11 | 5/2-3/2 | -0.645D-04 | 0.320D-04 | 0.305D-02 | 0.753D-03 | | | 0.171D 04 | 0.422D 03 |
| | | 5/2-5/2 | -0.582D-04 | 0.286D-04 | 0.177D-03 | 0.427D-04 | | | 0.667D 02 | 0.161D 02 |
| | | 7/2-5/2 | -0.796D-04 | 0.100D-03 | 0.497D-02 | 0.787D-02 | | | 0.250D 04 | 0.396D 04 |
| 7 | 12 | 5/2-3/2 | -0.479D-04 | 0.248D-04 | 0.120D-02 | 0.323D-03 | | | 0.132D 04 | 0.355D 03 |
| | | 5/2-5/2 | -0.439D-04 | 0.221D-04 | 0.720D-04 | 0.182D-04 | | | 0.531D 02 | 0.134D 02 |
| | | 7/2-5/2 | -0.448D-04 | 0.548D-04 | 0.112D-02 | 0.168D-02 | | | 0.110D 04 | 0.166D 04 |
| 7 | 13 | 5/2-3/2 | -0.375D-04 | 0.205D-04 | 0.611D-03 | 0.183D-03 | | | 0.982D 03 | 0.294D 03 |
| | | 5/2-5/2 | -0.343D-04 | 0.183D-04 | 0.364D-04 | 0.103D-04 | | | 0.391D 02 | 0.111D 02 |
| | | 7/2-5/2 | -0.313D-04 | 0.401D-04 | 0.456D-03 | 0.745D-03 | | | 0.653D 03 | 0.107D 04 |
| 7 | 14 | 5/2-3/2 | -0.306D-04 | 0.174D-04 | 0.360D-03 | 0.116D-03 | | | 0.738D 03 | 0.238D 03 |
| | | 5/2-5/2 | -0.278D-04 | 0.155D-04 | 0.212D-04 | 0.655D-05 | | | 0.290D 02 | 0.897D 01 |
| | | 7/2-5/2 | -0.241D-04 | 0.310D-04 | 0.239D-03 | 0.395D-03 | | | 0.438D 03 | 0.722D 03 |
| 8 | 11 | 5/2-3/2 | -0.126D-04 | 0.375D-05 | 0.400D-03 | 0.356D-04 | | | 0.190D 02 | 0.169D 01 |
| | | 5/2-5/2 | -0.303D-05 | 0.313D-06 | 0.163D-05 | 0.174D-07 | | | 0.531D-01 | 0.566D-03 |
| | | 7/2-5/2 | -0.210D-04 | 0.690D-05 | 0.118D-02 | 0.127D-03 | | | 0.512D 02 | 0.551D 01 |
| 8 | 12 | 5/2-3/2 | -0.117D-04 | 0.656D-05 | 0.146D-03 | 0.456D-04 | | | 0.393D 02 | 0.122D 02 |
| | | 5/2-5/2 | -0.523D-05 | 0.332D-05 | 0.206D-05 | 0.330D-06 | | | 0.372D 00 | 0.150D 00 |
| | | 7/2-5/2 | -0.173D-04 | 0.878D-05 | 0.340D-03 | 0.872D-04 | | | 0.820D 02 | 0.210D 02 |
| 8 | 13 | 5/2-3/2 | -0.963D-05 | 0.282D-05 | 0.691D-04 | 0.592D-05 | | | 0.376D 02 | 0.322D 01 |
| | | 5/2-5/2 | -0.609D-05 | 0.150D-06 | 0.197D-05 | 0.120D-08 | | | 0.717D 00 | 0.436D-03 |
| | | 7/2-5/2 | -0.132D-04 | 0.594D-05 | 0.138D-03 | 0.281D-04 | | | 0.670D 02 | 0.136D 02 |
| 8 | 14 | 5/2-3/2 | -0.748D-05 | 0.256D-05 | 0.341D-04 | 0.401D-05 | | | 0.277D 02 | 0.326D 01 |
| | | 5/2-5/2 | -0.424D-05 | 0.310D-06 | 0.781D-06 | 0.418D-08 | | | 0.425D 00 | 0.227D-02 |
| | | 7/2-5/2 | -0.103D-04 | 0.496D-05 | 0.696D-04 | 0.160D-04 | | | 0.505D 02 | 0.116D 02 |

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| TRANSITION | | | $\bar{M}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J′ | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 12 | 5/2-3/2 | -0.397D-03 | -0.138D-04 | 0.560D 00 | 0.680D-03 | | | 0.134D 05 | 0.162D 02 |
| | | 5/2-5/2 | 0.599D-03 | -0.184D-04 | 0.897D-01 | 0.347D-04 | | | 0.147D 04 | 0.139D 01 |
| | | 7/2-5/2 | -0.793D-03 | -0.149D-04 | 0.236D 01 | 0.838D-03 | | | 0.516D 05 | 0.183D 02 |
| 9 | 13 | 5/2-3/2 | -0.332D-03 | 0.208D-04 | 0.162D 00 | 0.638D-03 | | | 0.226D 05 | 0.890D 02 |
| | | 5/2-5/2 | 0.500D-03 | 0.126D-04 | 0.262D-01 | 0.166D-04 | | | 0.246D 04 | 0.156D 01 |
| | | 7/2-5/2 | -0.662D-03 | 0.198D-04 | 0.688D 00 | 0.615D-03 | | | 0.862D 05 | 0.770D 02 |
| 9 | 14 | 5/2-3/2 | -0.281D-03 | 0.607D-04 | 0.806D-01 | 0.376D-02 | | | 0.233D 05 | 0.109D 04 |
| | | 5/2-5/2 | 0.423D-03 | 0.511D-04 | 0.130D-01 | 0.190D-03 | | | 0.253D 04 | 0.368D 02 |
| | | 7/2-5/2 | -0.560D-03 | 0.602D-04 | 0.343D 00 | 0.396D-02 | | | 0.886D 05 | 0.102D 04 |
| 10 | 13 | 5/2-3/2 | -0.261D-03 | -0.113D-03 | 0.329D 00 | 0.620D-01 | | | 0.425D 04 | 0.801D 03 |
| | | 5/2-5/2 | 0.388D-03 | -0.117D-03 | 0.513D-01 | 0.469D-02 | | | 0.456D 03 | 0.417D 02 |
| | | 7/2-5/2 | -0.520D-03 | -0.116D-03 | 0.138D 01 | 0.689D-01 | | | 0.163D 05 | 0.815D 03 |
| 10 | 14 | 5/2-3/2 | -0.246D-03 | -0.182D-03 | 0.119D 00 | 0.653D-01 | | | 0.924D 04 | 0.505D 04 |
| | | 5/2-5/2 | 0.366D-03 | -0.188D-03 | 0.189D-01 | 0.499D-02 | | | 0.982D 03 | 0.260D 03 |
| | | 7/2-5/2 | -0.490D-03 | -0.185D-03 | 0.506D 00 | 0.723D-01 | | | 0.352D 05 | 0.502D 04 |
| 11 | 14 | 5/2-3/2 | -0.675D-04 | -0.146D-03 | 0.292D-01 | 0.136D 00 | | | 0.215D 03 | 0.100D 04 |
| | | 5/2-5/2 | 0.977D-04 | -0.148D-03 | 0.430D-02 | 0.983D-02 | | | 0.218D 02 | 0.498D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd\,^2D_J - mf\,^2F_J$, CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION | | | $\tilde{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 5 | 4 | 3/2-5/2 | -0.219D-02 | 0.214D-02 | 0.395D 00 | 0.379D 00 | 0.302D 00 | | 0.175D 08 | 0.167D 08 |
| | | 5/2-5/2 | -0.221D-02 | 0.219D-02 | 0.194D-01 | 0.191D-01 | 0.324D 00 | | 0.126D 07 | 0.124D 07 |
| | | 5/2-7/2 | -0.219D-02 | 0.218D-02 | 0.382D 00 | 0.379D 00 | | | 0.186D 08 | 0.185D 08 |
| 5 | 5 | 3/2-5/2 | -0.185D-02 | 0.157D-02 | 0.227D 00 | 0.162D 00 | 0.122D 00 | | 0.157D 08 | 0.112D 08 |
| | | 5/2-5/2 | -0.184D-02 | 0.158D-02 | 0.107D-01 | 0.792D-02 | 0.127D 00 | | 0.110D 07 | 0.809D 06 |
| | | 5/2-7/2 | -0.181D-02 | 0.157D-02 | 0.208D 00 | 0.156D 00 | | | 0.160D 08 | 0.120D 08 |
| 5 | 6 | 3/2-5/2 | -0.121D-02 | 0.109D-02 | 0.876D-01 | 0.707D-01 | 0.627D-01 | 0.712D-01 | 0.745D 07 | 0.601D 07 |
| | | 5/2-5/2 | -0.121D-02 | 0.110D-02 | 0.416D-02 | 0.344D-02 | 0.650D-01 | | 0.524D 06 | 0.433D 06 |
| | | 5/2-7/2 | -0.133D-02 | 0.114D-02 | 0.102D 00 | 0.739D-01 | | | 0.957D 07 | 0.697D 07 |
| 5 | 7 | 3/2-5/2 | 0.608D-03 | -0.860D-03 | 0.208D-01 | 0.416D-01 | 0.373D-01 | 0.418D-01 | 0.198D 07 | 0.397D 07 |
| | | 5/2-5/2 | 0.629D-03 | -0.879D-03 | 0.107D-02 | 0.209D-02 | 0.383D-01 | 0.409D-01 | 0.151D 06 | 0.294D 06 |
| | | 5/2-7/2 | -0.109D-02 | 0.890D-03 | 0.642D-01 | 0.427D-01 | | | 0.680D 07 | 0.452D 07 |
| 5 | 8 | 3/2-5/2 | 0.589D-03 | -0.672D-03 | 0.188D-01 | 0.245D-01 | 0.235D-01 | | 0.193D 07 | 0.251D 07 |
| | | 5/2-5/2 | 0.599D-03 | -0.682D-03 | 0.934D-03 | 0.121D-02 | 0.241D-01 | 0.252D-01 | 0.142D 06 | 0.183D 06 |
| | | 5/2-7/2 | 0.548D-03 | -0.663D-03 | 0.157D-01 | 0.229D-01 | | | 0.178D 07 | 0.260D 07 |
| 5 | 9 | 3/2-5/2 | 0.502D-03 | -0.528D-03 | 0.134D-01 | 0.148D-01 | 0.160D-01 | 0.173D-01 | 0.144D 07 | 0.159D 07 |
| | | 5/2-5/2 | 0.509D-03 | -0.534D-03 | 0.657D-03 | 0.724D-03 | 0.164D-01 | 0.172D-01 | 0.105D 06 | 0.115D 06 |
| | | 5/2-7/2 | 0.480D-03 | -0.524D-03 | 0.117D-01 | 0.140D-01 | | | 0.140D 07 | 0.167D 07 |
| 5 | 10 | 3/2-5/2 | 0.427D-03 | -0.429D-03 | 0.952D-02 | 0.960D-02 | 0.114D-01 | 0.118D-01 | 0.106D 07 | 0.107D 07 |
| | | 5/2-5/2 | 0.432D-03 | -0.433D-03 | 0.466D-03 | 0.468D-03 | 0.115D-01 | 0.123D-01 | 0.766D 05 | 0.770D 05 |
| | | 5/2-7/2 | 0.412D-03 | -0.427D-03 | 0.847D-02 | 0.910D-02 | | | 0.104D 07 | 0.112D 07 |
| 5 | 11 | 3/2-5/2 | 0.368D-03 | -0.359D-03 | 0.696D-02 | 0.664D-02 | | 0.821D-02 | 0.792D 06 | 0.755D 06 |
| | | 5/2-5/2 | 0.371D-03 | -0.362D-03 | 0.340D-03 | 0.323D-03 | | 0.820D-02 | 0.572D 05 | 0.544D 05 |
| 6 | 4 | 3/2-5/2 | 0.226D-02 | -0.121D-02 | 0.223D 01 | 0.637D 00 | | | 0.352D 07 | 0.101D 07 |
| | | 5/2-5/2 | 0.224D-02 | -0.119D-02 | 0.107D 00 | 0.301D-01 | | | 0.241D 06 | 0.680D 05 |
| | | 5/2-7/2 | 0.224D-02 | -0.119D-02 | 0.215D 01 | 0.603D 00 | | | 0.364D 07 | 0.102D 07 |
| 6 | 5 | 3/2-5/2 | 0.293D-03 | -0.233D-03 | 0.161D-01 | 0.102D-01 | | | 0.138D 06 | 0.869D 05 |
| | | 5/2-5/2 | 0.257D-03 | -0.207D-03 | 0.598D-03 | 0.389D-03 | | | 0.750D 04 | 0.489D 04 |
| | | 5/2-7/2 | 0.280D-03 | -0.224D-03 | 0.142D-01 | 0.908D-02 | | | 0.134D 06 | 0.855D 05 |
| 6 | 6 | 3/2-5/2 | 0.125D-03 | -0.103D-03 | 0.225D-02 | 0.151D-02 | | | 0.329D 05 | 0.222D 05 |
| | | 5/2-5/2 | 0.995D-04 | -0.833D-04 | 0.682D-04 | 0.478D-04 | | | 0.148D 04 | 0.104D 04 |
| | | 5/2-7/2 | 0.123D-04 | -0.210D-04 | 0.207D-04 | 0.607D-04 | | | 0.336D 03 | 0.986D 03 |
| 6 | 7 | 3/2-5/2 | -0.435D-03 | 0.365D-03 | 0.238D-01 | 0.168D-01 | | | 0.455D 06 | 0.321D 06 |
| | | 5/2-5/2 | -0.415D-03 | 0.347D-03 | 0.104D-02 | 0.727D-03 | | | 0.294D 05 | 0.206D 05 |
| | | 5/2-7/2 | -0.994D-04 | 0.687D-04 | 0.119D-02 | 0.569D-03 | | | 0.253D 05 | 0.121D 05 |
| 6 | 8 | 3/2-5/2 | -0.174D-03 | 0.907D-04 | 0.352D-02 | 0.956D-03 | | | 0.788D 05 | 0.214D 05 |
| | | 5/2-5/2 | -0.156D-03 | 0.758D-04 | 0.136D-03 | 0.320D-04 | | | 0.450D 04 | 0.106D 04 |
| | | 5/2-7/2 | -0.187D-03 | 0.102D-03 | 0.389D-02 | 0.117D-02 | | | 0.966D 05 | 0.289D 05 |
| 6 | 9 | 3/2-5/2 | -0.817D-04 | 0.972D-05 | 0.738D-03 | 0.105D-04 | | | 0.182D 05 | 0.258D 03 |
| | | 5/2-5/2 | -0.669D-04 | -0.208D-05 | 0.237D-04 | 0.229D-07 | | | 0.869D 03 | 0.840D 00 |
| | | 5/2-7/2 | -0.650D-04 | 0.125D-04 | 0.765D-03 | 0.165D-04 | | | 0.210D 05 | 0.454D 03 |
| 6 | 10 | 3/2-5/2 | -0.405D-04 | -0.197D-04 | 0.176D-03 | 0.413D-04 | | | 0.465D 04 | 0.109D 04 |
| | | 5/2-5/2 | -0.283D-04 | -0.293D-04 | 0.409D-05 | 0.438D-05 | | | 0.161D 03 | 0.172D 03 |
| | | 5/2-7/2 | -0.410D-04 | -0.195D-04 | 0.172D-03 | 0.389D-04 | | | 0.506D 04 | 0.114D 04 |

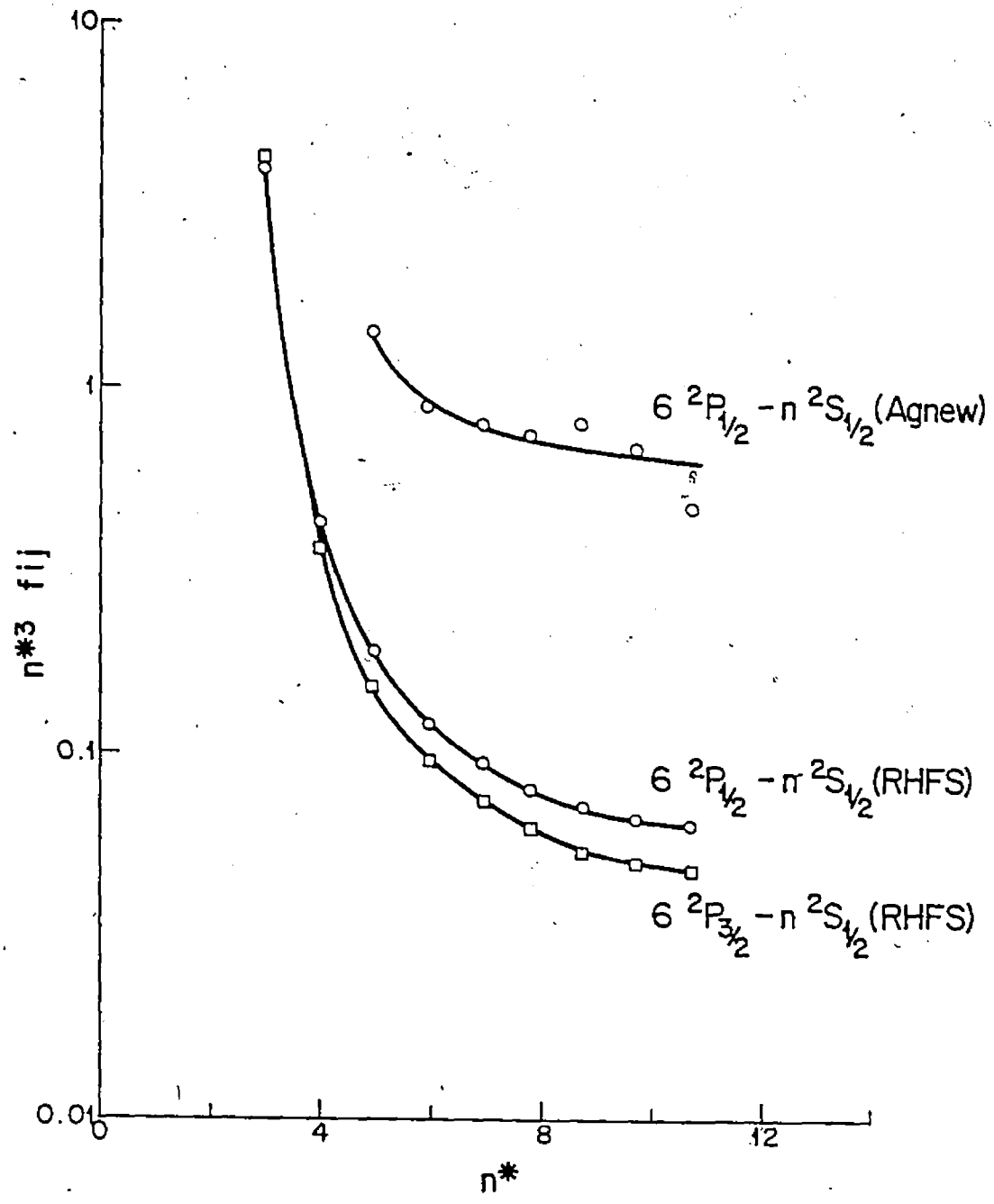
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

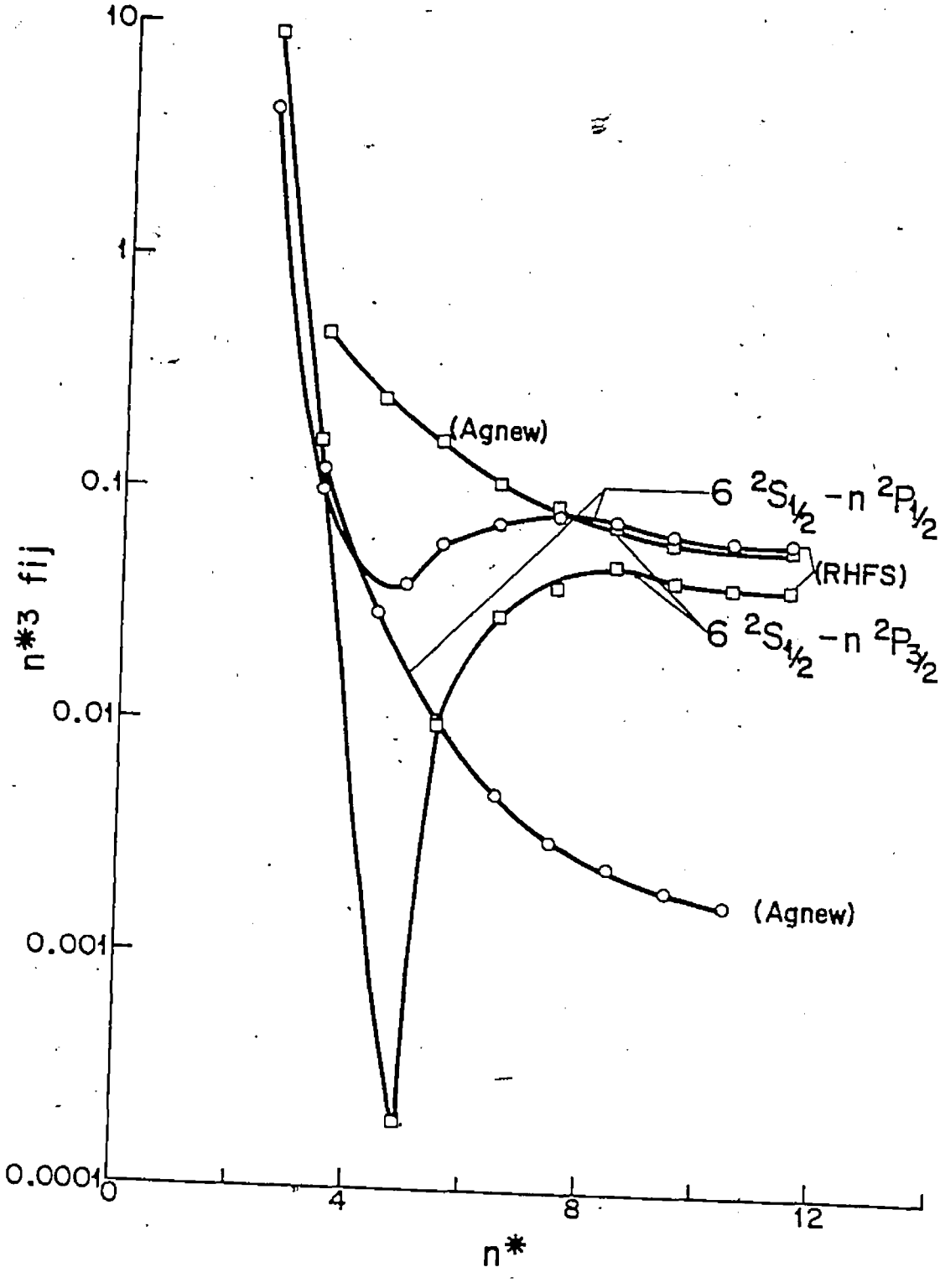
| TRANSITION | | | $\tilde{r}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 11 | 3/2-5/2 | -0.204D-04 | -0.302D-04 | 0.433D-04 | 0.952D-04 | | | 0.120D 04 | 0.265D 04 |
| | | 5/2-5/2 | -0.598D-05 | -0.382D-04 | 0.497D-06 | 0.729D-05 | | | 0.205D 02 | 0.301D 03 |
| 7 | 5 | 3/2-5/2 | 0.164D-02 | -0.952D-03 | 0.240D 01 | 0.809D 00 | | | 0.910D 06 | 0.307D 06 |
| | | 5/2-5/2 | 0.163D-02 | -0.938D-03 | 0.116D 00 | 0.383D-01 | | | 0.628D 05 | 0.208D 05 |
| | | 5/2-7/2 | 0.164D-02 | -0.939D-03 | 0.234D 01 | 0.767D 00 | | | 0.955D 06 | 0.312D 06 |
| 7 | 6 | 3/2-5/2 | 0.568D-03 | -0.427D-03 | 0.116D 00 | 0.658D-01 | | | 0.270D 06 | 0.152D 06 |
| | | 5/2-5/2 | 0.551D-03 | -0.414D-03 | 0.528D-02 | 0.297D-02 | | | 0.180D 05 | 0.101D 05 |
| | | 5/2-7/2 | 0.484D-03 | -0.367D-03 | 0.814D-01 | 0.467D-01 | | | 0.208D 06 | 0.119D 06 |
| 7 | 7 | 3/2-5/2 | -0.761D-03 | 0.750D-03 | 0.154D 00 | 0.149D 00 | | | 0.659D 06 | 0.639D 06 |
| | | 5/2-5/2 | -0.750D-03 | 0.739D-03 | 0.718D-02 | 0.696D-02 | | | 0.454D 05 | 0.440D 05 |
| | | 5/2-7/2 | 0.189D-03 | -0.151D-03 | 0.911D-02 | 0.582D-02 | | | 0.432D 05 | 0.276D 05 |
| 7 | 8 | 3/2-5/2 | -0.385D-03 | 0.329D-03 | 0.336D-01 | 0.246D-01 | | | 0.197D 06 | 0.144D 06 |
| | | 5/2-5/2 | -0.372D-03 | 0.318D-03 | 0.151D-02 | 0.110D-02 | | | 0.131D 05 | 0.953D 04 |
| | | 5/2-7/2 | -0.395D-03 | 0.340D-03 | 0.339D-01 | 0.251D-01 | | | 0.221D 06 | 0.164D 06 |
| 7 | 9 | 3/2-5/2 | -0.229D-03 | 0.175D-03 | 0.109D-01 | 0.633D-02 | | | 0.770D 05 | 0.449D 05 |
| | | 5/2-5/2 | -0.219D-03 | 0.166D-03 | 0.473D-03 | 0.271D-03 | | | 0.499D 04 | 0.285D 04 |
| | | 5/2-7/2 | -0.233D-03 | 0.179D-03 | 0.107D-01 | 0.632D-02 | | | 0.847D 05 | 0.499D 05 |
| 7 | 10 | 3/2-5/2 | -0.153D-03 | 0.106D-03 | 0.453D-02 | 0.218D-02 | | | 0.365D 05 | 0.175D 05 |
| | | 5/2-5/2 | -0.144D-03 | 0.982D-04 | 0.193D-03 | 0.894D-04 | | | 0.230D 04 | 0.107D 04 |
| | | 5/2-7/2 | -0.154D-03 | 0.107D-03 | 0.441D-02 | 0.214D-02 | | | 0.395D 05 | 0.192D 05 |
| 7 | 11 | 3/2-5/2 | -0.111D-03 | 0.707D-04 | 0.227D-02 | 0.926D-03 | | | 0.199D 05 | 0.814D 04 |
| | | 5/2-5/2 | -0.103D-03 | 0.641D-04 | 0.944D-04 | 0.365D-04 | | | 0.123D 04 | 0.476D 03 |
| 8 | 6 | 3/2-5/2 | 0.134D-02 | -0.744D-03 | 0.287D 01 | 0.881D 00 | | | 0.343D 06 | 0.105D 06 |
| | | 5/2-5/2 | 0.134D-02 | -0.737D-03 | 0.139D 00 | 0.420D-01 | | | 0.239D 05 | 0.720D 04 |
| | | 5/2-7/2 | 0.133D-02 | -0.754D-03 | 0.274D 01 | 0.881D 00 | | | 0.351D 06 | 0.113D 06 |
| 8 | 7 | 3/2-5/2 | -0.130D-02 | 0.165D-02 | 0.104D 01 | 0.169D 01 | | | 0.828D 06 | 0.134D 07 |
| | | 5/2-5/2 | -0.130D-02 | 0.167D-02 | 0.504D-01 | 0.822D-01 | | | 0.590D 05 | 0.963D 05 |
| | | 5/2-7/2 | 0.470D-03 | -0.365D-03 | 0.131D 00 | 0.791D-01 | | | 0.115D 06 | 0.695D 05 |
| 8 | 8 | 3/2-5/2 | -0.618D-03 | 0.630D-03 | 0.168D 00 | 0.175D 00 | | | 0.261D 06 | 0.272D 06 |
| | | 5/2-5/2 | -0.608D-03 | 0.621D-03 | 0.783D-02 | 0.814D-02 | | | 0.180D 05 | 0.187D 05 |
| | | 5/2-7/2 | -0.623D-03 | 0.633D-03 | 0.164D 00 | 0.170D 00 | | | 0.283D 06 | 0.292D 06 |
| 8 | 9 | 3/2-5/2 | -0.364D-03 | 0.335D-03 | 0.489D-01 | 0.414D-01 | | | 0.108D 06 | 0.915D 05 |
| | | 5/2-5/2 | -0.354D-03 | 0.326D-03 | 0.222D-02 | 0.188D-02 | | | 0.730D 04 | 0.617D 04 |
| | | 5/2-7/2 | -0.366D-03 | 0.337D-03 | 0.473D-01 | 0.401D-01 | | | 0.117D 06 | 0.987D 05 |
| 8 | 10 | 3/2-5/2 | -0.245D-03 | 0.213D-03 | 0.199D-01 | 0.151D-01 | | | 0.548D 05 | 0.416D 05 |
| | | 5/2-5/2 | -0.237D-03 | 0.205D-03 | 0.888D-03 | 0.668D-03 | | | 0.364D 04 | 0.274D 04 |
| | | 5/2-7/2 | -0.245D-03 | 0.213D-03 | 0.190D-01 | 0.144D-01 | | | 0.585D 05 | 0.443D 05 |
| 8 | 11 | 3/2-5/2 | -0.180D-03 | 0.151D-03 | 0.994D-02 | 0.701D-02 | | | 0.318D 05 | 0.224D 05 |
| | | 5/2-5/2 | -0.173D-03 | 0.144D-03 | 0.439D-03 | 0.306D-03 | | | 0.209D 04 | 0.145D 04 |
| 9 | 7 | 3/2-5/2 | -0.253D-03 | -0.680D-03 | 0.165D 00 | 0.119D 01 | | | 0.747D 04 | 0.541D 05 |
| | | 5/2-5/2 | -0.268D-03 | -0.662D-03 | 0.902D-02 | 0.551D-01 | | | 0.586D 03 | 0.358D 04 |
| | | 5/2-7/2 | 0.110D-02 | -0.627D-03 | 0.303D 01 | 0.989D 00 | | | 0.147D 06 | 0.482D 05 |

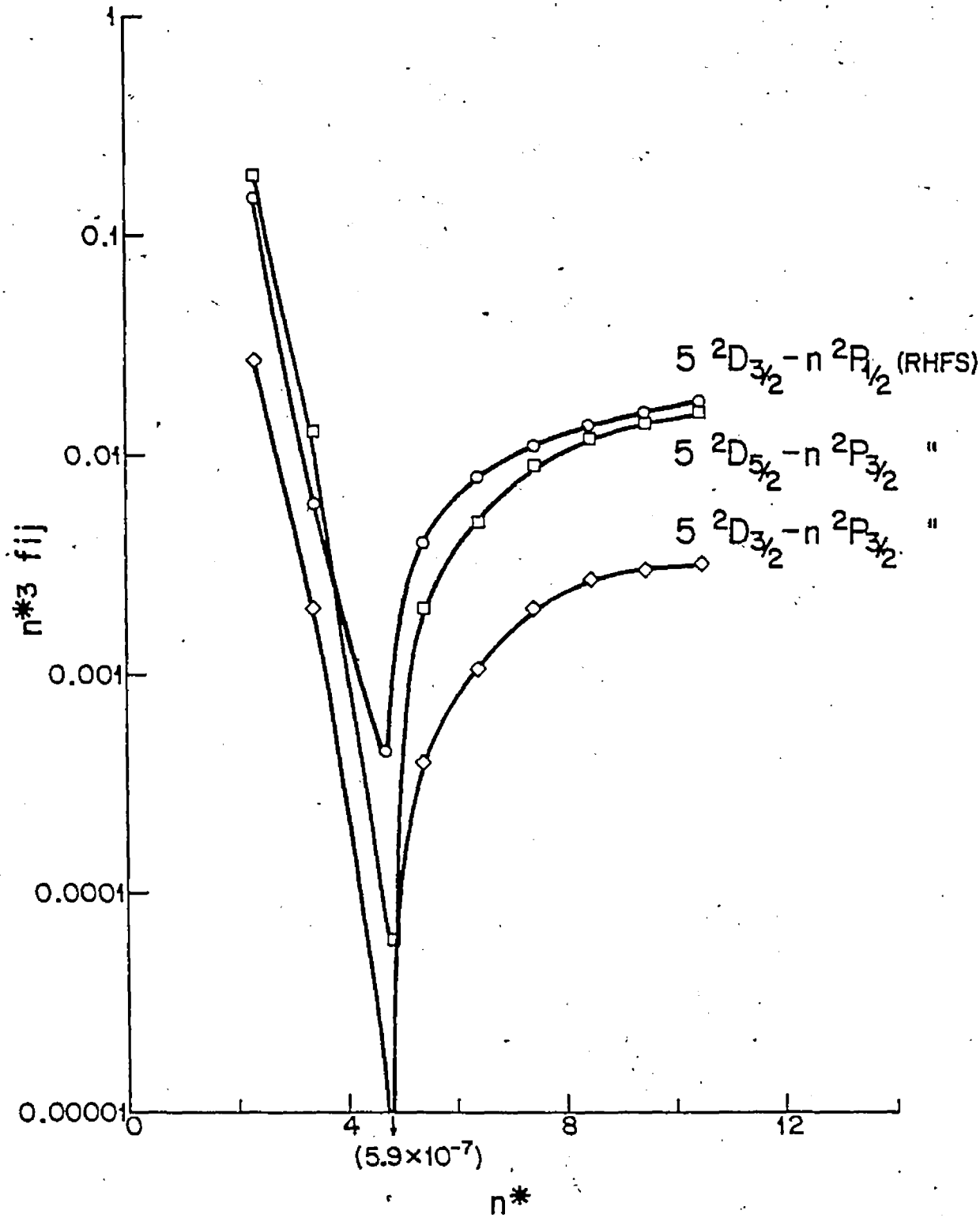
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_J$, CALCULATED USING THE RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

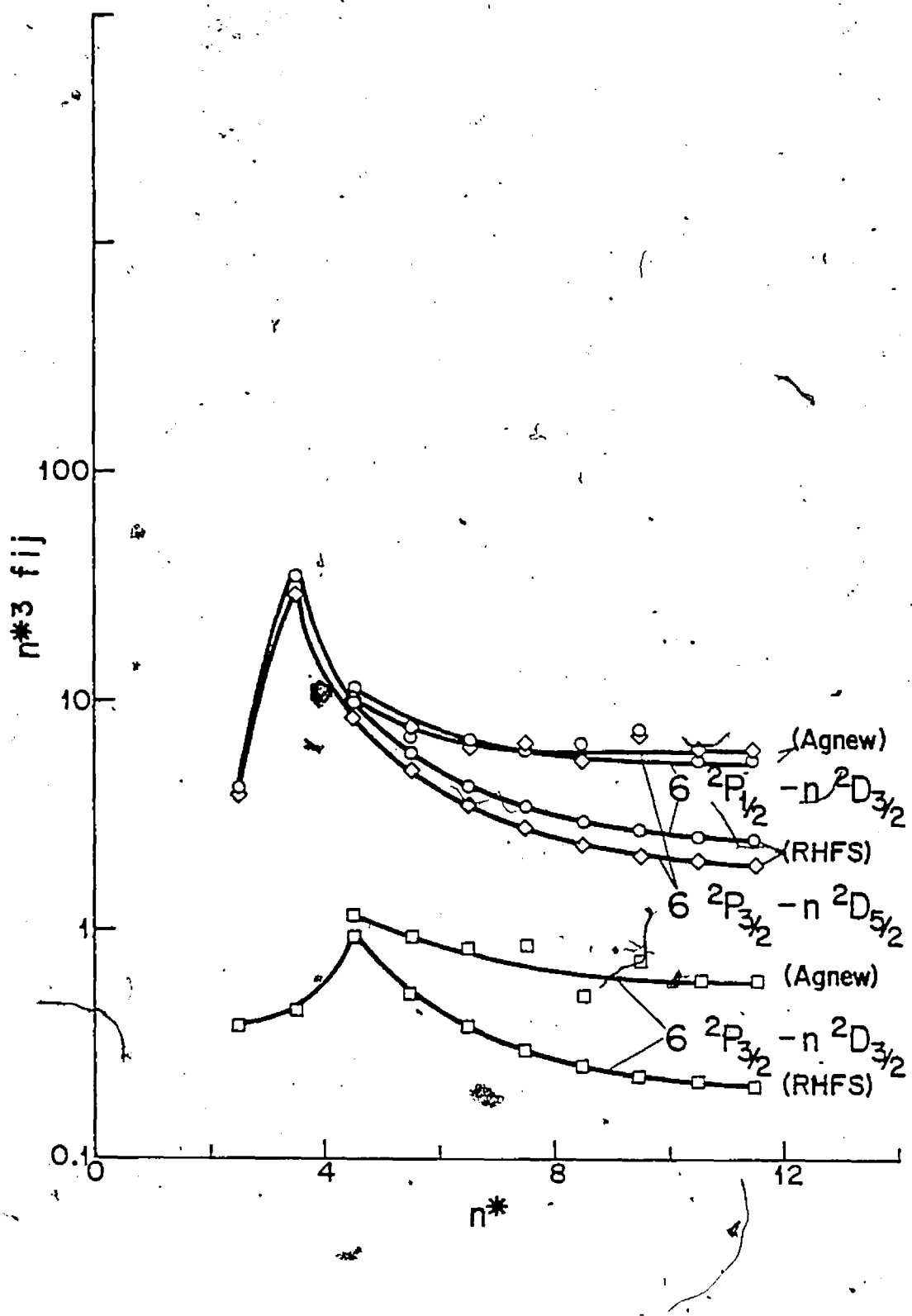
| TRANSITION | | | $\tilde{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 8 | 3/2-5/2 | -0.110D-02 | 0.151D-02 | 0.117D 01 | 0.222D 01 | | | 0.376D 06 | 0.713D 06 |
| | | 5/2-5/2 | -0.110D-02 | 0.152D-02 | 0.565D-01 | 0.108D 00 | | | 0.268D 05 | 0.512D 05 |
| | | 5/2-7/2 | -0.109D-02 | 0.149D-02 | 0.111D 01 | 0.206D 01 | | | 0.395D 06 | 0.731D 06 |
| 9 | 9 | 3/2-5/2 | -0.533D-03 | 0.565D-03 | 0.193D 00 | 0.216D 00 | | | 0.126D 06 | 0.142D 06 |
| | | 5/2-5/2 | -0.527D-03 | 0.558D-03 | 0.902D-02 | 0.101D-01 | | | 0.875D 04 | 0.982D 04 |
| | | 5/2-7/2 | -0.534D-03 | 0.563D-03 | 0.185D 00 | 0.207D 00 | | | 0.135D 06 | 0.150D 06 |
| 9 | 10 | 3/2-5/2 | -0.337D-03 | 0.324D-03 | 0.637D-01 | 0.587D-01 | | | 0.615D 05 | 0.566D 05 |
| | | 5/2-5/2 | -0.330D-03 | 0.318D-03 | 0.292D-02 | 0.271D-02 | | | 0.419D 04 | 0.388D 04 |
| | | 5/2-7/2 | -0.337D-03 | 0.324D-03 | 0.609D-01 | 0.563D-01 | | | 0.655D 05 | 0.605D 05 |
| 9 | 11 | 3/2-5/2 | -0.241D-03 | 0.223D-03 | 0.288D-01 | 0.246D-01 | | | 0.355D 05 | 0.303D 05 |
| | | 5/2-5/2 | -0.235D-03 | 0.217D-03 | 0.131D-02 | 0.111D-02 | | | 0.240D 04 | 0.204D 04 |
| 10 | 8 | 3/2-5/2 | -0.341D-03 | -0.599D-03 | 0.455D 00 | 0.141D 01 | | | 0.895D 04 | 0.277D 05 |
| | | 5/2-5/2 | -0.353D-03 | -0.582D-03 | 0.238D-01 | 0.647D-01 | | | 0.671D 03 | 0.183D 04 |
| | | 5/2-7/2 | -0.329D-03 | -0.591D-03 | 0.413D 00 | 0.133D 01 | | | 0.874D 04 | 0.282D 05 |
| 10 | 9 | 3/2-5/2 | -0.932D-03 | 0.134D-02 | 0.125D 01 | 0.259D 01 | | | 0.183D 06 | 0.379D 06 |
| | | 5/2-5/2 | -0.934D-03 | 0.135D-02 | 0.602D-01 | 0.126D 00 | | | 0.130D 05 | 0.273D 05 |
| | | 5/2-7/2 | -0.929D-03 | 0.133D-02 | 0.119D 01 | 0.243D 01 | | | 0.193D 06 | 0.395D 06 |
| 10 | 10 | 3/2-5/2 | -0.465D-03 | 0.510D-03 | 0.214D 00 | 0.257D 00 | | | 0.662D 05 | 0.793D 05 |
| | | 5/2-5/2 | -0.461D-03 | 0.504D-03 | 0.100D-01 | 0.120D-01 | | | 0.461D 04 | 0.551D 04 |
| | | 5/2-7/2 | -0.465D-03 | 0.507D-03 | 0.205D 00 | 0.243D 00 | | | 0.703D 05 | 0.837D 05 |
| 10 | 11 | 3/2-5/2 | -0.306D-03 | 0.301D-03 | 0.754D-01 | 0.726D-01 | | | 0.353D 05 | 0.340D 05 |
| | | 5/2-5/2 | -0.301D-03 | 0.297D-03 | 0.347D-02 | 0.339D-02 | | | 0.241D 04 | 0.236D 04 |
| 11 | 9 | 3/2-5/2 | -0.339D-03 | -0.548D-03 | 0.647D 00 | 0.170D 01 | | | 0.613D 04 | 0.161D 05 |
| | | 5/2-5/2 | -0.349D-03 | -0.533D-03 | 0.336D-01 | 0.781D-01 | | | 0.456D 03 | 0.106D 04 |
| | | 5/2-7/2 | -0.335D-03 | -0.538D-03 | 0.618D 00 | 0.160D 01 | | | 0.628D 04 | 0.162D 05 |
| 11 | 10 | 3/2-5/2 | -0.805D-03 | 0.120D-02 | 0.132D 01 | 0.292D 01 | | | 0.963D 05 | 0.213D 06 |
| | | 5/2-5/2 | -0.808D-03 | 0.121D-02 | 0.636D-01 | 0.142D 00 | | | 0.687D 04 | 0.154D 05 |
| | | 5/2-7/2 | -0.804D-03 | 0.119D-02 | 0.126D 01 | 0.276D 01 | | | 0.102D 06 | 0.224D 06 |
| 11 | 11 | 3/2-5/2 | -0.412D-03 | 0.464D-03 | 0.233D 00 | 0.297D 00 | | | 0.371D 05 | 0.472D 05 |
| | | 5/2-5/2 | -0.408D-03 | 0.459D-03 | 0.110D-01 | 0.139D-01 | | | 0.260D 04 | 0.328D 04 |
| 12 | 10 | 3/2-5/2 | -0.723D-03 | 0.198D-03 | 0.409D 01 | 0.307D 00 | | | 0.202D 05 | 0.151D 04 |
| | | 5/2-5/2 | -0.162D-02 | 0.197D-03 | 0.100D 01 | 0.148D-01 | | | 0.711D 04 | 0.105D 03 |
| | | 5/2-7/2 | -0.360D-03 | 0.191D-03 | 0.987D 00 | 0.279D 00 | | | 0.524D 04 | 0.148D 04 |
| 12 | 11 | 3/2-5/2 | -0.523D-03 | 0.523D-03 | 0.757D 00 | 0.757D 00 | | | 0.298D 05 | 0.298D 05 |
| | | 5/2-5/2 | -0.116D-02 | 0.524D-03 | 0.180D 00 | 0.365D-01 | | | 0.105D 05 | 0.212D 04 |
| 13 | 11 | 3/2-5/2 | -0.543D-03 | 0.259D-05 | 0.309D 01 | 0.702D-04 | | | 0.848D 04 | 0.192D 00 |
| | | 5/2-5/2 | -0.124D-02 | 0.617D-05 | 0.780D 00 | 0.194D-04 | | | 0.307D 04 | 0.765D-01 |

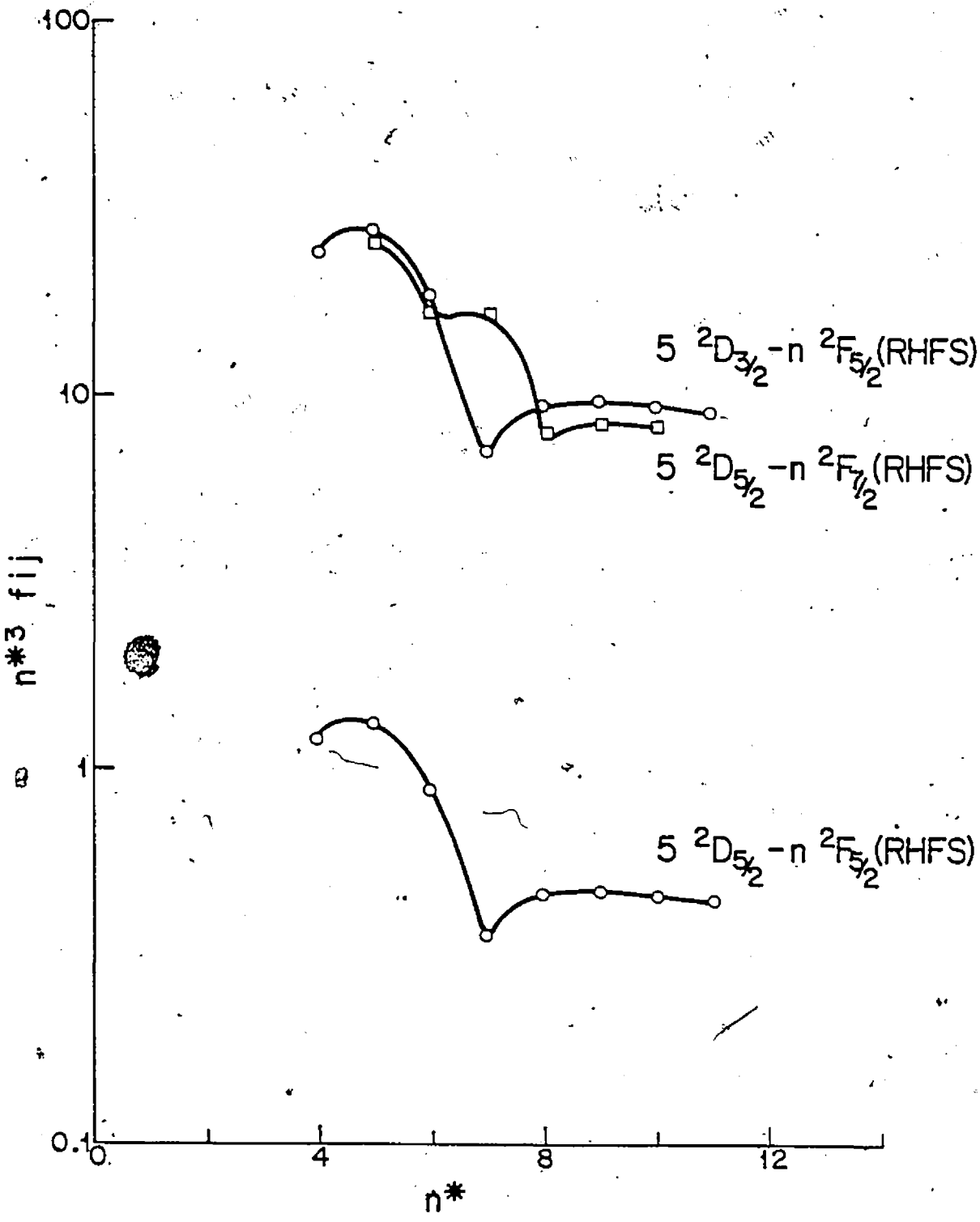
APPENDIX 4 : Plots of $n^{*3}f_{IJ}$ versus $n^*$ indicating the behavior of the relativistic oscillator strengths as a function of the effective principal quantum number for several Cesium I series. The oscillator strengths are taken from Appendix (3) and correspond to those derived in the velocity formulation. The theoretical curves are denoted by (RHFS) and the corresponding plots formed from Agnew's experimental data are designated by (AGNEW).

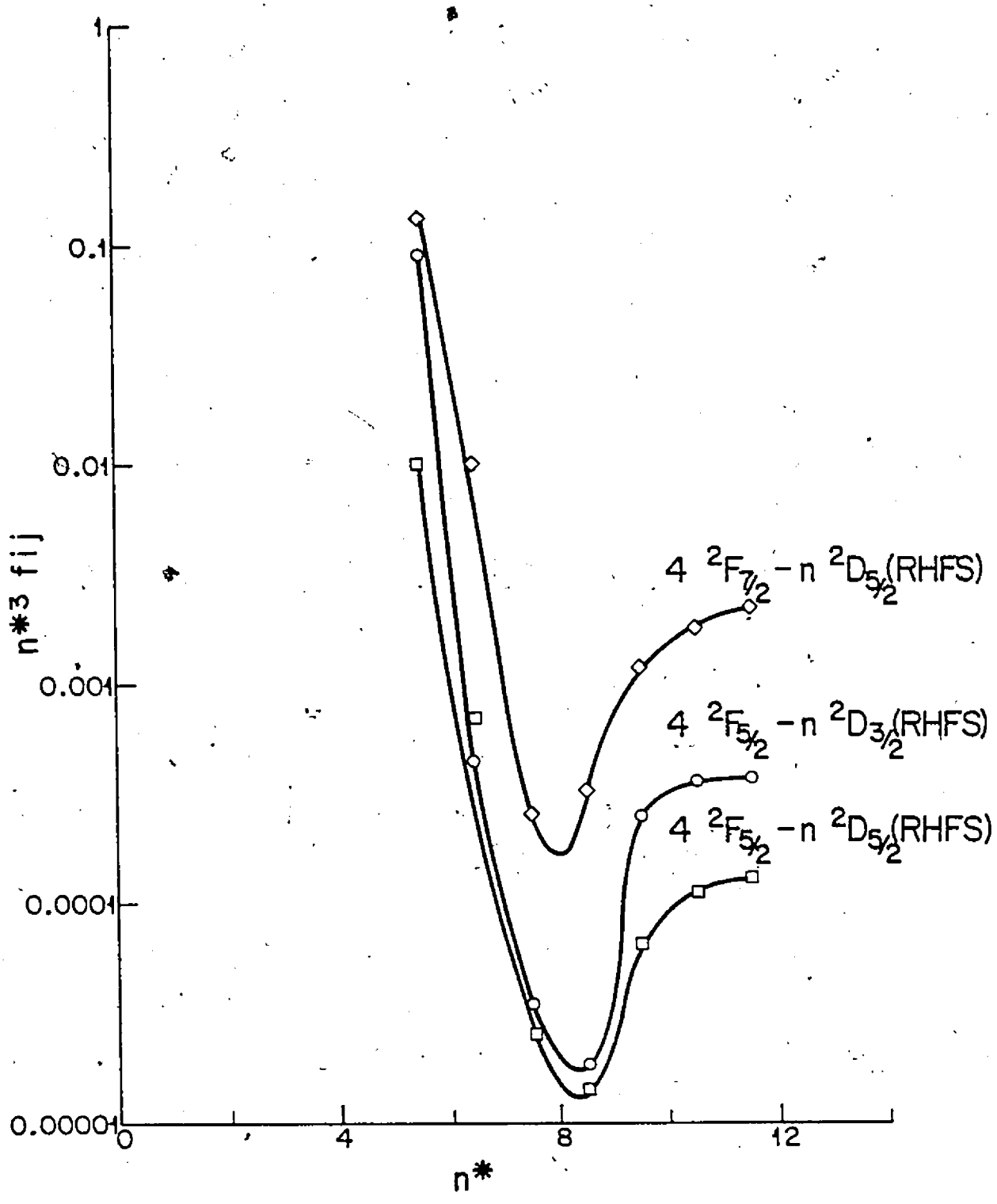












## APPENDIX 5 : Cesium Oscillator Strengths

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\tilde{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 7 | 1/2 - 1/2 | -0.202D-02 | 0.182D-02 | 0.253D 00 | 0.295D 00 | 0.171D 00 | | 0.914D 07 | 0.740D 07 |
| | | 3/2 - 1/2 | -0.201D-02 | 0.182D-02 | 0.273D 00 | 0.322D 00 | 0.208D 00 | | 0.168D 08 | 0.137D 08 |
| 6 | 8 | 1/2 - 1/2 | -0.832D-03 | 0.511D-03 | 0.241D-01 | 0.911D-02 | 0.202D-01 | | 0.278D 07 | 0.105D 07 |
| | | 3/2 - 1/2 | -0.799D-03 | 0.467D-03 | 0.232D-01 | 0.795D-02 | 0.204D-01 | | 0.492D 07 | 0.168D 07 |
| 6 | 9 | 1/2 - 1/2 | -0.520D-03 | 0.276D-03 | 0.786D-02 | 0.221D-02 | 0.702D-02 | 0.122D-01 | 0.130D 07 | 0.365D 06 |
| | | 3/2 - 1/2 | -0.497D-03 | 0.247D-03 | 0.746D-02 | 0.184D-02 | 0.687D-02 | | 0.229D 07 | 0.566D 06 |
| 6 | 10 | 1/2 - 1/2 | -0.385D-03 | 0.187D-03 | 0.397D-02 | 0.940D-03 | 0.326D-02 | 0.433D-02 | 0.777D 06 | 0.184D 06 |
| | | 3/2 - 1/2 | -0.368D-03 | 0.166D-03 | 0.375D-02 | 0.765D-03 | 0.299D-02 | 0.381D-02 | 0.137D 07 | 0.290D 06 |
| 6 | 11 | 1/2 - 1/2 | -0.298D-03 | 0.138D-03 | 0.227D-02 | 0.486D-03 | 0.193D-02 | 0.243D-02 | 0.488D 06 | 0.104D 06 |
| | | 3/2 - 1/2 | -0.285D-03 | 0.122D-03 | 0.214D-02 | 0.390D-03 | 0.186D-02 | 0.261D-02 | 0.864D 06 | 0.158D 06 |
| 6 | 12 | 1/2 - 1/2 | -0.239D-03 | 0.107D-03 | 0.142D-02 | 0.285D-03 | 0.122D-01 | 0.151D-02 | 0.324D 06 | 0.649D 05 |
| | | 3/2 - 1/2 | -0.229D-03 | 0.943D-04 | 0.134D-02 | 0.227D-03 | 0.127D-02 | 0.140D-02 | 0.575D 06 | 0.972D 05 |
| 6 | 13 | 1/2 - 1/2 | -0.198D-03 | 0.862D-04 | 0.951D-03 | 0.181D-03 | 0.820D-03 | 0.121D-02 | 0.224D 06 | 0.426D 05 |
| | | 3/2 - 1/2 | -0.185D-03 | 0.756D-04 | 0.896D-03 | 0.144D-03 | 0.780D-03 | 0.104D-02 | 0.397D 06 | 0.637D 05 |
| 6 | 14 | 1/2 - 1/2 | -0.167D-03 | 0.717D-04 | 0.667D-03 | 0.123D-03 | 0.590D-03 | 0.706D-03 | 0.162D 06 | 0.299D 05 |
| | | 3/2 - 1/2 | -0.159D-03 | 0.628D-04 | 0.628D-03 | 0.976D-04 | 0.560D-03 | 0.690D-03 | 0.287D 06 | 0.446D 05 |
| 6 | 15 | 1/2 - 1/2 | -0.143D-03 | 0.609D-04 | 0.485D-03 | 0.880D-04 | | 0.380D-03 | 0.120D 06 | 0.218D 05 |
| | | 3/2 - 1/2 | -0.137D-03 | 0.533D-04 | 0.457D-03 | 0.694D-04 | | | 0.214D 06 | 0.325D 05 |
| 7 | 8 | 1/2 - 1/2 | -0.161D-02 | 0.131D-02 | 0.466D 00 | 0.308D 00 | 0.297D 00 | | 0.202D 07 | 0.134D 07 |
| | | 3/2 - 1/2 | -0.159D-02 | 0.132D-02 | 0.489D 00 | 0.337D 00 | 0.333D 00 | | 0.367D 07 | 0.253D 07 |
| 7 | 9 | 1/2 - 1/2 | -0.703D-03 | 0.467D-03 | 0.440D-01 | 0.194D-01 | 0.305D-01 | | 0.777D 06 | 0.343D 06 |
| | | 3/2 - 1/2 | -0.658D-03 | 0.422D-03 | 0.400D-01 | 0.165D-01 | 0.256D-01 | | 0.131D 07 | 0.542D 06 |
| 7 | 10 | 1/2 - 1/2 | -0.478D-03 | 0.289D-03 | 0.160D-01 | 0.385D-02 | 0.964D-02 | | 0.455D 06 | 0.167D 06 |
| | | 3/2 - 1/2 | -0.445D-03 | 0.255D-03 | 0.143D-01 | 0.470D-02 | 0.842D-02 | | 0.769D 06 | 0.253D 06 |
| 7 | 11 | 1/2 - 1/2 | -0.357D-03 | 0.204D-03 | 0.790D-02 | 0.260D-02 | 0.501D-02 | | 0.286D 06 | 0.943D 05 |
| | | 3/2 - 1/2 | -0.331D-03 | 0.179D-03 | 0.700D-02 | 0.204D-02 | 0.455D-02 | | 0.484D 06 | 0.140D 06 |
| 7 | 12 | 1/2 - 1/2 | -0.280D-03 | 0.156D-03 | 0.456D-02 | 0.140D-02 | 0.287D-02 | | 0.150D 06 | 0.583D 05 |
| | | 3/2 - 1/2 | -0.261D-03 | 0.135D-03 | 0.403D-02 | 0.108D-02 | 0.259D-02 | | 0.320D 06 | 0.864D 05 |
| 7 | 13 | 1/2 - 1/2 | -0.228D-03 | 0.123D-03 | 0.292D-02 | 0.946D-03 | 0.193D-02 | | 0.131D 06 | 0.380D 05 |
| | | 3/2 - 1/2 | -0.212D-03 | 0.107D-03 | 0.258D-02 | 0.849D-03 | 0.164D-02 | | 0.221D 06 | 0.558D 05 |
| 7 | 14 | 1/2 - 1/2 | -0.191D-03 | 0.102D-03 | 0.198D-02 | 0.360D-03 | 0.126D-02 | | 0.947D 05 | 0.268D 05 |
| | | 3/2 - 1/2 | -0.178D-03 | 0.879D-04 | 0.174D-02 | 0.427D-03 | 0.113D-02 | | 0.160D 06 | 0.392D 05 |
| 7 | 15 | 1/2 - 1/2 | -0.163D-03 | 0.861D-04 | 0.140D-02 | 0.391D-03 | | | 0.707D 05 | 0.196D 05 |
| | | 3/2 - 1/2 | -0.152D-03 | 0.742D-04 | 0.124D-02 | 0.297D-03 | | | 0.119D 06 | 0.286D 05 |
| 8 | 9 | 1/2 - 1/2 | -0.129D-02 | 0.103D-02 | 0.632D 00 | 0.401D 00 | | | 0.608D 06 | 0.387D 06 |
| | | 3/2 - 1/2 | -0.127D-02 | 0.104D-02 | 0.665D 00 | 0.439D 00 | | | 0.111D 07 | 0.732D 06 |
| 8 | 10 | 1/2 - 1/2 | -0.602D-03 | 0.428D-03 | 0.640D-01 | 0.324D-01 | | | 0.266D 06 | 0.145D 06 |
| | | 3/2 - 1/2 | -0.564D-03 | 0.393D-03 | 0.581D-01 | 0.281D-01 | | | 0.488D 06 | 0.236D 06 |
| 8 | 11 | 1/2 - 1/2 | -0.407D-03 | 0.272D-03 | 0.222D-01 | 0.737D-02 | | | 0.173D 06 | 0.769D 05 |
| | | 3/2 - 1/2 | -0.379D-03 | 0.244D-03 | 0.197D-01 | 0.618D-02 | | | 0.294D 06 | 0.122D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ns^2S_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION N | TRANSITION N' | TRANSITION J-J' | $R^e_{ij}$ VELOCITY | $R^e_{ij}$ LENGTH | $f_{ij}$ VELOCITY | $f_{ij}$ LENGTH | $f_{ij}$ STONE | $f_{ij}$ AGNEW | $A_{ij}$ ($sec^{-1}$) VELOCITY | $A_{ij}$ ($sec^{-1}$) LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 12 | 1/2 - 1/2 | -0.306D-03 | 0.197D-03 | 0.109D-01 | 0.449D-02 | | | 0.113D 06 | 0.467D 05 |
| | | 3/2 - 1/2 | -0.285D-03 | 0.175D-03 | 0.961D-02 | 0.364D-02 | | | 0.192D 06 | 0.728D 05 |
| 8 | 13 | 1/2 - 1/2 | -0.244D-03 | 0.151D-03 | 0.639D-02 | 0.244D-02 | | | 0.773D 05 | 0.295D 05 |
| | | 3/2 - 1/2 | -0.227D-03 | 0.133D-03 | 0.564D-02 | 0.195D-02 | | | 0.131D 06 | 0.455D 05 |
| 8 | 14 | 1/2 - 1/2 | -0.201D-03 | 0.123D-03 | 0.407D-02 | 0.152D-02 | | | 0.558D 05 | 0.209D 05 |
| | | 3/2 - 1/2 | -0.187D-03 | 0.108D-03 | 0.359D-02 | 0.121D-02 | | | 0.951D 05 | 0.320D 05 |
| 8 | 15 | 1/2 - 1/2 | -0.170D-03 | 0.103D-03 | 0.278D-02 | 0.102D-02 | | | 0.418D 05 | 0.153D 05 |
| | | 3/2 - 1/2 | -0.158D-03 | 0.907D-04 | 0.245D-02 | 0.808D-03 | | | 0.707D 05 | 0.234D 05 |
| 9 | 10 | 1/2 - 1/2 | -0.107D-02 | 0.854D-03 | 0.798D 00 | 0.504D 00 | | | 0.234D 06 | 0.148D 06 |
| | | 3/2 - 1/2 | -0.106D-02 | 0.861D-03 | 0.839D 00 | 0.549D 00 | | | 0.430D 06 | 0.280D 06 |
| 9 | 11 | 1/2 - 1/2 | -0.495D-03 | 0.353D-03 | 0.751D-01 | 0.382D-01 | | | 0.112D 06 | 0.566D 05 |
| | | 3/2 - 1/2 | -0.463D-03 | 0.323D-03 | 0.679D-01 | 0.329D-01 | | | 0.190D 06 | 0.922D 05 |
| 9 | 12 | 1/2 - 1/2 | -0.336D-03 | 0.225D-03 | 0.255D-01 | 0.115D-01 | | | 0.703D 05 | 0.315D 05 |
| | | 3/2 - 1/2 | -0.313D-03 | 0.202D-03 | 0.226D-01 | 0.940D-02 | | | 0.119D 06 | 0.492D 05 |
| 9 | 13 | 1/2 - 1/2 | -0.255D-03 | 0.161D-03 | 0.128D-01 | 0.508D-02 | | | 0.463D 05 | 0.184D 05 |
| | | 3/2 - 1/2 | -0.237D-03 | 0.142D-03 | 0.112D-01 | 0.406D-02 | | | 0.781D 05 | 0.282D 05 |
| 9 | 14 | 1/2 - 1/2 | -0.205D-03 | 0.127D-03 | 0.736D-02 | 0.285D-02 | | | 0.334D 05 | 0.129D 05 |
| | | 3/2 - 1/2 | -0.190D-03 | 0.112D-03 | 0.646D-02 | 0.224D-02 | | | 0.566D 05 | 0.197D 05 |
| 9 | 15 | 1/2 - 1/2 | -0.170D-03 | 0.104D-03 | 0.471D-02 | 0.178D-02 | | | 0.249D 05 | 0.938D 04 |
| | | 3/2 - 1/2 | -0.158D-03 | 0.916D-04 | 0.412D-02 | 0.139D-02 | | | 0.422D 05 | 0.142D 05 |
| 10 | 11 | 1/2 - 1/2 | -0.903D-03 | 0.743D-03 | 0.926D 00 | 0.627D 00 | | | 0.100D 06 | 0.678D 05 |
| | | 3/2 - 1/2 | -0.892D-03 | 0.746D-03 | 0.912D 00 | 0.678D 00 | | | 0.164D 06 | 0.128D 06 |
| 10 | 12 | 1/2 - 1/2 | -0.411D-03 | 0.313D-03 | 0.822D-01 | 0.479D-01 | | | 0.484D 05 | 0.282D 05 |
| | | 3/2 - 1/2 | -0.383D-03 | 0.286D-03 | 0.737D-01 | 0.412D-01 | | | 0.819D 05 | 0.459D 05 |
| 10 | 13 | 1/2 - 1/2 | -0.280D-03 | 0.192D-03 | 0.290D-01 | 0.137D-01 | | | 0.297D 05 | 0.140D 05 |
| | | 3/2 - 1/2 | -0.259D-03 | 0.172D-03 | 0.254D-01 | 0.112D-01 | | | 0.496D 05 | 0.220D 05 |
| 10 | 14 | 1/2 - 1/2 | -0.214D-03 | 0.148D-03 | 0.138D-01 | 0.660D-02 | | | 0.212D 05 | 0.101D 05 |
| | | 3/2 - 1/2 | -0.198D-03 | 0.131D-03 | 0.120D-01 | 0.527D-02 | | | 0.356D 05 | 0.156D 05 |
| 10 | 15 | 1/2 - 1/2 | -0.172D-03 | 0.119D-03 | 0.789D-02 | 0.374D-02 | | | 0.157D 05 | 0.744D 04 |
| | | 3/2 - 1/2 | -0.159D-03 | 0.105D-03 | 0.686D-02 | 0.295D-02 | | | 0.264D 05 | 0.113D 05 |
| 11 | 12 | 1/2 - 1/2 | -0.777D-03 | 0.655D-03 | 0.105D 01 | 0.749D 00 | | | 0.464D 05 | 0.344D 05 |
| | | 3/2 - 1/2 | -0.768D-03 | 0.656D-03 | 0.110D 01 | 0.805D 00 | | | 0.881D 05 | 0.645D 05 |
| 11 | 13 | 1/2 - 1/2 | -0.350D-03 | 0.251D-03 | 0.998D-01 | 0.514D-01 | | | 0.210D 05 | 0.108D 05 |
| | | 3/2 - 1/2 | -0.325D-03 | 0.228D-03 | 0.891D-01 | 0.437D-01 | | | 0.351D 05 | 0.172D 05 |
| 11 | 14 | 1/2 - 1/2 | -0.240D-03 | 0.173D-03 | 0.314D-01 | 0.164D-01 | | | 0.148D 05 | 0.773D 04 |
| | | 3/2 - 1/2 | -0.221D-03 | 0.157D-03 | 0.271D-01 | 0.137D-01 | | | 0.246D 05 | 0.124D 05 |
| 11 | 15 | 1/2 - 1/2 | -0.183D-03 | 0.134D-03 | 0.146D-01 | 0.790D-02 | | | 0.107D 05 | 0.579D 04 |
| | | 3/2 - 1/2 | -0.169D-03 | 0.118D-03 | 0.126D-01 | 0.619D-02 | | | 0.179D 05 | 0.876D 04 |
| 12 | 13 | 1/2 - 1/2 | -0.683D-03 | 0.361D-03 | 0.191D 01 | 0.634D 00 | | | 0.160D 05 | 0.446D 04 |
| | | 3/2 - 1/2 | -0.674D-03 | 0.348D-03 | 0.208D 01 | 0.553D 00 | | | 0.277D 05 | 0.740D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM . OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $R^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 12 | 14 | 1/2 - 1/2 | -0.305D-03 | 0.226D-03 | 0.108D 00 | 0.596D-01 | | | 0.112D 05 | 0.612D 04 |
| | | 3/2 - 1/2 | -0.283D-03 | 0.206D-03 | 0.963D-01 | 0.509D-01 | | | 0.186D 05 | 0.984D 04 |
| 12 | 15 | 1/2 - 1/2 | -0.211D-03 | 0.156D-03 | 0.339D-01 | 0.185D-01 | | | 0.814D 04 | 0.442D 04 |
| | | 3/2 - 1/2 | -0.192D-03 | 0.140D-03 | 0.287D-01 | 0.152D-01 | | | 0.132D 05 | 0.699D 04 |
| 13 | 14 | 1/2 - 1/2 | -0.633D-03 | 0.308D-03 | 0.231D 01 | 0.545D 00 | | | 0.972D 04 | 0.230D 04 |
| | | 3/2 - 1/2 | -0.625D-03 | 0.299D-03 | 0.252D 01 | 0.576D 00 | | | 0.169D 05 | 0.387D 04 |
| 13 | 15 | 1/2 - 1/2 | -0.297D-03 | 0.216D-03 | 0.141D 00 | 0.751D-01 | | | 0.769D 04 | 0.409D 04 |
| | | 3/2 - 1/2 | -0.278D-03 | 0.200D-03 | 0.128D 00 | 0.661D-01 | | | 0.131D 05 | 0.678D 04 |
| 14 | 15 | 1/2 - 1/2 | -0.568D-03 | 0.274D-03 | 0.252D 01 | 0.586D 00 | | | 0.579D 04 | 0.134D 04 |
| | | 3/2 - 1/2 | -0.559D-03 | 0.269D-03 | 0.274D 01 | 0.631D 00 | | | 0.100D 05 | 0.231D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - np^2P_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM . OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\bar{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}$ (sec$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | N' | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 6 | 1/2 - 1/2 | 0.289D-02 | -0.317D-02 | 0.342D 00 | 0.411D 00 | 0.394D 00 | | 0.265D 08 | 0.342D 08 |
| | | 1/2 - 3/2 | 0.302D-02 | -0.331D-02 | 0.712D 00 | 0.854D 00 | 0.814D 00 | | 0.327D 08 | 0.392D 08 |
| 6 | 7 | 1/2 - 1/2 | 0.377D-03 | -0.355D-03 | 0.299D-02 | 0.265D-02 | 0.284D-02 | 0.320D-02 | 0.947D 06 | 0.839D 06 |
| | | 1/2 - 3/2 | 0.587D-03 | -0.563D-03 | 0.144D-01 | 0.132D-01 | 0.174D-01 | 0.133D-01 | 0.231D 07 | 0.213D 07 |
| 6 | 8 | 1/2 - 1/2 | 0.106D-03 | -0.755D-04 | 0.201D-03 | 0.102D-03 | 0.317D-03 | 0.385D-03 | 0.865D 05 | 0.446D 05 |
| | | 1/2 - 3/2 | 0.260D-03 | -0.218D-03 | 0.240D-02 | 0.168D-02 | 0.349D-02 | 0.294D-02 | 0.533D 06 | 0.373D 06 |
| 6 | 9 | 1/2 - 1/2 | 0.365D-04 | -0.123D-04 | 0.221D-04 | 0.249D-05 | 0.725D-04 | 0.830D-04 | 0.112D 05 | 0.127D 04 |
| | | 1/2 - 3/2 | 0.150D-03 | -0.112D-03 | 0.743D-03 | 0.418D-03 | 0.125D-02 | 0.910D-03 | 0.190D 06 | 0.177D 06 |
| 6 | 10 | 1/2 - 1/2 | 0.129D-04 | 0.588D-05 | 0.267D-05 | 0.550D-06 | 0.289D-04 | 0.190D-04 | 0.147D 04 | 0.303D 03 |
| | | 1/2 - 3/2 | 0.599D-04 | -0.689D-04 | 0.318D-03 | 0.151D-03 | 0.620D-03 | 0.417D-03 | 0.876D 05 | 0.418D 05 |
| 6 | 11 | 1/2 - 1/2 | 0.361D-05 | 0.114D-04 | 0.202D-06 | 0.201D-05 | 0.124D-04 | 0.800D-05 | 0.117D 03 | 0.116D 04 |
| | | 1/2 - 3/2 | 0.728D-04 | -0.471D-04 | 0.165D-03 | 0.692D-04 | 0.356D-03 | 0.223D-03 | 0.475D 05 | 0.200D 05 |
| 6 | 12 | 1/2 - 1/2 | -0.456D-06 | 0.127D-04 | 0.319D-08 | 0.247D-05 | 0.620D-05 | 0.430D-05 | 0.190D 01 | 0.147D 04 |
| | | 1/2 - 3/2 | 0.562D-04 | -0.347D-04 | 0.969D-04 | 0.370D-04 | 0.208D-03 | 0.126D-03 | 0.288D 05 | 0.110D 05 |
| 6 | 13 | 1/2 - 1/2 | -0.350D-05 | 0.146D-04 | 0.186D-06 | 0.324D-05 | | 0.240D-05 | 0.112D 03 | 0.197D 04 |
| | | 1/2 - 3/2 | 0.488D-04 | -0.285D-04 | 0.723D-04 | 0.247D-04 | | 0.790D-04 | 0.220D 05 | 0.748D 04 |
| 6 | 14 | 1/2 - 1/2 | -0.429D-05 | 0.136D-04 | 0.277D-06 | 0.278D-05 | | 0.160D-05 | 0.171D 03 | 0.171D 04 |
| | | 1/2 - 3/2 | 0.397D-04 | -0.225D-04 | 0.475D-04 | 0.152D-04 | | 0.580D-04 | 0.146D 05 | 0.467D 04 |
| 6 | 15 | 1/2 - 1/2 | -0.452D-05 | 0.124D-04 | 0.306D-06 | 0.232D-05 | | | 0.151D 03 | 0.145D 04 |
| | | 1/2 - 3/2 | 0.334D-04 | -0.184D-04 | 0.333D-04 | 0.101D-04 | | 0.430D-04 | 0.104D 05 | 0.316D 04 |
| 7 | 7 | 1/2 - 1/2 | 0.227D-02 | -0.174D-02 | 0.734D 00 | 0.431D 00 | 0.556D 00 | | 0.513D 07 | 0.300D 07 |
| | | 1/2 - 3/2 | 0.238D-02 | -0.180D-02 | 0.152D 01 | 0.871D 00 | 0.112D 01 | | 0.567D 07 | 0.338D 07 |
| 7 | 8 | 1/2 - 1/2 | 0.555D-03 | -0.297D-03 | 0.197D-01 | 0.364D-02 | 0.516D-02 | | 0.674D 06 | 0.193D 06 |
| | | 1/2 - 3/2 | 0.721D-03 | -0.434D-03 | 0.655D-01 | 0.237D-01 | 0.256D-02 | | 0.115D 07 | 0.418D 06 |
| 7 | 9 | 1/2 - 1/2 | 0.271D-03 | -0.944D-04 | 0.369D-02 | 0.449D-03 | 0.620D-03 | | 0.204D 06 | 0.248D 05 |
| | | 1/2 - 3/2 | 0.392D-03 | -0.191D-03 | 0.154D-01 | 0.363D-02 | 0.502D-02 | | 0.430D 06 | 0.101D 06 |
| 7 | 10 | 1/2 - 1/2 | 0.167D-03 | -0.360D-04 | 0.125D-02 | 0.382D-04 | 0.170D-03 | | 0.864D 05 | 0.403D 04 |
| | | 1/2 - 3/2 | 0.259D-03 | -0.107D-03 | 0.601D-02 | 0.102D-02 | 0.187D-02 | | 0.209D 06 | 0.356D 05 |
| 7 | 11 | 1/2 - 1/2 | 0.116D-03 | -0.140D-04 | 0.568D-03 | 0.827D-05 | 0.620D-04 | | 0.446D 05 | 0.653D 03 |
| | | 1/2 - 3/2 | 0.139D-03 | -0.687D-04 | 0.300D-02 | 0.397D-03 | 0.911D-03 | | 0.119D 06 | 0.157D 05 |
| 7 | 12 | 1/2 - 1/2 | 0.671D-04 | -0.444D-05 | 0.307D-03 | 0.799D-06 | 0.270D-04 | | 0.262D 05 | 0.682D 02 |
| | | 1/2 - 3/2 | 0.146D-03 | -0.464D-04 | 0.173D-02 | 0.189D-03 | 0.486D-03 | | 0.740D 05 | 0.810D 04 |
| 7 | 13 | 1/2 - 1/2 | 0.736D-04 | 0.147D-05 | 0.215D-03 | 0.853D-07 | | | 0.154D 05 | 0.769D 01 |
| | | 1/2 - 3/2 | 0.128D-03 | -0.380D-04 | 0.129D-02 | 0.113D-03 | | | 0.563D 05 | 0.513D 04 |
| 7 | 14 | 1/2 - 1/2 | 0.591D-04 | 0.376D-05 | 0.135D-03 | 0.945D-06 | | | 0.127D 05 | 0.513D 02 |
| | | 1/2 - 3/2 | 0.105D-03 | -0.290D-04 | 0.844D-03 | 0.651D-04 | | | 0.356D 05 | 0.306D 04 |
| 7 | 15 | 1/2 - 1/2 | 0.485D-04 | 0.476D-05 | 0.912D-04 | 0.362D-06 | | | 0.881D 04 | 0.831D 02 |
| | | 1/2 - 3/2 | 0.882D-04 | -0.232D-04 | 0.592D-03 | 0.410D-04 | | | 0.286D 05 | 0.198D 04 |
| 8 | 8 | 1/2 - 1/2 | 0.167D-02 | -0.130D-02 | 0.920D 00 | 0.553D 00 | | | 0.119D 07 | 0.715D 06 |
| | | 1/2 - 3/2 | 0.176D-02 | -0.133D-02 | 0.191D 01 | 0.110D 01 | | | 0.139D 07 | 0.798D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - np^2P_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $R^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | N | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 8 | 9 | 1/2 - 1/2 | 0.443D-03 | -0.246D-03 | 0.271D-01 | 0.835D-02 | | | 0.199D 06 | 0.612D 05 |
| | | 1/2 - 3/2 | 0.564D-03 | -0.341D-03 | 0.866D-01 | 0.317D-01 | | | 0.327D 06 | 0.119D 06 |
| 8 | 10 | 1/2 - 1/2 | 0.236D-03 | -0.963D-04 | 0.576D-02 | 0.963D-03 | | | 0.748D 05 | 0.125D 05 |
| | | 1/2 - 3/2 | 0.225D-03 | -0.165D-03 | 0.218D-01 | 0.361D-02 | | | 0.143D 06 | 0.368D 05 |
| 8 | 11 | 1/2 - 1/2 | 0.154D-03 | -0.477D-04 | 0.214D-02 | 0.204D-03 | | | 0.369D 05 | 0.353D 04 |
| | | 1/2 - 3/2 | 0.223D-03 | -0.995D-04 | 0.892D-02 | 0.178D-02 | | | 0.773D 05 | 0.154D 05 |
| 8 | 12 | 1/2 - 1/2 | 0.112D-03 | -0.267D-04 | 0.104D-02 | 0.588D-04 | | | 0.212D 05 | 0.120D 04 |
| | | 1/2 - 3/2 | 0.167D-03 | -0.676D-04 | 0.461D-02 | 0.755D-03 | | | 0.471D 05 | 0.773D 04 |
| 8 | 13 | 1/2 - 1/2 | 0.929D-04 | -0.159D-04 | 0.675D-03 | 0.197D-04 | | | 0.154D 05 | 0.451D 03 |
| | | 1/2 - 3/2 | 0.143D-03 | -0.518D-04 | 0.318D-02 | 0.420D-03 | | | 0.363D 05 | 0.480D 04 |
| 8 | 14 | 1/2 - 1/2 | 0.734D-04 | -0.944D-05 | 0.406D-03 | 0.672D-05 | | | 0.100D 05 | 0.165D 03 |
| | | 1/2 - 3/2 | 0.115D-03 | -0.390D-04 | 0.198D-02 | 0.229D-03 | | | 0.245D 05 | 0.283D 04 |
| 8 | 15 | 1/2 - 1/2 | 0.602D-04 | -0.578D-05 | 0.266D-03 | 0.245D-05 | | | 0.650D 04 | 0.637D 02 |
| | | 1/2 - 3/2 | 0.956D-04 | -0.309D-04 | 0.135D-02 | 0.140D-03 | | | 0.175D 05 | 0.182D 04 |
| 9 | 9 | 1/2 - 1/2 | 0.127D-02 | -0.106D-02 | 0.102D 01 | 0.705D 00 | | | 0.360D 06 | 0.248D 06 |
| | | 1/2 - 3/2 | 0.134D-02 | -0.108D-02 | 0.213D 01 | 0.140D 01 | | | 0.422D 06 | 0.277D 06 |
| 9 | 10 | 1/2 - 1/2 | 0.342D-03 | -0.213D-03 | 0.294D-01 | 0.115D-01 | | | 0.649D 05 | 0.253D 05 |
| | | 1/2 - 3/2 | 0.434D-03 | -0.288D-03 | 0.934D-01 | 0.412D-01 | | | 0.106D 06 | 0.467D 05 |
| 9 | 11 | 1/2 - 1/2 | 0.188D-03 | -0.936D-04 | 0.650D-02 | 0.161D-02 | | | 0.270D 05 | 0.666D 04 |
| | | 1/2 - 3/2 | 0.256D-03 | -0.148D-03 | 0.240D-01 | 0.800D-02 | | | 0.504D 05 | 0.168D 05 |
| 9 | 12 | 1/2 - 1/2 | 0.127D-03 | -0.525D-04 | 0.249D-02 | 0.430D-03 | | | 0.144D 05 | 0.248D 04 |
| | | 1/2 - 3/2 | 0.180D-03 | -0.944D-04 | 0.100D-01 | 0.276D-02 | | | 0.291D 05 | 0.806D 04 |
| 9 | 13 | 1/2 - 1/2 | 0.100D-03 | -0.340D-04 | 0.141D-02 | 0.162D-03 | | | 0.956D 04 | 0.115D 04 |
| | | 1/2 - 3/2 | 0.147D-03 | -0.696D-04 | 0.603D-02 | 0.136D-02 | | | 0.214D 05 | 0.484D 04 |
| 9 | 14 | 1/2 - 1/2 | 0.770D-04 | -0.223D-04 | 0.779D-03 | 0.655D-04 | | | 0.628D 04 | 0.529D 03 |
| | | 1/2 - 3/2 | 0.115D-03 | -0.512D-04 | 0.349D-02 | 0.688D-03 | | | 0.142D 05 | 0.279D 04 |
| 9 | 15 | 1/2 - 1/2 | 0.620D-04 | -0.156D-04 | 0.481D-03 | 0.305D-04 | | | 0.430D 04 | 0.272D 03 |
| | | 1/2 - 3/2 | 0.947D-04 | -0.399D-04 | 0.225D-02 | 0.398D-03 | | | 0.100D 05 | 0.178D 04 |
| 10 | 10 | 1/2 - 1/2 | 0.105D-02 | -0.383D-03 | 0.117D 01 | 0.836D 00 | | | 0.142D 06 | 0.102D 06 |
| | | 1/2 - 3/2 | 0.110D-02 | -0.904D-03 | 0.243D 01 | 0.165D 01 | | | 0.167D 06 | 0.113D 06 |
| 10 | 11 | 1/2 - 1/2 | 0.300D-03 | -0.209D-03 | 0.373D-01 | 0.181D-01 | | | 0.303D 05 | 0.147D 05 |
| | | 1/2 - 3/2 | 0.373D-03 | -0.268D-03 | 0.114D 00 | 0.587D-01 | | | 0.475D 05 | 0.246D 05 |
| 10 | 12 | 1/2 - 1/2 | 0.172D-03 | -0.104D-03 | 0.874D-02 | 0.320D-02 | | | 0.141D 05 | 0.513D 04 |
| | | 1/2 - 3/2 | 0.228D-03 | -0.148D-03 | 0.303D-01 | 0.129D-01 | | | 0.247D 05 | 0.105D 05 |
| 10 | 13 | 1/2 - 1/2 | 0.126D-03 | -0.670D-04 | 0.391D-02 | 0.110D-02 | | | 0.910D 04 | 0.256D 04 |
| | | 1/2 - 3/2 | 0.173D-03 | -0.103D-03 | 0.146D-01 | 0.522D-02 | | | 0.172D 05 | 0.612D 04 |
| 10 | 14 | 1/2 - 1/2 | 0.925D-04 | -0.451D-04 | 0.191D-02 | 0.446D-03 | | | 0.588D 04 | 0.130D 04 |
| | | 1/2 - 3/2 | 0.131D-03 | -0.741D-04 | 0.753D-02 | 0.240D-02 | | | 0.111D 05 | 0.352D 04 |
| 10 | 15 | 1/2 - 1/2 | 0.736D-04 | -0.329D-04 | 0.110D-02 | 0.219D-03 | | | 0.374D 04 | 0.748D 03 |
| | | 1/2 - 3/2 | 0.106D-03 | -0.569D-04 | 0.450D-02 | 0.131D-02 | | | 0.773D 04 | 0.224D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - np^2P_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM . OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\tilde{H}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 11 | 11 | 1/2 - 1/2 | 0.875D-03 | -0.764D-03 | 0.129D 01 | 0.977D 00 | | | 0.645D 05 | 0.488D 05 |
| | | 1/2 - 3/2 | 0.921D-03 | -0.782D-03 | 0.267D 01 | 0.192D 01 | | | 0.752D 05 | 0.546D 05 |
| 11 | 12 | 1/2 - 1/2 | 0.261D-03 | -0.196D-03 | 0.431D-01 | 0.243D-01 | | | 0.150D 05 | 0.847D 04 |
| | | 1/2 - 3/2 | 0.321D-03 | -0.245D-03 | 0.128D 00 | 0.749D-01 | | | 0.231D 05 | 0.135D 05 |
| 11 | 13 | 1/2 - 1/2 | 0.161D-03 | -0.107D-03 | 0.115D-01 | 0.506D-02 | | | 0.823D 04 | 0.362D 04 |
| | | 1/2 - 3/2 | 0.210D-03 | -0.145D-03 | 0.387D-01 | 0.184D-01 | | | 0.141D 05 | 0.670D 04 |
| 11 | 14 | 1/2 - 1/2 | 0.111D-03 | -0.669D-04 | 0.444D-02 | 0.162D-02 | | | 0.471D 04 | 0.172D 04 |
| | | 1/2 - 3/2 | 0.149D-03 | -0.974D-04 | 0.160D-01 | 0.684D-02 | | | 0.860D 04 | 0.368D 04 |
| 11 | 15 | 1/2 - 1/2 | 0.835D-04 | -0.470D-04 | 0.223D-02 | 0.705D-03 | | | 0.306D 04 | 0.967D 03 |
| | | 1/2 - 3/2 | 0.115D-03 | -0.713D-04 | 0.843D-02 | 0.323D-02 | | | 0.583D 04 | 0.223D 04 |
| 12 | 12 | 1/2 - 1/2 | 0.756D-03 | -0.677D-03 | 0.140D 01 | 0.112D 01 | | | 0.327D 05 | 0.262D 05 |
| | | 1/2 - 3/2 | 0.791D-03 | -0.693D-03 | 0.288D 01 | 0.221D 01 | | | 0.380D 05 | 0.291D 05 |
| 12 | 13 | 1/2 - 1/2 | 0.238D-03 | -0.186D-03 | 0.518D-01 | 0.316D-01 | | | 0.864D 04 | 0.525D 04 |
| | | 1/2 - 3/2 | 0.291D-03 | -0.229D-03 | 0.152D 00 | 0.946D-01 | | | 0.131D 05 | 0.914D 04 |
| 12 | 14 | 1/2 - 1/2 | 0.138D-03 | -0.928D-04 | 0.119D-01 | 0.542D-02 | | | 0.422D 04 | 0.191D 04 |
| | | 1/2 - 3/2 | 0.179D-03 | -0.124D-03 | 0.400D-01 | 0.192D-01 | | | 0.719D 04 | 0.344D 04 |
| 12 | 15 | 1/2 - 1/2 | 0.564D-04 | -0.617D-04 | 0.474D-02 | 0.194D-02 | | | 0.255D 04 | 0.104D 04 |
| | | 1/2 - 3/2 | 0.128D-03 | -0.874D-04 | 0.166D-01 | 0.776D-02 | | | 0.451D 04 | 0.211D 04 |
| 13 | 13 | 1/2 - 1/2 | 0.674D-03 | -0.923D-03 | 0.103D 01 | 0.134D 01 | | | 0.279D 05 | 0.525D 05 |
| | | 1/2 - 3/2 | 0.706D-03 | -0.926D-03 | 0.218D 01 | 0.374D 01 | | | 0.320D 05 | 0.550D 05 |
| 13 | 14 | 1/2 - 1/2 | 0.193D-03 | -0.150D-03 | 0.400D-01 | 0.239D-01 | | | 0.492D 04 | 0.293D 04 |
| | | 1/2 - 3/2 | 0.239D-03 | -0.197D-03 | 0.120D 00 | 0.814D-01 | | | 0.757D 04 | 0.513D 04 |
| 13 | 15 | 1/2 - 1/2 | 0.114D-03 | -0.643D-04 | 0.992D-02 | 0.317D-02 | | | 0.237D 04 | 0.757D 03 |
| | | 1/2 - 3/2 | 0.151D-03 | -0.975D-04 | 0.344D-01 | 0.144D-01 | | | 0.418D 04 | 0.175D 04 |
| 14 | 14 | 1/2 - 1/2 | 0.584D-03 | -0.850D-03 | 0.106D 01 | 0.224D 01 | | | 0.154D 05 | 0.326D 05 |
| | | 1/2 - 3/2 | 0.613D-03 | -0.855D-03 | 0.223D 01 | 0.434D 01 | | | 0.177D 05 | 0.344D 05 |
| 14 | 15 | 1/2 - 1/2 | 0.163D-03 | -0.148D-03 | 0.385D-01 | 0.317D-01 | | | 0.259D 04 | 0.213D 04 |
| | | 1/2 - 3/2 | 0.204D-03 | -0.196D-03 | 0.119D 00 | 0.110D 00 | | | 0.411D 04 | 0.380D 04 |
| 15 | 15 | 1/2 - 1/2 | 0.521D-03 | -0.777D-03 | 0.112D 01 | 0.248D 01 | | | 0.926D 04 | 0.205D 05 |
| | | 1/2 - 3/2 | 0.549D-03 | -0.779D-03 | 0.238D 01 | 0.478D 01 | | | 0.107D 05 | 0.215D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 5 | 7 | 3/2 - 1/2 | 0.530D-03 | -0.617D-03 | 0.177D-01 | 0.240D-01 | | | 0.124D 07 | 0.169D 07 |
| | | 3/2 - 3/2 | 0.487D-03 | -0.558D-03 | 0.292D-02 | 0.383D-02 | | | 0.108D 06 | 0.142D 06 |
| | | 5/2 - 3/2 | 0.821D-03 | -0.597D-03 | 0.203D-01 | 0.266D-01 | | | 0.110D 07 | 0.144D 07 |
| 5 | 8 | 3/2 - 1/2 | 0.173D-03 | -0.188D-03 | 0.122D-02 | 0.144D-02 | | | 0.205D 06 | 0.241D 06 |
| | | 3/2 - 3/2 | 0.164D-03 | -0.178D-03 | 0.218D-03 | 0.258D-03 | | | 0.165D 05 | 0.220D 05 |
| | | 5/2 - 3/2 | 0.180D-03 | -0.191D-03 | 0.160D-02 | 0.178D-02 | | | 0.200D 06 | 0.224D 06 |
| 5 | 9 | 3/2 - 1/2 | 0.781D-04 | -0.858D-04 | 0.213D-03 | 0.257D-03 | | | 0.488D 05 | 0.591D 05 |
| | | 3/2 - 3/2 | 0.738D-04 | -0.825D-04 | 0.379D-04 | 0.473D-04 | | | 0.438D 04 | 0.550D 04 |
| | | 5/2 - 3/2 | 0.850D-04 | -0.892D-04 | 0.304D-03 | 0.334D-03 | | | 0.521D 05 | 0.575D 05 |
| 5 | 10 | 3/2 - 1/2 | 0.418D-04 | -0.479D-04 | 0.561D-04 | 0.740D-04 | | | 0.152D 05 | 0.200D 05 |
| | | 3/2 - 3/2 | 0.389D-04 | -0.462D-04 | 0.973D-05 | 0.137D-04 | | | 0.132D 04 | 0.186D 04 |
| | | 5/2 - 3/2 | 0.473D-04 | -0.506D-04 | 0.868D-04 | 0.996D-04 | | | 0.174D 05 | 0.200D 05 |
| 5 | 11 | 3/2 - 1/2 | 0.250D-04 | -0.304D-04 | 0.192D-04 | 0.283D-04 | | | 0.571D 04 | 0.839D 04 |
| | | 3/2 - 3/2 | 0.228D-04 | -0.292D-04 | 0.319D-05 | 0.523D-05 | | | 0.475D 03 | 0.777D 03 |
| | | 5/2 - 3/2 | 0.294D-04 | -0.325D-04 | 0.320D-04 | 0.391D-04 | | | 0.703D 04 | 0.860D 04 |
| 5 | 12 | 3/2 - 1/2 | 0.162D-04 | -0.210D-04 | 0.785D-05 | 0.131D-04 | | | 0.247D 04 | 0.413D 04 |
| | | 3/2 - 3/2 | 0.144D-04 | -0.201D-04 | 0.124D-05 | 0.240D-05 | | | 0.155D 03 | 0.378D 03 |
| | | 5/2 - 3/2 | 0.198D-04 | -0.226D-04 | 0.141D-04 | 0.184D-04 | | | 0.328D 04 | 0.430D 04 |
| 5 | 13 | 3/2 - 1/2 | 0.114D-04 | -0.159D-04 | 0.378D-05 | 0.740D-05 | | | 0.124D 04 | 0.242D 04 |
| | | 3/2 - 3/2 | 0.575D-05 | -0.151D-04 | 0.555D-06 | 0.134D-05 | | | 0.910D 02 | 0.219D 03 |
| | | 5/2 - 3/2 | 0.147D-04 | -0.174D-04 | 0.757D-05 | 0.106D-04 | | | 0.164D 04 | 0.258D 04 |
| 5 | 14 | 3/2 - 1/2 | 0.765D-05 | -0.119D-04 | 0.177D-05 | 0.406D-05 | | | 0.559D 03 | 0.137D 04 |
| | | 3/2 - 3/2 | 0.647D-05 | -0.112D-04 | 0.241D-06 | 0.725D-06 | | | 0.407D 02 | 0.122D 03 |
| | | 5/2 - 3/2 | 0.106D-04 | -0.131D-04 | 0.390D-05 | 0.593D-05 | | | 0.976D 03 | 0.148D 04 |
| 5 | 15 | 3/2 - 1/2 | 0.566D-05 | -0.926D-05 | 0.914D-06 | 0.244D-05 | | | 0.315D 03 | 0.839D 03 |
| | | 3/2 - 3/2 | 0.449D-05 | -0.873D-05 | 0.115D-06 | 0.435D-06 | | | 0.198D 02 | 0.748D 02 |
| | | 5/2 - 3/2 | 0.803D-05 | -0.103D-04 | 0.222D-05 | 0.364D-05 | | | 0.566D 03 | 0.930D 03 |
| 6 | 8 | 3/2 - 1/2 | 0.189D-03 | -0.265D-03 | 0.523D-02 | 0.103D-01 | | | 0.678D 05 | 0.134D 06 |
| | | 3/2 - 3/2 | 0.997D-04 | -0.197D-03 | 0.284D-03 | 0.111D-02 | | | 0.154D 04 | 0.757D 04 |
| | | 5/2 - 3/2 | 0.130D-03 | -0.212D-03 | 0.295D-02 | 0.784D-02 | | | 0.255D 05 | 0.791D 05 |
| 6 | 9 | 3/2 - 1/2 | 0.673D-04 | -0.166D-03 | 0.411D-03 | 0.249D-02 | | | 0.140D 05 | 0.847D 05 |
| | | 3/2 - 3/2 | 0.200D-04 | -0.128D-03 | 0.720D-05 | 0.293D-03 | | | 0.124D 03 | 0.508D 04 |
| | | 5/2 - 3/2 | 0.376D-04 | -0.137D-03 | 0.154D-03 | 0.203D-02 | | | 0.352D 04 | 0.517D 05 |
| 6 | 10 | 3/2 - 1/2 | 0.283D-04 | -0.115D-03 | 0.597D-04 | 0.382D-03 | | | 0.300D 04 | 0.492D 05 |
| | | 3/2 - 3/2 | -0.364D-05 | -0.895D-04 | 0.197D-06 | 0.119D-03 | | | 0.500D 01 | 0.301D 04 |
| | | 5/2 - 3/2 | 0.649D-05 | -0.954D-04 | 0.646D-05 | 0.816D-03 | | | 0.242D 03 | 0.306D 05 |
| 6 | 11 | 3/2 - 1/2 | 0.125D-04 | -0.858D-04 | 0.106D-04 | 0.494D-03 | | | 0.653D 03 | 0.306D 05 |
| | | 3/2 - 3/2 | -0.113D-04 | -0.672D-04 | 0.173D-05 | 0.606D-04 | | | 0.537D 02 | 0.189D 04 |
| | | 5/2 - 3/2 | -0.221D-05 | -0.715D-04 | 0.396D-06 | 0.414D-03 | | | 0.183D 02 | 0.191D 05 |
| 6 | 12 | 3/2 - 1/2 | 0.529D-05 | -0.675D-04 | 0.177D-05 | 0.237D-03 | | | 0.124D 03 | 0.202D 05 |
| | | 3/2 - 3/2 | -0.136D-04 | -0.530D-04 | 0.233D-05 | 0.354D-04 | | | 0.823D 02 | 0.125D 04 |
| | | 5/2 - 3/2 | -0.637D-05 | -0.563D-04 | 0.308D-05 | 0.241D-03 | | | 0.161D 03 | 0.126D 05 |
| 6 | 13 | 3/2 - 1/2 | 0.713D-06 | -0.592D-04 | 0.307D-07 | 0.212D-03 | | | 0.235D 01 | 0.162D 05 |
| | | 3/2 - 3/2 | -0.161D-04 | -0.465D-04 | 0.313D-05 | 0.261D-04 | | | 0.120D 03 | 0.100D 04 |
| | | 5/2 - 3/2 | -0.563D-05 | -0.493D-04 | 0.675D-05 | 0.177D-03 | | | 0.384D 03 | 0.101D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\tilde{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 14 | 3/2 - 1/2 | -0.131D-05 | -0.486D-04 | 0.101D-06 | 0.139D-03 | | | 0.823D 01 | 0.112D 05 |
| | | 3/2 - 3/2 | -0.152D-04 | -0.382D-04 | 0.272D-05 | 0.171D-04 | | | 0.111D 03 | 0.699D 03 |
| | | 5/2 - 3/2 | -0.928D-05 | -0.405D-04 | 0.690D-05 | 0.116D-03 | | | 0.418D 03 | 0.703D 04 |
| 6 | 15 | 3/2 - 1/2 | -0.231D-05 | -0.410D-04 | 0.306D-06 | 0.965D-04 | | | 0.260D 02 | 0.819D 04 |
| | | 3/2 - 3/2 | -0.142D-04 | -0.324D-04 | 0.230D-05 | 0.120D-04 | | | 0.980D 02 | 0.513D 03 |
| | | 5/2 - 3/2 | -0.962D-05 | -0.343D-04 | 0.640D-05 | 0.816D-04 | | | 0.403D 03 | 0.513D 04 |
| 7 | 9 | 3/2 - 1/2 | -0.258D-03 | -0.308D-03 | 0.192D-01 | 0.274D-01 | | | 0.649D 05 | 0.922D 05 |
| | | 3/2 - 3/2 | 0.174D-03 | -0.245D-03 | 0.170D-02 | 0.335D-02 | | | 0.303D 04 | 0.595D 04 |
| | | 5/2 - 3/2 | 0.194D-03 | -0.255D-03 | 0.128D-01 | 0.222D-01 | | | 0.333D 05 | 0.579D 05 |
| 7 | 10 | 3/2 - 1/2 | 0.125D-03 | -0.194D-03 | 0.268D-02 | 0.644D-02 | | | 0.257D 05 | 0.616D 05 |
| | | 3/2 - 3/2 | 0.807D-04 | -0.159D-03 | 0.220D-03 | 0.861D-03 | | | 0.107D 04 | 0.422D 04 |
| | | 5/2 - 3/2 | 0.521D-04 | -0.166D-03 | 0.173D-02 | 0.562D-02 | | | 0.125D 05 | 0.406D 05 |
| 7 | 11 | 3/2 - 1/2 | 0.764D-04 | -0.139D-03 | 0.797D-03 | 0.262D-02 | | | 0.120D 05 | 0.394D 05 |
| | | 3/2 - 3/2 | 0.462D-04 | -0.115D-03 | 0.580D-04 | 0.361D-03 | | | 0.438D 03 | 0.274D 04 |
| | | 5/2 - 3/2 | 0.542D-04 | -0.120D-03 | 0.481D-03 | 0.235D-02 | | | 0.542D 04 | 0.265D 05 |
| 7 | 12 | 3/2 - 1/2 | 0.525D-04 | -0.107D-03 | 0.332D-03 | 0.137D-02 | | | 0.641D 04 | 0.265D 05 |
| | | 3/2 - 3/2 | 0.298D-04 | -0.894D-04 | 0.213D-04 | 0.192D-03 | | | 0.207D 03 | 0.186D 04 |
| | | 5/2 - 3/2 | 0.359D-04 | -0.927D-04 | 0.187D-03 | 0.124D-02 | | | 0.269D 04 | 0.179D 05 |
| 7 | 13 | 3/2 - 1/2 | 0.411D-04 | -0.916D-04 | 0.187D-03 | 0.934D-03 | | | 0.426D 04 | 0.211D 05 |
| | | 3/2 - 3/2 | 0.214D-04 | -0.770D-04 | 0.102D-04 | 0.132D-03 | | | 0.116D 03 | 0.150D 04 |
| | | 5/2 - 3/2 | 0.268D-04 | -0.797D-04 | 0.961D-04 | 0.851D-03 | | | 0.162D 04 | 0.143D 05 |
| 7 | 14 | 3/2 - 1/2 | 0.312D-04 | -0.746D-04 | 0.103D-03 | 0.586D-03 | | | 0.259D 04 | 0.148D 05 |
| | | 3/2 - 3/2 | 0.153D-04 | -0.629D-04 | 0.494D-05 | 0.932D-04 | | | 0.624D 02 | 0.105D 04 |
| | | 5/2 - 3/2 | 0.197D-04 | -0.651D-04 | 0.493D-04 | 0.537D-03 | | | 0.926D 03 | 0.401D 05 |
| 7 | 15 | 3/2 - 1/2 | 0.248D-04 | -0.625D-04 | 0.625D-04 | 0.396D-03 | | | 0.170D 04 | 0.107D 05 |
| | | 3/2 - 3/2 | 0.116D-04 | -0.530D-04 | 0.271D-05 | 0.569D-04 | | | 0.370D 02 | 0.777D 03 |
| | | 5/2 - 3/2 | 0.153D-04 | -0.548D-04 | 0.285D-04 | 0.367D-03 | | | 0.575D 03 | 0.744D 04 |
| 8 | 10 | 3/2 - 1/2 | 0.268D-03 | -0.285D-03 | 0.360D-01 | 0.407D-01 | | | 0.402D 05 | 0.455D 05 |
| | | 3/2 - 3/2 | 0.192D-03 | -0.228D-03 | 0.358D-02 | 0.506D-02 | | | 0.212D 04 | 0.300D 04 |
| | | 5/2 - 3/2 | 0.209D-03 | -0.239D-03 | 0.259D-01 | 0.337D-01 | | | 0.224D 05 | 0.292D 05 |
| 8 | 11 | 3/2 - 1/2 | 0.142D-03 | -0.184D-03 | 0.578D-02 | 0.971D-02 | | | 0.196D 05 | 0.328D 05 |
| | | 3/2 - 3/2 | 0.100D-03 | -0.152D-03 | 0.570D-03 | 0.131D-02 | | | 0.984D 03 | 0.226D 04 |
| | | 5/2 - 3/2 | 0.110D-03 | -0.158D-03 | 0.419D-02 | 0.857D-02 | | | 0.107D 05 | 0.219D 05 |
| 8 | 12 | 3/2 - 1/2 | 0.524D-04 | -0.133D-03 | 0.191D-02 | 0.399D-02 | | | 0.107D 05 | 0.222D 05 |
| | | 3/2 - 3/2 | 0.637D-04 | -0.111D-03 | 0.181D-03 | 0.351D-03 | | | 0.508D 03 | 0.155D 04 |
| | | 5/2 - 3/2 | 0.706D-04 | -0.116D-03 | 0.135D-02 | 0.362D-02 | | | 0.562D 04 | 0.151D 05 |
| 8 | 13 | 3/2 - 1/2 | 0.705D-04 | -0.110D-03 | 0.966D-03 | 0.235D-02 | | | 0.715D 04 | 0.174D 05 |
| | | 3/2 - 3/2 | 0.467D-04 | -0.922D-04 | 0.846D-04 | 0.329D-03 | | | 0.315D 03 | 0.123D 04 |
| | | 5/2 - 3/2 | 0.529D-04 | -0.958D-04 | 0.654D-03 | 0.214D-02 | | | 0.362D 04 | 0.119D 05 |
| 8 | 14 | 3/2 - 1/2 | 0.529D-04 | -0.876D-04 | 0.497D-03 | 0.136D-02 | | | 0.442D 04 | 0.121D 05 |
| | | 3/2 - 3/2 | 0.342D-04 | -0.738D-04 | 0.413D-04 | 0.193D-03 | | | 0.165D 03 | 0.860D 03 |
| | | 5/2 - 3/2 | 0.392D-04 | -0.765D-04 | 0.328D-03 | 0.125D-02 | | | 0.218D 04 | 0.831D 04 |
| 8 | 15 | 3/2 - 1/2 | 0.418D-04 | -0.724D-04 | 0.291D-03 | 0.871D-03 | | | 0.254D 04 | 0.981D 04 |
| | | 3/2 - 3/2 | 0.265D-04 | -0.614D-04 | 0.234D-04 | 0.125D-03 | | | 0.118D 03 | 0.633D 03 |
| | | 5/2 - 3/2 | 0.307D-04 | -0.635D-04 | 0.189D-03 | 0.307D-03 | | | 0.143D 04 | 0.608D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM . OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\tilde{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 11 | 3/2 - 1/2 | 0.257D-03 | -0.251D-03 | 0.526D-01 | 0.502D-01 | | | 0.232D 05 | 0.221D 05 |
| | | 3/2 - 3/2 | 0.189D-03 | -0.201D-03 | 0.551D-02 | 0.623D-02 | | | 0.129D 04 | 0.146D 04 |
| | | 5/2 - 3/2 | 0.204D-03 | -0.210D-03 | 0.390D-01 | 0.415D-01 | | | 0.134D 05 | 0.142D 05 |
| 9 | 12 | 3/2 - 1/2 | 0.144D-03 | -0.166D-03 | 0.925D-02 | 0.124D-01 | | | 0.129D 05 | 0.173D 05 |
| | | 3/2 - 3/2 | 0.105D-03 | -0.137D-03 | 0.982D-03 | 0.166D-02 | | | 0.703D 03 | 0.119D 04 |
| | | 5/2 - 3/2 | 0.115D-03 | -0.142D-03 | 0.701D-02 | 0.108D-01 | | | 0.740D 04 | 0.115D 05 |
| 9 | 13 | 3/2 - 1/2 | 0.103D-03 | -0.128D-03 | 0.362D-02 | 0.557D-02 | | | 0.864D 04 | 0.133D 05 |
| | | 3/2 - 3/2 | 0.741D-04 | -0.106D-03 | 0.374D-03 | 0.759D-03 | | | 0.451D 03 | 0.918D 03 |
| | | 5/2 - 3/2 | 0.805D-04 | -0.111D-03 | 0.266D-02 | 0.503D-02 | | | 0.475D 04 | 0.901D 04 |
| 9 | 14 | 3/2 - 1/2 | 0.742D-04 | -0.983D-04 | 0.161D-02 | 0.283D-02 | | | 0.525D 04 | 0.922D 04 |
| | | 3/2 - 3/2 | 0.524D-04 | -0.821D-04 | 0.160D-03 | 0.393D-03 | | | 0.263D 03 | 0.645D 03 |
| | | 5/2 - 3/2 | 0.577D-04 | -0.856D-04 | 0.117D-02 | 0.258D-02 | | | 0.286D 04 | 0.628D 04 |
| 9 | 15 | 3/2 - 1/2 | 0.572D-04 | -0.796D-04 | 0.864D-03 | 0.167D-02 | | | 0.347D 04 | 0.670D 04 |
| | | 3/2 - 3/2 | 0.397D-04 | -0.671D-04 | 0.832D-04 | 0.237D-03 | | | 0.168D 03 | 0.480D 03 |
| | | 5/2 - 3/2 | 0.443D-04 | -0.695D-04 | 0.623D-03 | 0.153D-02 | | | 0.167D 04 | 0.459D 04 |
| 10 | 12 | 3/2 - 1/2 | 0.246D-03 | -0.228D-03 | 0.723D-01 | 0.619D-01 | | | 0.142D 05 | 0.122D 05 |
| | | 3/2 - 3/2 | 0.186D-03 | -0.183D-03 | 0.800D-02 | 0.773D-02 | | | 0.829D 03 | 0.910D 03 |
| | | 5/2 - 3/2 | 0.199D-03 | -0.192D-03 | 0.555D-01 | 0.515D-01 | | | 0.852D 04 | 0.790D 04 |
| 10 | 13 | 3/2 - 1/2 | 0.150D-03 | -0.159D-03 | 0.147D-01 | 0.165D-01 | | | 0.955D 04 | 0.107D 05 |
| | | 3/2 - 3/2 | 0.113D-03 | -0.132D-03 | 0.165D-02 | 0.225D-02 | | | 0.550D 03 | 0.748D 03 |
| | | 5/2 - 3/2 | 0.122D-03 | -0.136D-03 | 0.116D-01 | 0.146D-01 | | | 0.571D 04 | 0.715D 04 |
| 10 | 14 | 3/2 - 1/2 | 0.102D-03 | -0.113D-03 | 0.516D-02 | 0.629D-02 | | | 0.567D 04 | 0.715D 04 |
| | | 3/2 - 3/2 | 0.774D-04 | -0.929D-04 | 0.590D-03 | 0.849D-03 | | | 0.341D 03 | 0.492D 03 |
| | | 5/2 - 3/2 | 0.821D-04 | -0.981D-04 | 0.400D-02 | 0.571D-02 | | | 0.343D 04 | 0.492D 04 |
| 10 | 15 | 3/2 - 1/2 | 0.755D-04 | -0.878D-04 | 0.238D-02 | 0.323D-02 | | | 0.381D 04 | 0.517D 04 |
| | | 3/2 - 3/2 | 0.565D-04 | -0.740D-04 | 0.266D-03 | 0.456D-03 | | | 0.215D 03 | 0.368D 03 |
| | | 5/2 - 3/2 | 0.608D-04 | -0.776D-04 | 0.186D-02 | 0.302D-02 | | | 0.223D 04 | 0.363D 04 |
| 11 | 13 | 3/2 - 1/2 | 0.244D-03 | -0.214D-03 | 0.101D 00 | 0.779D-01 | | | 0.976D 04 | 0.752D 04 |
| | | 3/2 - 3/2 | 0.188D-03 | -0.173D-03 | 0.117D-01 | 0.984D-02 | | | 0.599D 03 | 0.508D 03 |
| | | 5/2 - 3/2 | 0.200D-03 | -0.181D-03 | 0.798D-01 | 0.656D-01 | | | 0.604D 04 | 0.496D 04 |
| 11 | 14 | 3/2 - 1/2 | 0.141D-03 | -0.138D-03 | 0.182D-01 | 0.176D-01 | | | 0.599D 04 | 0.579D 04 |
| | | 3/2 - 3/2 | 0.108D-03 | -0.116D-03 | 0.213D-02 | 0.245D-02 | | | 0.360D 03 | 0.413D 03 |
| | | 5/2 - 3/2 | 0.117D-03 | -0.119D-03 | 0.150D-01 | 0.136D-01 | | | 0.375D 04 | 0.389D 04 |
| 11 | 15 | 3/2 - 1/2 | 0.993D-04 | -0.972D-04 | 0.678D-02 | 0.648D-02 | | | 0.402D 04 | 0.384D 04 |
| | | 3/2 - 3/2 | 0.791D-04 | -0.813D-04 | 0.854D-03 | 0.902D-03 | | | 0.257D 03 | 0.271D 03 |
| | | 5/2 - 3/2 | 0.818D-04 | -0.868D-04 | 0.550D-02 | 0.620D-02 | | | 0.246D 04 | 0.277D 04 |
| 12 | 14 | 3/2 - 1/2 | 0.234D-03 | -0.231D-03 | 0.128D 00 | 0.124D 00 | | | 0.657D 04 | 0.637D 04 |
| | | 3/2 - 3/2 | 0.186D-03 | -0.193D-03 | 0.157D-01 | 0.169D-01 | | | 0.430D 03 | 0.463D 03 |
| | | 5/2 - 3/2 | 0.196D-03 | -0.201D-03 | 0.105D 00 | 0.111D 00 | | | 0.422D 04 | 0.442D 04 |
| 12 | 15 | 3/2 - 1/2 | 0.136D-03 | -0.158D-03 | 0.231D-01 | 0.311D-01 | | | 0.413D 04 | 0.554D 04 |
| | | 3/2 - 3/2 | 0.107D-03 | -0.138D-03 | 0.285D-02 | 0.472D-02 | | | 0.262D 03 | 0.434D 03 |
| | | 5/2 - 3/2 | 0.117D-03 | -0.140D-03 | 0.203D-01 | 0.291D-01 | | | 0.276D 04 | 0.396D 04 |
| 13 | 15 | 3/2 - 1/2 | 0.230D-03 | -0.217D-03 | 0.165D 00 | 0.147D 00 | | | 0.475D 04 | 0.426D 04 |
| | | 3/2 - 3/2 | 0.187D-03 | -0.179D-03 | 0.212D-01 | 0.194D-01 | | | 0.326D 03 | 0.298D 03 |
| | | 5/2 - 3/2 | 0.195D-03 | -0.187D-03 | 0.139D 00 | 0.128D 00 | | | 0.315D 04 | 0.289D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $R^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 5 | 1/2 - 3/2 | -0.960D-03 | 0.961D-03 | 0.254D 00 | 0.254D 00 | 0.251D 00 | | 0.934D 06 | 0.934D 06 |
| | | 3/2 - 3/2 | -0.829D-03 | 0.805D-03 | 0.227D-01 | 0.214D-01 | 0.211D-01 | | 0.116D 06 | 0.110D 06 |
| | | 3/2 - 5/2 | -0.900D-03 | 0.848D-03 | 0.233D 00 | 0.207D 00 | 0.204D-01 | | 0.852D 06 | 0.757D 06 |
| 6 | 6 | 1/2 - 3/2 | 0.284D-02 | -0.252D-02 | 0.649D 00 | 0.510D 00 | 0.258D 00 | | 0.282D 08 | 0.222D 08 |
| | | 3/2 - 3/2 | 0.291D-02 | -0.261D-02 | 0.712D-01 | 0.574D-01 | 0.397D-01 | | 0.558D 07 | 0.451D 07 |
| | | 3/2 - 5/2 | 0.286D-02 | -0.255D-02 | 0.617D 00 | 0.490D 00 | 0.322D 00 | | 0.326D 08 | 0.259D 08 |
| 6 | 7 | 1/2 - 3/2 | 0.149D-02 | -0.110D-02 | 0.137D 00 | 0.743D-01 | 0.927D-01 | 0.123D 00 | 0.101D 08 | 0.550D 07 |
| | | 3/2 - 3/2 | 0.146D-02 | -0.107D-02 | 0.136D-01 | 0.727D-02 | 0.110D-01 | 0.130D-01 | 0.185D 07 | 0.992D 06 |
| | | 3/2 - 5/2 | 0.146D-02 | -0.107D-02 | 0.122D 00 | 0.653D-01 | 0.951D-01 | 0.111D 00 | 0.112D 08 | 0.595D 07 |
| 6 | 8 | 1/2 - 3/2 | 0.103D-02 | -0.694D-03 | 0.580D-01 | 0.265D-01 | 0.419D-01 | 0.419D-01 | 0.533D 07 | 0.245D 07 |
| | | 3/2 - 3/2 | 0.985D-03 | -0.657D-03 | 0.553D-02 | 0.246D-02 | 0.480D-02 | 0.561D-02 | 0.955D 06 | 0.422D 06 |
| | | 3/2 - 5/2 | 0.988D-03 | -0.659D-03 | 0.500D-01 | 0.223D-01 | 0.418D-01 | 0.439D-01 | 0.575D 07 | 0.256D 07 |
| 6 | 9 | 1/2 - 3/2 | 0.777D-03 | -0.498D-03 | 0.313D-01 | 0.129D-01 | 0.228D-01 | 0.251D-01 | 0.325D 07 | 0.134D 07 |
| | | 3/2 - 3/2 | 0.739D-03 | -0.465D-03 | 0.293D-02 | 0.116D-02 | 0.250D-02 | 0.300D-02 | 0.571D 06 | 0.226D 06 |
| | | 3/2 - 5/2 | 0.743D-03 | -0.469D-03 | 0.266D-01 | 0.106D-01 | 0.223D-01 | 0.237D-01 | 0.346D 07 | 0.138D 07 |
| 6 | 10 | 1/2 - 3/2 | 0.607D-03 | -0.377D-03 | 0.184D-01 | 0.711D-02 | 0.139D-01 | 0.152D-01 | 0.205D 07 | 0.794D 06 |
| | | 3/2 - 3/2 | 0.574D-03 | -0.349D-03 | 0.170D-02 | 0.627D-03 | 0.150D-02 | 0.200D-02 | 0.357D 06 | 0.131D 06 |
| | | 3/2 - 5/2 | 0.578D-03 | -0.352D-03 | 0.155D-01 | 0.577D-02 | 0.135D-01 | 0.153D-01 | 0.217D 07 | 0.806D 06 |
| 6 | 11 | 1/2 - 3/2 | 0.485D-03 | -0.298D-03 | 0.117D-01 | 0.434D-02 | 0.920D-02 | 0.108D-01 | 0.137D 07 | 0.508D 06 |
| | | 3/2 - 3/2 | 0.461D-03 | -0.274D-03 | 0.107D-02 | 0.378D-03 | 0.100D-02 | 0.810D-03 | 0.236D 06 | 0.831D 05 |
| | | 3/2 - 5/2 | 0.465D-03 | -0.277D-03 | 0.981D-02 | 0.349D-02 | 0.880D-02 | 0.893D-02 | 0.144D 07 | 0.513D 06 |
| 6 | 12 | 1/2 - 3/2 | 0.405D-03 | -0.243D-03 | 0.790D-02 | 0.285D-02 | | 0.869D-02 | 0.951D 06 | 0.344D 06 |
| | | 3/2 - 3/2 | 0.381D-03 | -0.223D-03 | 0.720D-03 | 0.246D-03 | | 0.837D-02 | 0.164D 06 | 0.558D 05 |
| | | 3/2 - 5/2 | 0.384D-03 | -0.226D-03 | 0.659D-02 | 0.227D-02 | | 0.837D-02 | 0.100D 07 | 0.345D 06 |
| 6 | 13 | 1/2 - 3/2 | 0.342D-03 | -0.204D-03 | 0.558D-02 | 0.197D-02 | | 0.470D-02 | 0.690D 06 | 0.243D 06 |
| | | 3/2 - 3/2 | 0.321D-03 | -0.186D-03 | 0.507D-03 | 0.170D-03 | | 0.530D-02 | 0.118D 06 | 0.395D 05 |
| | | 3/2 - 5/2 | 0.324D-03 | -0.189D-03 | 0.464D-02 | 0.157D-02 | | 0.530D-02 | 0.719D 06 | 0.243D 06 |
| 6 | 14 | 1/2 - 3/2 | 0.295D-03 | -0.174D-03 | 0.410D-02 | 0.143D-02 | | 0.380D-02 | 0.517D 06 | 0.179D 06 |
| | | 3/2 - 3/2 | 0.277D-03 | -0.159D-03 | 0.372D-03 | 0.122D-03 | | 0.396D-02 | 0.881D 05 | 0.290D 05 |
| | | 3/2 - 5/2 | 0.279D-03 | -0.161D-03 | 0.341D-02 | 0.113D-02 | | 0.396D-02 | 0.537D 06 | 0.179D 06 |
| 7 | 6 | 1/2 - 3/2 | 0.256D-03 | 0.478D-03 | 0.728D-01 | 0.254D 00 | 0.327D 00 | | 0.165D 05 | 0.575D 05 |
| | | 3/2 - 3/2 | 0.402D-03 | 0.370D-03 | 0.231D-01 | 0.195D-01 | 0.320D-01 | | 0.637D 04 | 0.537D 04 |
| | | 3/2 - 5/2 | 0.351D-03 | 0.399D-03 | 0.148D 00 | 0.191D 00 | 0.309D 00 | | 0.309D 05 | 0.399D 05 |
| 7 | 7 | 1/2 - 3/2 | 0.193D-02 | -0.177D-02 | 0.800D 00 | 0.667D 00 | 0.237D 00 | | 0.468D 07 | 0.408D 07 |
| | | 3/2 - 3/2 | 0.200D-02 | -0.188D-02 | 0.895D-01 | 0.787D-01 | 0.340D-01 | | 0.100D 07 | 0.885D 06 |
| | | 3/2 - 5/2 | 0.198D-02 | -0.185D-02 | 0.781D 00 | 0.688D 00 | 0.282D 00 | | 0.551D 07 | 0.521D 07 |
| 7 | 8 | 1/2 - 3/2 | 0.121D-02 | -0.964D-03 | 0.222D 00 | 0.141D 00 | 0.822D-01 | | 0.271D 07 | 0.172D 07 |
| | | 3/2 - 3/2 | 0.120D-02 | -0.967D-03 | 0.225D-01 | 0.146D-01 | 0.105D-01 | | 0.517D 06 | 0.335D 06 |
| | | 3/2 - 5/2 | 0.119D-02 | -0.963D-03 | 0.199D 00 | 0.130D 00 | 0.890D-01 | | 0.306D 07 | 0.200D 07 |
| 7 | 9 | 1/2 - 3/2 | 0.884D-03 | -0.658D-03 | 0.101D 00 | 0.361D-01 | 0.391D-01 | | 0.169D 07 | 0.934D 06 |
| | | 3/2 - 3/2 | 0.860D-03 | -0.645D-03 | 0.985D-02 | 0.353D-02 | 0.470D-02 | | 0.311D 06 | 0.175D 06 |
| | | 3/2 - 5/2 | 0.859D-03 | -0.646D-03 | 0.882D-01 | 0.499D-01 | 0.410D-01 | | 0.186D 07 | 0.105D 07 |
| 7 | 10 | 1/2 - 3/2 | 0.678D-03 | -0.486D-03 | 0.547D-01 | 0.280D-01 | 0.221D-01 | | 0.108D 07 | 0.554D 06 |
| | | 3/2 - 3/2 | 0.654D-03 | -0.470D-03 | 0.521D-02 | 0.269D-02 | 0.260D-02 | | 0.196D 06 | 0.102D 06 |
| | | 3/2 - 5/2 | 0.654D-03 | -0.472D-03 | 0.468D-01 | 0.244D-01 | 0.228D-01 | | 0.118D 07 | 0.616D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM . OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\bar{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | $M_1$ | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 7 | 11 | 1/2 - 3/2 | 0.541D-03 | -0.379D-03 | 0.330D-01 | 0.162D-01 | 0.139D-01 | | 0.728D 06 | 0.356D 06 |
| | | 3/2 - 3/2 | 0.519D-03 | -0.364D-03 | 0.310D-02 | 0.153D-02 | 0.160D-02 | | 0.131D 06 | 0.645D 05 |
| | | 3/2 - 5/2 | 0.520D-03 | -0.366D-03 | 0.280D-01 | 0.139D-01 | 0.142D-01 | | 0.785D 06 | 0.391D 06 |
| 7 | 12 | 1/2 - 3/2 | 0.445D-03 | -0.307D-03 | 0.216D-01 | 0.102D-01 | | | 0.513D 06 | 0.243D 06 |
| | | 3/2 - 3/2 | 0.426D-03 | -0.293D-03 | 0.201D-02 | 0.956D-03 | | | 0.914D 05 | 0.434D 05 |
| | | 3/2 - 5/2 | 0.426D-03 | -0.296D-03 | 0.182D-01 | 0.873D-02 | | | 0.550D 06 | 0.264D 06 |
| 7 | 13 | 1/2 - 3/2 | 0.375D-03 | -0.256D-03 | 0.149D-01 | 0.693D-02 | | | 0.372D 06 | 0.173D 06 |
| | | 3/2 - 3/2 | 0.357D-03 | -0.244D-03 | 0.138D-02 | 0.642D-03 | | | 0.661D 05 | 0.307D 05 |
| | | 3/2 - 5/2 | 0.358D-03 | -0.246D-03 | 0.125D-01 | 0.587D-02 | | | 0.399D 06 | 0.187D 06 |
| 7 | 14 | 1/2 - 3/2 | 0.322D-03 | -0.218D-03 | 0.108D-01 | 0.494D-02 | | | 0.279D 06 | 0.128D 06 |
| | | 3/2 - 3/2 | 0.306D-03 | -0.207D-03 | 0.995D-03 | 0.455D-03 | | | 0.496D 05 | 0.226D 05 |
| | | 3/2 - 5/2 | 0.307D-03 | -0.209D-03 | 0.900D-02 | 0.416D-02 | | | 0.298D 06 | 0.138D 06 |
| 8 | 7 | 1/2 - 3/2 | 0.169D-03 | 0.375D-03 | 0.769D-01 | 0.380D 00 | | | 0.294D 04 | 0.146D 05 |
| | | 3/2 - 3/2 | 0.307D-03 | 0.281D-03 | 0.336D-01 | 0.282D-01 | | | 0.147D 04 | 0.124D 04 |
| | | 3/2 - 5/2 | 0.276D-03 | 0.306D-03 | 0.226D 00 | 0.278D 00 | | | 0.769D 04 | 0.951D 04 |
| 8 | 8 | 1/2 - 3/2 | 0.138D-02 | -0.117D-02 | 0.829D 00 | 0.596D 00 | | | 0.122D 07 | 0.876D 06 |
| | | 3/2 - 3/2 | 0.146D-02 | -0.128D-02 | 0.966D-01 | 0.738D-01 | | | 0.263D 06 | 0.201D 06 |
| | | 3/2 - 5/2 | 0.144D-02 | -0.126D-02 | 0.837D 00 | 0.642D 00 | | | 0.154D 07 | 0.118D 07 |
| 8 | 9 | 1/2 - 3/2 | 0.917D-03 | -0.690D-03 | 0.247D 00 | 0.140D 00 | | | 0.802D 06 | 0.455D 06 |
| | | 3/2 - 3/2 | 0.931D-03 | -0.711D-03 | 0.262D-01 | 0.153D-01 | | | 0.161D 06 | 0.938D 05 |
| | | 3/2 - 5/2 | 0.924D-03 | -0.709D-03 | 0.231D 00 | 0.136D 00 | | | 0.951D 06 | 0.562D 06 |
| 8 | 10 | 1/2 - 3/2 | 0.677D-03 | -0.481D-03 | 0.112D 00 | 0.563D-01 | | | 0.525D 06 | 0.265D 06 |
| | | 3/2 - 3/2 | 0.676D-03 | -0.485D-03 | 0.114D-01 | 0.586D-02 | | | 0.103D 06 | 0.529D 05 |
| | | 3/2 - 5/2 | 0.673D-03 | -0.485D-03 | 0.102D 00 | 0.527D-01 | | | 0.612D 06 | 0.318D 06 |
| 8 | 11 | 1/2 - 3/2 | 0.530D-03 | -0.364D-03 | 0.614D-01 | 0.290D-01 | | | 0.359D 05 | 0.169D 05 |
| | | 3/2 - 3/2 | 0.525D-03 | -0.363D-03 | 0.614D-02 | 0.294D-02 | | | 0.650D 05 | 0.330D 05 |
| | | 3/2 - 5/2 | 0.523D-03 | -0.364D-03 | 0.549D-01 | 0.266D-01 | | | 0.412D 06 | 0.200D 06 |
| 8 | 12 | 1/2 - 3/2 | 0.431D-03 | -0.290D-03 | 0.379D-01 | 0.172D-01 | | | 0.254D 06 | 0.115D 06 |
| | | 3/2 - 3/2 | 0.424D-03 | -0.287D-03 | 0.374D-02 | 0.171D-02 | | | 0.464D 05 | 0.222D 05 |
| | | 3/2 - 5/2 | 0.423D-03 | -0.288D-03 | 0.335D-01 | 0.155D-01 | | | 0.290D 06 | 0.134D 06 |
| 8 | 13 | 1/2 - 3/2 | 0.360D-03 | -0.239D-03 | 0.252D-01 | 0.111D-01 | | | 0.186D 06 | 0.823D 05 |
| | | 3/2 - 3/2 | 0.353D-03 | -0.235D-03 | 0.247D-02 | 0.110D-02 | | | 0.352D 05 | 0.156D 05 |
| | | 3/2 - 5/2 | 0.353D-03 | -0.236D-03 | 0.222D-01 | 0.996D-02 | | | 0.211D 06 | 0.947D 05 |
| 8 | 14 | 1/2 - 3/2 | 0.307D-03 | -0.202D-03 | 0.177D-01 | 0.768D-02 | | | 0.141D 06 | 0.608D 05 |
| | | 3/2 - 3/2 | 0.301D-03 | -0.198D-03 | 0.173D-02 | 0.751D-03 | | | 0.265D 05 | 0.115D 05 |
| | | 3/2 - 5/2 | 0.300D-03 | -0.199D-03 | 0.155D-01 | 0.684D-02 | | | 0.158D 06 | 0.699D 05 |
| 9 | 8 | 1/2 - 3/2 | 0.111D-03 | 0.305D-03 | 0.643D-01 | 0.490D 00 | | | 0.649D 03 | 0.496D 04 |
| | | 3/2 - 3/2 | 0.222D-03 | 0.225D-03 | 0.380D-01 | 0.388D-01 | | | 0.426D 03 | 0.399D 03 |
| | | 3/2 - 5/2 | 0.205D-03 | 0.247D-03 | 0.245D 00 | 0.356D 00 | | | 0.217D 04 | 0.315D 04 |
| 9 | 9 | 1/2 - 3/2 | 0.104D-02 | -0.902D-03 | 0.832D 00 | 0.626D 00 | | | 0.354D 06 | 0.266D 06 |
| | | 3/2 - 3/2 | 0.112D-02 | -0.953D-03 | 0.995D-01 | 0.738D-01 | | | 0.872D 05 | 0.690D 05 |
| | | 3/2 - 5/2 | 0.110D-02 | -0.977D-03 | 0.861D 00 | 0.681D 00 | | | 0.508D 06 | 0.403D 06 |
| 9 | 10 | 1/2 - 3/2 | 0.693D-03 | -0.542D-03 | 0.240D 00 | 0.147D 00 | | | 0.268D 06 | 0.165D 06 |
| | | 3/2 - 3/2 | 0.715D-03 | -0.566D-03 | 0.262D-01 | 0.164D-01 | | | 0.558D 05 | 0.349D 05 |
| | | 3/2 - 5/2 | 0.708D-03 | -0.562D-03 | 0.231D 00 | 0.145D 00 | | | 0.329D 06 | 0.207D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION N | TRANSITION M | TRANSITION J-J' | $\bar{R}^0_{IJ}$ VELOCITY | $\bar{R}^0_{IJ}$ LENGTH | $f_{IJ}$ VELOCITY | $f_{IJ}$ LENGTH | $f_{IJ}$ STONE | $f_{IJ}$ AGNEW | $A_{IJ}(sec^{-1})$ VELOCITY | $A_{IJ}(sec^{-1})$ LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 11 | 1/2 - 3/2 | 0.519D-03 | -0.387D-03 | 0.109D 00 | 0.607D-01 | | | 0.166D 06 | 0.103D 06 |
| | | 3/2 - 3/2 | 0.527D-03 | -0.396D-03 | 0.115D-01 | 0.649D-02 | | | 0.376D 05 | 0.212D 05 |
| | | 3/2 - 5/2 | 0.524D-03 | -0.394D-03 | 0.102D 00 | 0.578D-01 | | | 0.223D 06 | 0.127D 06 |
| 9 | 12 | 1/2 - 3/2 | 0.412D-03 | -0.300D-03 | 0.968D-01 | 0.321D-01 | | | 0.133D 06 | 0.703D 05 |
| | | 3/2 - 3/2 | 0.415D-03 | -0.303D-03 | 0.128D-02 | 0.434D-02 | | | 0.265D 05 | 0.141D 05 |
| | | 3/2 - 5/2 | 0.413D-03 | -0.302D-03 | 0.859D-01 | 0.299D-01 | | | 0.158D 06 | 0.843D 05 |
| 9 | 13 | 1/2 - 3/2 | 0.339D-03 | -0.243D-03 | 0.380D-01 | 0.195D-01 | | | 0.976D 05 | 0.500D 05 |
| | | 3/2 - 3/2 | 0.340D-03 | -0.244D-03 | 0.388D-02 | 0.199D-02 | | | 0.193D 05 | 0.992D 04 |
| | | 3/2 - 5/2 | 0.339D-03 | -0.244D-03 | 0.346D-01 | 0.179D-01 | | | 0.115D 06 | 0.595D 05 |
| 9 | 14 | 1/2 - 3/2 | 0.287D-03 | -0.203D-03 | 0.256D-01 | 0.129D-01 | | | 0.740D 05 | 0.371D 05 |
| | | 3/2 - 3/2 | 0.287D-03 | -0.203D-03 | 0.260D-02 | 0.130D-02 | | | 0.146D 05 | 0.728D 04 |
| | | 3/2 - 5/2 | 0.286D-03 | -0.203D-03 | 0.232D-01 | 0.117D-01 | | | 0.868D 05 | 0.438D 05 |
| 10 | 9 | 1/2 - 3/2 | 0.685D-04 | 0.258D-03 | 0.704D-01 | 0.599D 00 | | | 0.243D 03 | 0.207D 04 |
| | | 3/2 - 3/2 | 0.193D-03 | 0.188D-03 | 0.454D-01 | 0.433D-01 | | | 0.170D 03 | 0.162D 03 |
| | | 3/2 - 5/2 | 0.171D-03 | 0.208D-03 | 0.292D 00 | 0.433D 00 | | | 0.876D 03 | 0.130D 04 |
| 10 | 10 | 1/2 - 3/2 | 0.820D-03 | -0.748D-03 | 0.831D 00 | 0.692D 00 | | | 0.153D 06 | 0.127D 06 |
| | | 3/2 - 3/2 | 0.887D-03 | -0.826D-03 | 0.101D 00 | 0.874D-01 | | | 0.344D 05 | 0.298D 05 |
| | | 3/2 - 5/2 | 0.872D-03 | -0.812D-03 | 0.871D 00 | 0.755D 00 | | | 0.201D 06 | 0.174D 06 |
| 10 | 11 | 1/2 - 3/2 | 0.548D-03 | -0.457D-03 | 0.235D 00 | 0.164D 00 | | | 0.107D 06 | 0.748D 05 |
| | | 3/2 - 3/2 | 0.571D-03 | -0.480D-03 | 0.261D-01 | 0.135D-01 | | | 0.228D 05 | 0.161D 05 |
| | | 3/2 - 5/2 | 0.565D-03 | -0.476D-03 | 0.230D 00 | 0.163D 00 | | | 0.134D 06 | 0.955D 05 |
| 10 | 12 | 1/2 - 3/2 | 0.415D-03 | -0.332D-03 | 0.107D 00 | 0.686D-01 | | | 0.773D 05 | 0.492D 05 |
| | | 3/2 - 3/2 | 0.426D-03 | -0.342D-03 | 0.115D-01 | 0.744D-02 | | | 0.160D 05 | 0.103D 05 |
| | | 3/2 - 5/2 | 0.423D-03 | -0.340D-03 | 0.192D 00 | 0.660D-01 | | | 0.947D 05 | 0.612D 05 |
| 10 | 13 | 1/2 - 3/2 | 0.332D-03 | -0.261D-03 | 0.599D-01 | 0.369D-01 | | | 0.571D 05 | 0.351D 05 |
| | | 3/2 - 3/2 | 0.339D-03 | -0.266D-03 | 0.633D-02 | 0.390D-02 | | | 0.117D 05 | 0.719D 04 |
| | | 3/2 - 5/2 | 0.337D-03 | -0.265D-03 | 0.562D-01 | 0.349D-01 | | | 0.690D 05 | 0.430D 05 |
| 10 | 14 | 1/2 - 3/2 | 0.277D-03 | -0.215D-03 | 0.378D-01 | 0.228D-01 | | | 0.434D 05 | 0.261D 05 |
| | | 3/2 - 3/2 | 0.281D-03 | -0.217D-03 | 0.395D-02 | 0.237D-02 | | | 0.876D 04 | 0.529D 04 |
| | | 3/2 - 5/2 | 0.279D-03 | -0.217D-03 | 0.351D-01 | 0.213D-01 | | | 0.521D 05 | 0.316D 05 |
| 11 | 10 | 1/2 - 3/2 | 0.698D-04 | 0.225D-03 | 0.688D-01 | 0.713D 00 | | | 0.963D 02 | 0.100D 04 |
| | | 3/2 - 3/2 | 0.160D-03 | 0.164D-03 | 0.492D-01 | 0.517D-01 | | | 0.740D 02 | 0.777D 02 |
| | | 3/2 - 5/2 | 0.140D-03 | 0.180D-03 | 0.312D 00 | 0.512D 00 | | | 0.377D 03 | 0.620D 03 |
| 11 | 11 | 1/2 - 3/2 | 0.673D-03 | -0.625D-03 | 0.841D 00 | 0.749D 00 | | | 0.662D 05 | 0.608D 05 |
| | | 3/2 - 3/2 | 0.732D-03 | -0.703D-03 | 0.103D 00 | 0.951D-01 | | | 0.155D 05 | 0.143D 05 |
| | | 3/2 - 5/2 | 0.718D-03 | -0.690D-03 | 0.889D 00 | 0.820D 00 | | | 0.905D 05 | 0.835D 05 |
| 11 | 12 | 1/2 - 3/2 | 0.451D-03 | -0.393D-03 | 0.234D 00 | 0.178D 00 | | | 0.492D 05 | 0.375D 05 |
| | | 3/2 - 3/2 | 0.473D-03 | -0.414D-03 | 0.264D-01 | 0.202D-01 | | | 0.106D 05 | 0.810D 04 |
| | | 3/2 - 5/2 | 0.468D-03 | -0.410D-03 | 0.232D 00 | 0.178D 00 | | | 0.624D 05 | 0.480D 05 |
| 11 | 13 | 1/2 - 3/2 | 0.343D-03 | -0.287D-03 | 0.107D 00 | 0.743D-01 | | | 0.365D 05 | 0.254D 05 |
| | | 3/2 - 3/2 | 0.355D-03 | -0.300D-03 | 0.116D-01 | 0.827D-02 | | | 0.765D 04 | 0.546D 04 |
| | | 3/2 - 5/2 | 0.353D-03 | -0.297D-03 | 0.103D 00 | 0.729D-01 | | | 0.455D 05 | 0.322D 05 |
| 11 | 14 | 1/2 - 3/2 | 0.276D-03 | -0.228D-03 | 0.600D-01 | 0.404D-01 | | | 0.277D 05 | 0.186D 05 |
| | | 3/2 - 3/2 | 0.286D-03 | -0.233D-03 | 0.644D-02 | 0.430D-02 | | | 0.579D 04 | 0.386D 04 |
| | | 3/2 - 5/2 | 0.283D-03 | -0.232D-03 | 0.568D-01 | 0.383D-01 | | | 0.340D 05 | 0.230D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | N | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 12 | 11 | 1/2 - 3/2 | 0.554D-04 | 0.199D-03 | 0.642D-01 | 0.829D 00 | | | 0.411D 02 | 0.529D 03 |
| | | 3/2 - 3/2 | 0.135D-03 | 0.148D-03 | 0.522D-01 | 0.628D-01 | | | 0.354D 02 | 0.426D 02 |
| | | 3/2 - 5/2 | 0.117D-03 | 0.159D-03 | 0.320D 00 | 0.392D 00 | | | 0.176D 03 | 0.325D 03 |
| 12 | 12 | 1/2 - 3/2 | 0.568D-03 | -0.549D-03 | 0.859D 00 | 0.802D 00 | | | 0.339D 05 | 0.317D 05 |
| | | 3/2 - 3/2 | 0.620D-03 | -0.609D-03 | 0.106D 00 | 0.102D 00 | | | 0.781D 04 | 0.752D 04 |
| | | 3/2 - 5/2 | 0.605D-03 | -0.597D-03 | 0.913D 00 | 0.879D 00 | | | 0.455D 05 | 0.438D 05 |
| 12 | 13 | 1/2 - 3/2 | 0.381D-03 | -0.344D-03 | 0.237D 00 | 0.193D 00 | | | 0.250D 05 | 0.204D 05 |
| | | 3/2 - 3/2 | 0.403D-03 | -0.364D-03 | 0.270D-01 | 0.221D-01 | | | 0.546D 04 | 0.446D 04 |
| | | 3/2 - 5/2 | 0.397D-03 | -0.362D-03 | 0.235D 00 | 0.195D 00 | | | 0.320D 05 | 0.265D 05 |
| 12 | 14 | 1/2 - 3/2 | 0.293D-03 | -0.251D-03 | 0.108D 00 | 0.791D-01 | | | 0.151D 05 | 0.140D 05 |
| | | 3/2 - 3/2 | 0.303D-03 | -0.263D-03 | 0.118D-01 | 0.885D-02 | | | 0.402D 04 | 0.302D 04 |
| | | 3/2 - 5/2 | 0.303D-03 | -0.259D-03 | 0.105D 00 | 0.772D-01 | | | 0.241D 05 | 0.177D 05 |
| 13 | 12 | 1/2 - 3/2 | 0.330D-04 | 0.179D-03 | 0.322D-01 | 0.942D 00 | | | 0.103D 02 | 0.302D 03 |
| | | 3/2 - 3/2 | 0.108D-03 | 0.138D-03 | 0.474D-01 | 0.780D-01 | | | 0.160D 02 | 0.264D 02 |
| | | 3/2 - 5/2 | 0.891D-04 | 0.142D-03 | 0.264D 00 | 0.668D 00 | | | 0.723D 02 | 0.183D 03 |
| 13 | 13 | 1/2 - 3/2 | 0.484D-03 | -0.442D-03 | 0.858D 00 | 0.715D 00 | | | 0.179D 05 | 0.149D 05 |
| | | 3/2 - 3/2 | 0.533D-03 | -0.497D-03 | 0.108D 00 | 0.936D-01 | | | 0.422D 04 | 0.364D 04 |
| | | 3/2 - 5/2 | 0.525D-03 | -0.486D-03 | 0.927D 00 | 0.799D 00 | | | 0.244D 05 | 0.210D 05 |
| 13 | 14 | 1/2 - 3/2 | 0.336D-03 | -0.294D-03 | 0.250D 00 | 0.190D 00 | | | 0.143D 05 | 0.109D 05 |
| | | 3/2 - 3/2 | 0.360D-03 | -0.315D-03 | 0.293D-01 | 0.224D-01 | | | 0.322D 04 | 0.246D 04 |
| | | 3/2 - 5/2 | 0.352D-03 | -0.313D-03 | 0.251D 00 | 0.198D 00 | | | 0.185D 05 | 0.146D 05 |
| 14 | 13 | 1/2 - 3/2 | 0.115D-04 | 0.166D-03 | 0.526D-02 | 0.110D 01 | | | 0.918D 00 | 0.193D 03 |
| | | 3/2 - 3/2 | 0.784D-04 | 0.129D-03 | 0.340D-01 | 0.923D-01 | | | 0.620D 01 | 0.169D 02 |
| | | 3/2 - 5/2 | 0.614D-04 | 0.132D-03 | 0.170D 00 | 0.784D 00 | | | 0.252D 02 | 0.117D 03 |
| 14 | 14 | 1/2 - 3/2 | 0.416D-03 | -0.381D-03 | 0.845D 00 | 0.711D 00 | | | 0.988D 04 | 0.831D 04 |
| | | 3/2 - 3/2 | 0.459D-03 | -0.437D-03 | 0.107D 00 | 0.965D-01 | | | 0.234D 04 | 0.211D 04 |
| | | 3/2 - 5/2 | 0.451D-03 | -0.426D-03 | 0.919D 00 | 0.821D 00 | | | 0.136D 05 | 0.121D 05 |
| 15 | 14 | 1/2 - 3/2 | 0.173D-05 | 0.153D-03 | 0.159D-03 | 0.125D 01 | | | 0.157D-01 | 0.123D 03 |
| | | 3/2 - 3/2 | 0.620D-04 | 0.116D-03 | 0.282D-01 | 0.985D-01 | | | 0.293D 01 | 0.102D 02 |
| | | 3/2 - 5/2 | 0.475D-04 | 0.124D-03 | 0.135D 00 | 0.910D 00 | | | 0.115D 02 | 0.773D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $r_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 4 | 7 | 5/2 - 3/2 | -0.301D-03 | 0.924D-03 | 0.316D-01 | 0.298D 00 | | | 0.765D 05 | 0.740D 06 |
| | | 5/2 - 5/2 | -0.306D-03 | 0.928D-03 | 0.230D-02 | 0.212D-01 | | | 0.392D 04 | 0.360D 05 |
| | | 7/2 - 5/2 | -0.309D-03 | 0.931D-03 | 0.352D-01 | 0.320D 00 | | | 0.758D 05 | 0.723D 06 |
| 4 | 8 | 5/2 - 3/2 | 0.120D-04 | 0.112D-03 | 0.236D-04 | 0.207D-02 | | | 0.263D 03 | 0.231D 05 |
| | | 5/2 - 5/2 | 0.704D-05 | 0.120D-03 | 0.581D-06 | 0.168D-03 | | | 0.434D 01 | 0.126D 04 |
| | | 7/2 - 5/2 | 0.564D-05 | 0.119D-03 | 0.559D-05 | 0.247D-02 | | | 0.558D 02 | 0.247D 05 |
| 4 | 9 | 5/2 - 3/2 | 0.183D-04 | 0.654D-04 | 0.421D-04 | 0.540D-03 | | | 0.802D 03 | 0.103D 05 |
| | | 5/2 - 5/2 | 0.154D-04 | 0.699D-04 | 0.213D-05 | 0.439D-04 | | | 0.271D 02 | 0.558D 03 |
| | | 7/2 - 5/2 | 0.142D-04 | 0.691D-04 | 0.272D-04 | 0.645D-03 | | | 0.463D 03 | 0.109D 05 |
| 4 | 10 | 5/2 - 3/2 | 0.163D-04 | 0.463D-04 | 0.293D-04 | 0.235D-03 | | | 0.732D 03 | 0.587D 04 |
| | | 5/2 - 5/2 | 0.144D-04 | 0.494D-04 | 0.162D-05 | 0.192D-04 | | | 0.271D 02 | 0.320D 03 |
| | | 7/2 - 5/2 | 0.134D-04 | 0.487D-04 | 0.211D-04 | 0.279D-03 | | | 0.467D 03 | 0.620D 04 |
| 4 | 11 | 5/2 - 3/2 | 0.139D-04 | 0.354D-04 | 0.195D-04 | 0.127D-03 | | | 0.575D 03 | 0.373D 04 |
| | | 5/2 - 5/2 | 0.124D-04 | 0.377D-04 | 0.111D-05 | 0.103D-04 | | | 0.219D 02 | 0.202D 03 |
| | | 7/2 - 5/2 | 0.116D-04 | 0.372D-04 | 0.146D-04 | 0.150D-03 | | | 0.363D 03 | 0.394D 04 |
| 4 | 12 | 5/2 - 3/2 | 0.118D-04 | 0.284D-04 | 0.134D-04 | 0.772D-04 | | | 0.438D 03 | 0.253D 04 |
| | | 5/2 - 5/2 | 0.106D-04 | 0.302D-04 | 0.777D-06 | 0.626D-05 | | | 0.170D 02 | 0.137D 03 |
| | | 7/2 - 5/2 | 0.998D-05 | 0.299D-04 | 0.102D-04 | 0.917D-04 | | | 0.259D 03 | 0.267D 04 |
| 4 | 13 | 5/2 - 3/2 | 0.102D-04 | 0.235D-04 | 0.953D-05 | 0.510D-04 | | | 0.337D 03 | 0.190D 04 |
| | | 5/2 - 5/2 | 0.920D-05 | 0.250D-04 | 0.558D-06 | 0.413D-05 | | | 0.131D 02 | 0.976D 02 |
| | | 7/2 - 5/2 | 0.863D-05 | 0.247D-04 | 0.738D-05 | 0.607D-04 | | | 0.232D 03 | 0.191D 04 |
| 4 | 14 | 5/2 - 3/2 | 0.884D-05 | 0.199D-04 | 0.703D-05 | 0.358D-04 | | | 0.263D 03 | 0.134D 04 |
| | | 5/2 - 5/2 | 0.803D-05 | 0.212D-04 | 0.414D-06 | 0.290D-05 | | | 0.103D 02 | 0.723D 02 |
| | | 7/2 - 5/2 | 0.754D-05 | 0.210D-04 | 0.548D-05 | 0.425D-04 | | | 0.162D 03 | 0.141D 04 |
| 5 | 8 | 5/2 - 3/2 | -0.392D-03 | 0.872D-03 | 0.100D 00 | 0.497D 00 | | | 0.707D 05 | 0.351D 06 |
| | | 5/2 - 5/2 | -0.398D-03 | 0.876D-03 | 0.731D-02 | 0.354D-01 | | | 0.353D 04 | 0.171D 05 |
| | | 7/2 - 5/2 | -0.400D-03 | 0.889D-03 | 0.111D 00 | 0.546D 00 | | | 0.715D 05 | 0.352D 06 |
| 5 | 9 | 5/2 - 3/2 | -0.222D-04 | 0.114D-03 | 0.146D-03 | 0.387D-02 | | | 0.504D 03 | 0.134D 05 |
| | | 5/2 - 5/2 | -0.289D-04 | 0.124D-03 | 0.176D-04 | 0.322D-03 | | | 0.408D 02 | 0.748D 03 |
| | | 7/2 - 5/2 | -0.285D-04 | 0.119D-03 | 0.256D-03 | 0.449D-02 | | | 0.790D 03 | 0.138D 05 |
| 5 | 10 | 5/2 - 3/2 | 0.322D-05 | 0.590D-04 | 0.229D-05 | 0.766D-03 | | | 0.143D 02 | 0.480D 04 |
| | | 7/2 - 5/2 | -0.127D-05 | 0.620D-04 | 0.378D-06 | 0.904D-03 | | | 0.210D 01 | 0.504D 04 |
| | | 5/2 - 5/2 | -0.102D-05 | 0.647D-04 | 0.162D-07 | 0.656D-04 | | | 0.678D-01 | 0.274D 03 |
| 5 | 11 | 5/2 - 3/2 | 0.877D-05 | 0.391D-04 | 0.145D-04 | 0.287D-03 | | | 0.124D 03 | 0.246D 04 |
| | | 5/2 - 5/2 | 0.581D-05 | 0.432D-04 | 0.453D-06 | 0.251D-04 | | | 0.259D 01 | 0.143D 03 |
| | | 7/2 - 5/2 | 0.521D-05 | 0.410D-04 | 0.546D-05 | 0.338D-03 | | | 0.418D 02 | 0.258D 04 |
| 5 | 12 | 5/2 - 3/2 | 0.583D-05 | 0.286D-04 | 0.165D-04 | 0.140D-03 | | | 0.172D 03 | 0.146D 04 |
| | | 5/2 - 5/2 | 0.750D-05 | 0.318D-04 | 0.684D-06 | 0.123D-04 | | | 0.475D 01 | 0.856D 02 |
| | | 7/2 - 5/2 | 0.696D-05 | 0.302D-04 | 0.883D-05 | 0.166D-03 | | | 0.819D 02 | 0.154D 04 |
| 5 | 13 | 5/2 - 3/2 | 0.561D-05 | 0.223D-04 | 0.147D-04 | 0.794D-04 | | | 0.175D 03 | 0.943D 03 |
| | | 5/2 - 5/2 | 0.770D-05 | 0.249D-04 | 0.675D-06 | 0.703D-05 | | | 0.533D 01 | 0.558D 02 |
| | | 7/2 - 5/2 | 0.723D-05 | 0.236D-04 | 0.892D-05 | 0.955D-04 | | | 0.943D 02 | 0.101D 04 |
| 5 | 14 | 5/2 - 3/2 | 0.902D-05 | 0.181D-04 | 0.124D-04 | 0.300D-04 | | | 0.162D 03 | 0.653D 03 |
| | | 5/2 - 5/2 | 0.741D-05 | 0.202D-04 | 0.597D-06 | 0.445D-05 | | | 0.521D 01 | 0.387D 02 |
| | | 7/2 - 5/2 | 0.698D-05 | 0.193D-04 | 0.795D-05 | 0.606D-04 | | | 0.922D 02 | 0.703D 03 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN.

| TRANSITION N | M | J-J' | $\tilde{r}_{IJ}$ VELOCITY | $\tilde{r}_{IJ}$ LENGTH | $f_{IJ}$ VELOCITY | $f_{IJ}$ LENGTH | $f_{IJ}$ STONE | $f_{IJ}$ AGNEW | $A_{IJ}(sec^{-1})$ VELOCITY | $A_{IJ}(sec^{-1})$ LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 9 | 5/2 - 3/2 | -0.406D-03 | 0.909D-03 | 0.181D 00 | 0.409D 00 | | | 0.451D 05 | 0.227D 06 |
| | | 5/2 - 5/2 | -0.414D-03 | 0.915D-03 | 0.133D-01 | 0.648D-01 | | | 0.229D 04 | 0.111D 05 |
| | | 7/2 - 5/2 | -0.425D-03 | 0.873D-03 | 0.210D 00 | 0.897D 00 | | | 0.480D 05 | 0.202D 06 |
| 6 | 10 | 5/2 - 3/2 | -0.268D-04 | 0.478D-04 | 0.346D-03 | 0.110D-02 | | | 0.446D 03 | 0.143D 04 |
| | | 7/2 - 5/2 | -0.462D-04 | 0.894D-04 | 0.110D-02 | 0.411D-02 | | | 0.128D 04 | 0.480D 04 |
| | | 5/2 - 5/2 | -0.342D-04 | 0.580D-04 | 0.402D-04 | 0.116D-03 | | | 0.351D 02 | 0.101D 03 |
| 6 | 11 | 5/2 - 3/2 | -0.866D-05 | 0.193D-04 | 0.263D-04 | 0.131D-03 | | | 0.645D 02 | 0.322D 03 |
| | | 5/2 - 5/2 | -0.133D-04 | 0.249D-04 | 0.445D-05 | 0.155D-04 | | | 0.732D 01 | 0.255D 02 |
| | | 7/2 - 5/2 | -0.176D-04 | 0.442D-04 | 0.116D-03 | 0.733D-03 | | | 0.255D 03 | 0.161D 04 |
| 6 | 12 | 5/2 - 3/2 | -0.353D-05 | 0.118D-04 | 0.366D-05 | 0.410D-04 | | | 0.128D 02 | 0.143D 03 |
| | | 5/2 - 5/2 | -0.642D-05 | 0.161D-04 | 0.865D-06 | 0.542D-05 | | | 0.202D 01 | 0.127D 02 |
| | | 7/2 - 5/2 | -0.866D-05 | 0.288D-04 | 0.236D-04 | 0.261D-03 | | | 0.736D 02 | 0.810D 03 |
| 6 | 13 | 5/2 - 3/2 | -0.168D-05 | 0.790D-05 | 0.740D-06 | 0.164D-04 | | | 0.322D 01 | 0.715D 02 |
| | | 5/2 - 5/2 | -0.400D-05 | 0.110D-04 | 0.301D-06 | 0.228D-05 | | | 0.876D 00 | 0.666D 01 |
| | | 7/2 - 5/2 | -0.476D-05 | 0.209D-04 | 0.639D-05 | 0.124D-03 | | | 0.248D 02 | 0.480D 03 |
| 6 | 14 | 5/2 - 3/2 | -0.811D-06 | 0.559D-05 | 0.161D-06 | 0.703D-05 | | | 0.814D 00 | 0.387D 02 |
| | | 5/2 - 5/2 | -0.280D-05 | 0.797D-05 | 0.137D-06 | 0.111D-05 | | | 0.463D 00 | 0.374D 01 |
| | | 7/2 - 5/2 | -0.276D-05 | 0.163D-04 | 0.200D-05 | 0.691D-04 | | | 0.901D 01 | 0.312D 03 |
| 7 | 10 | 5/2 - 3/2 | -0.213D-03 | 0.160D-03 | 0.778D-01 | 0.441D-01 | | | 0.758D 04 | 0.451D 04 |
| | | 7/2 - 5/2 | -0.411D-03 | 0.808D-03 | 0.305D 00 | 0.118D 01 | | | 0.267D 05 | 0.111D 06 |
| | | 5/2 - 5/2 | -0.211D-03 | 0.158D-03 | 0.540D-02 | 0.302D-02 | | | 0.380D 03 | 0.213D 03 |
| 7 | 11 | 5/2 - 3/2 | -0.825D-04 | 0.146D-03 | 0.499D-02 | 0.157D-01 | | | 0.280D 04 | 0.881D 04 |
| | | 5/2 - 5/2 | -0.837D-04 | 0.145D-03 | 0.365D-03 | 0.109D-02 | | | 0.138D 03 | 0.411D 03 |
| | | 7/2 - 5/2 | -0.540D-04 | 0.949D-04 | 0.228D-02 | 0.706D-02 | | | 0.115D 04 | 0.355D 04 |
| 7 | 12 | 5/2 - 3/2 | -0.372D-04 | 0.117D-03 | 0.727D-03 | 0.712D-02 | | | 0.758D 03 | 0.795D 04 |
| | | 5/2 - 5/2 | -0.390D-04 | 0.115D-03 | 0.569D-04 | 0.497D-03 | | | 0.418D 02 | 0.366D 03 |
| | | 7/2 - 5/2 | -0.243D-04 | 0.509D-04 | 0.330D-03 | 0.145D-02 | | | 0.325D 03 | 0.143D 04 |
| 7 | 13 | 5/2 - 3/2 | -0.171D-04 | 0.950D-04 | 0.127D-03 | 0.391D-02 | | | 0.204D 03 | 0.628D 04 |
| | | 5/2 - 5/2 | -0.187D-04 | 0.943D-04 | 0.108D-04 | 0.275D-03 | | | 0.116D 02 | 0.256D 03 |
| | | 7/2 - 5/2 | -0.141D-04 | 0.348D-04 | 0.924D-04 | 0.560D-03 | | | 0.132D 03 | 0.802D 03 |
| 7 | 14 | 5/2 - 3/2 | -0.709D-05 | 0.794D-04 | 0.193D-04 | 0.242D-02 | | | 0.396D 02 | 0.496D 04 |
| | | 5/2 - 5/2 | -0.853D-05 | 0.790D-04 | 0.199D-05 | 0.171D-03 | | | 0.273D 01 | 0.234D 03 |
| | | 7/2 - 5/2 | -0.936D-05 | 0.264D-04 | 0.359D-04 | 0.285D-03 | | | 0.657D 02 | 0.521D 03 |
| 8 | 11 | 5/2 - 3/2 | -0.154D-04 | 0.216D-04 | 0.596D-03 | 0.118D-02 | | | 0.262D 02 | 0.558D 02 |
| | | 5/2 - 5/2 | -0.780D-05 | 0.180D-04 | 0.108D-04 | 0.574D-04 | | | 0.351D 00 | 0.187D 01 |
| | | 7/2 - 5/2 | -0.153D-03 | 0.127D-03 | 0.627D-01 | 0.433D-01 | | | 0.272D 04 | 0.188D 04 |
| 8 | 12 | 5/2 - 3/2 | -0.203D-05 | 0.305D-04 | 0.436D-05 | 0.936D-03 | | | 0.117D 01 | 0.265D 03 |
| | | 5/2 - 5/2 | 0.261D-05 | 0.273D-04 | 0.513D-06 | 0.964D-04 | | | 0.926D-01 | 0.102D 02 |
| | | 7/2 - 5/2 | -0.544D-04 | 0.126D-03 | 0.334D-02 | 0.180D-01 | | | 0.806D 03 | 0.434D 04 |
| 8 | 13 | 5/2 - 3/2 | 0.399D-05 | 0.278D-04 | 0.119D-04 | 0.575D-03 | | | 0.645D 01 | 0.313D 03 |
| | | 5/2 - 5/2 | 0.581D-05 | 0.246D-04 | 0.179D-05 | 0.321D-04 | | | 0.653D 00 | 0.117D 02 |
| | | 7/2 - 5/2 | -0.184D-04 | 0.103D-03 | 0.271D-03 | 0.851D-02 | | | 0.131D 03 | 0.413D 04 |
| 8 | 14 | 5/2 - 3/2 | 0.729D-05 | 0.250D-04 | 0.324D-04 | 0.382D-03 | | | 0.263D 02 | 0.311D 03 |
| | | 5/2 - 5/2 | 0.893D-05 | 0.225D-04 | 0.347D-05 | 0.220D-04 | | | 0.189D 01 | 0.120D 02 |
| | | 7/2 - 5/2 | -0.261D-05 | 0.861D-04 | 0.443D-05 | 0.483D-02 | | | 0.321D 01 | 0.350D 04 |

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| TRANSITION | | | $R^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 9 | 12 | 5/2 - 3/2 | 0.158D-04 | 0.167D-05 | 0.883D-03 | 0.996D-05 | | | 0.211D 02 | 0.238D 00 |
| | | 5/2 - 5/2 | 0.230D-04 | -0.189D-05 | 0.132D-03 | 0.893D-06 | | | 0.217D 01 | 0.146D-01 |
| | | 7/2 - 5/2 | 0.236D-05 | 0.123D-04 | 0.209D-04 | 0.571D-03 | | | 0.455D 00 | 0.125D 02 |
| 9 | 13 | 5/2 - 3/2 | 0.124D-04 | 0.843D-05 | 0.226D-03 | 0.104D-03 | | | 0.316D 02 | 0.146D 02 |
| | | 5/2 - 5/2 | 0.187D-04 | 0.579D-05 | 0.366D-04 | 0.351D-05 | | | 0.344D 01 | 0.330D 00 |
| | | 7/2 - 5/2 | 0.704D-05 | 0.195D-04 | 0.778D-04 | 0.396D-03 | | | 0.976D 01 | 0.744D 02 |
| 9 | 14 | 5/2 - 3/2 | 0.104D-04 | 0.626D-05 | 0.110D-03 | 0.401D-04 | | | 0.319D 02 | 0.116D 02 |
| | | 5/2 - 5/2 | 0.119D-04 | 0.293D-05 | 0.103D-04 | 0.623D-06 | | | 0.199D 01 | 0.121D 00 |
| | | 7/2 - 5/2 | 0.103D-04 | 0.197D-04 | 0.116D-03 | 0.424D-03 | | | 0.301D 02 | 0.110D 03 |
| 10 | 13 | 5/2 - 3/2 | 0.156D-04 | -0.259D-05 | 0.185D-02 | 0.325D-04 | | | 0.240D 02 | 0.418D 00 |
| | | 5/2 - 5/2 | 0.263D-04 | -0.595D-05 | 0.236D-03 | 0.121D-04 | | | 0.210D 01 | 0.107D 00 |
| | | 7/2 - 5/2 | 0.185D-04 | -0.566D-06 | 0.175D-02 | 0.164D-05 | | | 0.208D 02 | 0.193D-01 |
| 10 | 14 | 5/2 - 3/2 | 0.133D-04 | 0.146D-05 | 0.350D-03 | 0.419D-05 | | | 0.271D 02 | 0.324D 00 |
| | | 5/2 - 5/2 | 0.203D-04 | -0.440D-06 | 0.576D-04 | 0.273D-07 | | | 0.300D 01 | 0.142D-02 |
| | | 7/2 - 5/2 | 0.127D-04 | 0.363D-05 | 0.340D-03 | 0.278D-04 | | | 0.236D 02 | 0.193D 01 |
| 11 | 14 | 5/2 - 3/2 | 0.162D-04 | -0.526D-05 | 0.169D-02 | 0.177D-03 | | | 0.125D 02 | 0.131D 01 |
| | | 5/2 - 5/2 | 0.205D-04 | -0.876D-05 | 0.190D-03 | 0.345D-04 | | | 0.963D 00 | 0.175D 00 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - nf^2F_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

| TRANSITION | | | $r_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 5 | 4 | 3/2 - 5/2 | -0.219D-02 | 0.214D-02 | 0.355D 00 | 0.379D 00 | 0.302D 00 | | 0.174D 08 | 0.167D 08 |
| | | 5/2 - 5/2 | -0.221D-02 | 0.219D-02 | 0.194D-01 | 0.191D-01 | 0.324D 00 | | 0.126D 07 | 0.124D 07 |
| | | 5/2 - 7/2 | -0.219D-02 | 0.218D-02 | 0.342D 00 | 0.379D 00 | | | 0.186D 08 | 0.185D 08 |
| 5 | 5 | 3/2 - 5/2 | -0.190D-02 | 0.182D-02 | 0.238D 00 | 0.174D 00 | 0.122D 00 | | 0.165D 08 | 0.120D 08 |
| | | 5/2 - 5/2 | -0.189D-02 | 0.184D-02 | 0.113D-01 | 0.851D-02 | 0.127D 00 | | 0.115D 07 | 0.868D 06 |
| | | 5/2 - 7/2 | -0.186D-02 | 0.183D-02 | 0.220D 00 | 0.168D 00 | | | 0.168D 08 | 0.129D 08 |
| 5 | 6 | 3/2 - 5/2 | -0.110D-02 | 0.983D-03 | 0.725D-01 | 0.576D-01 | 0.627D-01 | 0.712D-01 | 0.616D 07 | 0.488D 07 |
| | | 5/2 - 5/2 | -0.110D-02 | 0.990D-03 | 0.345D-02 | 0.280D-02 | 0.650D-01 | | 0.434D 06 | 0.352D 06 |
| | | 5/2 - 7/2 | -0.129D-02 | 0.110D-02 | 0.945D-01 | 0.687D-01 | | | 0.893D 07 | 0.649D 07 |
| 5 | 7 | 3/2 - 5/2 | -0.231D-02 | 0.130D-02 | 0.301D 00 | 0.945D-01 | 0.373D-01 | 0.418D-01 | 0.287D 08 | 0.901D 07 |
| | | 5/2 - 5/2 | -0.222D-02 | 0.127D-02 | 0.133D-01 | 0.432D-02 | 0.383D-01 | 0.409D-01 | 0.188D 07 | 0.612D 06 |
| | | 5/2 - 7/2 | -0.106D-02 | 0.860D-03 | 0.603D-01 | 0.399D-01 | | | 0.637D 07 | 0.422D 07 |
| 5 | 8 | 3/2 - 5/2 | -0.324D-03 | -0.153D-03 | 0.571D-02 | 0.127D-02 | 0.253D-01 | | 0.587D 06 | 0.130D 06 |
| | | 5/2 - 5/2 | -0.277D-03 | -0.176D-03 | 0.200D-03 | 0.804D-04 | 0.241D-01 | 0.252D-01 | 0.303D 05 | 0.122D 05 |
| | | 5/2 - 7/2 | -0.208D-02 | 0.105D-02 | 0.226D 00 | 0.576D-01 | | | 0.258D 09 | 0.657D 07 |
| 5 | 9 | 3/2 - 5/2 | 0.875D-04 | -0.340D-03 | 0.406D-03 | 0.614D-02 | 0.160D-01 | 0.173D-01 | 0.434D 05 | 0.661D 06 |
| | | 5/2 - 5/2 | 0.115D-03 | -0.355D-03 | 0.337D-04 | 0.320D-03 | 0.164D-01 | 0.172D-01 | 0.537D 04 | 0.508D 05 |
| | | 5/2 - 7/2 | -0.273D-03 | -0.139D-03 | 0.378D-02 | 0.989D-03 | | | 0.451D 06 | 0.118D 06 |
| 5 | 10 | 3/2 - 5/2 | 0.185D-03 | -0.344D-03 | 0.179D-02 | 0.617D-02 | 0.114D-01 | 0.118D-01 | 0.198D 06 | 0.686D 06 |
| | | 5/2 - 5/2 | 0.204D-03 | -0.355D-03 | 0.104D-03 | 0.314D-03 | 0.115D-01 | 0.123D-01 | 0.172D 05 | 0.517D 05 |
| | | 5/2 - 7/2 | 0.517D-04 | -0.275D-03 | 0.134D-03 | 0.378D-02 | | | 0.165D 05 | 0.467D 06 |
| 5 | 11 | 3/2 - 5/2 | 0.205D-03 | -0.315D-03 | 0.217D-02 | 0.512D-02 | | 0.821D-02 | 0.246D 06 | 0.583D 06 |
| | | 5/2 - 5/2 | 0.219D-03 | -0.323D-03 | 0.119D-03 | 0.238D-03 | | 0.820D-02 | 0.200D 05 | 0.434D 05 |
| 6 | 4 | 3/2 - 5/2 | 0.151D-02 | -0.114D-02 | 0.994D 00 | 0.569D 00 | | | 0.157D 07 | 0.897D 06 |
| | | 5/2 - 5/2 | 0.147D-02 | -0.112D-02 | 0.460D-01 | 0.267D-01 | | | 0.104D 06 | 0.604D 05 |
| | | 5/2 - 7/2 | 0.148D-02 | -0.112D-02 | 0.937D 00 | 0.535D 00 | | | 0.159D 07 | 0.905D 06 |
| 6 | 5 | 3/2 - 5/2 | -0.464D-03 | -0.679D-04 | 0.405D-01 | 0.867D-03 | | | 0.346D 06 | 0.740D 04 |
| | | 5/2 - 5/2 | -0.502D-03 | -0.372D-04 | 0.228D-02 | 0.125D-04 | | | 0.267D 05 | 0.157D 03 |
| | | 5/2 - 7/2 | -0.464D-03 | -0.587D-04 | 0.389D-01 | 0.624D-03 | | | 0.367D 06 | 0.587D 04 |
| 6 | 6 | 3/2 - 5/2 | -0.375D-03 | 0.100D-03 | 0.202D-01 | 0.144D-02 | | | 0.256D 06 | 0.212D 05 |
| | | 5/2 - 5/2 | -0.402D-03 | 0.122D-03 | 0.111D-02 | 0.102D-03 | | | 0.241D 05 | 0.221D 04 |
| | | 5/2 - 7/2 | -0.553D-03 | 0.168D-03 | 0.422D-01 | 0.390D-02 | | | 0.686D 06 | 0.633D 05 |
| 6 | 7 | 3/2 - 5/2 | -0.202D-02 | 0.871D-03 | 0.513D 00 | 0.254D-01 | | | 0.980D 07 | 0.182D 07 |
| | | 5/2 - 5/2 | -0.201D-02 | 0.984D-03 | 0.243D-01 | 0.471D-02 | | | 0.690D 06 | 0.134D 06 |
| | | 5/2 - 7/2 | -0.574D-03 | 0.236D-03 | 0.397D-01 | 0.672D-02 | | | 0.843D 06 | 0.143D 06 |
| 6 | 8 | 3/2 - 5/2 | -0.749D-03 | 0.360D-03 | 0.653D-01 | 0.151D-01 | | | 0.146D 07 | 0.337D 06 |
| | | 5/2 - 5/2 | -0.719D-03 | 0.347D-03 | 0.288D-02 | 0.670D-03 | | | 0.955D 05 | 0.222D 05 |
| | | 5/2 - 7/2 | -0.206D-02 | 0.914D-03 | 0.472D 00 | 0.930D-01 | | | 0.117D 08 | 0.231D 07 |
| 6 | 9 | 3/2 - 5/2 | -0.316D-03 | 0.157D-03 | 0.111D-01 | 0.273D-02 | | | 0.273D 06 | 0.674D 05 |
| | | 5/2 - 5/2 | -0.290D-03 | 0.143D-03 | 0.446D-03 | 0.109D-03 | | | 0.163D 05 | 0.399D 04 |
| | | 5/2 - 7/2 | -0.636D-03 | 0.288D-03 | 0.428D-01 | 0.376D-02 | | | 0.117D 07 | 0.241D 06 |
| 6 | 10 | 3/2 - 5/2 | -0.155D-03 | 0.780D-04 | 0.258D-02 | 0.650D-03 | | | 0.682D 05 | 0.172D 05 |
| | | 5/2 - 5/2 | -0.134D-03 | 0.660D-04 | 0.916D-04 | 0.223D-04 | | | 0.360D 04 | 0.876D 03 |
| | | 5/2 - 7/2 | -0.273D-03 | 0.121D-03 | 0.760D-02 | 0.149D-02 | | | 0.224D 06 | 0.438D 05 |

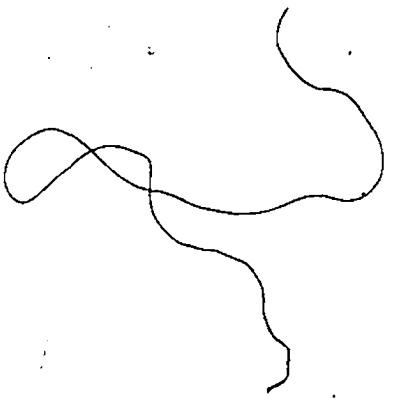
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

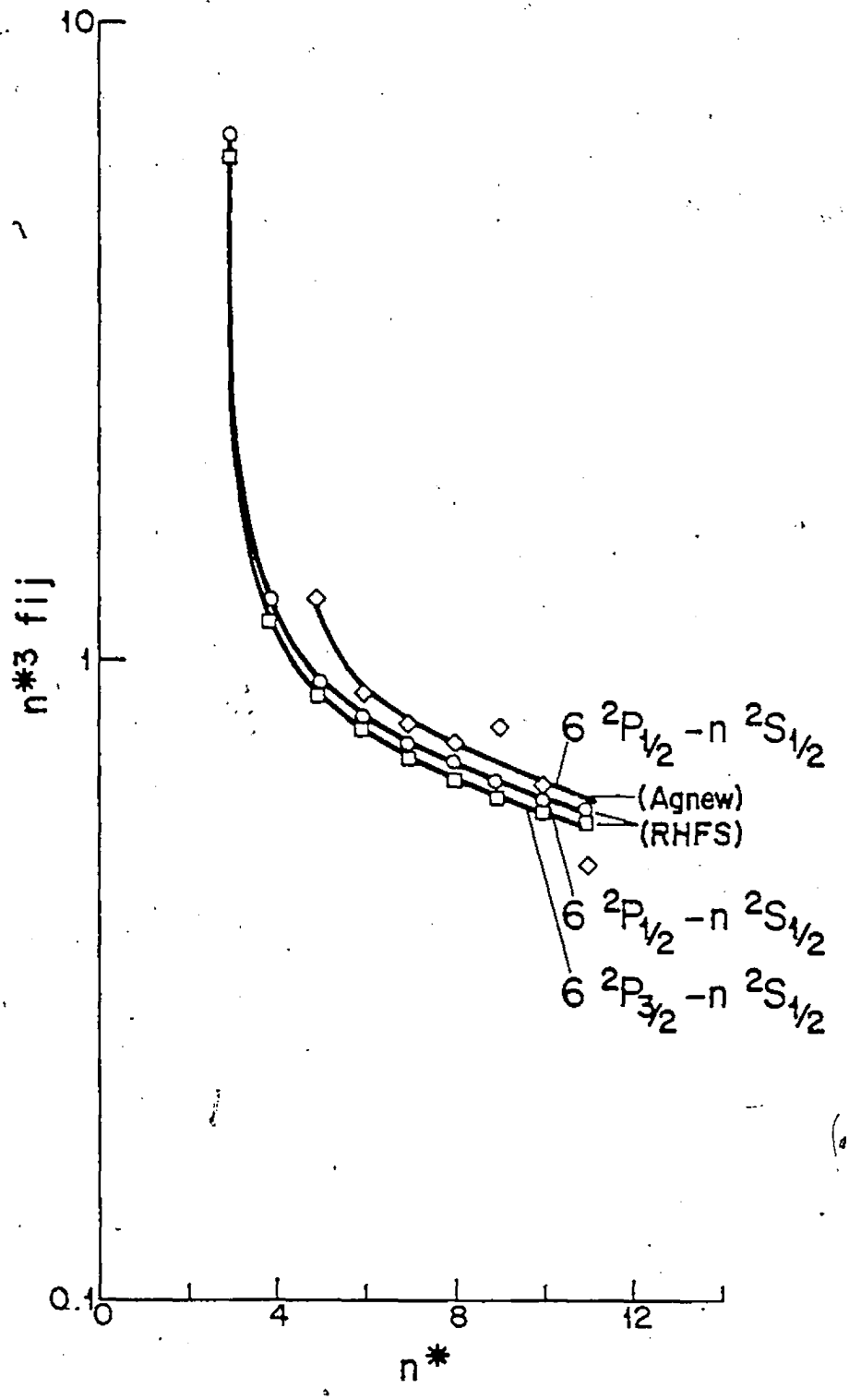
| TRANSITION | | | $\bar{R}^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | STONE | AGNEW | VELOCITY | LENGTH |
| 6 | 11 | 3/2 - 5/2 | -0.813D-04 | 0.469D-04 | 0.690D-03 | 0.174D-03 | | | 0.192D 05 | 0.484D 04 |
| | | 5/2 - 5/2 | -0.633D-04 | 0.306D-04 | 0.200D-04 | 0.466D-05 | | | 0.823D 03 | 0.192D 03 |
| 7 | 5 | 3/2 - 5/2 | 0.132D-02 | -0.940D-03 | 0.156D 01 | 0.789D 00 | | | 0.591D 06 | 0.299D 06 |
| | | 5/2 - 5/2 | 0.131D-02 | -0.926D-03 | 0.743D-01 | 0.373D-01 | | | 0.404D 05 | 0.203D 05 |
| | | 5/2 - 7/2 | 0.133D-02 | -0.927D-03 | 0.153D 01 | 0.748D 00 | | | 0.624D 06 | 0.305D 06 |
| 7 | 6 | 3/2 - 5/2 | 0.263D-03 | -0.276D-03 | 0.250D-01 | 0.275D-01 | | | 0.579D 05 | 0.637D 05 |
| | | 5/2 - 5/2 | 0.243D-03 | -0.261D-03 | 0.103D-02 | 0.119D-02 | | | 0.351D 04 | 0.404D 04 |
| | | 5/2 - 7/2 | 0.176D-03 | -0.252D-03 | 0.998D-02 | 0.221D-01 | | | 0.255D 05 | 0.562D 05 |
| 7 | 7 | 3/2 - 5/2 | -0.113D-02 | 0.485D-03 | 0.337D 00 | 0.625D-01 | | | 0.144D 07 | 0.267D 06 |
| | | 5/2 - 5/2 | -0.113D-02 | 0.502D-03 | 0.164D-01 | 0.321D-02 | | | 0.104D 06 | 0.203D 05 |
| | | 5/2 - 7/2 | -0.797D-04 | -0.334D-04 | 0.162D-02 | 0.285D-03 | | | 0.769D 04 | 0.135D 04 |
| 7 | 8 | 3/2 - 5/2 | -0.724D-03 | 0.462D-03 | 0.119D 00 | 0.485D-01 | | | 0.699D 06 | 0.284D 06 |
| | | 5/2 - 5/2 | -0.710D-03 | 0.457D-03 | 0.547D-02 | 0.227D-02 | | | 0.475D 05 | 0.197D 05 |
| | | 5/2 - 7/2 | -0.129D-02 | 0.664D-03 | 0.363D 00 | 0.958D-01 | | | 0.226D 07 | 0.624D 06 |
| 7 | 9 | 3/2 - 5/2 | -0.413D-03 | 0.283D-03 | 0.352D-01 | 0.165D-01 | | | 0.250D 06 | 0.117D 06 |
| | | 5/2 - 5/2 | -0.398D-03 | 0.275D-03 | 0.157D-02 | 0.748D-03 | | | 0.165D 05 | 0.790D 04 |
| | | 5/2 - 7/2 | -0.596D-03 | 0.370D-03 | 0.703D-01 | 0.270D-01 | | | 0.554D 06 | 0.214D 06 |
| 7 | 10 | 3/2 - 5/2 | -0.268D-03 | 0.190D-03 | 0.139D-01 | 0.699D-02 | | | 0.112D 06 | 0.562D 05 |
| | | 5/2 - 5/2 | -0.255D-03 | 0.183D-03 | 0.602D-03 | 0.310D-03 | | | 0.719D 04 | 0.371D 04 |
| | | 5/2 - 7/2 | -0.337D-03 | 0.222D-03 | 0.211D-01 | 0.914D-02 | | | 0.189D 06 | 0.819D 05 |
| 7 | 11 | 3/2 - 5/2 | -0.185D-03 | 0.137D-03 | 0.661D-02 | 0.350D-02 | | | 0.563D 05 | 0.308D 05 |
| | | 5/2 - 5/2 | -0.178D-03 | 0.131D-03 | 0.280D-03 | 0.153D-03 | | | 0.366D 04 | 0.200D 04 |
| 8 | 6 | 3/2 - 5/2 | 0.121D-02 | -0.784D-03 | 0.234D 01 | 0.376D 00 | | | 0.279D 06 | 0.117D 06 |
| | | 5/2 - 5/2 | 0.121D-02 | -0.774D-03 | 0.113D 00 | 0.465D-01 | | | 0.193D 05 | 0.798D 04 |
| | | 5/2 - 7/2 | 0.117D-02 | -0.778D-03 | 0.213D 01 | 0.937D 00 | | | 0.273D 06 | 0.120D 06 |
| 8 | 7 | 3/2 - 5/2 | -0.424D-03 | -0.401D-03 | 0.111D 00 | 0.989D-01 | | | 0.881D 05 | 0.785D 05 |
| | | 5/2 - 5/2 | -0.437D-08 | -0.385D-03 | 0.566D-02 | 0.440D-02 | | | 0.666D 04 | 0.517D 04 |
| | | 5/2 - 7/2 | 0.312D-03 | -0.384D-03 | 0.576D-01 | 0.875D-01 | | | 0.504D 05 | 0.769D 05 |
| 8 | 8 | 3/2 - 5/2 | -0.750D-03 | 0.419D-03 | 0.248D 00 | 0.773D-01 | | | 0.385D 06 | 0.120D 06 |
| | | 5/2 - 5/2 | -0.741D-03 | 0.414D-03 | 0.116D-01 | 0.363D-02 | | | 0.267D 05 | 0.835D 04 |
| | | 5/2 - 7/2 | -0.793D-03 | -0.422D-04 | 0.266D 00 | 0.752D-03 | | | 0.459D 06 | 0.129D 04 |
| 8 | 9 | 3/2 - 5/2 | -0.476D-03 | 0.279D-03 | 0.836D-01 | 0.237D-01 | | | 0.165D 06 | 0.637D 05 |
| | | 5/2 - 5/2 | -0.464D-03 | 0.272D-03 | 0.381D-02 | 0.131D-02 | | | 0.125D 05 | 0.430D 04 |
| | | 5/2 - 7/2 | -0.575D-03 | 0.250D-03 | 0.117D 00 | 0.222D-01 | | | 0.288D 06 | 0.546D 05 |
| 8 | 10 | 3/2 - 5/2 | -0.325D-03 | 0.191D-03 | 0.350D-01 | 0.121D-01 | | | 0.967D 05 | 0.335D 05 |
| | | 5/2 - 5/2 | -0.315D-03 | 0.185D-03 | 0.157D-02 | 0.542D-03 | | | 0.645D 04 | 0.222D 04 |
| | | 5/2 - 7/2 | -0.367D-03 | 0.185D-03 | 0.426D-01 | 0.109D-01 | | | 0.131D 06 | 0.334D 05 |
| 8 | 11 | 3/2 - 5/2 | -0.239D-03 | 0.140D-03 | 0.175D-01 | 0.606D-02 | | | 0.562D 05 | 0.194D 05 |
| | | 5/2 - 5/2 | -0.230D-03 | 0.135D-03 | 0.775D-03 | 0.267D-03 | | | 0.369D 04 | 0.127D 04 |
| 9 | 7 | 3/2 - 5/2 | 0.239D-03 | -0.374D-03 | 0.147D 00 | 0.362D 00 | | | 0.670D 04 | 0.164D 05 |
| | | 5/2 - 5/2 | 0.230D-03 | -0.368D-03 | 0.663D-02 | 0.171D-01 | | | 0.430D 03 | 0.111D 04 |
| | | 5/2 - 7/2 | 0.101D-02 | -0.635D-03 | 0.258D 01 | 0.101D 01 | | | 0.126D 06 | 0.492D 05 |

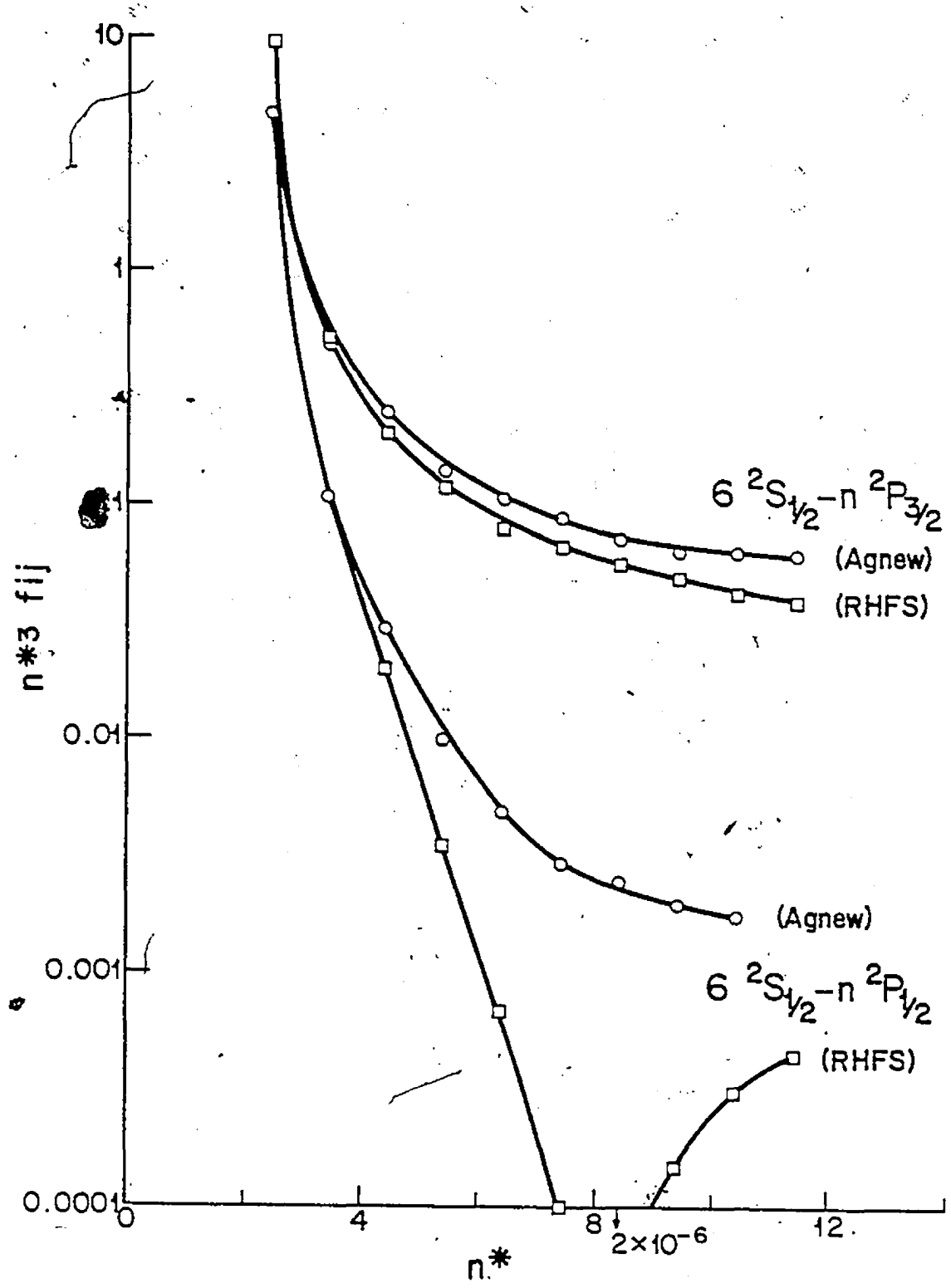
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_J$, CALCULATED USING THE ORTHOGONALIZED RELATIVISTIC H-F-S WAVE FUNCTIONS FOR CESIUM. OSCILLATOR STRENGTHS FROM THE MODEL POTENTIAL CALCULATIONS PERFORMED BY STONE AND THE EXPERIMENTAL VALUES OBTAINED BY AGNEW ARE ALSO SHOWN

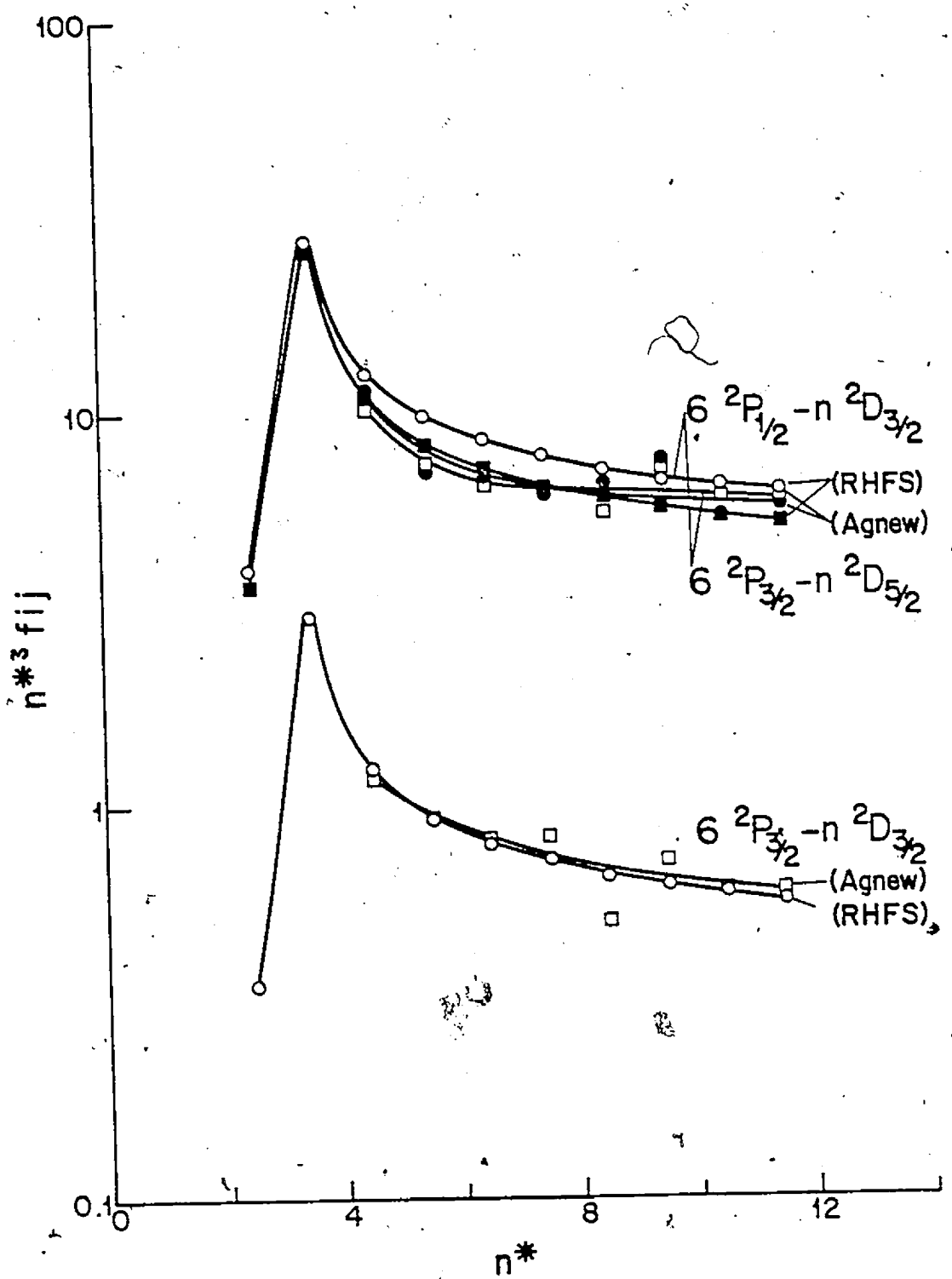
| TRANSITION N | M | J-J' | $R^0_{ij}$ VELOCITY | $R^0_{ij}$ LENGTH | $f_{ij}$ VELOCITY | $f_{ij}$ LENGTH | $f_{ij}$ STONE | $f_{ij}$ AGNEW | $A_{ij}(sec^{-1})$ VELOCITY | $A_{ij}(sec^{-1})$ LENGTH |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 8 | 3/2 - 5/2 | -0.108D-02 | 0.130D-02 | 0.113D 01 | 0.164D 01 | | | 0.365D 06 | 0.529D 06 |
| | | 5/2 - 5/2 | -0.108D-02 | 0.131D-02 | 0.548D-01 | 0.803D-01 | | | 0.260D 05 | 0.381D 05 |
| | | 5/2 - 7/2 | -0.388D-03 | -0.182D-03 | 0.140D 00 | 0.308D-01 | | | 0.500D 05 | 0.110D 05 |
| 9 | 9 | 3/2 - 5/2 | -0.555D-03 | 0.518D-03 | 0.241D 00 | 0.182D 00 | | | 0.158D 06 | 0.119D 06 |
| | | 5/2 - 5/2 | -0.587D-03 | 0.512D-03 | 0.112D-01 | 0.852D-02 | | | 0.109D 05 | 0.827D 04 |
| | | 5/2 - 7/2 | -0.617D-03 | 0.402D-03 | 0.247D 00 | 0.105D 00 | | | 0.180D 06 | 0.769D 05 |
| 9 | 10 | 3/2 - 5/2 | -0.391D-03 | 0.300D-03 | 0.855D-01 | 0.503D-01 | | | 0.827D 05 | 0.488D 05 |
| | | 5/2 - 5/2 | -0.383D-03 | 0.295D-03 | 0.392D-02 | 0.233D-02 | | | 0.562D 04 | 0.334D 04 |
| | | 5/2 - 7/2 | -0.409D-03 | 0.267D-03 | 0.897D-01 | 0.383D-01 | | | 0.963D 05 | 0.411D 05 |
| 9 | 11 | 3/2 - 5/2 | -0.283D-03 | 0.204D-03 | 0.395D-01 | 0.207D-01 | | | 0.488D 05 | 0.255D 05 |
| | | 5/2 - 5/2 | -0.275D-03 | 0.199D-03 | 0.179D-02 | 0.935D-03 | | | 0.329D 04 | 0.172D 04 |
| 10 | 8 | 3/2 - 5/2 | -0.314D-03 | -0.592D-03 | 0.385D 00 | 0.137D 01 | | | 0.761D 04 | 0.270D 05 |
| | | 5/2 - 5/2 | -0.325D-03 | -0.576D-03 | 0.201D-01 | 0.633D-01 | | | 0.566D 03 | 0.179D 04 |
| | | 5/2 - 7/2 | 0.124D-03 | -0.328D-03 | 0.588D-01 | 0.411D 00 | | | 0.124D 04 | 0.872D 04 |
| 10 | 9 | 3/2 - 5/2 | -0.548D-03 | 0.127D-02 | 0.129D 01 | 0.233D 01 | | | 0.189D 06 | 0.341D 06 |
| | | 5/2 - 5/2 | -0.550D-03 | 0.128D-02 | 0.622D-01 | 0.114D 00 | | | 0.134D 05 | 0.246D 05 |
| | | 5/2 - 7/2 | -0.922D-03 | 0.120D-02 | 0.117D 01 | 0.198D 01 | | | 0.190D 06 | 0.321D 06 |
| 10 | 10 | 3/2 - 5/2 | -0.499D-03 | 0.468D-03 | 0.246D 00 | 0.236D 00 | | | 0.761D 05 | 0.728D 05 |
| | | 5/2 - 5/2 | -0.493D-03 | 0.483D-03 | 0.115D-01 | 0.110D-01 | | | 0.529D 04 | 0.508D 04 |
| | | 5/2 - 7/2 | -0.506D-03 | 0.480D-03 | 0.242D 00 | 0.218D 00 | | | 0.835D 05 | 0.748D 05 |
| 10 | 11 | 3/2 - 5/2 | -0.336D-03 | 0.292D-03 | 0.905D-01 | 0.685D-01 | | | 0.422D 05 | 0.321D 05 |
| | | 5/2 - 5/2 | -0.329D-03 | 0.289D-03 | 0.416D-02 | 0.321D-02 | | | 0.289D 04 | 0.223D 04 |
| 11 | 9 | 3/2 - 5/2 | -0.345D-03 | -0.547D-03 | 0.673D 00 | 0.169D 01 | | | 0.637D 04 | 0.160D 05 |
| | | 5/2 - 5/2 | -0.355D-03 | -0.532D-03 | 0.347D-01 | 0.779D-01 | | | 0.471D 03 | 0.106D 04 |
| | | 5/2 - 7/2 | -0.317D-03 | -0.535D-03 | 0.553D 00 | 0.157D 01 | | | 0.562D 04 | 0.160D 05 |
| 11 | 10 | 3/2 - 5/2 | -0.819D-03 | 0.117D-02 | 0.136D 01 | 0.277D 01 | | | 0.956D 05 | 0.203D 06 |
| | | 5/2 - 5/2 | -0.821D-03 | 0.118D-02 | 0.657D-01 | 0.135D 00 | | | 0.711D 04 | 0.146D 05 |
| | | 5/2 - 7/2 | -0.817D-03 | 0.195D-02 | 0.130D 01 | 0.256D 01 | | | 0.105D 06 | 0.208D 06 |
| 11 | 11 | 3/2 - 5/2 | -0.431D-03 | 0.450D-03 | 0.256D 00 | 0.280D 00 | | | 0.407D 05 | 0.446D 05 |
| | | 5/2 - 5/2 | -0.427D-03 | 0.445D-03 | 0.120D-01 | 0.131D-01 | | | 0.284D 04 | 0.309D 04 |
| 12 | 10 | 3/2 - 5/2 | -0.329D-03 | -0.507D-03 | 0.846D 00 | 0.201D 01 | | | 0.418D 04 | 0.992D 04 |
| | | 5/2 - 5/2 | -0.338D-03 | -0.493D-03 | 0.435D-01 | 0.926D-01 | | | 0.308D 03 | 0.657D 03 |
| | | 5/2 - 7/2 | -0.326D-03 | -0.498D-03 | 0.807D 00 | 0.189D 01 | | | 0.430D 04 | 0.100D 05 |
| 12 | 11 | 3/2 - 5/2 | -0.717D-03 | 0.106D-02 | 0.142D 01 | 0.314D 01 | | | 0.562D 05 | 0.124D 06 |
| | | 5/2 - 5/2 | -0.719D-03 | 0.107D-02 | 0.687D-01 | 0.153D 00 | | | 0.399D 04 | 0.893D 04 |
| 13 | 11 | 3/2 - 5/2 | -0.306D-03 | -0.472D-03 | 0.986D 00 | 0.234D 01 | | | 0.270D 04 | 0.641D 04 |
| | | 5/2 - 5/2 | -0.315D-03 | -0.459D-03 | 0.508D-01 | 0.108D 00 | | | 0.200D 03 | 0.422D 03 |

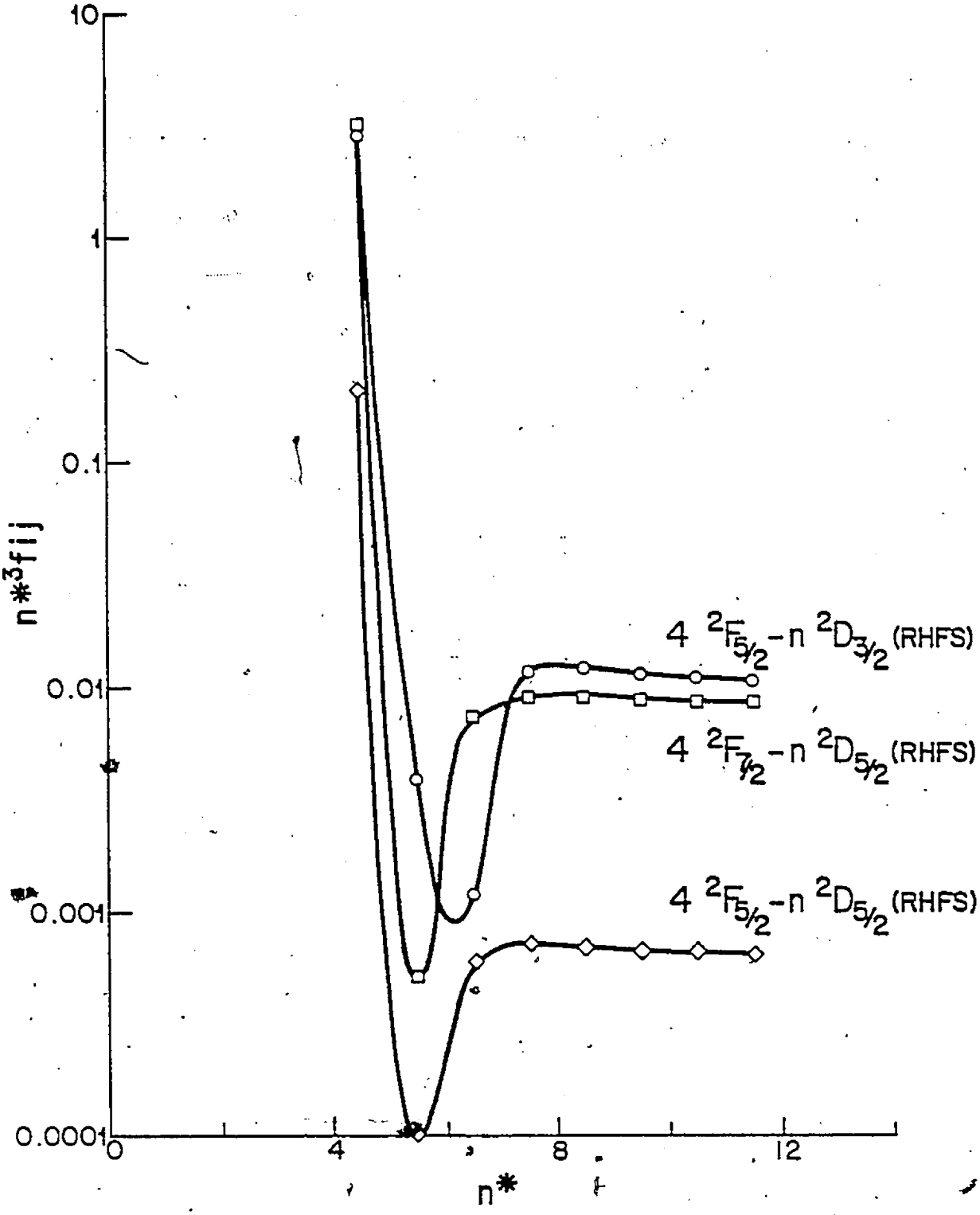
APPENDIX 6 : Plots of $n^{*3}f_{ij}$ versus $n^*$ indicating the behavior of the relativistic oscillator strengths as a function of the effective principal quantum number for several Cesium I series. The oscillator strengths were calculated from the orthogonalized free-core Hartree-Fock-Slater wave functions and are taken from Appendix (5). The oscillator strengths correspond to those derived in the velocity formulation. The theoretical curves are denoted by (RHFS) and the corresponding plots formed from Agnew's experimental data are designated by (AGNEW).











## APPENDIX 7: CESIUM$_I$ LIFETIMES

Atomic lifetimes for $Cs_I$ are calculated from both the length and velocity forms of the transition probabilities determined from the HFS wave functions and from the orthogonalized HFS wave functions. These lifetimes are compared to those found from the Bates-Damgaard (B-D) transition probabilities shown in Appendix (13), and to existing experimental values.

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $7^2S_{1/2}$ | 60.7 | 36.8 | 48.8 | 38.6 | 47.4 | 43 | 56.2 | |
| $8^2S_{1/2}$ | 164 | 125 | 144 | 74.7 | 152 | 113 | | $87\pm9$[b]; $96\pm14$[c] |
| $9^2S_{1/2}$ | 339 | 283 | 311 | 135 | 341 | 238 | 188 | $147\pm15$[b]; $231\pm35$[e] |
| $10^2S_{1/2}$ | 618 | 577 | 598 | 208 | 591 | 400 | 313 | $260\pm12$[a]; $270\pm5$[f] |
| $11^2S_{1/2}$ | 1020 | 1010 | 1015 | 315 | 962 | 639 | 492 | $343\pm22$[a]; $411\pm8$[f] |
| $12^2S_{1/2}$ | 1570 | 1600 | 1585 | 461 | 1471 | 966 | 738 | $545\pm30$[a]; $517\pm15$[f] |
| $13^2S_{1/2}$ | 2470 | 2840 | 2655 | 673 | 2515 | 1594 | 5340 | $754\pm35$[f] |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $14^2S_{1/2}$ | 3580 | 3940 | 3760 | 911 | 3402 | 2157 | 7959 | $959\pm50$(f) |
| $15^2S_{1/2}$ | 4690 | 4640 | 4665 | 1203 | 4464 | 2232 | 11177 | |
| $6^2P_{1/2}$ | 35.1 | 29.2 | 32.2 | 35.1 | 29.2 | 32.2 | 34.7 | |
| $6^2P_{3/2}$ | 30.6 | 25.5 | 28.1 | 30.6 | 25.5 | 28.1 | 30.6 | |
| $7^2P_{1/2}$ | 203 | 147 | 175 | 137 | 181 | 159 | 143 | $158\pm5$(d); $158\pm3$(f) |
| $7^2P_{3/2}$ | 162 | 157 | 159 | 107 | 141 | 124 | 116 | $136\pm4$(d); $135\pm3$(f) |
| $8^2P_{1/2}$ | 668 | 256 | 462 | 449 | 753 | 601 | 456 | |
| $8^2P_{3/2}$ | 601 | 32.6 | 317 | 301 | 521 | 411 | 371 | 274(e) |
| $9^2P_{1/2}$ | 1150 | 3700 | 2425 | 1109 | 1750 | 2859 | 656 | |
| $9^2P_{3/2}$ | 1280 | 502 | 891 | 682 | 1270 | 976 | 563 | 502(e) |
| $10^2P_{1/2}$ | 1700 | 2220 | 1960 | 2204 | 3121 | 2663 | 1044 | |
| $10^2P_{3/2}$ | 2120 | 720 | 1420 | 1299 | 2461 | 1880 | 906 | |
| $11^2P_{1/2}$ | 2770 | 7660 | 5215 | 3780 | 4789 | 4284 | 1594 | |
| $11^2P_{3/2}$ | 3150 | 1010 | 2080 | 2190 | 4056 | 3123 | 1359 | |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $12^2P_{1/2}$ | 4020 | 1060 | 2540 | 5868 | 6777 | 6322 | 1723 | |
| $12^2P_{3/2}$ | 4140 | 1390 | 2765 | 3390 | 6085 | 4738 | 1529 | |
| $13^2P_{1/2}$ | 4340 | 1660 | 3000 | 7176 | 6404 | 6790 | 1754 | |
| $13^2P_{3/2}$ | 6980 | 2220 | 4600 | 4156 | 6085 | 5121 | 1609 | |
| $14^2P_{1/2}$ | 5960 | 2070 | 4015 | 10496 | 9917 | 10206 | 1837 | |
| $14^2P_{3/2}$ | 7360 | 2670 | 5015 | 6038 | 8719 | 7378 | 1722 | |
| $15^2P_{1/2}$ | 6480 | 2390 | 4435 | 14507 | 12186 | 13346 | 1979 | |
| $15^2P_{3/2}$ | 12300 | 2900 | 7600 | 8298 | 11956 | 10127 | 4359 | |
| $5^2D_{3/2}$ | 951 | 957 | 954 | 952 | 958 | 955 | 845 | |
| $5^2D_{5/2}$ | 1180 | 1320 | 1250 | 1174 | 1321 | 1248 | 1202 | |
| $6^2D_{3/2}$ | 27 | 18.2 | 22.6 | 29.6 | 37.4 | 33.5 | 72.8 | |
| $6^2D_{5/2}$ | 28.2 | 19 | 23.6 | 30.6 | 38.6 | 34.6 | 71.1 | |
| $7^2D_{3/2}$ | 68.4 | 58 | 63.2 | 55.8 | 75.3 | 65.6 | 106 | $98\pm10$[b] |
| $7^2D_{5/2}$ | 72.2 | 60.4 | 66.3 | 58.1 | 83.8 | 71 | 104 | $88\pm9$[b] |
| $8^2D_{3/2}$ | 137 | 143 | 140 | 90.4 | 157 | 124 | 167 | $152\pm3$[f] |
| $8^2D_{5/2}$ | 144 | 73.3 | 109 | 95.9 | 163 | 129 | 164 | |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $9^2D_{3/2}$ | 237 | 266 | 251 | 137 | 260 | 198 | 116 | $218\pm4^{(f)}$ |
| $9^2D_{5/2}$ | 255 | 283 | 269 | 146 | 275 | 210 | 252 | |
| $10^2D_{3/2}$ | 386 | 389 | 388 | 207 | 440 | 324 | 373 | $311\pm6^{(f)}$ |
| $10^2D_{5/2}$ | 413 | 494 | 453 | 221 | 445 | 333 | 369 | |
| $11^2D_{3/2}$ | 579 | 761 | 670 | 300 | 658 | 479 | 526 | $428\pm12^{(f)}$ |
| $11^2D_{5/2}$ | 629 | 818 | 723 | 324 | 603 | 464 | 520 | |
| $12^2D_{3/2}$ | 843 | 748 | 795 | 421 | 939 | 680 | 719 | $561\pm18^{(f)}$ |
| $12^2D_{5/2}$ | 857 | 1170 | 1014 | 454 | 987 | 720 | 713 | |
| $13^2D_{3/2}$ | 1080 | 1000 | 1040 | 571 | 1298 | 934 | 958 | $741\pm22^{(f)}$ |
| $13^2D_{5/2}$ | 1110 | 1680 | 1395 | 619 | 1397 | 1008 | 957 | |
| $14^2D_{3/2}$ | 1370 | 1250 | 1310 | 753 | 1732 | 1242 | 1104 | $980\pm30^{(f)}$ |
| $14^2D_{5/2}$ | 1400 | 750 | 1075 | 818 | 1863 | 1340 | 1084 | |
| $4^2F_{5/2}$ | 44.4 | 52.6 | 48.5 | 49.2 | 52.9 | 51.1 | 46.7 | |
| $4^2F_{7/2}$ | 45 | 51.2 | 48.1 | 49.5 | 51.5 | 50.5 | 46.8 | |
| $5^2F_{5/2}$ | 55.8 | 80.5 | 68.1 | 53.6 | 75.8 | 64.7 | 80.3 | |
| $5^2F_{7/2}$ | 58.5 | 80.7 | 69.6 | 56.2 | 75.7 | 66 | 79.9 | |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $6^2F_{5/2}$ | 115 | 131 | 123 | 137 | 184 | 160 | 130 | |
| $6^2F_{7/2}$ | 98.7 | 139 | 119 | 101 | 76.1 | 88.6 | 129 | |
| $7^2F_{5/2}$ | 237 | 147 | 192 | 234 | 83.5 | 158 | 198 | |
| $7^2F_{7/2}$ | 140 | 214 | 177 | 135 | 222 | 178 | 198 | |
| $8^2F_{5/2}$ | 327 | 252 | 290 | 268 | 654 | 461 | 288 | |
| $8^2F_{7/2}$ | 359 | 260 | 310 | 24.8 | 105 | 64.9 | 288 | |
| $9^2F_{5/2}$ | 476 | 359 | 417 | 847 | 673 | 760 | 404 | |
| $9^2F_{7/2}$ | 511 | 420 | 466 | 352 | 960 | 656 | 403 | |
| $10^2F_{5/2}$ | 664 | 630 | 647 | 1265 | 826 | 1046 | 547 | |
| $10^2F_{7/2}$ | 721 | 543 | 682 | 1177 | 1042 | 1110 | 548 | |
| $11^2F_{5/2}$ | 932 | 1000 | 968 | 1635 | 1071 | 1353 | 724 | |

a) Lundberg and Svanberg[80]

b) Marek[81]

c) Marek and Niemax[82]

d) Pace and Atkinson[83]

e) Bulos, Gupta and Happer[84]

f) Deech, Luypaert, Pendrill and Series[85]

## APPENDIX B : Thallium I Oscillator Strengths

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ns^2S_{1/2}$ CALCULATED USING THE ORTHOGONALIZED P-F-S WAVE FUNCTIONS. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $\bar{M}^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 7 | 1/2 - 1/2 | -0.226D-02 | 0.325D-02 | 0.880D-01 | 0.182D 00 | 0.131D 00 | 0.136D 00 | 0.412D 08 | 0.852D 08 |
| | | 3/2 - 1/2 | -0.208D-02 | 0.315D-02 | 0.106D 00 | 0.243D 00 | 0.176D 00 | 0.154D 00 | 0.496D 08 | 0.113D 09 |
| 6 | 8 | 1/2 - 1/2 | -0.115D-02 | 0.143D-02 | 0.155D-01 | 0.242D-01 | 0.166D-01 | 0.179D-01 | 0.155D 08 | 0.242D 08 |
| | | 3/2 - 1/2 | -0.901D-03 | 0.110D-02 | 0.120D-01 | 0.179D-01 | 0.159D-01 | 0.139D-01 | 0.153D 08 | 0.229D 08 |
| 6 | 9 | 1/2 - 1/2 | -0.792D-03 | 0.912D-03 | 0.665D-02 | 0.882D-02 | 0.579D-02 | 0.630D-02 | 0.827D 07 | 0.110D 08 |
| | | 3/2 - 1/2 | -0.617D-03 | 0.682D-03 | 0.493D-02 | 0.602D-02 | 0.521D-02 | 0.490D-02 | 0.823D 07 | 0.100D 08 |
| 6 | 10 | 1/2 - 1/2 | -0.583D-03 | 0.643D-03 | 0.344D-02 | 0.418D-02 | 0.285D-02 | | 0.471D 07 | 0.571D 07 |
| | | 3/2 - 1/2 | -0.455D-03 | 0.477D-03 | 0.253D-02 | 0.278D-02 | 0.258D-02 | 0.310D-02 | 0.475D 07 | 0.521D 07 |
| 6 | 11 | 1/2 - 1/2 | -0.450D-03 | 0.484D-03 | 0.199D-02 | 0.231D-02 | 0.156D-02 | 0.220D-02 | 0.267D 07 | 0.312D 07 |
| | | 3/2 - 1/2 | -0.352D-03 | 0.357D-03 | 0.147D-02 | 0.151D-02 | 0.136D-02 | | 0.292D 07 | 0.302D 07 |
| 7 | 8 | 1/2 - 1/2 | -0.198D-02 | 0.141D-02 | 0.393D 00 | 0.198D 00 | 0.269D 00 | | 0.550D 07 | 0.277D 07 |
| | | 3/2 - 1/2 | -0.196D-02 | 0.134D-02 | 0.492D 00 | 0.229D 00 | 0.303D 00 | | 0.343D 07 | 0.393D 07 |
| 7 | 9 | 1/2 - 1/2 | -0.555D-03 | 0.591D-03 | 0.463D-01 | 0.178D-01 | 0.226D-01 | | 0.251D 07 | 0.963D 06 |
| | | 3/2 - 1/2 | -0.862D-03 | 0.502D-03 | 0.425D-01 | 0.144D-01 | 0.164D-01 | | 0.363D 07 | 0.123D 07 |
| 7 | 10 | 1/2 - 1/2 | -0.633D-03 | 0.361D-03 | 0.165D-01 | 0.537D-02 | 0.769D-02 | | 0.136D 07 | 0.442D 06 |
| | | 3/2 - 1/2 | -0.567D-03 | 0.299D-03 | 0.145D-01 | 0.405D-02 | 0.546D-02 | | 0.199D 07 | 0.554D 06 |
| 7 | 11 | 1/2 - 1/2 | -0.465D-03 | 0.253D-03 | 0.806D-02 | 0.238D-02 | 0.352D-02 | | 0.814D 06 | 0.240D 06 |
| | | 3/2 - 1/2 | -0.416D-03 | 0.209D-03 | 0.702D-02 | 0.175D-02 | 0.237D-02 | | 0.119D 07 | 0.297D 06 |
| 8 | 9 | 1/2 - 1/2 | -0.150D-02 | 0.112D-02 | 0.576D 00 | 0.321D 00 | | | 0.124D 07 | 0.690D 06 |
| | | 3/2 - 1/2 | -0.145D-02 | 0.105D-02 | 0.675D 00 | 0.352D 00 | | | 0.183D 07 | 0.955D 06 |
| 8 | 10 | 1/2 - 1/2 | -0.675D-03 | 0.433D-03 | 0.531D-01 | 0.218D-01 | | | 0.546D 06 | 0.224D 06 |
| | | 3/2 - 1/2 | -0.574D-03 | 0.332D-03 | 0.424D-01 | 0.142D-01 | | | 0.715D 06 | 0.240D 05 |
| 8 | 11 | 1/2 - 1/2 | -0.449D-03 | 0.263D-03 | 0.181D-01 | 0.623D-02 | | | 0.313D 06 | 0.107D 06 |
| | | 3/2 - 1/2 | -0.377D-03 | 0.193D-03 | 0.138D-01 | 0.362D-02 | | | 0.410D 06 | 0.107D 06 |
| 9 | 10 | 1/2 - 1/2 | -0.122D-02 | 0.935D-03 | 0.747D 00 | 0.437D 00 | | | 0.418D 06 | 0.245D 06 |
| | | 3/2 - 1/2 | -0.116D-02 | 0.877D-03 | 0.843D 00 | 0.480D 00 | | | 0.608D 06 | 0.345D 06 |
| 9 | 11 | 1/2 - 1/2 | -0.551D-03 | 0.374D-03 | 0.671D-01 | 0.308D-01 | | | 0.193D 06 | 0.885D 05 |
| | | 3/2 - 1/2 | -0.454D-03 | 0.281D-03 | 0.498D-01 | 0.190D-01 | | | 0.238D 06 | 0.910D 05 |
| 10 | 11 | 1/2 - 1/2 | -0.101D-02 | 0.783D-03 | 0.907D 00 | 0.542D 00 | | | 0.162D 06 | 0.967D 05 |
| | | 3/2 - 1/2 | -0.961D-03 | 0.727D-03 | 0.102D 01 | 0.606D 00 | | | 0.233D 06 | 0.134D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - np^2P_{J'}$ CALCULATED USING THE ORTHOGONALIZED H-F-S WAVE FUNCTIONS. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PEKRIS AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $R^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}$ ($sec^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 7 | 7 | 1/2 - 1/2 | 0.281D-02 | -0.272D-02 | 0.471D 00 | 0.442D 00 | 0.463D 00 | | 0.186D 08 | 0.174D 08 |
| | | 1/2 - 3/2 | 0.313D-02 | -0.289D-02 | 0.104D 01 | 0.984D 00 | 0.937D 00 | | 0.260D 08 | 0.222D 08 |
| 7 | 8 | 1/2 - 1/2 | 0.497D-03 | -0.216D-03 | 0.761D-02 | 0.143D-02 | 0.118D-01 | | 0.112D 07 | 0.212D 06 |
| | | 1/2 - 3/2 | 0.895D-03 | -0.537D-03 | 0.484D-01 | 0.173D-01 | 0.547D-01 | | 0.376D 07 | 0.134D 07 |
| 7 | 9 | 1/2 - 1/2 | 0.238D-03 | -0.323D-04 | 0.144D-02 | 0.266D-04 | 0.255D-02 | | 0.309D 06 | 0.571D 04 |
| | | 1/2 - 3/2 | 0.526D-03 | -0.249D-03 | 0.140D-01 | 0.314D-02 | 0.154D-01 | | 0.153D 07 | 0.343D 06 |
| 7 | 10 | 1/2 - 1/2 | 0.144D-03 | 0.951D-05 | 0.488D-03 | 0.213D-05 | 0.940D-03 | | 0.123D 06 | 0.537D 03 |
| | | 1/2 - 3/2 | 0.364D-03 | -0.148D-03 | 0.621D-02 | 0.103D-02 | 0.674D-02 | | 0.794D 05 | 0.131D 06 |
| 8 | 8 | 1/2 - 1/2 | 0.198D-02 | -0.177D-02 | 0.688D 00 | 0.549D 00 | | | 0.315D 07 | 0.252D 07 |
| | | 1/2 - 3/2 | 0.216D-02 | -0.190D-02 | 0.143D 01 | 0.111D 01 | | | 0.426D 07 | 0.331D 07 |
| 8 | 9 | 1/2 - 1/2 | 0.517D-03 | -0.319D-03 | 0.218D-01 | 0.828D-02 | | | 0.459D 06 | 0.175D 06 |
| | | 1/2 - 3/2 | 0.752D-03 | -0.552D-03 | 0.387D-01 | 0.480D-01 | | | 0.112D 07 | 0.342D 06 |
| 8 | 10 | 1/2 - 1/2 | 0.276D-03 | -0.128D-03 | 0.487D-02 | 0.104D-02 | | | 0.168D 06 | 0.358D 05 |
| | | 1/2 - 3/2 | 0.495D-03 | -0.297D-03 | 0.295D-01 | 0.110D-01 | | | 0.525D 06 | 0.196D 06 |
| 9 | 9 | 1/2 - 1/2 | 0.155D-02 | -0.132D-02 | 0.910D 00 | 0.056D 00 | | | 0.897D 06 | 0.645D 06 |
| | | 1/2 - 3/2 | 0.168D-02 | -0.140D-02 | 0.184D 01 | 0.129D 01 | | | 0.120D 07 | 0.839D 06 |
| 9 | 10 | 1/2 - 3/2 | 0.667D-03 | -0.453D-03 | 0.142D 00 | 0.053D-01 | | | 0.391D 06 | 0.180D 06 |
| | | 1/2 - 1/2 | 0.456D-03 | -0.275D-03 | 0.346D-01 | 0.125D-01 | | | 0.178D 06 | 0.641D 05 |
| 10 | 10 | 1/2 - 1/2 | 0.123D-02 | -0.104D-02 | 0.108D 01 | 0.772D 00 | | | 0.298D 06 | 0.212D 06 |
| | | 1/2 - 3/2 | 0.133D-02 | -0.111D-02 | 0.216D 01 | 0.150D 01 | | | 0.402D 06 | 0.286D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_J$, CALCULATED USING THE ORTHOGONALIZED H-F-S WAVE FUNCTIONS. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $R^0_{IJ}$ | | $f_{IJ}$ | | $f_{IJ}$ | | $A_{IJ}$ (sec$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 8 | 3/2 - 1/2 | 0.590D-03 | -0.105D-02 | 0.304D-01 | 0.958D-01 | | | 0.112D 07 | 0.352D 07 |
| | | 3/2 - 3/2 | 0.422D-03 | -0.912D-03 | 0.290D-02 | 0.135D-01 | | | 0.612D 05 | 0.285D 06 |
| | | 5/2 - 3/2 | 0.449D-03 | -0.937D-03 | 0.200D-01 | 0.870D-01 | | | 0.612D 06 | 0.267D 07 |
| 6 | 9 | 3/2 - 1/2 | 0.216D-03 | -0.419D-03 | 0.260D-02 | 0.974D-02 | | | 0.236D 06 | 0.889D 06 |
| | | 3/2 - 3/2 | 0.147D-03 | -0.402D-03 | 0.235D-03 | 0.175D-02 | | | 0.112D 05 | 0.831D 05 |
| | | 5/2 - 3/2 | 0.161D-03 | -0.409D-03 | 0.170D-02 | 0.110D-01 | | | 0.119D 06 | 0.769D 06 |
| 6 | 10 | 3/2 - 1/2 | 0.119D-03 | -0.251D-03 | 0.663D-03 | 0.295D-02 | | | 0.852D 05 | 0.379D 06 |
| | | 3/2 - 3/2 | 0.756D-04 | -0.251D-03 | 0.527D-04 | 0.582D-03 | | | 0.346D 04 | 0.382D 05 |
| | | 5/2 - 3/2 | 0.850D-04 | -0.255D-03 | 0.404D-03 | 0.463D-02 | | | 0.392D 05 | 0.352D 06 |
| 7 | 9 | 3/2 - 1/2 | 0.882D-03 | -0.714D-03 | 0.589D-01 | 0.985D-01 | | | 0.442D 06 | 0.716D 06 |
| | | 3/2 - 3/2 | 0.362D-03 | -0.567D-03 | 0.471D-02 | 0.116D-01 | | | 0.204D 05 | 0.500D 05 |
| | | 5/2 - 3/2 | 0.409D-03 | -0.616D-03 | 0.366D-01 | 0.329D-01 | | | 0.231D 06 | 0.525D 06 |
| 7 | 10 | 3/2 - 1/2 | 0.237D-03 | -0.340D-03 | 0.656D-02 | 0.135D-01 | | | 0.135D 06 | 0.278D 06 |
| | | 3/2 - 3/2 | 0.147D-03 | -0.291D-03 | 0.490D-03 | 0.192D-02 | | | 0.533D 04 | 0.208D 05 |
| | | 5/2 - 3/2 | 0.171D-03 | -0.309D-03 | 0.402D-02 | 0.131D-01 | | | 0.641D 05 | 0.210D 06 |
| 8 | 10 | 3/2 - 1/2 | 0.472D-03 | -0.535D-03 | 0.807D-01 | 0.103D 00 | | | 0.173D 06 | 0.222D 06 |
| | | 3/2 - 3/2 | 0.290D-03 | -0.397D-03 | 0.560D-02 | 0.105D-01 | | | 0.703D 04 | 0.132D 05 |
| | | 5/2 - 3/2 | 0.339D-03 | -0.444D-03 | 0.467D-01 | 0.301D-01 | | | 0.852D 05 | 0.146D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$
CALCULATED USING THE ORTHOGONALIZED H-F-S WAVE FUNCTIONS.
OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

| TRANSITION | | | $R^e_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}$ (sec$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 6 | 1/2 - 3/2 | 0.3890-02 | -0.4260-02 | 0.3830 00 | 0.4600 00 | 0.4100 00 | 0.2900 00 | 0.1670 09 | 0.2000 09 |
| | | 3/2 - 3/2 | 0.3950-02 | -0.4500-02 | 0.5050-01 | 0.5550-01 | 0.5500-01 | 0.4000-01 | 0.2700 08 | 0.3510 08 |
| | | 3/2 - 5/2 | 0.3890-02 | -0.4440-02 | 0.4380 00 | 0.5730 00 | 0.4700 00 | 0.3500 00 | 0.1570 09 | 0.2050 09 |
| 6 | 7 | 1/2 - 3/2 | 0.2300-02 | -0.3170-02 | 0.2370 00 | 0.2190 00 | 0.1100 00 | 0.7400-01 | 0.1400 09 | 0.1290 09 |
| | | 3/2 - 3/2 | 0.2990-02 | -0.2950-02 | 0.2400-01 | 0.2330-01 | 0.1300-01 | 0.9100-02 | 0.1670 08 | 0.1820 08 |
| | | 3/2 - 5/2 | 0.2940-02 | -0.2920-02 | 0.2080 00 | 0.2060 00 | 0.1100 00 | 0.8100-01 | 0.1090 09 | 0.1070 09 |
| 6 | 8 | 1/2 - 3/2 | 0.2540-02 | -0.2250-02 | 0.1320 00 | 0.1030 00 | 0.4900-01 | 0.2800-01 | 0.9810 08 | 0.6960 08 |
| | | 3/2 - 3/2 | 0.2190-02 | -0.1960-02 | 0.1190-01 | 0.9500-02 | 0.5200-02 | 0.4000-02 | 0.1080 09 | 0.8600 07 |
| | | 3/2 - 5/2 | 0.2190-02 | -0.1980-02 | 0.1070 00 | 0.9730-01 | 0.4500-01 | 0.2800-01 | 0.6450 09 | 0.5290 08 |
| 6 | 9 | 1/2 - 3/2 | 0.1890-02 | -0.1590-02 | 0.7090-01 | 0.5040-01 | 0.2600-01 | 0.1400-01 | 0.5040 08 | 0.3570 08 |
| | | 3/2 - 3/2 | 0.1590-02 | -0.1340-02 | 0.6020-02 | 0.4260-02 | 0.2600-02 | 0.2000-02 | 0.5910 07 | 0.4180 07 |
| | | 3/2 - 5/2 | 0.1600-02 | -0.1370-02 | 0.5540-01 | 0.4040-01 | 0.2300-01 | 0.1500-01 | 0.3610 08 | 0.2640 08 |
| 7 | 6 | 1/2 - 3/2 | -0.5350-03 | 0.8490-03 | 0.4050 00 | 0.5370 00 | | | 0.5250 06 | 0.4300 06 |
| | | 3/2 - 3/2 | -0.4050-03 | 0.4180-03 | 0.1600-01 | 0.1970-01 | | | 0.9800 04 | 0.1020 05 |
| | | 3/2 - 5/2 | -0.4720-03 | 0.4580-03 | 0.1770 00 | 0.1670 00 | | | 0.8520 05 | 0.7980 05 |
| 7 | 7 | 1/2 - 3/2 | 0.1890-02 | -0.1090-02 | 0.4180 00 | 0.1380 00 | | | 0.8600 07 | 0.2830 07 |
| | | 3/2 - 3/2 | 0.2310-02 | -0.1400-02 | 0.7130-01 | 0.2610-01 | | | 0.2230 07 | 0.8190 06 |
| | | 3/2 - 5/2 | 0.2210-02 | -0.1330-02 | 0.5830 00 | 0.2110 00 | | | 0.1230 08 | 0.4460 07 |
| 7 | 8 | 1/2 - 3/2 | 0.1610-02 | -0.9090-03 | 0.2250 00 | 0.7190-01 | | | 0.8270 07 | 0.2650 07 |
| | | 3/2 - 3/2 | 0.1770-02 | -0.1030-02 | 0.3010-01 | 0.1010-01 | | | 0.1810 07 | 0.6120 06 |
| | | 3/2 - 5/2 | 0.1730-02 | -0.1010-02 | 0.2580 00 | 0.8740-01 | | | 0.1040 08 | 0.3530 07 |
| 7 | 9 | 1/2 - 3/2 | 0.1220-02 | -0.6660-03 | 0.1140 00 | 0.3400-01 | | | 0.5420 07 | 0.1620 07 |
| | | 3/2 - 3/2 | 0.1290-02 | -0.7120-03 | 0.1390-01 | 0.4240-02 | | | 0.1110 07 | 0.3390 06 |
| | | 3/2 - 5/2 | 0.1280-02 | -0.7110-03 | 0.1230 00 | 0.3810-01 | | | 0.6530 07 | 0.2030 07 |
| 8 | 7 | 1/2 - 3/2 | -0.5010-03 | 0.5380-03 | 0.3570 00 | 0.4130 00 | | | 0.4920 05 | 0.5710 05 |
| | | 3/2 - 3/2 | -0.1130-03 | 0.2300-03 | 0.4310-02 | 0.1790-01 | | | 0.2100 03 | 0.8720 03 |
| | | 3/2 - 5/2 | -0.2010-03 | 0.2650-03 | 0.1080 00 | 0.1080 00 | | | 0.4590 04 | 0.7940 04 |
| 8 | 8 | 1/2 - 3/2 | 0.1290-02 | -0.9150-03 | 0.4610 00 | 0.2320 00 | | | 0.1680 07 | 0.8430 06 |
| | | 3/2 - 3/2 | 0.1580-02 | -0.1140-02 | 0.7820-01 | 0.4030-01 | | | 0.4460 06 | 0.2310 06 |
| | | 3/2 - 5/2 | 0.1500-02 | -0.1060-02 | 0.6270 00 | 0.3140 00 | | | 0.2430 07 | 0.1220 07 |
| 8 | 9 | 1/2 - 3/2 | 0.5830-03 | -0.6580-03 | 0.1870 00 | 0.8390-01 | | | 0.1400 07 | 0.6240 06 |
| | | 3/2 - 3/2 | 0.1100-02 | -0.7290-03 | 0.2520-01 | 0.1120-01 | | | 0.3200 06 | 0.1410 06 |
| | | 3/2 - 5/2 | 0.1070-02 | -0.7080-03 | 0.2150 00 | 0.9470-01 | | | 0.1820 07 | 0.8020 06 |
| 9 | 8 | 1/2 - 3/2 | -0.2650-03 | 0.4010-03 | 0.2210 00 | 0.3060 00 | | | 0.6280 04 | 0.1430 05 |
| | | 3/2 - 3/2 | 0.6140-04 | 0.1520-03 | 0.3130-02 | 0.1920-01 | | | 0.2530 02 | 0.1550 03 |
| | | 3/2 - 5/2 | -0.2390-04 | 0.1830-03 | 0.3630-02 | 0.2110 00 | | | 0.2730 02 | 0.1600 04 |
| 9 | 9 | 1/2 - 3/2 | 0.5560-03 | -0.7420-03 | 0.4870 00 | 0.2940 00 | | | 0.4800 06 | 0.2890 06 |
| | | 3/2 - 3/2 | 0.1190-02 | -0.9370-03 | 0.8460-01 | 0.5240-01 | | | 0.1330 06 | 0.9230 05 |
| | | 3/2 - 5/2 | 0.1130-02 | -0.8730-03 | 0.6740 00 | 0.4160 00 | | | 0.7190 06 | 0.4340 06 |
| 10 | 9 | 1/2 - 3/2 | -0.1880-03 | 0.3310-03 | 0.2030 00 | 0.3300 00 | | | 0.1720 04 | 0.5330 04 |
| | | 3/2 - 3/2 | 0.6760-04 | 0.1190-03 | 0.1280-01 | 0.2350-01 | | | 0.2570 02 | 0.4710 02 |
| | | 3/2 - 5/2 | 0.1380-04 | 0.1400-03 | 0.2340-02 | 0.2430 00 | | | 0.4630 01 | 0.4800 03 |

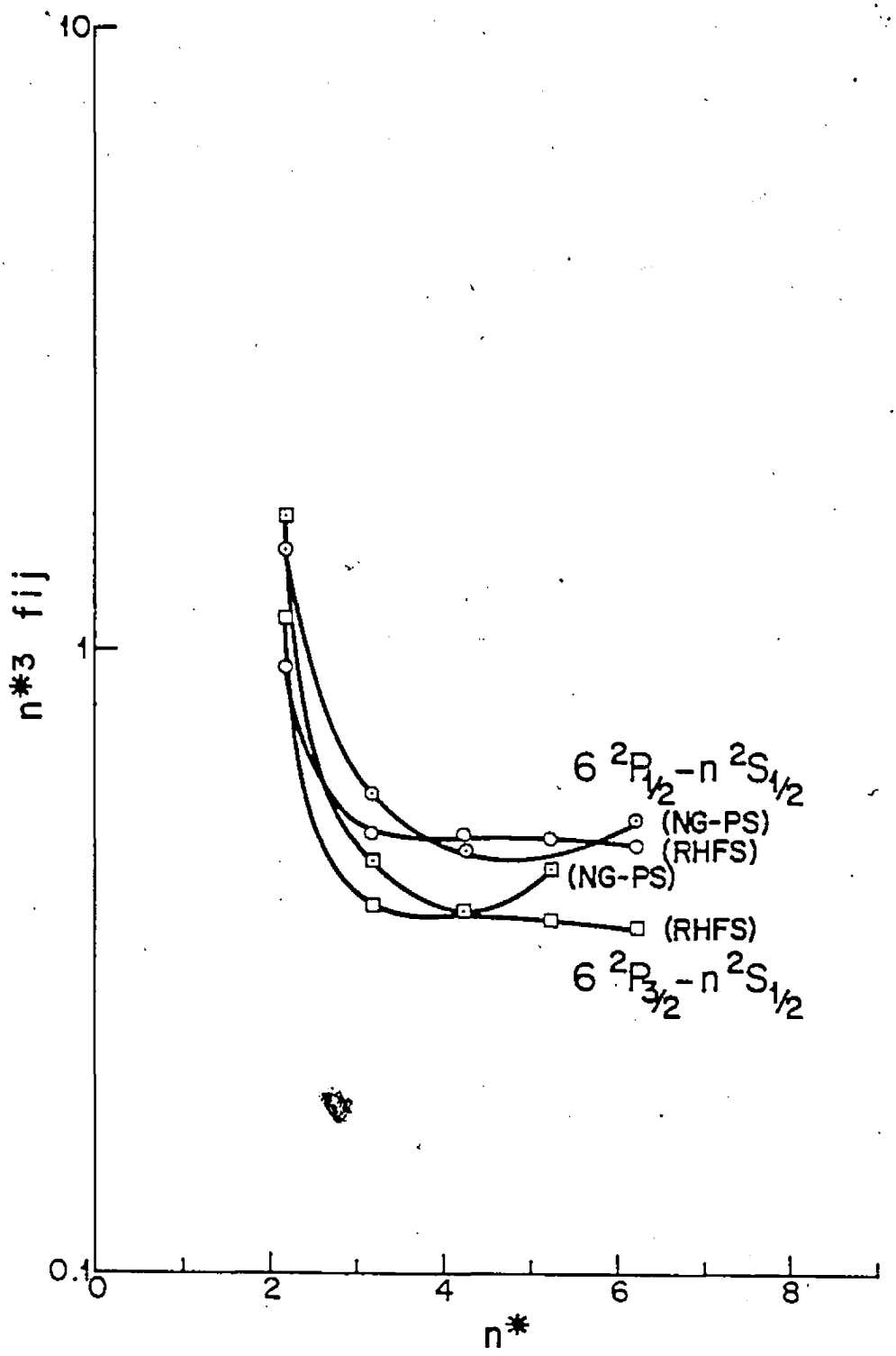
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED USING THE ORTHOGONALIZED P-F-S WAVE FUNCTIONS.
OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

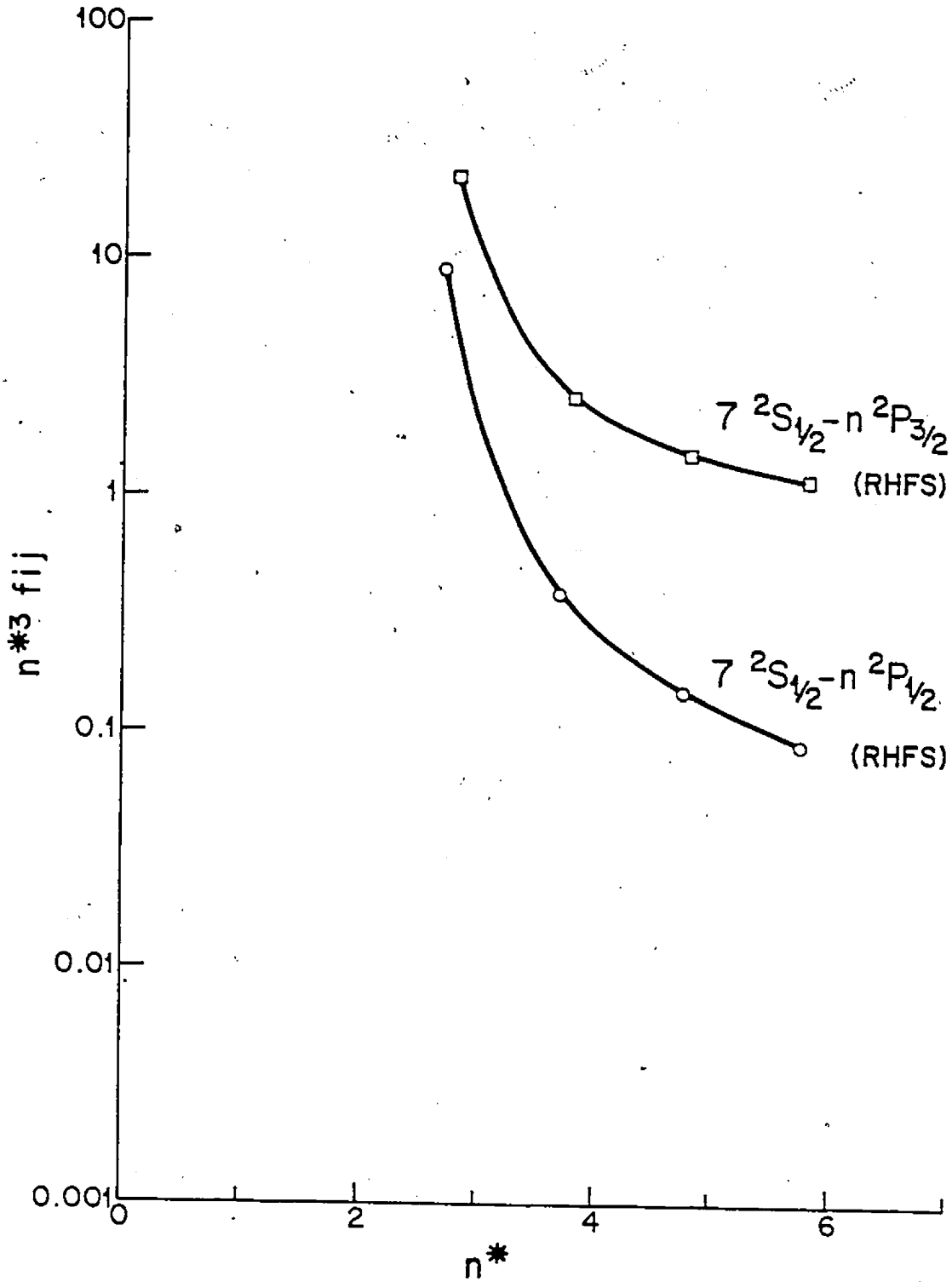
| TRANSITION | | | $\bar{R}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}$ ($sec^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 6 | 5 | 3/2 - 5/2 | -0.257D-02 | 0.274D-02 | 0.875D 00 | 0.997D 00 | | | 0.150D 08 | 0.170D 08 |
| | | 5/2 - 5/2 | -0.257D-02 | 0.275D-02 | 0.424D-01 | 0.485D-01 | | | 0.106D 07 | 0.121D 07 |
| | | 5/2 - 7/2 | -0.257D-02 | 0.275D-02 | 0.847D 00 | 0.970D 00 | | | 0.159D 08 | 0.182D 08 |
| 6 | 6 | 3/2 - 5/2 | -0.133D-02 | 0.138D-02 | 0.167D 00 | 0.180D 00 | | | 0.562D 07 | 0.604D 07 |
| | | 5/2 - 5/2 | -0.131D-02 | 0.136D-02 | 0.784D-02 | 0.847D-02 | | | 0.389D 06 | 0.422D 06 |
| | | 5/2 - 7/2 | -0.131D-02 | 0.136D-02 | 0.157D 00 | 0.169D 00 | | | 0.583D 07 | 0.628D 07 |
| 7 | 5 | 3/2 - 5/2 | 0.230D-03 | -0.223D-03 | 0.142D 00 | 0.134D 00 | | | 0.595D 04 | 0.562D 04 |
| | | 5/2 - 5/2 | 0.186D-03 | -0.196D-03 | 0.502D-02 | 0.560D-02 | | | 0.243D 03 | 0.271D 03 |
| | | 5/2 - 7/2 | 0.186D-03 | -0.196D-03 | 0.100D 00 | 0.112D 00 | | | 0.365D 04 | 0.407D 04 |
| 7 | 6 | 3/2 - 5/2 | -0.146D-02 | 0.120D-02 | 0.645D 00 | 0.423D 00 | | | 0.227D 07 | 0.148D 07 |
| | | 5/2 - 5/2 | -0.152D-02 | 0.126D-02 | 0.326D-01 | 0.224D-01 | | | 0.167D 06 | 0.115D 06 |
| | | 5/2 - 7/2 | -0.152D-02 | 0.126D-02 | 0.653D 00 | 0.448D 00 | | | 0.251D 07 | 0.173D 07 |
| 8 | 6 | 3/2 - 5/2 | 0.483D-03 | -0.206D-03 | 0.127D 01 | 0.233D 00 | | | 0.129D 05 | 0.236D 04 |
| | | 5/2 - 5/2 | 0.422D-03 | -0.180D-03 | 0.535D-01 | 0.969D-02 | | | 0.612D 03 | 0.111D 03 |
| | | 5/2 - 7/2 | 0.422D-03 | -0.180D-03 | 0.107D 01 | 0.194D 00 | | | 0.918D 04 | 0.166D 04 |

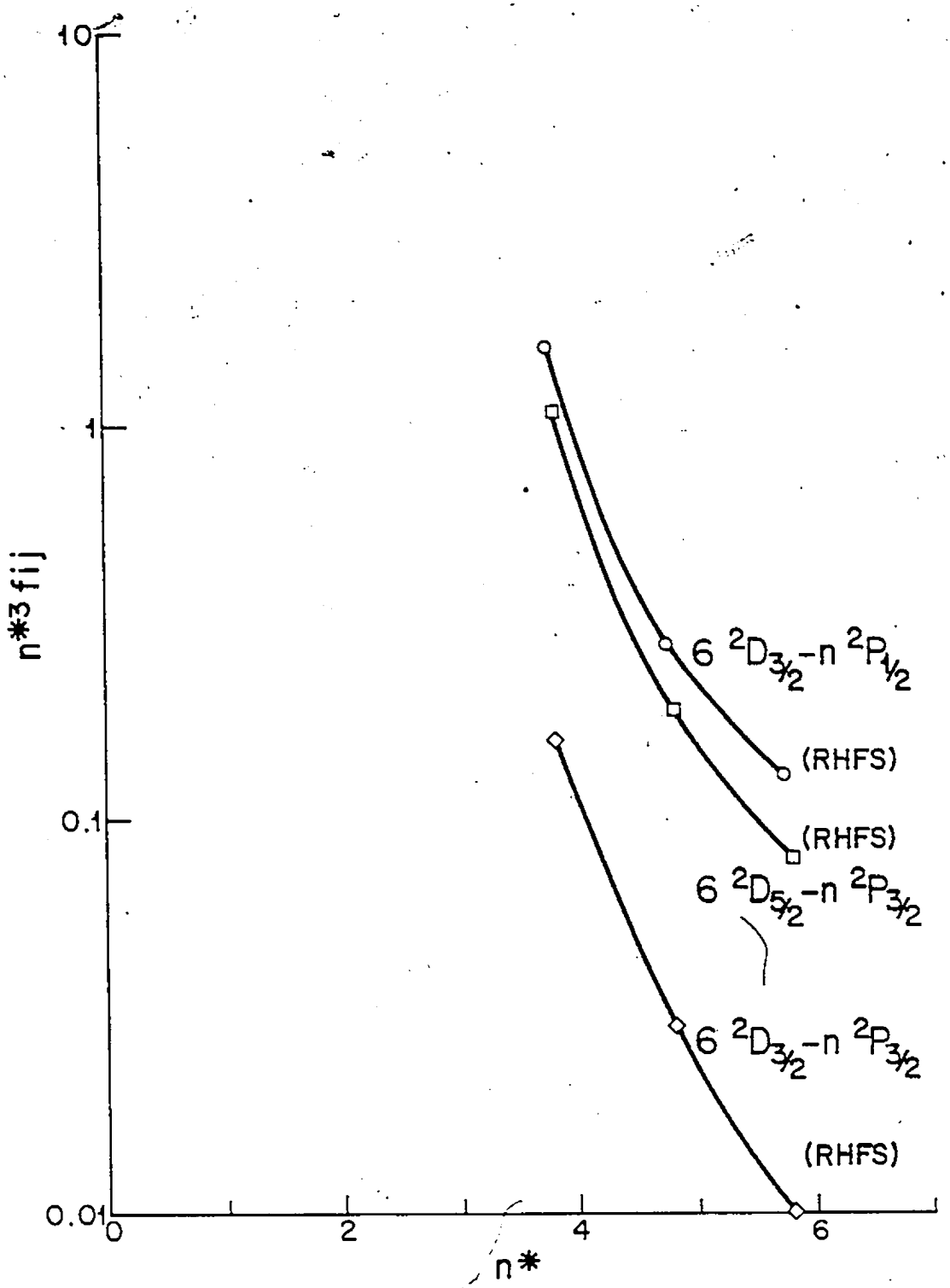
THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED USING THE ORTHOGONALIZED H-F-S WAVE FUNCTIONS. OSCILLATOR STRENGTHS FROM THE SEMI-EMPIRICAL CALCULATIONS PERFORMED BY MIGDALEK AND THE COMBINED EXPERIMENTAL DATA OBTAINED BY NORTON AND GALLAGHER AND PENKIN AND SHABANOVA (NG-PS) ARE ALSO SHOWN.

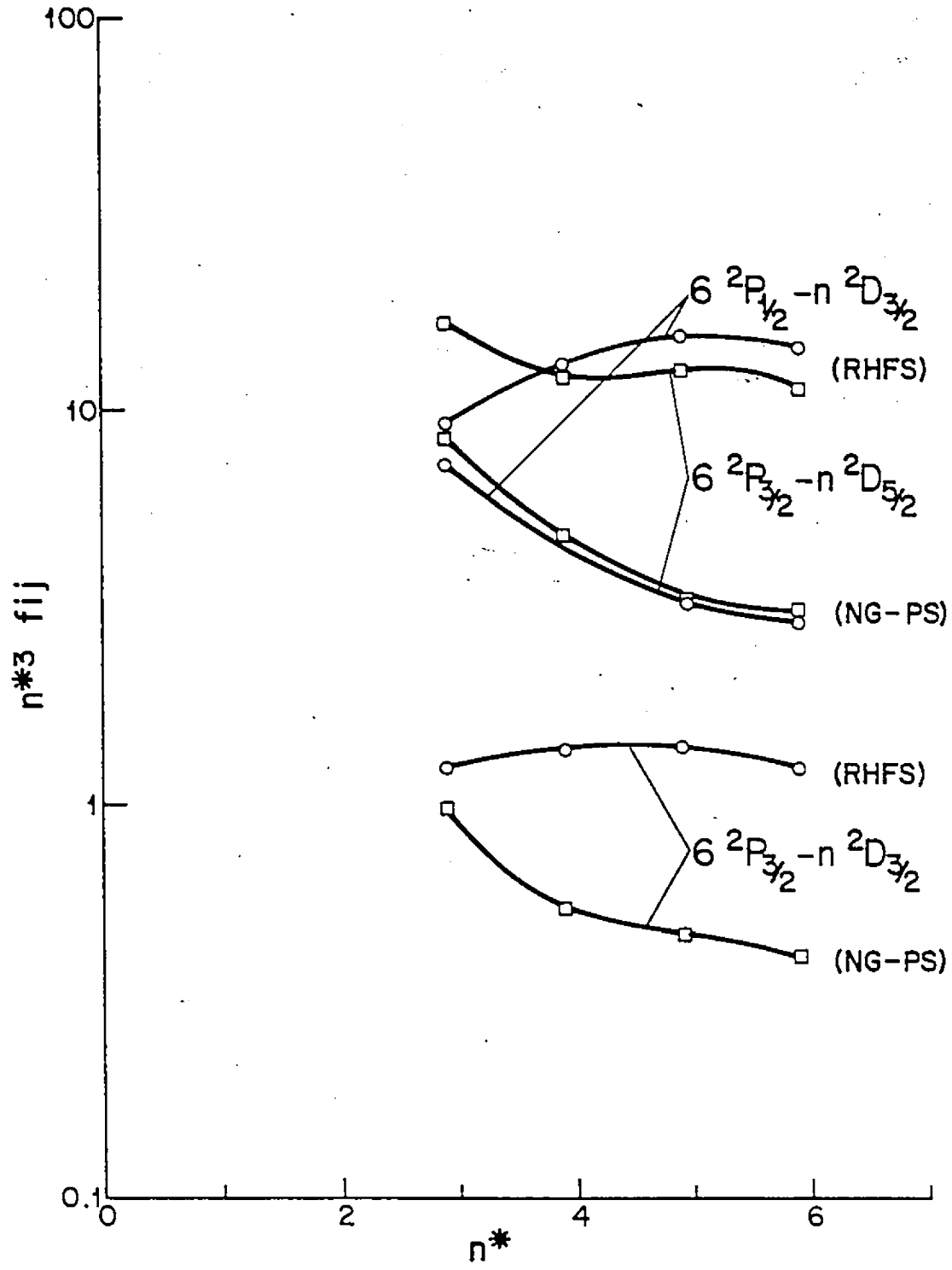
| TRANSITION | | | $\bar{M}^0_{ij}$ | | $f_{ij}$ | | $f_{ij}$ | | $A_{ij}(sec^{-1})$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | VELOCITY | LENGTH | VELOCITY | LENGTH | MIGDALEK | NG-PS | VELOCITY | LENGTH |
| 5 | 8 | 5/2 - 3/2 | -0.311D-03 | 0.561D-03 | 0.225D-01 | 0.734D-01 | | | 0.125D 06 | 0.407D 06 |
| | | 5/2 - 5/2 | -0.294D-03 | 0.524D-03 | 0.143D-02 | 0.454D-02 | | | 0.537D 04 | 0.171D 05 |
| | | 7/2 - 5/2 | -0.294D-03 | 0.524D-03 | 0.214D-01 | 0.682D-01 | | | 0.107D 06 | 0.342D 06 |
| 5 | 9 | 5/2 - 3/2 | -0.119D-03 | 0.237D-03 | 0.207D-02 | 0.820D-02 | | | 0.256D 05 | 0.117D 06 |
| | | 5/2 - 5/2 | -0.116D-03 | 0.230D-03 | 0.139D-03 | 0.550D-03 | | | 0.133D 04 | 0.525D 04 |
| | | 7/2 - 5/2 | -0.116D-03 | 0.230D-03 | 0.208D-02 | 0.824D-02 | | | 0.267D 05 | 0.105D 06 |
| 6 | 9 | 5/2 - 3/2 | -0.432D-03 | 0.730D-03 | 0.803D-01 | 0.2300 00 | | | 0.131D 05 | 0.373D 06 |
| | | 5/2 - 5/2 | -0.413D-03 | 0.690D-03 | 0.521D-02 | 0.145D-01 | | | 0.576D 04 | 0.160D 05 |
| | | 7/2 - 5/2 | -0.413D-03 | 0.690D-03 | 0.782D-01 | 0.218D 00 | | | 0.115D 06 | 0.320D 06 |

APPENDIX 9 : Plots of $n^{*3}f_{ij}$ versus $n^*$ indicating the behavior of the relativistic oscillator strengths as a function of the effective principal quantum number for several Thallium I series. The oscillator strengths were calculated from the orthogonalized free-core Hartree-Fock-Slater wave functions and are taken from Appendix (8). The oscillator strengths correspond to those derived in the velocity formulation. The theoretical curves are denoted by (RHFS) and the corresponding plots formed from the combined experimental data of Norton and Gallagher, and Penkin and Shabanova are designated by (NG-PS).









## APPENDIX 10: THALLIUM$_I$ LIFETIMES

Atomic lifetimes for $Tl_I$ are calculated from both the length and velocity forms of the transition probabilities determined from the HFS wave functions and from the orthogonalized wave functions. The lifetimes are compared to those found from the Bates-Damgaard (B-D) transition probabilities shown in Appendix (12), and to existing experimental values.

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $7^2S_{1/2}$ | 11 | 5.1 | 8.1 | 11 | 5.1 | 8.1 | 16.9 | $7.7\pm0.5$[a]; 7.65[b]; $7.55\pm0.08$[c] |
| $8^2S_{1/2}$ | 31.6 | 30.8 | 31.2 | 22.4 | 18.6 | 20.5 | 43 | $23\pm9$[a] |
| $9^2S_{1/2}$ | 74.4 | 108 | 91.2 | 38.9 | 40.2 | 39.6 | 94 | |
| $10^2S_{1/2}$ | 153 | 282 | 217 | 66.2 | 78.6 | 72.4 | 174 | |
| $11^2S_{1/2}$ | 277 | 600 | 438 | 107 | 133 | 120 | | |
| $7^2P_{1/2}$ | 73.5 | 52.9 | 63.2 | 53.8 | 57.5 | 55.7 | 61.7 | |
| $7^2P_{3/2}$ | 52.4 | 38.8 | 45.6 | 38.5 | 45 | 41.8 | 48.3 | |
| $8^2P_{1/2}$ | 200 | 152 | 176 | 186 | 160 | 173 | 183 | |
| $8^2P_{3/2}$ | 148 | 126 | 137 | 115 | 131 | 123 | 193 | |
| $9^2P_{1/2}$ | 461 | 359 | 410 | 427 | 408 | 418 | 333 | |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{B-D}$(nsec) | $\tau_{EXPT}$(nsec) |
| $9^2P_{3/2}$ | 345 | 334 | 339 | 236 | 317 | 278 | 234 | |
| $10^2P_{1/2}$ | 885 | 637 | 761 | 728 | 763 | 746 | | |
| $10^2P_{3/2}$ | 695 | 674 | 685 | 475 | 689 | 582 | | |
| $6^2D_{3/2}$ | 5.1 | 4.3 | 4.7 | 5.1 | 4.2 | 4.7 | 6.7 | $6.8\pm0.5$[a]; $6.9\pm0.4$[b]; |
| $6^2D_{5/2}$ | 6.4 | 4.9 | 5.6 | 6.4 | 4.9 | 5.6 | 7.4 | $7.6\pm0.5$[a] |
| $7^2D_{3/2}$ | 8.5 | 10.4 | 9.5 | 5.9 | 6.6 | 6.3 | 14.9 | $16\pm4$[a] |
| $7^2D_{5/2}$ | 12 | 14.2 | 13.1 | 8.2 | 9.0 | 8.6 | 16.5 | $19\pm4$[a] |
| $8^2D_{3/2}$ | 18.7 | 30.7 | 24.7 | 9.0 | 12.2 | 10.6 | 28 | |
| $8^2D_{5/2}$ | 27.1 | 45.4 | 36.2 | 12.9 | 17.2 | 15.1 | 31.3 | $50\pm10$[a] |
| $9^2D_{3/2}$ | 38.5 | 74.5 | 56.5 | 15.3 | 23 | 19.2 | | |
| $9^2D_{5/2}$ | 56.4 | 113 | 85 | 22.1 | 33.2 | 27.7 | | |
| $5^2F_{5/2}$ | 62.1 | 54.9 | 58.5 | 62.2 | 54.9 | 58.6 | 58.4 | |
| $5^2F_{7/2}$ | 62.8 | 54.9 | 58.9 | 62.9 | 54.9 | 58.9 | 58.8 | |

| | NON-ORTHOGONAL WAVE FUNCTIONS | | | ORTHOGONAL WAVE FUNCTIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| STATE | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{VEL}$(nsec) | $\tau_{LNG}$(nsec) | $\tau_{AVG}$(nsec) | $\tau_{BAD}$(nsec) | $\tau_{EXPT}$(nsec) |
| $6^2F_{5/2}$ | 128 | 121 | 125 | 118 | 124 | 121 | 107 | |
| $6^2F_{7/2}$ | 129 | 130 | 130 | 120 | 125 | 123 | 109 | |

a) Anderson and Sørensen[86]

b) Cunningham and Link[87]

c) Hsieh[88]

## APPENDIX 11: COMPARISON OF OBSERVED AND PREDICTED ENERGIES FOR $Tl_I$ AND $Cs_I$ STATES

TABLE 1: $THALLIUM_I$

| STATE | OBSERVED ENERGY($cm^{-1}$) | NON-ORTHOGONALIZED RELATIVISTIC HFS ENERGY($cm^{-1}$) | PERCENTAGE DIFFERENCE |
|---|---|---|---|
| $7^2S_{1/2}$ | 22786.7 | 22598.4 | 0.8 |
| $8^2S_{1/2}$ | 10518.3 | 10997.2 | 4.6 |
| $9^2S_{1/2}$ | 6098.0 | 6472.3 | 6.1 |
| $10^2S_{1/2}$ | 3967.4 | 4228.6 | 6.6 |
| $11^2S_{1/2}$ | 2807.3 | 2968.2 | 5.7 |
| $6^2P_{1/2}$ | 49264.2 | 42110.3 | 14.5 |
| $6^2P_{3/2}$ | 41471.5 | 35293.6 | 14.9 |
| $7^2P_{1/2}$ | 15104.3 | 16116.7 | 6.7 |
| $7^2P_{3/2}$ | 14103.1 | 15136.2 | 7.3 |
| $8^2P_{1/2}$ | 7896.1 | 8448.9 | 7.0 |
| $8^2P_{3/2}$ | 7523.4 | 8060.0 | 7.1 |
| $9^2P_{1/2}$ | 4883.3 | 5249.6 | 7.5 |
| $9^2P_{3/2}$ | 4701.7 | 5044.1 | 7.3 |
| $10^2P_{1/2}$ | 3324.9 | 3560.9 | 7.1 |
| $10^2P_{3/2}$ | 3220.6 | 3443.9 | 6.9 |
| $6^2D_{3/2}$ | 13146.3 | 12652.4 | 3.8 |
| $6^2D_{5/2}$ | 13064.3 | 12564.9 | 3.8 |
| $7^2D_{3/2}$ | 7252.8 | 7593.3 | 4.7 |
| $7^2D_{5/2}$ | 7215.2 | 7505.3 | 4.0 |
| $8^2D_{3/2}$ | 4591.6 | 4961.7 | 8.1 |

TABLE 1: $THALLIUM_I$

| STATE | OBSERVED ENERGY($cm^{-1}$) | NON-ORTHOGONALIZED RELATIVISTIC HFS ENERGY($cm^{-1}$) | PERCENTAGE DIFFERENCE |
|---|---|---|---|
| $8^2D_{5/2}$ | 4571.5 | 4907.7 | 7.4 |
| $9^2D_{3/2}$ | 3165.7 | 3428.5 | 8.3 |
| $9^2D_{5/2}$ | 3153.9 | 3397.2 | 7.7 |
| $5^2F_{5/2}$ | 6945.8 | 6876.7 | 1.0 |
| $5^2F_{7/2}$ | 6945.8 | 6876.7 | 1.0 |
| $6^2F_{5/2}$ | 4440.7 | 4415.7 | 0.6 |
| $6^2F_{7/2}$ | 4440.7 | 4415.6 | 0.6 |

TABLE 2: CESIUM I

| STATE | OBSERVED ENERGY($cm^{-1}$) | NON-ORTHOGONALIZED RELATIVISTIC HFS ENERGY($cm^{-1}$) | PERCENTAGE DIFFERENCE |
|---|---|---|---|
| $6^2S_{1/2}$ | 31406.71 | 29814.8 | 5.1 |
| $7^2S_{1/2}$ | 12871.20 | 13797.4 | 8.2 |
| $8^2S_{1/2}$ | 7089.54 | 7669.3 | 8.2 |
| $9^2S_{1/2}$ | 4496.03 | 4826.4 | 7.4 |
| $10^2S_{1/2}$ | 3106.43 | 3322.6 | 7.0 |
| $11^2S_{1/2}$ | 2276.71 | 2419.2 | 6.3 |
| $12^2S_{1/2}$ | 1740.71 | 1837.4 | 5.6 |
| $13^2S_{1/2}$ | | 1441.9 | |
| $14^2S_{1/2}$ | | 1161.2 | |
| $15^2S_{1/2}$ | | 954.9 | |
| $6^2P_{1/2}$ | 20228.47 | 19929.4 | 1.5 |
| $6^2P_{3/2}$ | 19674.36 | 19397.3 | 1.4 |
| $7^2P_{1/2}$ | 9641.06 | 10237.4 | 6.2 |
| $7^2P_{3/2}$ | 9460.05 | 9975.0 | 5.4 |
| $8^2P_{1/2}$ | 5697.57 | 6142.7 | 7.8 |
| $8^2P_{3/2}$ | 5614.93 | 6016.9 | 7.2 |
| $9^2P_{1/2}$ | 3769.42 | 4053.7 | 7.5 |
| $9^2P_{3/2}$ | 3724.75 | 3986.8 | 7.0 |
| $10^2P_{1/2}$ | 2679.62 | 2863.8 | 6.9 |
| $10^2P_{1/2}$ | 2652.78 | 2824.8 | 6.5 |
| $11^2P_{1/2}$ | 2003.03 | 2127.1 | 6.2 |

TABLE 2: CESIUM I

| STATE | OBSERVED ENERGY($cm^{-1}$) | NON-ORTHOGONALIZED RELATIVISTIC HFS ENERGY($cm^{-1}$) | PERCENTAGE DIFFERENCE |
|---|---|---|---|
| $11^2P_{3/2}$ | 1985.61 | 2102.4 | 5.9 |
| $12^2P_{1/2}$ | 1553.86 | 1640.9 | 5.6 |
| $12^2P_{3/2}$ | 1541.99 | 1624.4 | 5.3 |
| $13^2P_{1/2}$ | 1240.71 | 1311.6 | 5.7 |
| $13^2P_{3/2}$ | 1232.20 | 1299.7 | 5.5 |
| $14^2P_{1/2}$ | 1013.55 | 1066.5 | 5.2 |
| $14^2P_{3/2}$ | 1007.22 | 1057.9 | 5.0 |
| $15^2P_{1/2}$ | 843.44 | 883.9 | 4.8 |
| $15^2P_{3/2}$ | 838.73 | 877.5 | 4.6 |
| $5^2D_{3/2}$ | 16907.22 | 16379.2 | 3.1 |
| $5^2D_{5/2}$ | 16809.63 | 16198.9 | 3.6 |
| $6^2D_{3/2}$ | 8817.82 | 10463.6 | 18.7 |
| $6^2D_{5/2}$ | 8774.88 | 10402.6 | 18.6 |
| $7^2D_{3/2}$ | 5358.85 | 6121.8 | 14.2 |
| $7^2D_{5/2}$ | 5337.88 | 6099.7 | 14.3 |
| $8^2D_{3/2}$ | 3595.46 | 4043.4 | 12.5 |
| $8^2D_{5/2}$ | 3683.77 | 4030.3 | 9.4 |
| $9^2D_{3/2}$ | 2577.81 | 2867.2 | 11.2 |
| $9^2D_{5/2}$ | 2570.65 | 2859.3 | 11.2 |
| $10^2D_{3/2}$ | 1938.17 | 2131.9 | 10.0 |
| $10^2D_{5/2}$ | 1933.49 | 2126.9 | 10.0 |
| $11^2D_{3/2}$ | 1510.07 | 1644.9 | 8.9 |

TABLE 2: $CESIUM_I$

| STATE | OBSERVED ENERGY($cm^{-1}$) | NON-ORTHOGONALIZED RELATIVISTIC HFS ENERGY($cm^{-1}$) | PERCENTAGE DIFFERENCE |
|---|---|---|---|
| $11^2D_{5/2}$ | 1506.82 | 1641.5 | 8.9 |
| $12^2D_{3/2}$ | 1209.69 | 1306.8 | 8.0 |
| $12^2D_{5/2}$ | 1207.36 | 1304.3 | 8.0 |
| $13^2D_{3/2}$ | 990.65 | 1062.7 | 7.3 |
| $13^2D_{5/2}$ | 988.95 | 1060.9 | 7.3 |
| $14^2D_{3/2}$ | 826.25 | 880.9 | 6.6 |
| $14^2D_{5/2}$ | 824.92 | 879.6 | 6.6 |
| $4^2F_{5/2}$ | 6934.42 | 6924.9 | 0.1 |
| $4^2F_{7/2}$ | 6934.25 | 6919.9 | 0.2 |
| $5^2F_{5/2}$ | 4435.30 | 4533.1 | 2.2 |
| $5^2F_{7/2}$ | 4435.15 | 4522.7 | 2.0 |
| $6^2F_{5/2}$ | 3076.95 | 3103.2 | 0.9 |
| $6^2F_{7/2}$ | 3077.05 | 3133.3 | 1.8 |
| $7^2F_{5/2}$ | 2258.49 | 2989.6 | 32.4 |
| $7^2F_{7/2}$ | 2258.55 | 2308.5 | 2.2 |
| $8^2F_{5/2}$ | 1727.73 | 2251.7 | 30.3 |
| $8^2F_{7/2}$ | 1727.78 | 2241.7 | 29.7 |
| $9^2F_{5/2}$ | 1364.17 | 1734.7 | 27.2 |
| $9^2F_{7/2}$ | 1364.20 | 1730.0 | 26.8 |
| $10^2F_{5/2}$ | 1104.32 | 1373.1 | 24.3 |
| $10^2F_{7/2}$ | 1104.33 | 1370.4 | 24.1 |
| $11^2F_{5/2}$ | 912.12 | 1112.3 | 22.0 |

## APPENDIX 12 : Non-Relativistic Cesium I Oscillator Strengths

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 6 | 7 | 1/2 - 1/2 | 0.480D 01 | 0.171D 00 | 0.618D 07 | 0.162D 00 | 0.196D-03 | 0.709D 04 |
| | | 3/2 - 1/2 | 0.521D 01 | 0.187D 00 | 0.116D 08 | 0.889D 00 | 0.545D-02 | 0.336D 06 |
| 6 | 9 | 1/2 - 1/2 | 0.602D 00 | 0.578D-02 | 0.954D 06 | -0.185D 01 | 0.547D-01 | 0.903D 07 |
| | | 3/2 - 1/2 | 0.605D 00 | 0.563D-02 | 0.173D 07 | -0.192D 01 | 0.564D-01 | 0.173D 08 |
| 6 | 10 | 1/2 - 1/2 | -0.397D 00 | 0.273D-02 | 0.533D 06 | -0.106D 01 | 0.196D-01 | 0.383D 07 |
| | | 3/2 - 1/2 | -0.397D 00 | 0.264D-02 | 0.967D 06 | -0.118D 01 | 0.233D-01 | 0.854D 07 |
| 6 | 11 | 1/2 - 1/2 | 0.290D 00 | 0.152D-02 | 0.328D 06 | -0.464D 00 | 0.391D-02 | 0.840D 06 |
| | | 3/2 - 1/2 | 0.289D 00 | 0.147D-02 | 0.593D 06 | -0.587D 00 | 0.607D-02 | 0.245D 07 |
| 6 | 12 | 1/2 - 1/2 | -0.225D 00 | 0.944D-03 | 0.215D 06 | -0.605D-01 | 0.686D-04 | 0.156D 05 |
| | | 3/2 - 1/2 | -0.223D 00 | 0.905D-03 | 0.388D 06 | -0.175D 00 | 0.553D-03 | 0.237D 06 |
| 6 | 13 | 1/2 - 1/2 | 0.107D 00 | 0.218D-03 | 0.513D 05 | 0.235D-01 | 0.105D-04 | 0.248D 04 |
| | | 3/2 - 1/2 | 0.918D-01 | 0.156D-03 | 0.690D 05 | -0.755D-01 | 0.105D-03 | 0.466D 05 |
| 6 | 14 | 1/2 - 1/2 | -0.874D-01 | 0.148D-03 | 0.358D 05 | 0.220D 00 | 0.930D-03 | 0.226D 06 |
| | | 3/2 - 1/2 | -0.746D-01 | 0.104D-03 | 0.477D 05 | 0.133D 00 | 0.332D-03 | 0.152D 06 |
| 6 | 15 | 1/2 - 1/2 | 0.736D-01 | 0.106D-03 | 0.262D 05 | 0.344D 00 | 0.231D-02 | 0.571D 06 |
| | | 3/2 - 1/2 | 0.626D-01 | 0.743D-04 | 0.347D 05 | 0.270D 00 | 0.139D-02 | 0.647D 06 |
| 7 | 9 | 1/2 - 1/2 | -0.235D 01 | 0.287D-01 | 0.507D 06 | -0.196D 01 | 0.201D-01 | 0.354D 06 |
| | | 3/2 - 1/2 | -0.231D 01 | 0.269D-01 | 0.885D 06 | -0.163D 01 | 0.134D-01 | 0.441D 06 |
| 7 | 10 | 1/2 - 1/2 | 0.119D 01 | 0.938D-02 | 0.267D 06 | -0.265D 01 | 0.463D-01 | 0.132D 07 |
| | | 3/2 - 1/2 | 0.116D 01 | 0.862D-02 | 0.464D 06 | -0.252D 01 | 0.410D-01 | 0.221D 07 |
| 7 | 11 | 1/2 - 1/2 | -0.769D 00 | 0.441D-02 | 0.160D 06 | -0.237D 01 | 0.419D-01 | 0.152D 07 |
| | | 3/2 - 1/2 | -0.743D 00 | 0.402D-02 | 0.276D 06 | -0.235D 01 | 0.403D-01 | 0.277D 07 |
| 7 | 12 | 1/2 - 1/2 | 0.556D 00 | 0.247D-02 | 0.103D 06 | -0.190D 01 | 0.289D-01 | 0.120D 07 |
| | | 3/2 - 1/2 | 0.534D 00 | 0.223D-02 | 0.177D 06 | -0.194D 01 | 0.294D-01 | 0.234D 07 |
| 7 | 13 | 1/2 - 1/2 | -0.188D 00 | 0.292D-03 | 0.131D 05 | -0.156D 01 | 0.201D-01 | 0.902D 06 |
| | | 3/2 - 1/2 | -0.140D 00 | 0.159D-03 | 0.137D 05 | -0.160D 01 | 0.207D-01 | 0.178D 07 |
| 7 | 14 | 1/2 - 1/2 | 0.147D 00 | 0.186D-03 | 0.890D 04 | -0.120D 01 | 0.123D-01 | 0.590D 06 |
| | | 3/2 - 1/2 | 0.108D 00 | 0.988D-04 | 0.908D 04 | -0.126D 01 | 0.133D-01 | 0.123D 07 |
| 7 | 15 | 1/2 - 1/2 | -0.120D 00 | 0.128D-03 | 0.642D 04 | -0.883D 00 | 0.686D-02 | 0.345D 06 |
| | | 3/2 - 1/2 | -0.883D-01 | 0.671D-04 | 0.648D 04 | -0.957D 00 | 0.789D-02 | 0.761D 06 |
| 8 | 9 | 1/2 - 1/2 | 0.195D 02 | 0.462D 00 | 0.445D 06 | 0.107D 02 | 0.139D 00 | 0.134D 06 |
| | | 3/2 - 1/2 | 0.207D 02 | 0.486D 00 | 0.811D 06 | 0.123D 02 | 0.170D 00 | 0.285D 06 |
| 8 | 10 | 1/2 - 1/2 | -0.384D 01 | 0.386D-01 | 0.173D 06 | -0.606D 00 | 0.962D-03 | 0.431D 04 |
| | | 3/2 - 1/2 | -0.373D 01 | 0.354D-01 | 0.297D 06 | -0.134D 00 | 0.457D-04 | 0.384D 03 |
| 8 | 11 | 1/2 - 1/2 | 0.189D 01 | 0.123D-01 | 0.963D 05 | -0.241D 01 | 0.202D-01 | 0.157D 06 |
| | | 3/2 - 1/2 | 0.181D 01 | 0.110D-01 | 0.164D 06 | -0.216D 01 | 0.156D-01 | 0.235D 06 |
| 8 | 12 | 1/2 - 1/2 | -0.120D 01 | 0.576D-02 | 0.602D 05 | -0.273D 01 | 0.299D-01 | 0.313D 06 |
| | | 3/2 - 1/2 | -0.114D 01 | 0.508D-02 | 0.102D 06 | -0.260D 01 | 0.265D-01 | 0.531D 06 |
| 8 | 13 | 1/2 - 1/2 | 0.314D 00 | 0.425D-03 | 0.514D 04 | -0.230D 01 | 0.228D-01 | 0.275D 06 |
| | | 3/2 - 1/2 | 0.207D 00 | 0.182D-03 | 0.422D 04 | -0.220D 01 | 0.205D-01 | 0.476D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 8 | 14 | 1/2 - 1/2 | -0.232D 00 | 0.246D-03 | 0.338D 04 | -0.219D 01 | 0.221D-01 | 0.303D 06 |
| | | 3/2 - 1/2 | -0.149D 00 | 0.101D-03 | 0.266D 04 | -0.215D 01 | 0.208D-01 | 0.551D 06 |
| 8 | 15 | 1/2 - 1/2 | 0.182D 00 | 0.160D-03 | 0.240D 04 | -0.197D 01 | 0.187D-01 | 0.281D 06 |
| | | 3/2 - 1/2 | 0.116D 00 | 0.636D-04 | 0.184D 04 | -0.197D 01 | 0.182D-01 | 0.529D 06 |
| 9 | 10 | 1/2 - 1/2 | 0.299D 02 | 0.598D 00 | 0.175D 06 | 0.178D 02 | 0.212D 00 | 0.622D 05 |
| | | 3/2 - 1/2 | 0.316D 02 | 0.626D 00 | 0.319D 06 | 0.198D 02 | 0.245D 00 | 0.125D 06 |
| 9 | 11 | 1/2 - 1/2 | -0.561D 01 | 0.476D-01 | 0.708D 05 | 0.126D 01 | 0.242D-02 | 0.359D 04 |
| | | 3/2 - 1/2 | -0.541D 01 | 0.430D-01 | 0.120D 06 | 0.184D 01 | 0.499D-02 | 0.140D 05 |
| 9 | 12 | 1/2 - 1/2 | 0.270D 01 | 0.150D-01 | 0.410D 05 | -0.165D 01 | 0.559D-02 | 0.153D 05 |
| | | 3/2 - 1/2 | 0.255D 01 | 0.131D-01 | 0.687D 05 | -0.131D 01 | 0.343D-02 | 0.180D 05 |
| 9 | 13 | 1/2 - 1/2 | -0.555D 00 | 0.725D-03 | 0.262D 04 | -0.156D 01 | 0.576D-02 | 0.208D 05 |
| | | 3/2 - 1/2 | -0.329D 00 | 0.250D-03 | 0.174D 04 | -0.132D 01 | 0.406D-02 | 0.282D 05 |
| 9 | 14 | 1/2 - 1/2 | 0.370D 00 | 0.361D-03 | 0.164D 04 | -0.215D 01 | 0.122D-01 | 0.556D 05 |
| | | 3/2 - 1/2 | 0.209D 00 | 0.114D-03 | 0.995D 03 | -0.199D 01 | 0.102D-01 | 0.898D 05 |
| 9 | 15 | 1/2 - 1/2 | -0.274D 00 | 0.214D-03 | 0.113D 04 | -0.233D 01 | 0.155D-01 | 0.920D 05 |
| | | 3/2 - 1/2 | -0.151D 00 | 0.640D-04 | 0.655D 03 | -0.222D 01 | 0.138D-01 | 0.142D 06 |
| 10 | 11 | 1/2 - 1/2 | 0.425D 02 | 0.736D 00 | 0.797D 05 | 0.263D 02 | 0.292D 00 | 0.306D 05 |
| | | 3/2 - 1/2 | 0.449D 02 | 0.767D 00 | 0.145D 06 | 0.288D 02 | 0.316D 00 | 0.596D 05 |
| 10 | 12 | 1/2 - 1/2 | -0.767D 01 | 0.560D-01 | 0.329D 05 | 0.353D 01 | 0.119D-01 | 0.697D 04 |
| | | 3/2 - 1/2 | -0.735D 01 | 0.499D-01 | 0.553D 05 | 0.420D 01 | 0.163D-01 | 0.131D 05 |
| 10 | 13 | 1/2 - 1/2 | 0.116D 01 | 0.167D-02 | 0.171D 04 | 0.135D 01 | 0.228D-02 | 0.233D 04 |
| | | 3/2 - 1/2 | 0.645D 00 | 0.510D-03 | 0.998D 03 | 0.172D 01 | 0.365D-02 | 0.713D 04 |
| 10 | 14 | 1/2 - 1/2 | -0.638D 00 | 0.626D-03 | 0.963D 03 | -0.735D 00 | 0.832D-03 | 0.128D 04 |
| | | 3/2 - 1/2 | -0.322D 00 | 0.157D-03 | 0.466D 03 | -0.450D 00 | 0.306D-03 | 0.908D 03 |
| 10 | 15 | 1/2 - 1/2 | 0.427D 00 | 0.318D-03 | 0.631D 03 | -0.170D 01 | 0.567D-02 | 0.101D 05 |
| | | 3/2 - 1/2 | 0.264D 00 | 0.716D-04 | 0.275D 03 | -0.149D 01 | 0.379D-02 | 0.146D 05 |
| 11 | 12 | 1/2 - 1/2 | 0.574D 02 | 0.874D 00 | 0.401D 05 | 0.363D 02 | 0.350D 00 | 0.161D 05 |
| | | 3/2 - 1/2 | 0.605D 02 | 0.907D 00 | 0.726D 05 | 0.393D 02 | 0.383D 00 | 0.307D 05 |
| 11 | 13 | 1/2 - 1/2 | -0.376D 01 | 0.805D-02 | 0.169D 04 | 0.965D 01 | 0.527D-01 | 0.111D 05 |
| | | 3/2 - 1/2 | -0.229D 01 | 0.287D-02 | 0.113D 04 | 0.102D 02 | 0.572D-01 | 0.226D 05 |
| 11 | 14 | 1/2 - 1/2 | 0.133D 01 | 0.150D-02 | 0.709D 03 | 0.292D 01 | 0.729D-02 | 0.344D 04 |
| | | 3/2 - 1/2 | 0.640D 00 | 0.342D-03 | 0.310D 03 | 0.332D 01 | 0.923D-02 | 0.836D 04 |
| 11 | 15 | 1/2 - 1/2 | -0.729D 00 | 0.564D-03 | 0.413D 03 | 0.256D 00 | 0.696D-04 | 0.510D 02 |
| | | 3/2 - 1/2 | -0.310D 00 | 0.100D-03 | 0.142D 03 | 0.574D 00 | 0.344D-03 | 0.488D 03 |
| 12 | 13 | 1/2 - 1/2 | 0.937D 02 | 0.994D 00 | 0.831D 04 | 0.691D 02 | 0.541D 00 | 0.452D 04 |
| | | 3/2 - 1/2 | 0.966D 02 | 0.946D 00 | 0.126D 05 | 0.727D 02 | 0.536D 00 | 0.716D 04 |
| 12 | 14 | 1/2 - 1/2 | -0.438D 01 | 0.764D-02 | 0.786D 03 | 0.128D 02 | 0.655D-01 | 0.673D 04 |
| | | 3/2 - 1/2 | -0.246D 01 | 0.233D-02 | 0.450D 03 | 0.134D 02 | 0.691D-01 | 0.134D 05 |
| 12 | 15 | 1/2 - 1/2 | 0.151D 01 | 0.138D-02 | 0.330D 03 | 0.463D 01 | 0.130D-01 | 0.312D 04 |
| | | 3/2 - 1/2 | 0.628D 00 | 0.235D-03 | 0.108D 03 | 0.505D 01 | 0.151D-01 | 0.696D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 13 | 14 | 1/2 - 1/2 | 0.118D 03 | 0.112D 01 | 0.470D 04 | 0.855D 02 | 0.589D 00 | 0.248D 04 |
| | | 3/2 - 1/2 | 0.121D 03 | 0.106D 01 | 0.711D 04 | 0.898D 02 | 0.580D 00 | 0.390D 04 |
| 13 | 15 | 1/2 - 1/2 | -0.514D 01 | 0.763D-02 | 0.416D 03 | 0.162D 02 | 0.762D-01 | 0.415D 04 |
| | | 3/2 - 1/2 | -0.269D 01 | 0.204D-02 | 0.209D 03 | 0.168D 02 | 0.794D-01 | 0.815D 04 |
| 14 | 15 | 1/2 - 1/2 | 0.144D 03 | 0.124D 01 | 0.284D 04 | 0.103D 03 | 0.636D 00 | 0.146D 04 |
| | | 3/2 - 1/2 | 0.149D 03 | 0.117D 01 | 0.428D 04 | 0.108D 03 | 0.624D 00 | 0.228D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - mp^2P_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 6 | 6 | 1/2 - 1/2 | 0.552D 01 | 0.345D 00 | 0.288D 08 | -0.135D 02 | 0.207D 01 | 0.173D 09 |
| | | 1/2 - 3/2 | 0.547D 01 | 0.712D 00 | 0.327D 08 | -0.130D 02 | 0.399D 01 | 0.183D 09 |
| 6 | 7 | 1/2 - 1/2 | -0.578D 00 | 0.735D-02 | 0.232D 07 | -0.260D 01 | 0.149D 00 | 0.470D 08 |
| | | 1/2 - 3/2 | -0.715D 00 | 0.227D-01 | 0.365D 07 | -0.238D 01 | 0.251D 00 | 0.404D 08 |
| 6 | 8 | 1/2 - 1/2 | 0.257D 00 | 0.172D-02 | 0.760D 06 | 0.446D-01 | 0.517D-04 | 0.228D 05 |
| | | 1/2 - 3/2 | 0.337D 00 | 0.592D-02 | 0.131D 07 | 0.178D 00 | 0.165D-02 | 0.366D 06 |
| 6 | 9 | 1/2 - 1/2 | -0.159D 00 | 0.707D-03 | 0.360D 06 | 0.101D 01 | 0.285D-01 | 0.145D 08 |
| | | 1/2 - 3/2 | -0.213D 00 | 0.253D-02 | 0.648D 06 | 0.108D 01 | 0.656D-01 | 0.168D 08 |
| 6 | 10 | 1/2 - 1/2 | 0.113D 00 | 0.369D-03 | 0.203D 06 | 0.130D 01 | 0.495D-01 | 0.273D 08 |
| | | 1/2 - 3/2 | 0.152D 00 | 0.135D-02 | 0.373D 06 | 0.134D 01 | 0.105D 00 | 0.290D 08 |
| 6 | 11 | 1/2 - 1/2 | -0.860D-01 | 0.220D-03 | 0.127D 06 | 0.133D 01 | 0.524D-01 | 0.302D 08 |
| | | 1/2 - 3/2 | -0.117D 00 | 0.818D-03 | 0.236D 06 | 0.135D 01 | 0.108D 00 | 0.311D 08 |
| 6 | 12 | 1/2 - 1/2 | 0.692D-01 | 0.145D-03 | 0.860D 05 | 0.124D 01 | 0.465D-01 | 0.276D 08 |
| | | 1/2 - 3/2 | 0.944D-01 | 0.539D-03 | 0.160D 06 | 0.125D 01 | 0.942D-01 | 0.280D 08 |
| 6 | 13 | 1/2 - 1/2 | -0.571D-01 | 0.996D-04 | 0.605D 05 | 0.112D 01 | 0.382D-01 | 0.232D 08 |
| | | 1/2 - 3/2 | -0.783D-01 | 0.374D-03 | 0.114D 06 | 0.112D 01 | 0.766D-01 | 0.233D 08 |
| 6 | 14 | 1/2 - 1/2 | 0.483D-01 | 0.718D-04 | 0.442D 05 | 0.991D 00 | 0.302D-01 | 0.186D 08 |
| | | 1/2 - 3/2 | 0.664D-01 | 0.272D-03 | 0.837D 05 | 0.990D 00 | 0.604D-01 | 0.186D 08 |
| 6 | 15 | 1/2 - 1/2 | -0.419D-01 | 0.544D-04 | 0.339D 05 | 0.873D 00 | 0.236D-01 | 0.147D 08 |
| | | 1/2 - 3/2 | -0.573D-01 | 0.203D-03 | 0.634D 05 | 0.870D 00 | 0.469D-01 | 0.146D 08 |
| 7 | 7 | 1/2 - 1/2 | 0.125D 02 | 0.509D 00 | 0.354D 07 | -0.274D 02 | 0.246D 01 | 0.171D 08 |
| | | 1/2 - 3/2 | 0.122D 02 | 0.104D 01 | 0.402D 07 | -0.268D 02 | 0.496D 01 | 0.192D 08 |
| 7 | 8 | 1/2 - 1/2 | -0.121D 01 | 0.107D-01 | 0.368D 06 | -0.767D 01 | 0.427D 00 | 0.147D 08 |
| | | 1/2 - 3/2 | -0.149D 01 | 0.325D-01 | 0.571D 06 | -0.758D 01 | 0.843D 00 | 0.144D 09 |
| 7 | 9 | 1/2 - 1/2 | 0.485D 00 | 0.217D-02 | 0.120D 06 | -0.386D 01 | 0.138D 00 | 0.760D 07 |
| | | 1/2 - 3/2 | 0.642D 00 | 0.762D-02 | 0.213D 06 | -0.373D 01 | 0.254D 00 | 0.719D 07 |
| 7 | 10 | 1/2 - 1/2 | -0.280D 00 | 0.809D-03 | 0.561D 05 | -0.186D 01 | 0.354D-01 | 0.248D 07 |
| | | 1/2 - 3/2 | -0.386D 00 | 0.308D-02 | 0.107D 06 | -0.174D 01 | 0.630D-01 | 0.214D 07 |
| 7 | 11 | 1/2 - 1/2 | 0.190D 00 | 0.399D-03 | 0.314D 05 | -0.680D 00 | 0.598D-02 | 0.400D 06 |
| | | 1/2 - 3/2 | 0.269D 00 | 0.159D-02 | 0.628D 05 | -0.585D 00 | 0.754D-02 | 0.298D 06 |
| 7 | 12 | 1/2 - 1/2 | -0.142D 00 | 0.233D-03 | 0.199D 05 | 0.362D-01 | 0.150D-04 | 0.128D 04 |
| | | 1/2 - 3/2 | -0.204D 00 | 0.951D-03 | 0.407D 05 | 0.109D 00 | 0.273D-03 | 0.117D 05 |
| 7 | 13 | 1/2 - 1/2 | 0.112D 00 | 0.148D-03 | 0.133D 05 | 0.466D 00 | 0.255D-02 | 0.231D 06 |
| | | 1/2 - 3/2 | 0.162D 00 | 0.618D-03 | 0.279D 05 | 0.522D 00 | 0.642D-02 | 0.290D 06 |
| 7 | 14 | 1/2 - 1/2 | -0.914D-01 | 0.100D-03 | 0.941D 04 | 0.720D 00 | 0.622D-02 | 0.584D 06 |
| | | 1/2 - 3/2 | -0.134D 00 | 0.428D-03 | 0.201D 05 | 0.763D 00 | 0.140D-01 | 0.656D 06 |
| 7 | 15 | 1/2 - 1/2 | 0.775D-01 | 0.731D-04 | 0.705D 04 | 0.864D 00 | 0.907D-02 | 0.877D 06 |
| | | 1/2 - 3/2 | 0.113D 00 | 0.310D-03 | 0.150D 05 | 0.896D 00 | 0.196D-01 | 0.944D 06 |
| 8 | 8 | 1/2 - 1/2 | -0.139D 00 | 0.419D-03 | 0.128D 06 | -0.155D 01 | 0.523D-01 | 0.160D 08 |
| | | 1/2 - 3/2 | -0.317D-01 | 0.437D-04 | 0.671D 04 | -0.191D 01 | 0.159D 00 | 0.244D 08 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - mp^2P_{j'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 8 | 9 | 1/2 - 1/2 | 0.103D 00 | 0.250D-03 | 0.906D 05 | -0.303D 01 | 0.216D 00 | 0.785D 08 |
| | | 1/2 - 3/2 | 0.336D-01 | 0.534D-04 | 0.973D 04 | -0.319D 01 | 0.481D 00 | 0.876D 08 |
| 8 | 10 | 1/2 - 1/2 | -0.787D-01 | 0.153D-03 | 0.608D 05 | -0.323D 01 | 0.259D 00 | 0.103D 09 |
| | | 1/2 - 3/2 | -0.287D-01 | 0.408D-04 | 0.812D 04 | -0.330D 01 | 0.539D 00 | 0.107D 09 |
| 8 | 11 | 1/2 - 1/2 | 0.625D-01 | 0.992D-04 | 0.416D 05 | -0.298D 01 | 0.226D 00 | 0.947D 08 |
| | | 1/2 - 3/2 | 0.239D-01 | 0.290D-04 | 0.609D 04 | -0.300D 01 | 0.458D 00 | 0.963D 08 |
| 8 | 12 | 1/2 - 1/2 | -0.507D-01 | 0.664D-04 | 0.289D 05 | -0.259D 01 | 0.174D 00 | 0.757D 08 |
| | | 1/2 - 3/2 | -0.198D-01 | 0.202D-04 | 0.440D 04 | -0.259D 01 | 0.348D 00 | 0.757D 08 |
| 8 | 13 | 1/2 - 1/2 | 0.425D-01 | 0.473D-04 | 0.211D 05 | -0.220D 01 | 0.127D 00 | 0.564D 08 |
| | | 1/2 - 3/2 | 0.168D-01 | 0.148D-04 | 0.330D 04 | -0.219D 01 | 0.250D 00 | 0.558D 08 |
| 8 | 14 | 1/2 - 1/2 | -0.363D-01 | 0.349D-04 | 0.158D 05 | -0.184D 01 | 0.895D-01 | 0.406D 08 |
| | | 1/2 - 3/2 | -0.144D-01 | 0.110D-04 | 0.249D 04 | -0.182D 01 | 0.175D 00 | 0.399D 08 |
| 8 | 15 | 1/2 - 1/2 | 0.311D-01 | 0.258D-04 | 0.118D 05 | -0.153D 01 | 0.623D-01 | 0.286D 08 |
| | | 1/2 - 3/2 | 0.126D-01 | 0.845D-05 | 0.194D 04 | -0.151D 01 | 0.122D 00 | 0.280D 08 |
| 9 | 9 | 1/2 - 1/2 | 0.330D 02 | 0.803D 00 | 0.283D 06 | -0.624D 02 | 0.286D 01 | 0.101D 07 |
| | | 1/2 - 3/2 | 0.322D 02 | 0.162D 01 | 0.321D 06 | -0.615D 02 | 0.590D 01 | 0.117D 07 |
| 9 | 10 | 1/2 - 1/2 | -0.340D 01 | 0.213D-01 | 0.468D 05 | -0.144D 02 | 0.374D 00 | 0.835D 06 |
| | | 1/2 - 3/2 | -0.401D 01 | 0.600D-01 | 0.680D 05 | -0.147D 02 | 0.812D 00 | 0.920D 06 |
| 9 | 11 | 1/2 - 1/2 | 0.134D 01 | 0.453D-02 | 0.188D 05 | -0.917D 01 | 0.212D 00 | 0.880D 06 |
| | | 1/2 - 3/2 | 0.169D 01 | 0.145D-01 | 0.304D 05 | -0.927D 01 | 0.437D 00 | 0.919D 06 |
| 9 | 12 | 1/2 - 1/2 | -0.762D 00 | 0.173D-02 | 0.998D 04 | -0.668D 01 | 0.133D 00 | 0.767D 06 |
| | | 1/2 - 3/2 | -0.992D 00 | 0.589D-02 | 0.171D 05 | -0.668D 01 | 0.267D 00 | 0.777D 06 |
| 9 | 13 | 1/2 - 1/2 | 0.509D 00 | 0.852D-03 | 0.602D 04 | -0.504D 01 | 0.837D-01 | 0.591D 06 |
| | | 1/2 - 3/2 | 0.679D 00 | 0.305D-02 | 0.108D 05 | -0.500D 01 | 0.165D 00 | 0.587D 06 |
| 9 | 14 | 1/2 - 1/2 | -0.373D 00 | 0.491D-03 | 0.397D 04 | -0.384D 01 | 0.521D-01 | 0.421D 06 |
| | | 1/2 - 3/2 | -0.508D 00 | 0.182D-02 | 0.739D 04 | -0.379D 01 | 0.101D 00 | 0.412D 06 |
| 9 | 15 | 1/2 - 1/2 | 0.293D 00 | 0.317D-03 | 0.282D 04 | -0.294D 01 | 0.319D-01 | 0.234D 06 |
| | | 1/2 - 3/2 | 0.400D 00 | 0.119D-02 | 0.529D 04 | -0.288D 01 | 0.614D-01 | 0.274D 06 |
| 10 | 10 | 1/2 - 1/2 | 0.468D 02 | 0.946D 00 | 0.115D 06 | -0.840D 02 | 0.305D 01 | 0.370D 06 |
| | | 1/2 - 3/2 | 0.455D 02 | 0.190D 01 | 0.130D 06 | -0.829D 02 | 0.632D 01 | 0.434D 06 |
| 10 | 11 | 1/2 - 1/2 | -0.490D 01 | 0.268D-01 | 0.217D 05 | -0.169D 02 | 0.320D 00 | 0.260D 06 |
| | | 1/2 - 3/2 | -0.571D 01 | 0.741D-01 | 0.310D 05 | -0.176D 02 | 0.703D 00 | 0.294D 06 |
| 10 | 12 | 1/2 - 1/2 | 0.194D 01 | 0.521D-02 | 0.950D 04 | -0.109D 02 | 0.147D 00 | 0.301D 06 |
| | | 1/2 - 3/2 | 0.240D 01 | 0.182D-01 | 0.149D 05 | -0.112D 02 | 0.395D 00 | 0.322D 06 |
| 10 | 13 | 1/2 - 1/2 | -0.109D 01 | 0.226D-02 | 0.525D 04 | -0.828D 01 | 0.123D 00 | 0.300D 06 |
| | | 1/2 - 3/2 | -0.140D 01 | 0.745D-02 | 0.873D 04 | -0.837D 01 | 0.266D 00 | 0.312D 06 |
| 10 | 14 | 1/2 - 1/2 | 0.729D 00 | 0.113D-02 | 0.329D 04 | -0.659D 01 | 0.920D-01 | 0.269D 06 |
| | | 1/2 - 3/2 | 0.956D 00 | 0.389D-02 | 0.571D 04 | -0.662D 01 | 0.186D 00 | 0.273D 06 |
| 10 | 15 | 1/2 - 1/2 | -0.537D 00 | 0.662D-03 | 0.226D 04 | -0.535D 01 | 0.650D-01 | 0.224D 06 |
| | | 1/2 - 3/2 | -0.711D 00 | 0.232D-02 | 0.398D 04 | -0.534D 01 | 0.131D 00 | 0.225D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $ns^2S_{1/2} - mp^2P_J$, CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 11 | 11 | 1/2 - 1/2 | 0.626D 02 | 0.109D 01 | 0.543D 05 | -0.108D 03 | 0.325D 01 | 0.162D 06 |
| | | 1/2 - 3/2 | 0.608D 02 | 0.218D 01 | 0.615D 05 | -0.107D 03 | 0.676D 01 | 0.191D 06 |
| 11 | 12 | 1/2 - 1/2 | -0.675D 01 | 0.334D-01 | 0.116D 05 | -0.193D 02 | 0.272D 00 | 0.948D 05 |
| | | 1/2 - 3/2 | -0.779D 01 | 0.903D-01 | 0.162D 05 | -0.203D 02 | 0.611D 00 | 0.110D 06 |
| 11 | 13 | 1/2 - 1/2 | 0.268D 01 | 0.755D-02 | 0.541D 04 | -0.123D 02 | 0.159D 00 | 0.114D 06 |
| | | 1/2 - 3/2 | 0.327D 01 | 0.226D-01 | 0.823D 04 | -0.127D 02 | 0.342D 00 | 0.125D 06 |
| 11 | 14 | 1/2 - 1/2 | -0.152D 01 | 0.295D-02 | 0.313D 04 | -0.951D 01 | 0.116D 00 | 0.123D 06 |
| | | 1/2 - 3/2 | -0.191D 01 | 0.937D-02 | 0.504D 04 | -0.971D 01 | 0.242D 00 | 0.130D 06 |
| 11 | 15 | 1/2 - 1/2 | 0.102D 01 | 0.150D-02 | 0.206D 04 | -0.779D 01 | 0.688D-01 | 0.121D 06 |
| | | 1/2 - 3/2 | 0.130D 01 | 0.491D-02 | 0.339D 04 | -0.788D 01 | 0.181D 00 | 0.125D 06 |
| 12 | 12 | 1/2 - 1/2 | 0.805D 02 | 0.123D 01 | 0.286D 05 | -0.135D 03 | 0.346D 01 | 0.807D 05 |
| | | 1/2 - 3/2 | 0.780D 02 | 0.245D 01 | 0.323D 05 | -0.134D 03 | 0.721D 01 | 0.949D 05 |
| 12 | 13 | 1/2 - 1/2 | -0.854D 01 | 0.405D-01 | 0.675D 04 | -0.215D 02 | 0.234D 00 | 0.390D 05 |
| | | 1/2 - 3/2 | -0.102D 02 | 0.198D 00 | 0.927D 04 | -0.228D 02 | 0.537D 00 | 0.463D 05 |
| 12 | 14 | 1/2 - 1/2 | 0.358D 01 | 0.943D-02 | 0.333D 04 | -0.135D 02 | 0.134D 00 | 0.472D 05 |
| | | 1/2 - 3/2 | 0.430D 01 | 0.275D-01 | 0.494D 04 | -0.141D 02 | 0.294D 00 | 0.527D 05 |
| 12 | 15 | 1/2 - 1/2 | -0.204D 01 | 0.378D-02 | 0.203D 04 | -0.105D 02 | 0.100D 00 | 0.537D 05 |
| | | 1/2 - 3/2 | -0.251D 01 | 0.115D-01 | 0.312D 04 | -0.108D 02 | 0.213D 00 | 0.577D 05 |
| 13 | 13 | 1/2 - 1/2 | 0.726D 02 | 0.108D 01 | 0.290D 05 | -0.147D 03 | 0.439D 01 | 0.119D 06 |
| | | 1/2 - 3/2 | 0.686D 02 | 0.200D 01 | 0.293D 05 | -0.144D 03 | 0.885D 01 | 0.130D 06 |
| 13 | 14 | 1/2 - 1/2 | -0.168D 02 | 0.123D 00 | 0.150D 05 | -0.335D 02 | 0.480D 00 | 0.595D 05 |
| | | 1/2 - 3/2 | -0.170D 02 | 0.254D 00 | 0.160D 05 | -0.344D 02 | 0.104D 01 | 0.657D 05 |
| 13 | 15 | 1/2 - 1/2 | 0.828D 01 | 0.416D-01 | 0.993D 04 | -0.193D 02 | 0.227D 00 | 0.542D 05 |
| | | 1/2 - 3/2 | 0.852D 01 | 0.887D-01 | 0.108D 05 | -0.198D 02 | 0.479D 00 | 0.582D 05 |
| 14 | 14 | 1/2 - 1/2 | 0.885D 02 | 0.117D 01 | 0.170D 05 | -0.177D 03 | 0.464D 01 | 0.632D 05 |
| | | 1/2 - 3/2 | 0.834D 02 | 0.217D 01 | 0.172D 05 | -0.174D 03 | 0.946D 01 | 0.748D 05 |
| 14 | 15 | 1/2 - 1/2 | -0.205D 02 | 0.136D 00 | 0.915D 04 | -0.381D 02 | 0.466D 00 | 0.314D 05 |
| | | 1/2 - 3/2 | -0.207D 02 | 0.280D 00 | 0.970D 04 | -0.392D 02 | 0.100D 01 | 0.348D 05 |
| 15 | 15 | 1/2 - 1/2 | 0.106D 03 | 0.127D 01 | 0.105D 05 | -0.210D 03 | 0.498D 01 | 0.412D 05 |
| | | 1/2 - 3/2 | 0.100D 03 | 0.235D 01 | 0.106D 05 | -0.207D 03 | 0.100D 02 | 0.452D 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 5 | 7 | 3/2 - 1/2 | 0.147D 01 | 0.159D-01 | 0.112D 07 | 0.143D 01 | 0.151D-01 | 0.1060 07 |
| | | 3/2 - 3/2 | 0.129D 01 | 0.250D-02 | 0.925D 05 | 0.138D 01 | 0.288D-02 | 0.1060 06 |
| | | 5/2 - 3/2 | 0.135D 01 | 0.163D-01 | 0.881D 06 | 0.140D 01 | 0.175D-01 | 0.9480 06 |
| 5 | 8 | 3/2 - 1/2 | -0.356D 00 | 0.144D-02 | 0.241D 06 | 0.120D 00 | 0.164D-03 | 0.2750 05 |
| | | 3/2 - 3/2 | -0.314D 00 | 0.226D-03 | 0.192D 05 | 0.661D-01 | 0.100D-04 | 0.8500 03 |
| | | 5/2 - 3/2 | -0.332D 00 | 0.150D-02 | 0.188D 06 | 0.880D-01 | 0.105D-03 | 0.1320 05 |
| 5 | 9 | 3/2 - 1/2 | 0.154D 00 | 0.317D-03 | 0.730D 05 | -0.394D 00 | 0.206D-02 | 0.4750 06 |
| | | 3/2 - 3/2 | 0.134D 00 | 0.478D-04 | 0.554D 04 | -0.428D 00 | 0.490D-03 | 0.5670 05 |
| | | 5/2 - 3/2 | 0.143D 00 | 0.326D-03 | 0.558D 05 | -0.413D 00 | 0.271D-02 | 0.4640 06 |
| 5 | 10 | 3/2 - 1/2 | -0.837D-01 | 0.101D-03 | 0.272D 05 | -0.574D 00 | 0.475D-02 | 0.1280 07 |
| | | 3/2 - 3/2 | -0.704D-01 | 0.143D-04 | 0.194D 04 | -0.595D 00 | 0.102D-02 | 0.1380 06 |
| | | 5/2 - 3/2 | -0.766D-01 | 0.101D-03 | 0.202D 05 | -0.585D 00 | 0.583D-02 | 0.1180 07 |
| 5 | 11 | 3/2 - 1/2 | 0.511D-01 | 0.395D-04 | 0.117D 05 | -0.612D 00 | 0.566D-02 | 0.1680 07 |
| | | 3/2 - 3/2 | 0.415D-01 | 0.519D-05 | 0.771D 03 | -0.624D 00 | 0.119D-02 | 0.1750 06 |
| | | 5/2 - 3/2 | 0.460D-01 | 0.381D-04 | 0.837D 04 | -0.618D 00 | 0.688D-02 | 0.1510 07 |
| 5 | 12 | 3/2 - 1/2 | -0.336D-01 | 0.176D-04 | 0.553D 04 | -0.590D 00 | 0.540D-02 | 0.1700 07 |
| | | 3/2 - 3/2 | -0.261D-01 | 0.212D-05 | 0.313D 03 | -0.596D 00 | 0.110D-02 | 0.1740 06 |
| | | 5/2 - 3/2 | -0.296D-01 | 0.163D-04 | 0.380D 04 | -0.593D 00 | 0.652D-02 | 0.1520 07 |
| 5 | 13 | 3/2 - 1/2 | 0.234D-01 | 0.868D-05 | 0.284D 04 | -0.543D 00 | 0.468D-02 | 0.1530 07 |
| | | 3/2 - 3/2 | 0.172D-01 | 0.940D-06 | 0.154D 03 | -0.546D 00 | 0.947D-03 | 0.1550 06 |
| | | 5/2 - 3/2 | 0.201D-01 | 0.764D-05 | 0.185D 04 | -0.545D 00 | 0.563D-02 | 0.1370 07 |
| 5 | 14 | 3/2 - 1/2 | -0.169D-01 | 0.461D-05 | 0.155D 04 | -0.490D 00 | 0.387D-02 | 0.1300 07 |
| | | 3/2 - 3/2 | -0.117D-01 | 0.440D-06 | 0.742D 02 | -0.491D 00 | 0.777D-03 | 0.1310 06 |
| | | 5/2 - 3/2 | -0.141D-01 | 0.382D-05 | 0.953D 03 | -0.492D 00 | 0.464D-02 | 0.1160 07 |
| 5 | 15 | 3/2 - 1/2 | 0.125D-01 | 0.255D-05 | 0.877D 03 | -0.438D 00 | 0.312D-02 | 0.1070 07 |
| | | 3/2 - 3/2 | 0.811D-02 | 0.214D-06 | 0.369D 02 | -0.438D 00 | 0.623D-03 | 0.1070 06 |
| | | 5/2 - 3/2 | 0.102D-01 | 0.201D-05 | 0.512D 03 | -0.439D 00 | 0.374D-02 | 0.9550 06 |
| 6 | 8 | 3/2 - 1/2 | 0.411D 01 | 0.535D-01 | 0.694D 06 | 0.265D 01 | 0.222D-01 | 0.2890 06 |
| | | 3/2 - 3/2 | 0.361D 01 | 0.847D-02 | 0.580D 05 | 0.262D 01 | 0.443D-02 | 0.3040 05 |
| | | 5/2 - 3/2 | 0.377D 01 | 0.546D-01 | 0.546D 06 | 0.264D 01 | 0.267D-01 | 0.2670 06 |
| 6 | 9 | 3/2 - 1/2 | -0.127D 01 | 0.827D-02 | 0.281D 05 | 0.823D 00 | 0.346D-02 | 0.1180 06 |
| | | 3/2 - 3/2 | -0.115D 01 | 0.136D-02 | 0.235D 05 | 0.757D 00 | 0.531D-03 | 0.1020 05 |
| | | 5/2 - 3/2 | -0.119D 01 | 0.869D-02 | 0.222D 06 | 0.786D 00 | 0.379D-02 | 0.9680 05 |
| 6 | 10 | 3/2 - 1/2 | 0.675D 00 | 0.283D-02 | 0.142D 06 | -0.726D-02 | 0.328D-06 | 0.1650 02 |
| | | 3/2 - 3/2 | 0.611D 00 | 0.467D-03 | 0.118D 05 | -0.601D-01 | 0.451D-05 | 0.1140 03 |
| | | 5/2 - 3/2 | 0.633D 00 | 0.298D-02 | 0.112D 06 | -0.345D-01 | 0.883D-05 | 0.3310 03 |
| 6 | 11 | 3/2 - 1/2 | -0.408D 00 | 0.115D-02 | 0.712D 05 | -0.438D 00 | 0.133D-02 | 0.8210 05 |
| | | 3/2 - 3/2 | -0.446D 00 | 0.276D-03 | 0.858D 04 | -0.397D 00 | 0.218D-03 | 0.6790 04 |
| | | 5/2 - 3/2 | -0.426D 00 | 0.150D-02 | 0.690D 05 | -0.411D 00 | 0.140D-02 | 0.6430 05 |
| 6 | 12 | 3/2 - 1/2 | -0.557D 00 | 0.262D-02 | 0.185D 06 | 0.316D 00 | 0.711D-03 | 0.5160 05 |
| | | 3/2 - 3/2 | -0.624D 00 | 0.574D-03 | 0.203D 05 | 0.286D 00 | 0.120D-03 | 0.4250 04 |
| | | 5/2 - 3/2 | -0.608D 00 | 0.325D-02 | 0.170D 06 | 0.296D 00 | 0.771D-03 | 0.4030 05 |
| 6 | 13 | 3/2 - 1/2 | -0.675D 00 | 0.349D-02 | 0.267D 06 | -0.243D 00 | 0.453D-03 | 0.3470 05 |
| | | 3/2 - 3/2 | -0.654D 00 | 0.739D-03 | 0.284D 05 | -0.219D 00 | 0.740D-04 | 0.2840 04 |
| | | 5/2 - 3/2 | -0.682D 00 | 0.426D-02 | 0.243D 06 | -0.228D 00 | 0.475D-03 | 0.2700 05 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$, CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 14 | 3/2 - 1/2 | -0.693D 00 | 0.380D-02 | 0.308D 06 | 0.195D 00 | 0.301D-03 | 0.244D 05 |
| | | 3/2 - 3/2 | -0.706D 00 | 0.789D-03 | 0.321D 05 | 0.182D 00 | 0.314D-03 | 0.190D 05 |
| | | 5/2 - 3/2 | -0.698D 00 | 0.460D-02 | 0.277D 06 | -0.161D 00 | 0.210D-03 | 0.178D 05 |
| 6 | 15 | 3/2 - 1/2 | -0.680D 00 | 0.374D-02 | 0.317D 06 | 0.176D 00 | 0.490D-04 | 0.199D 04 |
| | | 3/2 - 3/2 | -0.146D 00 | 0.342D-04 | 0.145D 04 | -0.689D 00 | 0.763D-03 | 0.326D 05 |
| | | 5/2 - 3/2 | -0.151D 00 | 0.220D-03 | 0.139D 05 | -0.683D 00 | 0.450D-02 | 0.284D 06 |
| 7 | 9 | 3/2 - 1/2 | 0.765D 01 | 0.942D-01 | 0.317D 06 | 0.410D 01 | 0.271D-01 | 0.913D 05 |
| | | 3/2 - 3/2 | 0.674D 01 | 0.150D-01 | 0.268D 05 | 0.411D 01 | 0.559D-02 | 0.936D 04 |
| | | 5/2 - 3/2 | 0.702D 01 | 0.967D-01 | 0.252D 06 | 0.412D 01 | 0.333D-01 | 0.866D 05 |
| 7 | 10 | 3/2 - 1/2 | -0.243D 01 | 0.160D-01 | 0.154D 06 | 0.173D 01 | 0.807D-02 | 0.773D 05 |
| | | 3/2 - 3/2 | -0.221D 01 | 0.268D-02 | 0.131D 05 | 0.166D 01 | 0.151D-02 | 0.737D 04 |
| | | 5/2 - 3/2 | -0.228D 01 | 0.170D-01 | 0.123D 06 | 0.169D 01 | 0.931D-02 | 0.671D 05 |
| 7 | 11 | 3/2 - 1/2 | 0.131D 01 | 0.583D-02 | 0.876D 05 | 0.596D 00 | 0.121D-02 | 0.181D 05 |
| | | 3/2 - 3/2 | 0.120D 01 | 0.981D-03 | 0.745D 04 | 0.532D 00 | 0.194D-03 | 0.147D 04 |
| | | 5/2 - 3/2 | 0.124D 01 | 0.622D-02 | 0.699D 05 | 0.562D 00 | 0.129D-02 | 0.145D 05 |
| 7 | 12 | 3/2 - 1/2 | -0.860D 00 | 0.285D-02 | 0.550D 05 | -0.141D-01 | 0.767D-06 | 0.148D 02 |
| | | 3/2 - 3/2 | -0.789D 00 | 0.481D-03 | 0.467D 04 | -0.655D-01 | 0.332D-05 | 0.322D 02 |
| | | 5/2 - 3/2 | -0.813D 00 | 0.305D-02 | 0.439D 05 | -0.392D-01 | 0.703D-05 | 0.102D 03 |
| 7 | 13 | 3/2 - 1/2 | 0.627D 00 | 0.164D-02 | 0.370D 05 | -0.356D 00 | 0.530D-03 | 0.120D 05 |
| | | 3/2 - 3/2 | 0.575D 00 | 0.276D-03 | 0.314D 04 | -0.397D 00 | 0.132D-03 | 0.150D 04 |
| | | 5/2 - 3/2 | 0.592D 00 | 0.175D-02 | 0.295D 05 | -0.375D 00 | 0.700D-03 | 0.118D 05 |
| 7 | 14 | 3/2 - 1/2 | -0.486D 00 | 0.104D-02 | 0.262D 05 | -0.549D 00 | 0.133D-02 | 0.334D 05 |
| | | 3/2 - 3/2 | -0.446D 00 | 0.175D-03 | 0.221D 04 | -0.581D 00 | 0.297D-03 | 0.375D 04 |
| | | 5/2 - 3/2 | -0.459D 00 | 0.111D-02 | 0.208D 05 | -0.562D 00 | 0.166D-02 | 0.312D 05 |
| 7 | 15 | 3/2 - 1/2 | 0.393D 00 | 0.706D-03 | 0.192D 05 | -0.654D 00 | 0.195D-02 | 0.531D 05 |
| | | 3/2 - 3/2 | 0.361D 00 | 0.119D-03 | 0.162D 04 | -0.678D 00 | 0.420D-03 | 0.573D 04 |
| | | 5/2 - 3/2 | 0.372D 00 | 0.756D-03 | 0.153D 05 | -0.662D 00 | 0.240D-02 | 0.485D 05 |
| 8 | 10 | 3/2 - 1/2 | 0.122D 02 | 0.137D 00 | 0.153D 06 | 0.572D 01 | 0.303D-01 | 0.339D 05 |
| | | 3/2 - 3/2 | 0.107D 02 | 0.220D-01 | 0.130D 05 | 0.578D 01 | 0.639D-02 | 0.378D 04 |
| | | 5/2 - 3/2 | 0.112D 02 | 0.141D 00 | 0.122D 06 | 0.577D 01 | 0.377D-01 | 0.327D 05 |
| 8 | 11 | 3/2 - 1/2 | -0.388D 01 | 0.242D-01 | 0.820D 05 | 0.273D 01 | 0.120D-01 | 0.408D 05 |
| | | 3/2 - 3/2 | -0.354D 01 | 0.409D-02 | 0.706D 04 | 0.268D 01 | 0.234D-02 | 0.404D 04 |
| | | 5/2 - 3/2 | -0.365D 01 | 0.259D-01 | 0.661D 05 | 0.270D 01 | 0.142D-01 | 0.363D 05 |
| 8 | 12 | 3/2 - 1/2 | 0.209D 01 | 0.901D-02 | 0.501D 05 | 0.131D 01 | 0.352D-02 | 0.136D 05 |
| | | 3/2 - 3/2 | 0.192D 01 | 0.154D-02 | 0.432D 04 | 0.124D 01 | 0.633D-03 | 0.190D 04 |
| | | 5/2 - 3/2 | 0.198D 01 | 0.970D-02 | 0.404D 05 | 0.127D 01 | 0.400D-02 | 0.167D 05 |
| 8 | 13 | 3/2 - 1/2 | -0.137D 01 | 0.449D-02 | 0.332D 05 | 0.502D 00 | 0.601D-03 | 0.445D 04 |
| | | 3/2 - 3/2 | -0.127D 01 | 0.769D-03 | 0.286D 04 | 0.443D 00 | 0.937D-04 | 0.349D 03 |
| | | 5/2 - 3/2 | -0.130D 01 | 0.485D-02 | 0.268D 05 | 0.472D 00 | 0.636D-03 | 0.352D 04 |
| 8 | 14 | 3/2 - 1/2 | 0.100D 01 | 0.262D-02 | 0.233D 05 | 0.167D-01 | 0.729D-06 | 0.644D 01 |
| | | 3/2 - 3/2 | 0.925D 00 | 0.449D-03 | 0.200D 04 | -0.340D-01 | 0.603D-06 | 0.270D 01 |
| | | 5/2 - 3/2 | 0.950D 00 | 0.283D-02 | 0.188D 05 | -0.751D-02 | 0.177D-06 | 0.117D 01 |
| 8 | 15 | 3/2 - 1/2 | -0.777D 00 | 0.168D-02 | 0.170D 05 | -0.287D 00 | 0.230D-03 | 0.232D 04 |
| | | 3/2 - 3/2 | -0.719D 00 | 0.289D-03 | 0.146D 04 | -0.328D 00 | 0.601D-04 | 0.304D 03 |
| | | 5/2 - 3/2 | -0.739D 00 | 0.182D-02 | 0.137D 05 | -0.305D 00 | 0.310D-03 | 0.233D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 9 | 11 | 3/2 - 1/2 | 0.177D 02 | 0.181D 00 | 0.799D 05 | 0.748D 01 | 0.3260-01 | 0.144D 05 |
| | | 3/2 - 3/2 | 0.156D 02 | 0.293D-01 | 0.685D 04 | 0.762D 01 | 0.697D-02 | 0.163D 04 |
| | | 5/2 - 3/2 | 0.162D 02 | 0.188D 00 | 0.642D 05 | 0.759D 01 | 0.410D-01 | 0.140D 05 |
| 9 | 12 | 3/2 - 1/2 | -0.562D 01 | 0.327D-01 | 0.457D 05 | 0.383D 01 | 0.152D-01 | 0.212D 05 |
| | | 3/2 - 3/2 | -0.515D 01 | 0.556D-02 | 0.397D 04 | 0.379D 01 | 0.301D-02 | 0.215D 04 |
| | | 5/2 - 3/2 | -0.530D 01 | 0.351D-01 | 0.371D 05 | 0.381D 01 | 0.181D-01 | 0.192D 05 |
| 9 | 13 | 3/2 - 1/2 | 0.302D 01 | 0.123D-01 | 0.294D 05 | 0.209D 01 | 0.590D-02 | 0.141D 05 |
| | | 3/2 - 3/2 | 0.279D 01 | 0.212D-02 | 0.256D 04 | 0.202D 01 | 0.112D-02 | 0.135D 04 |
| | | 5/2 - 3/2 | 0.287D 01 | 0.133D-01 | 0.239D 05 | 0.205D 01 | 0.686D-02 | 0.123D 05 |
| 9 | 14 | 3/2 - 1/2 | -0.158D 01 | 0.621D-02 | 0.203D 05 | 0.109D 01 | 0.190D-02 | 0.619D 04 |
| | | 3/2 - 3/2 | -0.184D 01 | 0.107D-02 | 0.176D 04 | 0.103D 01 | 0.337D-03 | 0.555D 03 |
| | | 5/2 - 3/2 | -0.188D 01 | 0.674D-02 | 0.165D 05 | 0.106D 01 | 0.214D-02 | 0.522D 04 |
| 9 | 15 | 3/2 - 1/2 | 0.144D 01 | 0.364D-02 | 0.146D 05 | 0.471D 00 | 0.389D-03 | 0.156D 04 |
| | | 3/2 - 3/2 | 0.134D 01 | 0.632D-03 | 0.127D 04 | 0.415D 00 | 0.606D-04 | 0.122D 03 |
| | | 5/2 - 3/2 | 0.137D 01 | 0.397D-02 | 0.119D 05 | 0.443D 00 | 0.414D-03 | 0.124D 04 |
| 10 | 12 | 3/2 - 1/2 | 0.241D 02 | 0.226D 00 | 0.446D 05 | 0.940D 01 | 0.344D-01 | 0.677D 04 |
| | | 3/2 - 3/2 | 0.214D 02 | 0.367D-01 | 0.384D 04 | 0.963D 01 | 0.743D-02 | 0.778D 03 |
| | | 5/2 - 3/2 | 0.222D 02 | 0.235D 00 | 0.360D 05 | 0.957D 01 | 0.436D-01 | 0.668D 04 |
| 10 | 13 | 3/2 - 1/2 | -0.766D 01 | 0.414D-01 | 0.269D 05 | 0.500D 01 | 0.177D-01 | 0.115D 05 |
| | | 3/2 - 3/2 | -0.703D 01 | 0.707D-02 | 0.235D 04 | 0.498D 01 | 0.355D-02 | 0.118D 04 |
| | | 5/2 - 3/2 | -0.723D 01 | 0.446D-01 | 0.219D 05 | 0.500D 01 | 0.213D-01 | 0.105D 05 |
| 10 | 14 | 3/2 - 1/2 | 0.410D 01 | 0.157D-01 | 0.179D 05 | 0.293D 01 | 0.803D-02 | 0.915D 04 |
| | | 3/2 - 3/2 | 0.380D 01 | 0.272D-02 | 0.157D 04 | 0.287D 01 | 0.155D-02 | 0.897D 03 |
| | | 5/2 - 3/2 | 0.390D 01 | 0.171D-01 | 0.147D 05 | 0.290D 01 | 0.944D-02 | 0.811D 04 |
| 10 | 15 | 3/2 - 1/2 | -0.268D 01 | 0.795D-02 | 0.127D 05 | 0.174D 01 | 0.334D-02 | 0.535D 04 |
| | | 3/2 - 3/2 | -0.249D 01 | 0.139D-02 | 0.112D 04 | 0.167D 01 | 0.624D-03 | 0.503D 03 |
| | | 5/2 - 3/2 | -0.256D 01 | 0.868D-02 | 0.104D 05 | 0.170D 01 | 0.386D-02 | 0.463D 04 |
| 11 | 13 | 3/2 - 1/2 | 0.316D 02 | 0.273D 00 | 0.264D 05 | 0.115D 02 | 0.358D-01 | 0.346D 04 |
| | | 3/2 - 3/2 | 0.281D 02 | 0.443D-01 | 0.228D 04 | 0.118D 02 | 0.782D-02 | 0.402D 03 |
| | | 5/2 - 3/2 | 0.291D 02 | 0.283D 00 | 0.214D 05 | 0.117D 02 | 0.457D-01 | 0.345D 04 |
| 11 | 14 | 3/2 - 1/2 | -0.100D 02 | 0.503D-01 | 0.165D 05 | 0.625D 01 | 0.196D-01 | 0.646D 04 |
| | | 3/2 - 3/2 | -0.920D 01 | 0.862D-02 | 0.145D 04 | 0.626D 01 | 0.399D-02 | 0.673D 03 |
| | | 5/2 - 3/2 | -0.945D 01 | 0.542D-01 | 0.135D 05 | 0.627D 01 | 0.238D-01 | 0.595D 04 |
| 11 | 15 | 3/2 - 1/2 | 0.533D 01 | 0.191D-01 | 0.113D 05 | 0.382D 01 | 0.985D-02 | 0.534D 04 |
| | | 3/2 - 3/2 | 0.495D 01 | 0.334D-02 | 0.100D 04 | 0.377D 01 | 0.194D-02 | 0.592D 03 |
| | | 5/2 - 3/2 | 0.508D 01 | 0.209D-01 | 0.934D 04 | 0.380D 01 | 0.117D-01 | 0.522D 04 |
| 12 | 14 | 3/2 - 1/2 | 0.401D 02 | 0.319D 00 | 0.164D 05 | 0.137D 02 | 0.371D-01 | 0.193D 04 |
| | | 3/2 - 3/2 | 0.356D 02 | 0.519D-01 | 0.142D 04 | 0.141D 02 | 0.817D-02 | 0.223D 03 |
| | | 5/2 - 3/2 | 0.369D 02 | 0.331D 00 | 0.133D 05 | 0.140D 02 | 0.479D-01 | 0.191D 04 |
| 12 | 15 | 3/2 - 1/2 | -0.126D 02 | 0.590D-01 | 0.106D 05 | 0.758D 01 | 0.213D-01 | 0.331D 04 |
| | | 3/2 - 3/2 | -0.116D 02 | 0.102D-01 | 0.934D 03 | 0.763D 01 | 0.437D-02 | 0.431D 03 |
| | | 5/2 - 3/2 | -0.119D 02 | 0.640D-01 | 0.869D 04 | 0.762D 01 | 0.260D-01 | 0.354D 04 |
| 13 | 15 | 3/2 - 1/2 | 0.495D 02 | 0.365D 00 | 0.106D 05 | 0.160D 02 | 0.384D-01 | 0.111D 04 |
| | | 3/2 - 3/2 | 0.441D 02 | 0.599D-01 | 0.922D 03 | 0.166D 02 | 0.847D-02 | 0.130D 03 |
| | | 5/2 - 3/2 | 0.457D 02 | 0.382D 00 | 0.861D 04 | 0.164D 02 | 0.494D-01 | 0.111D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 6 | 5 | 1/2 - 3/2 | 0.656D C1 | 0.289D 00 | 0.106D 07 | 0.136D 02 | 0.124D 01 | 0.457D 07 |
| | | 3/2 - 3/2 | 0.655D 01 | 0.240D-01 | 0.123D 06 | 0.132D 02 | 0.973D-01 | 0.497D 06 |
| | | 3/2 - 5/2 | 0.661D 01 | 0.228D 00 | 0.832D 06 | 0.133D 02 | 0.924D 00 | 0.337D 07 |
| 6 | 6 | 1/2 - 3/2 | 0.335D 01 | 0.259D 00 | 0.112D 08 | -0.714D 01 | 0.113D 01 | 0.512D 08 |
| | | 3/2 - 3/2 | 0.376D 01 | 0.310D-01 | 0.244D 07 | -0.815D 01 | 0.140D 00 | 0.115D 08 |
| | | 3/2 - 5/2 | 0.366D 01 | 0.266D 00 | 0.140D 08 | -0.799D 01 | 0.127D 01 | 0.670D 08 |
| 6 | 7 | 1/2 - 3/2 | -0.163D 01 | 0.800D-01 | 0.590D 07 | -0.264D 01 | 0.210D 00 | 0.155D 08 |
| | | 3/2 - 3/2 | -0.176D 01 | 0.896D-02 | 0.122D 07 | -0.311D 01 | 0.280D-01 | 0.383D 07 |
| | | 3/2 - 5/2 | -0.173D 01 | 0.783D-01 | 0.716D 07 | -0.305D 01 | 0.243D 00 | 0.222D 08 |
| 6 | 8 | 1/2 - 3/2 | 0.102D 01 | 0.354D-01 | 0.326D 07 | -0.105D 01 | 0.371D-01 | 0.342D 07 |
| | | 3/2 - 3/2 | 0.109D 01 | 0.387D-02 | 0.667D 06 | -0.138D 01 | 0.617D-02 | 0.106D 07 |
| | | 3/2 - 5/2 | 0.108D 01 | 0.341D-01 | 0.392D 07 | -0.134D 01 | 0.527D-01 | 0.606D 07 |
| 6 | 9 | 1/2 - 3/2 | -0.728D 00 | 0.190D-01 | 0.197D 07 | -0.287D 00 | 0.293D-02 | 0.305D 06 |
| | | 3/2 - 3/2 | -0.769D 00 | 0.205D-02 | 0.399D 06 | -0.537D 00 | 0.993D-03 | 0.194D 06 |
| | | 3/2 - 5/2 | -0.762D 00 | 0.181D-01 | 0.235D 07 | -0.512D 00 | 0.818D-02 | 0.106D 07 |
| 6 | 10 | 1/2 - 3/2 | 0.555D 00 | 0.114D-01 | 0.127D 07 | 0.119D 00 | 0.529D-03 | 0.590D 05 |
| | | 3/2 - 3/2 | 0.584D 00 | 0.123D-02 | 0.257D 06 | -0.799D-01 | 0.230D-04 | 0.482D 04 |
| | | 3/2 - 5/2 | 0.579D 00 | 0.109D-01 | 0.152D 07 | -0.625D-01 | 0.126D-03 | 0.177D 05 |
| 6 | 11 | 1/2 - 3/2 | -0.443D 00 | 0.745D-02 | 0.870D 06 | 0.344D 00 | 0.443D-02 | 0.523D 06 |
| | | 3/2 - 3/2 | -0.465D 00 | 0.795D-03 | 0.175D 06 | 0.181D 00 | 0.121D-03 | 0.266D 05 |
| | | 3/2 - 5/2 | -0.462D 00 | 0.705D-02 | 0.104D 07 | 0.194D 00 | 0.125D-02 | 0.193D 06 |
| 6 | 12 | 1/2 - 3/2 | 0.365D 00 | 0.514D-02 | 0.620D 06 | 0.467D 00 | 0.339D-02 | 0.101D 07 |
| | | 3/2 - 3/2 | 0.383D 00 | 0.548D-03 | 0.125D 06 | 0.332D 00 | 0.413D-03 | 0.940D 05 |
| | | 3/2 - 5/2 | 0.380D 00 | 0.486D-02 | 0.737D 06 | 0.342D 00 | 0.374D-02 | 0.598D 06 |
| 6 | 13 | 1/2 - 3/2 | -0.308D 00 | 0.370D-02 | 0.457D 06 | 0.532D 00 | 0.110D-01 | 0.136D 07 |
| | | 3/2 - 3/2 | -0.322D 00 | 0.393D-03 | 0.916D 05 | 0.420D 00 | 0.666D-03 | 0.155D 06 |
| | | 3/2 - 5/2 | -0.320D 00 | 0.350D-02 | 0.543D 06 | 0.427D 00 | 0.622D-02 | 0.965D 06 |
| 6 | 14 | 1/2 - 3/2 | 0.265D 00 | 0.276D-02 | 0.347D 06 | 0.562D 00 | 0.124D-01 | 0.156D 07 |
| | | 3/2 - 3/2 | 0.277D 00 | 0.293D-03 | 0.694D 05 | 0.467D 00 | 0.832D-03 | 0.197D 06 |
| | | 3/2 - 5/2 | 0.275D 00 | 0.260D-02 | 0.411D 06 | 0.473D 00 | 0.768D-02 | 0.121D 07 |
| 7 | 6 | 1/2 - 3/2 | 0.156D 02 | 0.406D 00 | 0.918D 05 | 0.216D 02 | 0.777D 00 | 0.176D 06 |
| | | 3/2 - 3/2 | 0.156D 02 | 0.318D-01 | 0.876D 04 | 0.209D 02 | 0.570D-01 | 0.157D 05 |
| | | 3/2 - 5/2 | 0.157D 02 | 0.309D 00 | 0.645D 05 | 0.212D 02 | 0.563D 00 | 0.117D 06 |
| 7 | 7 | 1/2 - 3/2 | 0.548D 01 | 0.261D 00 | 0.159D 07 | -0.183D 02 | 0.290D 01 | 0.177D 08 |
| | | 3/2 - 3/2 | 0.623D 01 | 0.323D-01 | 0.362D 06 | -0.196D 02 | 0.320D 00 | 0.359D 07 |
| | | 3/2 - 5/2 | 0.604D 01 | 0.274D 00 | 0.207D 07 | -0.194D 02 | 0.293D 01 | 0.214D 08 |
| 7 | 8 | 1/2 - 3/2 | -0.265D 01 | 0.862D-01 | 0.105D 07 | -0.775D 01 | 0.734D 00 | 0.895D 07 |
| | | 3/2 - 3/2 | -0.289D 01 | 0.991D-02 | 0.227D 06 | -0.820D 01 | 0.793D-01 | 0.143D 07 |
| | | 3/2 - 5/2 | -0.283D 01 | 0.859D-01 | 0.132D 07 | -0.814D 01 | 0.773D 00 | 0.104D 08 |
| 7 | 9 | 1/2 - 3/2 | 0.168D 01 | 0.402D-01 | 0.668D 06 | 0.179D 01 | 0.447D-02 | 0.142D 06 |
| | | 1/2 - 3/2 | -0.450D 01 | 0.290D 00 | 0.482D 07 | -0.481D 01 | 0.323D-01 | 0.132D 07 |
| | | 3/2 - 5/2 | 0.177D 01 | 0.332D-01 | 0.828D 06 | -0.477D 01 | 0.286D 00 | 0.604D 07 |
| 7 | 10 | 1/2 - 3/2 | -0.120D 01 | 0.224D-01 | 0.443D 06 | -0.290D 01 | 0.131D 00 | 0.200D 07 |
| | | 3/2 - 3/2 | -0.127D 01 | 0.247D-02 | 0.931D 05 | -0.315D 01 | 0.152D-01 | 0.572D 06 |
| | | 3/2 - 5/2 | -0.126D 01 | 0.217D-01 | 0.545D 06 | -0.313D 01 | 0.134D 00 | 0.338D 07 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION N | TRANSITION M | TRANSITION J-J' | BATES-DAMGAARD APPROXIMATION $R_{ij}$ | BATES-DAMGAARD APPROXIMATION $f_{ij}$ | BATES-DAMGAARD APPROXIMATION $A_{ij}$ ($sec^{-1}$) | NON-RELATIVISTIC HYDROGENIC APPROXIMATION $R_{ij}$ | NON-RELATIVISTIC HYDROGENIC APPROXIMATION $f_{ij}$ | NON-RELATIVISTIC HYDROGENIC APPROXIMATION $A_{ij}$ ($sec^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 7 | 11 | 1/2 - 3/2 | 0.919D 00 | 0.139D-01 | 0.307D 06 | -0.195D 01 | 0.627D-01 | 0.138D 07 |
| | | 3/2 - 3/2 | 0.972D 00 | 0.152D-02 | 0.641D 05 | -0.217D 01 | 0.758D-02 | 0.320D 06 |
| | | 3/2 - 5/2 | 0.960D 00 | 0.134D-01 | 0.376D 06 | -0.215D 01 | 0.669D-01 | 0.188D 07 |
| 7 | 12 | 1/2 - 3/2 | -0.738D 00 | 0.931D-02 | 0.221D 06 | -0.134D 01 | 0.304D-01 | 0.722D 06 |
| | | 3/2 - 3/2 | -0.778D 00 | 0.101D-02 | 0.459D 05 | -0.153D 01 | 0.390D-02 | 0.177D 06 |
| | | 3/2 - 5/2 | -0.770D 00 | 0.891D-02 | 0.270D 06 | -0.151D 01 | 0.343D-01 | 0.104D 07 |
| 7 | 13 | 1/2 - 3/2 | 0.612D 00 | 0.655D-02 | 0.163D 06 | -0.913D 00 | 0.146D-01 | 0.364D 06 |
| | | 3/2 - 3/2 | 0.643D 00 | 0.709D-03 | 0.339D 05 | -0.108D 01 | 0.202D-02 | 0.964D 05 |
| | | 3/2 - 5/2 | 0.637D 00 | 0.626D-02 | 0.200D 06 | -0.107D 01 | 0.177D-01 | 0.564D 06 |
| 7 | 14 | 1/2 - 3/2 | -0.519D 00 | 0.481D-02 | 0.125D 06 | -0.615D 00 | 0.675D-02 | 0.175D 06 |
| | | 3/2 - 3/2 | -0.545D 00 | 0.519D-03 | 0.258D 05 | -0.768D 00 | 0.103D-02 | 0.513D 05 |
| | | 3/2 - 5/2 | -0.540D 00 | 0.458D-02 | 0.152D 06 | -0.756D 00 | 0.899D-02 | 0.298D 06 |
| 8 | 7 | 1/2 - 3/2 | 0.276D 02 | 0.524D 00 | 0.200D 05 | 0.323D 02 | 0.714D 00 | 0.273D 05 |
| | | 3/2 - 3/2 | 0.277D 02 | 0.399D-01 | 0.174D 04 | 0.313D 02 | 0.509D-01 | 0.223D 04 |
| | | 3/2 - 5/2 | 0.278D 02 | 0.391D 00 | 0.134D 05 | 0.317D 02 | 0.506D 00 | 0.173D 05 |
| 8 | 8 | 1/2 - 3/2 | 0.781D 01 | 0.260D 00 | 0.383D 06 | -0.312D 02 | 0.414D 01 | 0.610D 07 |
| | | 3/2 - 3/2 | 0.899D 01 | 0.331D-01 | 0.899D 05 | -0.329D 02 | 0.442D 00 | 0.120D 07 |
| | | 3/2 - 5/2 | 0.868D 01 | 0.279D 00 | 0.512D 06 | -0.326D 02 | 0.392D 01 | 0.720D 07 |
| 8 | 9 | 1/2 - 3/2 | -0.373D 01 | 0.879D-01 | 0.285D 06 | -0.128D 02 | 0.104D 01 | 0.338D 07 |
| | | 3/2 - 3/2 | -0.410D 01 | 0.104D-01 | 0.637D 05 | -0.132D 02 | 0.108D 00 | 0.661D 06 |
| | | 3/2 - 5/2 | -0.401D 01 | 0.892D-01 | 0.368D 06 | -0.132D 02 | 0.962D 00 | 0.397D 07 |
| 8 | 10 | 1/2 - 3/2 | 0.235D 01 | 0.421D-01 | 0.198D 06 | -0.779D 01 | 0.461D 00 | 0.217D 07 |
| | | 3/2 - 3/2 | 0.254D 01 | 0.481D-02 | 0.434D 05 | -0.802D 01 | 0.479D-01 | 0.432D 06 |
| | | 3/2 - 5/2 | 0.250D 01 | 0.418D-01 | 0.252D 06 | -0.799D 01 | 0.429D 00 | 0.258D 07 |
| 8 | 11 | 1/2 - 3/2 | -0.168D 01 | 0.240D-01 | 0.140D 06 | -0.541D 01 | 0.243D 00 | 0.145D 07 |
| | | 3/2 - 3/2 | -0.180D 01 | 0.270D-02 | 0.303D 05 | -0.561D 01 | 0.261D-01 | 0.294D 06 |
| | | 3/2 - 5/2 | -0.177D 01 | 0.235D-01 | 0.177D 06 | -0.558D 01 | 0.233D 00 | 0.175D 07 |
| 8 | 12 | 1/2 - 3/2 | 0.129D 01 | 0.152D-01 | 0.102D 06 | -0.401D 01 | 0.146D 00 | 0.931D 06 |
| | | 3/2 - 3/2 | 0.138D 01 | 0.169D-02 | 0.219D 05 | -0.419D 01 | 0.156D-01 | 0.202D 06 |
| | | 3/2 - 5/2 | 0.136D 01 | 0.148D-01 | 0.128D 06 | -0.417D 01 | 0.140D 00 | 0.121D 07 |
| 8 | 13 | 1/2 - 3/2 | -0.104D 01 | 0.103D-01 | 0.762D 05 | -0.308D 01 | 0.904D-01 | 0.668D 06 |
| | | 3/2 - 3/2 | -0.110D 01 | 0.114D-02 | 0.163D 05 | -0.324D 01 | 0.986D-02 | 0.141D 06 |
| | | 3/2 - 5/2 | -0.109D 01 | 0.100D-01 | 0.953D 05 | -0.323D 01 | 0.879D-01 | 0.836D 06 |
| 8 | 14 | 1/2 - 3/2 | 0.865D 00 | 0.738D-02 | 0.584D 05 | -0.242D 01 | 0.579D-01 | 0.458D 06 |
| | | 3/2 - 3/2 | 0.916D 00 | 0.814D-03 | 0.124D 05 | -0.258D 01 | 0.644D-02 | 0.984D 05 |
| | | 3/2 - 5/2 | 0.904D 00 | 0.714D-02 | 0.728D 05 | -0.256D 01 | 0.573D-01 | 0.585D 06 |
| 9 | 8 | 1/2 - 3/2 | 0.426D 02 | 0.640D 00 | 0.645D 04 | 0.452D 02 | 0.720D 00 | 0.727D 04 |
| | | 3/2 - 3/2 | 0.428D 02 | 0.479D-01 | 0.534D 03 | 0.440D 02 | 0.506D-01 | 0.564D 03 |
| | | 3/2 - 5/2 | 0.429D 02 | 0.473D 00 | 0.418D 04 | 0.444D 02 | 0.505D 00 | 0.447D 04 |
| 9 | 9 | 1/2 - 3/2 | 0.104D 02 | 0.262D 00 | 0.124D 05 | -0.462D 02 | 0.514D 01 | 0.243D 07 |
| | | 3/2 - 3/2 | 0.121D 02 | 0.341D-01 | 0.299D 05 | -0.483D 02 | 0.541D 00 | 0.474D 06 |
| | | 3/2 - 5/2 | 0.117D 02 | 0.286D 00 | 0.169D 06 | -0.478D 02 | 0.481D 01 | 0.285D 07 |
| 9 | 10 | 1/2 - 3/2 | -0.491D 01 | 0.896D-01 | 0.100D 06 | -0.181D 02 | 0.122D 01 | 0.136D 07 |
| | | 3/2 - 3/2 | -0.545D 01 | 0.108D-01 | 0.229D 05 | -0.184D 02 | 0.123D 00 | 0.261D 06 |
| | | 3/2 - 5/2 | -0.531D 01 | 0.922D-01 | 0.131D 06 | -0.184D 02 | 0.110D 01 | 0.157D 07 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}$ ($sec^{-1}$) | $R_{ij}$ | $f_{ij}$ | $A_{ij}$ ($sec^{-1}$) |
| 9 | 11 | 1/2 - 3/2 | 0.308D 01 | 0.434D-01 | 0.739D 05 | -0.110D 02 | 0.551D 00 | 0.938D 06 |
| | | 3/2 - 3/2 | 0.336D 01 | 0.505D-02 | 0.165D 05 | -0.111D 02 | 0.554D-01 | 0.181D 06 |
| | | 3/2 - 5/2 | 0.329D 01 | 0.437D-01 | 0.955D 05 | -0.111D 02 | 0.498D 00 | 0.109D 07 |
| 9 | 12 | 1/2 - 3/2 | -0.220D 01 | 0.251D-01 | 0.548D 05 | -0.777D 01 | 0.313D 00 | 0.684D 06 |
| | | 3/2 - 3/2 | -0.237D 01 | 0.287D-02 | 0.121D 05 | -0.789D 01 | 0.317D-01 | 0.134D 06 |
| | | 3/2 - 5/2 | -0.233D 01 | 0.249D-01 | 0.703D 05 | -0.788D 01 | 0.285D 00 | 0.803D 06 |
| 9 | 13 | 1/2 - 3/2 | 0.169D 01 | 0.161D-01 | 0.413D 05 | -0.593D 01 | 0.193D 00 | 0.510D 06 |
| | | 3/2 - 3/2 | 0.181D 01 | 0.182D-02 | 0.907D 04 | -0.605D 01 | 0.202D-01 | 0.101D 06 |
| | | 3/2 - 5/2 | 0.178D 01 | 0.158D-01 | 0.527D 05 | -0.604D 01 | 0.182D 00 | 0.605D 06 |
| 9 | 14 | 1/2 - 3/2 | -0.136D 01 | 0.110D-01 | 0.319D 05 | -0.473D 01 | 0.133D 00 | 0.385D 06 |
| | | 3/2 - 3/2 | -0.145D 01 | 0.124D-02 | 0.696D 04 | -0.484D 01 | 0.138D-01 | 0.770D 05 |
| | | 3/2 - 5/2 | -0.143D 01 | 0.108D-01 | 0.405D 05 | -0.483D 01 | 0.123D 00 | 0.461D 06 |
| 10 | 9 | 1/2 - 3/2 | 0.605D 02 | 0.755D 00 | 0.261D 04 | 0.604D 02 | 0.751D 00 | 0.260D 04 |
| | | 3/2 - 3/2 | 0.608D 02 | 0.561D-01 | 0.210D 03 | 0.588D 02 | 0.524D-01 | 0.197D 03 |
| | | 3/2 - 5/2 | 0.609D 02 | 0.556D 00 | 0.167D 04 | 0.593D 02 | 0.526D 00 | 0.158D 04 |
| 10 | 10 | 1/2 - 3/2 | 0.134D 02 | 0.268D 00 | 0.491D 05 | -0.633D 02 | 0.603D 01 | 0.110D 07 |
| | | 3/2 - 3/2 | 0.156D 02 | 0.354D-01 | 0.121D 05 | -0.659D 02 | 0.628D 00 | 0.214D 06 |
| | | 3/2 - 5/2 | 0.150D 02 | 0.296D 00 | 0.680D 05 | -0.653D 02 | 0.560D 01 | 0.129D 07 |
| 10 | 11 | 1/2 - 3/2 | -0.622D 01 | 0.915D-01 | 0.417D 05 | -0.237D 02 | 0.133D 01 | 0.606D 06 |
| | | 3/2 - 3/2 | -0.694D 01 | 0.112D-01 | 0.971D 04 | -0.238D 02 | 0.132D 00 | 0.115D 06 |
| | | 3/2 - 5/2 | -0.675D 01 | 0.952D-01 | 0.556D 05 | -0.238D 02 | 0.119D 01 | 0.693D 06 |
| 10 | 12 | 1/2 - 3/2 | 0.388D 01 | 0.447D-01 | 0.322D 05 | -0.141D 02 | 0.594D 00 | 0.428D 06 |
| | | 3/2 - 3/2 | 0.425D 01 | 0.528D-02 | 0.733D 04 | -0.142D 02 | 0.585D-01 | 0.813D 05 |
| | | 3/2 - 5/2 | 0.415D 01 | 0.455D-01 | 0.422D 05 | -0.142D 02 | 0.523D 00 | 0.491D 06 |
| 10 | 13 | 1/2 - 3/2 | -0.276D 01 | 0.260D-01 | 0.247D 05 | -0.100D 02 | 0.343D 00 | 0.327D 06 |
| | | 3/2 - 3/2 | -0.299D 01 | 0.301D-02 | 0.555D 04 | -0.100D 02 | 0.340D-01 | 0.626D 05 |
| | | 3/2 - 5/2 | -0.293D 01 | 0.261D-01 | 0.321D 05 | -0.101D 02 | 0.306D 00 | 0.377D 06 |
| 10 | 14 | 1/2 - 3/2 | 0.211D 01 | 0.168D-01 | 0.192D 05 | -0.773D 01 | 0.224D 00 | 0.257D 06 |
| | | 3/2 - 3/2 | 0.228D 01 | 0.193D-02 | 0.429D 04 | -0.777D 01 | 0.223D-01 | 0.496D 05 |
| | | 3/2 - 5/2 | 0.224D 01 | 0.167D-01 | 0.248D 05 | -0.777D 01 | 0.201D 00 | 0.299D 06 |
| 11 | 10 | 1/2 - 3/2 | 0.814D 02 | 0.870D 00 | 0.122D 04 | 0.777D 02 | 0.732D 00 | 0.111D 04 |
| | | 3/2 - 3/2 | 0.818D 02 | 0.643D-01 | 0.965D 02 | 0.757D 02 | 0.551D-01 | 0.826D 02 |
| | | 3/2 - 5/2 | 0.819D 02 | 0.637D 00 | 0.770D 03 | 0.763D 02 | 0.554D 00 | 0.669D 03 |
| 11 | 11 | 1/2 - 3/2 | 0.166D 02 | 0.275D 00 | 0.223D 05 | -0.828D 02 | 0.644D 01 | 0.554D 06 |
| | | 3/2 - 3/2 | 0.156D 02 | 0.369D-01 | 0.556D 04 | -0.857D 02 | 0.703D 00 | 0.107D 06 |
| | | 3/2 - 5/2 | 0.188D 02 | 0.307D 00 | 0.313D 05 | -0.851D 02 | 0.632D 01 | 0.644D 06 |
| 11 | 12 | 1/2 - 3/2 | -0.765D 01 | 0.340D-01 | 0.197D 05 | -0.296D 02 | 0.140D 01 | 0.235D 06 |
| | | 3/2 - 3/2 | -0.860D 01 | 0.116D-01 | 0.466D 04 | -0.296D 02 | 0.133D 00 | 0.552D 05 |
| | | 3/2 - 5/2 | -0.834D 01 | 0.988D-01 | 0.266D 05 | -0.296D 02 | 0.124D 01 | 0.335D 06 |
| 11 | 13 | 1/2 - 3/2 | 0.473D 01 | 0.459D-01 | 0.157D 05 | -0.173D 02 | 0.613D 00 | 0.209D 06 |
| | | 3/2 - 3/2 | 0.522D 01 | 0.549D-02 | 0.362D 04 | -0.172D 02 | 0.595D-01 | 0.373D 05 |
| | | 3/2 - 5/2 | 0.509D 01 | 0.471D-01 | 0.208D 05 | -0.172D 02 | 0.539D 00 | 0.238D 06 |
| 11 | 14 | 1/2 - 3/2 | -0.336D 01 | 0.269D-01 | 0.124D 05 | -0.122D 02 | 0.354D 00 | 0.163D 06 |
| | | 3/2 - 3/2 | -0.367D 01 | 0.316D-02 | 0.283D 04 | -0.121D 02 | 0.344D-01 | 0.309D 05 |
| | | 3/2 - 5/2 | -0.359D 01 | 0.272D-01 | 0.163D 05 | -0.121D 02 | 0.312D 00 | 0.187D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 12 | 11 | 1/2 - 3/2 | 0.105D 03 | 0.982D 00 | 0.628D 03 | 0.971D 02 | 0.837D 00 | 0.535D 03 |
| | | 3/2 - 3/2 | 0.106D 03 | 0.723D-01 | 0.492D 02 | 0.948D 02 | 0.583D-01 | 0.394D 02 |
| | | 3/2 - 5/2 | 0.106D 03 | 0.719D 00 | 0.395D 03 | 0.955D 02 | 0.585D 00 | 0.322D 03 |
| 12 | 12 | 1/2 - 3/2 | 0.203D 02 | 0.286D 00 | 0.113D 05 | -0.105D 03 | 0.761D 01 | 0.301D 06 |
| | | 3/2 - 3/2 | 0.240D 02 | 0.387D-01 | 0.285D 04 | -0.108D 03 | 0.735D 00 | 0.578D 05 |
| | | 3/2 - 5/2 | 0.229D 02 | 0.321D 00 | 0.160D 05 | -0.107D 03 | 0.701D 01 | 0.349D 06 |
| 12 | 13 | 1/2 - 3/2 | -0.921D 01 | 0.968D-01 | 0.102D 05 | -0.358D 02 | 0.146D 01 | 0.155D 06 |
| | | 3/2 - 3/2 | -0.104D 02 | 0.121D-01 | 0.245D 04 | -0.357D 02 | 0.142D 00 | 0.288D 05 |
| | | 3/2 - 5/2 | -0.101D 02 | 0.102D 00 | 0.139D 05 | -0.357D 02 | 0.129D 01 | 0.175D 06 |
| 12 | 14 | 1/2 - 3/2 | -0.205D 02 | 0.618D 00 | 0.109D 06 | 0.568D 01 | 0.475D-01 | 0.859D 04 |
| | | 3/2 - 3/2 | 0.629D 01 | 0.573D-02 | 0.196D 04 | -0.203D 02 | 0.595D-01 | 0.203D 05 |
| | | 3/2 - 5/2 | -0.203D 02 | 0.540D 00 | 0.123D 06 | 0.613D 01 | 0.490D-01 | 0.112D 05 |
| 13 | 12 | 1/2 - 3/2 | 0.132D 03 | 0.109D 01 | 0.351D 03 | 0.119D 03 | 0.886D 00 | 0.234D 03 |
| | | 3/2 - 3/2 | 0.133D 03 | 0.803D-01 | 0.271D 02 | 0.116D 03 | 0.612D-01 | 0.207D 02 |
| | | 3/2 - 5/2 | 0.133D 03 | 0.798D 00 | 0.219D 03 | 0.117D 03 | 0.618D 00 | 0.169D 03 |
| 13 | 13 | 1/2 - 3/2 | 0.241D 02 | 0.295D 00 | 0.615D 04 | -0.128D 03 | 0.835D 01 | 0.174D 06 |
| | | 3/2 - 3/2 | 0.287D 02 | 0.403D-01 | 0.157D 04 | -0.132D 03 | 0.853D 00 | 0.334D 05 |
| | | 3/2 - 5/2 | 0.274D 02 | 0.334D 00 | 0.879D 04 | -0.132D 03 | 0.767D 01 | 0.202D 06 |
| 13 | 14 | 1/2 - 3/2 | -0.109D 02 | 0.100D 00 | 0.573D 04 | -0.424D 02 | 0.151D 01 | 0.864D 05 |
| | | 3/2 - 3/2 | -0.124D 02 | 0.126D-01 | 0.138D 04 | -0.421D 02 | 0.145D 00 | 0.160D 05 |
| | | 3/2 - 5/2 | -0.120D 02 | 0.106D 00 | 0.785D 04 | -0.422D 02 | 0.132D 01 | 0.974D 05 |
| 14 | 13 | 1/2 - 3/2 | 0.162D 03 | 0.121D 01 | 0.212D 03 | 0.143D 03 | 0.943D 00 | 0.165D 03 |
| | | 3/2 - 3/2 | 0.163D 03 | 0.888D-01 | 0.163D 02 | 0.139D 03 | 0.651D-01 | 0.114D 02 |
| | | 3/2 - 5/2 | 0.163D 03 | 0.882D 00 | 0.131D 03 | 0.140D 03 | 0.655D 00 | 0.973D 02 |
| 14 | 14 | 1/2 - 3/2 | 0.284D 02 | 0.307D 00 | 0.359D 04 | -0.155D 03 | 0.907D 01 | 0.106D 06 |
| | | 3/2 - 3/2 | 0.340D 02 | 0.423D-01 | 0.923D 03 | -0.159D 03 | 0.929D 00 | 0.203D 05 |
| | | 3/2 - 5/2 | 0.324D 02 | 0.349D 00 | 0.516D 04 | -0.158D 03 | 0.831D 01 | 0.123D 06 |
| 15 | 14 | 1/2 - 3/2 | 0.194D 03 | 0.132D 01 | 0.130D 03 | 0.168D 03 | 0.983D 00 | 0.974D 02 |
| | | 3/2 - 3/2 | 0.196D 03 | 0.966D-01 | 0.100D 02 | 0.165D 03 | 0.683D-01 | 0.711D 01 |
| | | 3/2 - 5/2 | 0.196D 03 | 0.963D 00 | 0.816D 02 | 0.166D 03 | 0.692D 00 | 0.587D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 4 | 7 | 5/2 - 3/2 | 0.840D 01 | 0.115D 00 | 0.336D 06 | -0.139D 00 | 0.371D-04 | 0.920D 02 |
| | | 5/2 - 5/2 | 0.826D 01 | 0.945D-02 | 0.161D 05 | -0.137D 00 | 0.259D-05 | 0.440D 01 |
| | | 7/2 - 5/2 | 0.826D 01 | 0.142D 00 | 0.321D 06 | -0.137D 00 | 0.384D-04 | 0.880D 02 |
| 4 | 8 | 5/2 - 3/2 | -0.162D 01 | 0.106D-01 | 0.118D 06 | 0.332D-01 | 0.447D-05 | 0.499D 02 |
| | | 5/2 - 5/2 | -0.162D 01 | 0.764D-03 | 0.572D 04 | 0.352D-01 | 0.361D-06 | 0.270D 01 |
| | | 7/2 - 5/2 | -0.162D 01 | 0.115D-01 | 0.114D 06 | 0.353D-01 | 0.542D-05 | 0.541D 02 |
| 4 | 9 | 5/2 - 3/2 | 0.778D 00 | 0.320D-02 | 0.608D 05 | 0.774D-01 | 0.317D-04 | 0.602D 03 |
| | | 5/2 - 5/2 | 0.782D 00 | 0.231D-03 | 0.294D 04 | 0.787D-01 | 0.235D-05 | 0.298D 02 |
| | | 7/2 - 5/2 | 0.782D 00 | 0.347D-02 | 0.588D 05 | 0.787D-01 | 0.352D-04 | 0.596D 03 |
| 4 | 10 | 5/2 - 3/2 | -0.488D 00 | 0.144D-02 | 0.360D 05 | 0.872D-01 | 0.462D-04 | 0.115D 04 |
| | | 5/2 - 5/2 | -0.491D 00 | 0.105D-03 | 0.174D 04 | 0.881D-01 | 0.337D-05 | 0.561D 02 |
| | | 7/2 - 5/2 | -0.491D 00 | 0.157D-02 | 0.349D 05 | 0.881D-01 | 0.505D-04 | 0.112D 04 |
| 4 | 11 | 5/2 - 3/2 | 0.347D 00 | 0.792D-03 | 0.233D 05 | 0.860D-01 | 0.487D-04 | 0.143D 04 |
| | | 5/2 - 5/2 | 0.349D 00 | 0.575D-04 | 0.113D 04 | 0.865D-01 | 0.352D-05 | 0.692D 02 |
| | | 7/2 - 5/2 | 0.349D 00 | 0.862D-03 | 0.226D 05 | 0.865D-01 | 0.529D-04 | 0.139D 04 |
| 4 | 12 | 5/2 - 3/2 | -0.265D 00 | 0.489D-03 | 0.160D 05 | 0.809D-01 | 0.455D-04 | 0.149D 04 |
| | | 5/2 - 5/2 | -0.267D 00 | 0.355D-04 | 0.776D 03 | 0.812D-01 | 0.328D-05 | 0.717D 02 |
| | | 7/2 - 5/2 | -0.267D 00 | 0.532D-03 | 0.155D 05 | 0.812D-01 | 0.492D-04 | 0.144D 04 |
| 4 | 13 | 5/2 - 3/2 | 0.213D 00 | 0.326D-03 | 0.115D 05 | 0.747D-01 | 0.403D-04 | 0.142D 04 |
| | | 5/2 - 5/2 | 0.214D 00 | 0.237D-04 | 0.559D 03 | 0.750D-01 | 0.290D-05 | 0.683D 02 |
| | | 7/2 - 5/2 | 0.214D 00 | 0.356D-03 | 0.112D 05 | 0.750D-01 | 0.435D-04 | 0.137D 04 |
| 4 | 14 | 5/2 - 3/2 | -0.176D 00 | 0.230D-03 | 0.858D 04 | 0.685D-01 | 0.348D-04 | 0.130D 04 |
| | | 5/2 - 5/2 | -0.178D 00 | 0.167D-04 | 0.416D 03 | 0.687D-01 | 0.250D-05 | 0.622D 02 |
| | | 7/2 - 5/2 | -0.178D 00 | 0.251D-03 | 0.832D 04 | 0.687D-01 | 0.375D-04 | 0.124D 04 |
| 5 | 8 | 5/2 - 3/2 | 0.168D 02 | 0.288D 00 | 0.203D 06 | -0.336D 00 | 0.115D-03 | 0.810D 02 |
| | | 5/2 - 5/2 | 0.165D 02 | 0.202D-01 | 0.975D 04 | -0.331D 00 | 0.810D-05 | 0.392D 01 |
| | | 7/2 - 5/2 | 0.165D 02 | 0.302D 00 | 0.195D 06 | -0.331D 00 | 0.122D-03 | 0.784D 02 |
| 5 | 9 | 5/2 - 3/2 | -0.323D 01 | 0.235D-01 | 0.811D 05 | 0.255D-01 | 0.147D-05 | 0.508D 01 |
| | | 5/2 - 5/2 | -0.323D 01 | 0.169D-02 | 0.393D 04 | 0.296D-01 | 0.142D-06 | 0.329D 00 |
| | | 7/2 - 5/2 | -0.323D 01 | 0.254D-01 | 0.785D 05 | 0.297D-01 | 0.214D-05 | 0.661D 01 |
| 5 | 10 | 5/2 - 3/2 | 0.155D 01 | 0.724D-02 | 0.452D 05 | 0.126D 00 | 0.480D-04 | 0.299D 03 |
| | | 5/2 - 5/2 | 0.155D 01 | 0.525D-03 | 0.219D 04 | 0.128D 00 | 0.356D-05 | 0.149D 02 |
| | | 7/2 - 5/2 | 0.155D 01 | 0.787D-02 | 0.438D 05 | 0.128D 00 | 0.538D-04 | 0.299D 03 |
| 5 | 11 | 5/2 - 3/2 | -0.967D 00 | 0.332D-02 | 0.284D 05 | 0.154D 00 | 0.843D-04 | 0.721D 03 |
| | | 5/2 - 5/2 | -0.974D 00 | 0.241D-03 | 0.138D 04 | 0.156D 00 | 0.617D-05 | 0.353D 02 |
| | | 7/2 - 5/2 | -0.974D 00 | 0.362D-02 | 0.276D 05 | 0.156D 00 | 0.926D-04 | 0.706D 03 |
| 5 | 12 | 5/2 - 3/2 | 0.666D 00 | 0.185D-02 | 0.192D 05 | 0.158D 00 | 0.971D-04 | 0.101D 04 |
| | | 5/2 - 5/2 | 0.692D 00 | 0.134D-03 | 0.932D 03 | 0.159D 00 | 0.707D-05 | 0.491D 02 |
| | | 7/2 - 5/2 | 0.692D 00 | 0.201D-02 | 0.186D 05 | 0.159D 00 | 0.106D-03 | 0.983D 03 |
| 5 | 13 | 5/2 - 3/2 | -0.525D 00 | 0.115D-02 | 0.137D 05 | 0.152D 00 | 0.963D-04 | 0.115D 04 |
| | | 5/2 - 5/2 | -0.529D 00 | 0.838D-04 | 0.664D 03 | 0.153D 00 | 0.700D-05 | 0.554D 02 |
| | | 7/2 - 5/2 | -0.529D 00 | 0.126D-02 | 0.133D 05 | 0.153D 00 | 0.105D-03 | 0.111D 04 |
| 5 | 14 | 5/2 - 3/2 | 0.421D 00 | 0.776D-03 | 0.101D 05 | 0.143D 00 | 0.899D-04 | 0.117D 04 |
| | | 5/2 - 5/2 | 0.424D 00 | 0.564D-04 | 0.491D 03 | 0.144D 00 | 0.648D-05 | 0.563D 02 |
| | | 7/2 - 5/2 | 0.424D 00 | 0.847D-03 | 0.981D 04 | 0.144D 00 | 0.972D-04 | 0.113D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 8 | 10 | 3/2 - 5/2 | -0.821D 00 | 0.306D-02 | 0.845D 04 | -0.978D 01 | 0.434D 00 | 0.120D 07 |
| | | 5/2 - 5/2 | -0.857D 00 | 0.173D-03 | 0.710D 03 | -0.988D 01 | 0.210D-01 | 0.861D 05 |
| | | 5/2 - 7/2 | -0.858D 00 | 0.347D-02 | 0.107D 05 | -0.988D 01 | 0.420D 00 | 0.129D 07 |
| 8 | 11 | 3/2 - 5/2 | 0.708D 00 | 0.245D-02 | 0.784D 04 | -0.782D 01 | 0.299D 00 | 0.957D 06 |
| | | 5/2 - 5/2 | 0.766D 00 | 0.136D-03 | 0.647D 03 | -0.787D 01 | 0.144D-01 | 0.683D 05 |
| | | 5/2 - 7/2 | 0.766D 00 | 0.272D-02 | 0.971D 04 | -0.787D 01 | 0.287D 00 | 0.102D 07 |
| 8 | 12 | 3/2 - 5/2 | -0.602D 00 | 0.187D-02 | 0.666D 04 | -0.635D 01 | 0.208D 00 | 0.741D 06 |
| | | 5/2 - 5/2 | -0.649D 00 | 0.103D-03 | 0.545D 03 | -0.638D 01 | 0.995D-02 | 0.527D 05 |
| | | 5/2 - 7/2 | -0.649D 00 | 0.206D-02 | 0.818D 04 | -0.638D 01 | 0.199D 00 | 0.730D 06 |
| 9 | 7 | 3/2 - 5/2 | 0.584D 02 | 0.199D 01 | 0.901D 05 | -0.190D 02 | 0.210D 00 | 0.951D 04 |
| | | 5/2 - 5/2 | 0.588D 02 | 0.938D-01 | 0.610D 04 | -0.187D 02 | 0.951D-02 | 0.618D 03 |
| | | 5/2 - 7/2 | 0.588D 02 | 0.188D 01 | 0.914D 05 | -0.187D 02 | 0.190D 00 | 0.926D 04 |
| 9 | 8 | 3/2 - 5/2 | -0.181D 01 | 0.507D-02 | 0.163D 04 | 0.831D 02 | 0.107D 02 | 0.343D 07 |
| | | 5/2 - 5/2 | -0.139D 01 | 0.142D-03 | 0.674D 02 | 0.831D 02 | 0.505D 00 | 0.239D 06 |
| | | 5/2 - 7/2 | -0.139D 01 | 0.282D-02 | 0.100D 04 | 0.831D 02 | 0.101D 02 | 0.359D 07 |
| 9 | 9 | 3/2 - 5/2 | -0.394D 00 | 0.343D-03 | 0.224D 03 | -0.119D 02 | 0.314D 00 | 0.206D 06 |
| | | 5/2 - 5/2 | -0.610D 00 | 0.389D-04 | 0.378D 02 | -0.125D 02 | 0.163D-01 | 0.158D 05 |
| | | 5/2 - 7/2 | -0.611D 00 | 0.783D-03 | 0.570D 03 | -0.125D 02 | 0.325D 00 | 0.237D 06 |
| 9 | 10 | 3/2 - 5/2 | 0.665D 00 | 0.119D-02 | 0.115D 04 | -0.151D 02 | 0.615D 00 | 0.594D 06 |
| | | 5/2 - 5/2 | 0.803D 00 | 0.821D-04 | 0.118D 03 | -0.154D 02 | 0.301D-01 | 0.432D 05 |
| | | 5/2 - 7/2 | 0.804D 00 | 0.164D-02 | 0.177D 04 | -0.154D 02 | 0.602D 00 | 0.647D 06 |
| 9 | 11 | 3/2 - 5/2 | -0.657D 00 | 0.131D-02 | 0.162D 04 | -0.124D 02 | 0.466D 00 | 0.575D 06 |
| | | 5/2 - 5/2 | -0.755D 00 | 0.821D-04 | 0.151D 03 | -0.125D 02 | 0.223D-01 | 0.413D 05 |
| | | 5/2 - 7/2 | -0.755D 00 | 0.164D-02 | 0.226D 04 | -0.125D 02 | 0.450D 00 | 0.620D 06 |
| 9 | 12 | 3/2 - 5/2 | 0.581D 00 | 0.112D-02 | 0.163D 04 | -0.986D 01 | 0.321D 00 | 0.469D 06 |
| | | 5/2 - 5/2 | 0.657D 00 | 0.675D-04 | 0.147D 03 | -0.992D 01 | 0.154D-01 | 0.335D 05 |
| | | 5/2 - 7/2 | 0.657D 00 | 0.135D-02 | 0.220D 04 | -0.992D 01 | 0.308D 00 | 0.502D 06 |
| 10 | 8 | 3/2 - 5/2 | 0.771D 02 | 0.228D 01 | 0.449D 05 | -0.260D 02 | 0.259D 00 | 0.510D 04 |
| | | 5/2 - 5/2 | 0.776D 02 | 0.108D 00 | 0.304D 04 | -0.256D 02 | 0.117D-01 | 0.332D 03 |
| | | 5/2 - 7/2 | 0.776D 02 | 0.215D 01 | 0.456D 05 | -0.256D 02 | 0.233D 00 | 0.497D 04 |
| 10 | 9 | 3/2 - 5/2 | -0.352D 01 | 0.130D-01 | 0.190D 04 | 0.107D 03 | 0.121D 02 | 0.177D 07 |
| | | 5/2 - 5/2 | -0.301D 01 | 0.448D-03 | 0.968D 02 | 0.107D 03 | 0.571D 00 | 0.123D 06 |
| | | 5/2 - 7/2 | -0.301D 01 | 0.893D-02 | 0.145D 04 | 0.107D 03 | 0.114D 02 | 0.145D 07 |
| 10 | 10 | 3/2 - 5/2 | 0.218D 00 | 0.721D-04 | 0.223D 02 | -0.146D 02 | 0.324D 00 | 0.100D 06 |
| | | 5/2 - 5/2 | -0.454D-01 | 0.176D-06 | 0.806D-01 | -0.153D 02 | 0.163D-01 | 0.769D 04 |
| | | 5/2 - 7/2 | -0.505D-01 | 0.367D-05 | 0.126D 01 | -0.153D 02 | 0.330D 00 | 0.115D 06 |
| 10 | 11 | 3/2 - 5/2 | 0.343D 00 | 0.221D-03 | 0.103D 03 | -0.188D 02 | 0.653D 00 | 0.308D 06 |
| | | 5/2 - 5/2 | 0.514D 00 | 0.234D-04 | 0.163D 02 | -0.190D 02 | 0.322D-01 | 0.224D 05 |
| | | 5/2 - 7/2 | 0.514D 00 | 0.463D-03 | 0.244D 03 | -0.190D 02 | 0.643D 00 | 0.336D 06 |
| 10 | 12 | 3/2 - 5/2 | -0.431D 00 | 0.397D-03 | 0.242D 03 | -0.153D 02 | 0.499D 00 | 0.305D 06 |
| | | 5/2 - 5/2 | -0.553D 00 | 0.309D-04 | 0.281D 02 | -0.154D 02 | 0.241D-01 | 0.219D 05 |
| | | 5/2 - 7/2 | -0.553D 00 | 0.619D-03 | 0.422D 03 | -0.154D 02 | 0.482D 00 | 0.329D 06 |
| 11 | 9 | 3/2 - 5/2 | 0.981D 02 | 0.256D 01 | 0.242D 05 | -0.340D 02 | 0.307D 00 | 0.290D 04 |
| | | 5/2 - 5/2 | 0.988D 02 | 0.121D 00 | 0.164D 04 | -0.335D 02 | 0.137D-01 | 0.183D 03 |
| | | 5/2 - 7/2 | 0.988D 02 | 0.242D 01 | 0.246D 05 | -0.335D 02 | 0.279D 00 | 0.283D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_J$, CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 8 | 10 | 3/2 - 5/2 | -0.821D 00 | 0.306D-02 | 0.845D 04 | -0.978D 01 | 0.434D 00 | 0.120D 07 |
| | | 5/2 - 5/2 | -0.857D 00 | 0.173D-03 | 0.710D 03 | -0.988D 01 | 0.210D-01 | 0.861D 05 |
| | | 5/2 - 7/2 | -0.858D 00 | 0.347D-02 | 0.107D 05 | -0.988D 01 | 0.420D 00 | 0.129D 07 |
| 8 | 11 | 3/2 - 5/2 | 0.708D 00 | 0.245D-02 | 0.784D 04 | -0.782D 01 | 0.293D 00 | 0.957D 06 |
| | | 5/2 - 5/2 | 0.766D 00 | 0.136D-03 | 0.647D 03 | -0.787D 01 | 0.144D-01 | 0.683D 05 |
| | | 5/2 - 7/2 | 0.766D 00 | 0.272D-02 | 0.971D 04 | -0.787D 01 | 0.287D 00 | 0.102D 07 |
| 8 | 12 | 3/2 - 5/2 | -0.602D 00 | 0.187D-02 | 0.666D 04 | -0.635D 01 | 0.208D 00 | 0.741D 06 |
| | | 5/2 - 5/2 | -0.649D 00 | 0.103D-03 | 0.545D 03 | -0.638D 01 | 0.975D-02 | 0.527D 05 |
| | | 5/2 - 7/2 | -0.649D 00 | 0.206D-02 | 0.818D 04 | -0.638D 01 | 0.195D 00 | 0.790D 06 |
| 9 | 7 | 3/2 - 5/2 | 0.584D 02 | 0.199D 01 | 0.901D 05 | -0.190D 02 | 0.210D 00 | 0.951D 04 |
| | | 5/2 - 5/2 | 0.588D 02 | 0.938D-01 | 0.610D 04 | -0.187D 02 | 0.951D-02 | 0.618D 03 |
| | | 5/2 - 7/2 | 0.588D 02 | 0.188D 01 | 0.914D 05 | -0.187D 02 | 0.190D 00 | 0.926D 04 |
| 9 | 8 | 3/2 - 5/2 | -0.181D 01 | 0.507D-02 | 0.163D 04 | 0.831D 02 | 0.107D 02 | 0.343D 07 |
| | | 5/2 - 5/2 | -0.139D 01 | 0.142D-03 | 0.674D 02 | 0.831D 02 | 0.505D 00 | 0.239D 06 |
| | | 5/2 - 7/2 | -0.139D 01 | 0.282D-02 | 0.100D 04 | 0.831D 02 | 0.101D 02 | 0.359D 07 |
| 9 | 9 | 3/2 - 5/2 | -0.394D 00 | 0.343D-03 | 0.224D 03 | -0.119D 02 | 0.314D 00 | 0.206D 06 |
| | | 5/2 - 5/2 | -0.610D 00 | 0.389D-04 | 0.378D 02 | -0.125D 02 | 0.163D-01 | 0.158D 05 |
| | | 5/2 - 7/2 | -0.611D 00 | 0.783D-03 | 0.570D 03 | -0.125D 02 | 0.325D 00 | 0.237D 06 |
| 9 | 10 | 3/2 - 5/2 | 0.665D 00 | 0.119D-02 | 0.115D 04 | -0.151D 02 | 0.615D 00 | 0.594D 06 |
| | | 5/2 - 5/2 | 0.803D 00 | 0.821D-04 | 0.118D 03 | -0.154D 02 | 0.301D-01 | 0.432D 05 |
| | | 5/2 - 7/2 | 0.804D 00 | 0.164D-02 | 0.177D 04 | -0.154D 02 | 0.602D 00 | 0.647D 06 |
| 9 | 11 | 3/2 - 5/2 | -0.657D 00 | 0.131D-02 | 0.162D 04 | -0.124D 02 | 0.466D 00 | 0.575D 06 |
| | | 5/2 - 5/2 | -0.755D 00 | 0.821D-04 | 0.151D 03 | -0.125D 02 | 0.225D-01 | 0.413D 05 |
| | | 5/2 - 7/2 | -0.755D 00 | 0.164D-02 | 0.226D 04 | -0.125D 02 | 0.450D 00 | 0.620D 06 |
| 9 | 12 | 3/2 - 5/2 | 0.581D 00 | 0.112D-02 | 0.163D 04 | -0.986D 01 | 0.321D 00 | 0.469D 06 |
| | | 5/2 - 5/2 | 0.657D 00 | 0.675D-04 | 0.147D 03 | -0.992D 01 | 0.154D-01 | 0.335D 05 |
| | | 5/2 - 7/2 | 0.657D 00 | 0.135D-02 | 0.220D 04 | -0.992D 01 | 0.308D 00 | 0.502D 06 |
| 10 | 8 | 3/2 - 5/2 | 0.771D 02 | 0.228D 01 | 0.449D 05 | -0.260D 02 | 0.259D 00 | 0.510D 04 |
| | | 5/2 - 5/2 | 0.776D 02 | 0.108D 00 | 0.304D 04 | -0.256D 02 | 0.117D-01 | 0.332D 03 |
| | | 5/2 - 7/2 | 0.776D 02 | 0.215D 01 | 0.456D 05 | -0.256D 02 | 0.235D 00 | 0.497D 04 |
| 10 | 9 | 3/2 - 5/2 | -0.382D 01 | 0.130D-01 | 0.190D 04 | 0.107D 03 | 0.121D 02 | 0.177D 07 |
| | | 5/2 - 5/2 | -0.301D 01 | 0.448D-03 | 0.968D 02 | 0.107D 03 | 0.571D 00 | 0.123D 06 |
| | | 5/2 - 7/2 | -0.301D 01 | 0.893D-02 | 0.145D 04 | 0.107D 03 | 0.114D 02 | 0.145D 07 |
| 10 | 10 | 3/2 - 5/2 | 0.218D 00 | 0.721D-04 | 0.223D 02 | -0.146D 02 | 0.324D 00 | 0.100D 06 |
| | | 5/2 - 5/2 | -0.494D-01 | 0.176D-06 | 0.806D-01 | -0.153D 02 | 0.163D-01 | 0.769D 04 |
| | | 5/2 - 7/2 | -0.505D-01 | 0.367D-05 | 0.126D 01 | -0.153D 02 | 0.326D 00 | 0.115D 06 |
| 10 | 11 | 3/2 - 5/2 | 0.343D 00 | 0.221D-03 | 0.103D 03 | -0.188D 02 | 0.653D 00 | 0.308D 06 |
| | | 5/2 - 5/2 | 0.514D 00 | 0.234D-04 | 0.163D 02 | -0.190D 02 | 0.322D-01 | 0.224D 05 |
| | | 5/2 - 7/2 | 0.514D 00 | 0.463D-03 | 0.244D 03 | -0.190D 02 | 0.643D 00 | 0.336D 06 |
| 10 | 12 | 3/2 - 5/2 | -0.431D 00 | 0.397D-03 | 0.242D 03 | -0.153D 02 | 0.493D 00 | 0.305D 06 |
| | | 5/2 - 5/2 | -0.553D 00 | 0.309D-04 | 0.281D 02 | -0.154D 02 | 0.241D-01 | 0.219D 05 |
| | | 5/2 - 7/2 | -0.553D 00 | 0.619D-03 | 0.422D 03 | -0.154D 02 | 0.482D 00 | 0.329D 06 |
| 11 | 9 | 3/2 - 5/2 | 0.981D 02 | 0.256D 01 | 0.242D 05 | -0.340D 02 | 0.362D 00 | 0.290D 04 |
| | | 5/2 - 5/2 | 0.988D 02 | 0.121D 00 | 0.164D 04 | -0.335D 02 | 0.139D-01 | 0.189D 03 |
| | | 5/2 - 7/2 | 0.988D 02 | 0.242D 01 | 0.246D 05 | -0.335D 02 | 0.278D 00 | 0.283D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 11 | 10 | 3/2 - 5/2 | -0.544D 01 | 0.219D-01 | 0.160D 04 | 0.135D 03 | 0.134D 02 | 0.981D 06 |
| | | 5/2 - 5/2 | -0.482D 01 | 0.811D-03 | 0.876D 02 | 0.135D 03 | 0.634D 00 | 0.685D 05 |
| | | 5/2 - 7/2 | -0.481D 01 | 0.162D-01 | 0.131D 04 | 0.135D 03 | 0.127D 02 | 0.103D 07 |
| 11 | 11 | 3/2 - 5/2 | 0.923D 00 | 0.928D-03 | 0.147D 03 | -0.177D 02 | 0.340D 00 | 0.540D 05 |
| | | 5/2 - 5/2 | 0.597D 00 | 0.184D-04 | 0.434D 01 | -0.185D 02 | 0.175D-01 | 0.416D 04 |
| | | 5/2 - 7/2 | 0.597D 00 | 0.368D-03 | 0.651D 02 | -0.185D 02 | 0.353D 00 | 0.624D 05 |
| 11 | 12 | 3/2 - 5/2 | -0.727D-01 | 0.718D-05 | 0.177D 01 | -0.227D 02 | 0.701D 00 | 0.173D 06 |
| | | 5/2 - 5/2 | 0.134D 00 | 0.116D-05 | 0.426D 00 | -0.231D 02 | 0.343D-01 | 0.126D 05 |
| | | 5/2 - 7/2 | 0.134D 00 | 0.232D-04 | 0.638D 01 | -0.231D 02 | 0.686D 00 | 0.188D 06 |
| 12 | 10 | 3/2 - 5/2 | 0.121D 03 | 0.283D 01 | 0.140D 05 | -0.429D 02 | 0.354D 00 | 0.175D 04 |
| | | 5/2 - 5/2 | 0.122D 03 | 0.134D 00 | 0.948D 03 | -0.424D 02 | 0.161D-01 | 0.114D 03 |
| | | 5/2 - 7/2 | 0.122D 03 | 0.268D 01 | 0.142D 05 | -0.424D 02 | 0.321D 00 | 0.171D 04 |
| 12 | 11 | 3/2 - 5/2 | -0.764D 01 | 0.317D-01 | 0.125D 04 | 0.165D 03 | 0.147D 02 | 0.580D 06 |
| | | 5/2 - 5/2 | -0.691D 01 | 0.122D-02 | 0.711D 02 | 0.165D 03 | 0.697D 00 | 0.405D 05 |
| | | 5/2 - 7/2 | -0.691D 01 | 0.244D-01 | 0.107D 04 | 0.165D 03 | 0.139D 02 | 0.608D 06 |
| 12 | 12 | 3/2 - 5/2 | 0.182D 01 | 0.268D-02 | 0.235D 03 | -0.209D 02 | 0.353D 00 | 0.310D 05 |
| | | 5/2 - 5/2 | 0.144D 01 | 0.790D-04 | 0.103D 02 | -0.219D 02 | 0.183D-01 | 0.238D 04 |
| | | 5/2 - 7/2 | 0.144D 01 | 0.158D-02 | 0.154D 03 | -0.219D 02 | 0.367D 00 | 0.358D 05 |
| 13 | 11 | 3/2 - 5/2 | 0.147D 03 | 0.310D 01 | 0.849D 04 | -0.529D 02 | 0.400D 00 | 0.110D 04 |
| | | 5/2 - 5/2 | 0.148D 03 | 0.147D 00 | 0.577D 03 | -0.522D 02 | 0.192D-01 | 0.716D 02 |
| | | 5/2 - 7/2 | 0.148D 03 | 0.293D 01 | 0.866D 04 | -0.522D 02 | 0.364D 00 | 0.107D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_J$, CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 10 | 3/2 - 5/2 | -0.715D 00 | 0.719D-02 | 0.190D 06 | -0.355D 01 | 0.177D 00 | 0.468D 07 |
| | | 5/2 - 5/2 | -0.736D 00 | 0.361D-03 | 0.141D 05 | -0.357D 01 | 0.847D-02 | 0.332D 06 |
| | | 5/2 - 7/2 | -0.736D 00 | 0.721D-02 | 0.212D 06 | -0.357D 01 | 0.169D 00 | 0.499D 07 |
| 6 | 11 | 3/2 - 5/2 | 0.606D 00 | 0.529D-02 | 0.147D 06 | -0.295D 01 | 0.126D 00 | 0.349D 07 |
| | | 5/2 - 5/2 | 0.623D 00 | 0.265D-03 | 0.109D 05 | -0.296D 01 | 0.600D-02 | 0.247D 06 |
| | | 5/2 - 7/2 | 0.623D 00 | 0.529D-02 | 0.164D 06 | -0.296D 01 | 0.120D 00 | 0.371D 07 |
| 6 | 12 | 3/2 - 5/2 | -0.519D 00 | 0.395D-02 | 0.114D 06 | -0.251D 01 | 0.923D-01 | 0.266D 07 |
| | | 5/2 - 5/2 | -0.533D 00 | 0.197D-03 | 0.845D 04 | -0.252D 01 | 0.440D-02 | 0.188D 06 |
| | | 5/2 - 7/2 | -0.533D 00 | 0.395D-02 | 0.127D 06 | -0.252D 01 | 0.879D-01 | 0.282D 07 |
| 7 | 5 | 3/2 - 5/2 | 0.281D 02 | 0.133D 01 | 0.503D 06 | -0.794D 01 | 0.196D 00 | 0.402D 05 |
| | | 5/2 - 5/2 | 0.282D 02 | 0.623D-01 | 0.339D 05 | -0.783D 01 | 0.480D-02 | 0.251D 04 |
| | | 5/2 - 7/2 | 0.282D 02 | 0.125D 01 | 0.508D 06 | -0.783D 01 | 0.960D-01 | 0.391D 05 |
| 7 | 6 | 3/2 - 5/2 | 0.109D 01 | 0.498D-02 | 0.115D 05 | 0.431D 02 | 0.772D 01 | 0.179D 08 |
| | | 5/2 - 5/2 | 0.134D 01 | 0.352D-03 | 0.120D 04 | 0.431D 02 | 0.365D 00 | 0.124D 07 |
| | | 5/2 - 7/2 | 0.134D 01 | 0.708D-02 | 0.181D 05 | 0.431D 02 | 0.730D 01 | 0.187D 08 |
| 7 | 7 | 3/2 - 5/2 | -0.141D 01 | 0.112D-01 | 0.478D 05 | -0.782D 01 | 0.346D 00 | 0.148D 07 |
| | | 5/2 - 5/2 | -0.153D 01 | 0.627D-03 | 0.396D 04 | -0.814D 01 | 0.177D-01 | 0.112D 06 |
| | | 5/2 - 7/2 | -0.153D 01 | 0.126D-01 | 0.596D 05 | -0.815D 01 | 0.355D 00 | 0.168D 07 |
| 7 | 8 | 3/2 - 5/2 | 0.117D 01 | 0.902D-02 | 0.528D 05 | -0.916D 01 | 0.558D 00 | 0.326D 07 |
| | | 5/2 - 5/2 | 0.124D 01 | 0.485D-03 | 0.422D 04 | -0.931D 01 | 0.272D-01 | 0.236D 06 |
| | | 5/2 - 7/2 | 0.125D 01 | 0.972D-02 | 0.634D 05 | -0.932D 01 | 0.544D 00 | 0.354D 07 |
| 7 | 9 | 3/2 - 5/2 | -0.955D 00 | 0.663D-02 | 0.471D 05 | -0.748D 01 | 0.407D 00 | 0.289D 07 |
| | | 5/2 - 5/2 | -0.101D 01 | 0.351D-03 | 0.370D 04 | -0.755D 01 | 0.197D-01 | 0.207D 06 |
| | | 5/2 - 7/2 | -0.101D 01 | 0.704D-02 | 0.556D 05 | -0.755D 01 | 0.393D 00 | 0.311D 07 |
| 7 | 10 | 3/2 - 5/2 | 0.794D 00 | 0.489D-02 | 0.394D 05 | -0.598D 01 | 0.277D 00 | 0.223D 07 |
| | | 5/2 - 5/2 | 0.836D 00 | 0.257D-03 | 0.307D 04 | -0.602D 01 | 0.133D-01 | 0.159D 06 |
| | | 5/2 - 7/2 | 0.836D 00 | 0.514D-02 | 0.460D 05 | -0.602D 01 | 0.266D 00 | 0.239D 07 |
| 7 | 11 | 3/2 - 5/2 | -0.672D 00 | 0.365D-02 | 0.321D 05 | -0.487D 01 | 0.192D 00 | 0.169D 07 |
| | | 5/2 - 5/2 | -0.705D 00 | 0.191D-03 | 0.249D 04 | -0.489D 01 | 0.920D-02 | 0.120D 06 |
| | | 5/2 - 7/2 | -0.705D 00 | 0.382D-02 | 0.374D 05 | -0.489D 01 | 0.184D 00 | 0.180D 07 |
| 7 | 12 | 3/2 - 5/2 | 0.571D 00 | 0.273D-02 | 0.256D 05 | -0.406D 01 | 0.133D 00 | 0.129D 07 |
| | | 5/2 - 5/2 | 0.599D 00 | 0.142D-03 | 0.198D 04 | -0.407D 01 | 0.657D-02 | 0.916D 05 |
| | | 5/2 - 7/2 | 0.599D 00 | 0.284D-02 | 0.297D 05 | -0.407D 01 | 0.131D 00 | 0.137D 07 |
| 8 | 6 | 3/2 - 5/2 | 0.421D 02 | 0.168D 01 | 0.200D 06 | -0.130D 02 | 0.153D 00 | 0.190D 05 |
| | | 5/2 - 5/2 | 0.424D 02 | 0.790D-01 | 0.135D 05 | -0.128D 02 | 0.721D-02 | 0.123D 04 |
| | | 5/2 - 7/2 | 0.424D 02 | 0.158D 01 | 0.203D 06 | -0.128D 02 | 0.144D 00 | 0.135D 05 |
| 8 | 7 | 3/2 - 5/2 | -0.289D 00 | 0.204D-03 | 0.162D 03 | 0.616D 02 | 0.926D 01 | 0.718D 07 |
| | | 5/2 - 5/2 | 0.367D-01 | 0.155D-06 | 0.182D 00 | 0.617D 02 | 0.438D 00 | 0.512D 06 |
| | | 5/2 - 7/2 | 0.408D-01 | 0.384D-05 | 0.337D 01 | 0.617D 02 | 0.876D 01 | 0.769D 07 |
| 8 | 8 | 3/2 - 5/2 | -0.928D 00 | 0.293D-02 | 0.455D 04 | -0.965D 01 | 0.317D 00 | 0.431D 06 |
| | | 5/2 - 5/2 | -0.110D 01 | 0.194D-03 | 0.445D 03 | -0.101D 02 | 0.163D-01 | 0.375D 05 |
| | | 5/2 - 7/2 | -0.110D 01 | 0.389D-02 | 0.670D 04 | -0.101D 02 | 0.327D 00 | 0.563D 06 |
| 8 | 9 | 3/2 - 5/2 | 0.934D 00 | 0.355D-02 | 0.786D 04 | -0.119D 02 | 0.579D 00 | 0.128D 07 |
| | | 5/2 - 5/2 | 0.104D 01 | 0.209D-03 | 0.686D 03 | -0.121D 02 | 0.238D-01 | 0.931D 05 |
| | | 5/2 - 7/2 | 0.104D 01 | 0.418D-02 | 0.103D 05 | -0.121D 02 | 0.567D 00 | 0.140D 07 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd\,^2D_j - mf\,^2F_{j'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | j-j' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 5 | 4 | 3/2 - 5/2 | 0.481D 01 | 0.421D 00 | 0.186D 08 | 0.143D 02 | 0.372D 01 | 0.164D 09 |
| | | 5/2 - 5/2 | 0.489D 01 | 0.205D-01 | 0.134D 07 | 0.143D 02 | 0.175D 00 | 0.114D 08 |
| | | 5/2 - 7/2 | 0.490D 01 | 0.411D 00 | 0.200D 08 | 0.143D 02 | 0.351D 01 | 0.171D 09 |
| 5 | 5 | 3/2 - 5/2 | -0.261D 01 | 0.155D 00 | 0.107D 08 | -0.590D 01 | 0.792D 00 | 0.548D 08 |
| | | 5/2 - 5/2 | -0.264D 01 | 0.748D-02 | 0.764D 06 | -0.603D 01 | 0.391D-01 | 0.399D 07 |
| | | 5/2 - 7/2 | -0.264D 01 | 0.150D 00 | 0.115D 08 | -0.603D 01 | 0.781D 00 | 0.598D 08 |
| 5 | 6 | 3/2 - 5/2 | 0.173D 01 | 0.759D-01 | 0.645D 07 | -0.508D 01 | 0.649D 00 | 0.552D 08 |
| | | 5/2 - 5/2 | 0.175D 01 | 0.365D-02 | 0.459D 06 | -0.513D 01 | 0.314D-01 | 0.395D 07 |
| | | 5/2 - 7/2 | 0.175D 01 | 0.731D-01 | 0.689D 07 | -0.513D 01 | 0.628D 00 | 0.592D 08 |
| 5 | 7 | 3/2 - 5/2 | -0.128D 01 | 0.434D-01 | 0.414D 07 | -0.385D 01 | 0.357D 00 | 0.378D 08 |
| | | 5/2 - 5/2 | -0.129D 01 | 0.209D-02 | 0.295D 06 | -0.388D 01 | 0.190D-01 | 0.269D 07 |
| | | 5/2 - 7/2 | -0.129D 01 | 0.417D-01 | 0.442D 07 | -0.388D 01 | 0.381D 00 | 0.403D 08 |
| 5 | 8 | 3/2 - 5/2 | 0.955D 00 | 0.274D-01 | 0.280D 07 | -0.300D 01 | 0.248D 00 | 0.255D 08 |
| | | 5/2 - 5/2 | 0.100D 01 | 0.131D-02 | 0.199D 06 | -0.301D 01 | 0.119D-01 | 0.180D 07 |
| | | 5/2 - 7/2 | 0.100D 01 | 0.263D-01 | 0.299D 07 | -0.301D 01 | 0.238D 00 | 0.270D 08 |
| 5 | 9 | 3/2 - 5/2 | -0.807D 00 | 0.184D-01 | 0.198D 07 | -0.241D 01 | 0.164D 00 | 0.176D 08 |
| | | 5/2 - 5/2 | -0.812D 00 | 0.885D-03 | 0.141D 06 | -0.242D 01 | 0.783D-02 | 0.125D 07 |
| | | 5/2 - 7/2 | -0.812D 00 | 0.177D-01 | 0.211D 07 | -0.242D 01 | 0.157D 00 | 0.187D 08 |
| 5 | 10 | 3/2 - 5/2 | 0.673D 00 | 0.131D-01 | 0.145D 07 | -0.199D 01 | 0.114D 00 | 0.126D 08 |
| | | 5/2 - 5/2 | 0.678D 00 | 0.626D-03 | 0.103D 06 | -0.199D 01 | 0.542D-02 | 0.892D 06 |
| | | 5/2 - 7/2 | 0.678D 00 | 0.125D-01 | 0.154D 07 | -0.199D 01 | 0.108D 00 | 0.134D 08 |
| 5 | 11 | 3/2 - 5/2 | -0.573D 00 | 0.958D-02 | 0.109D 07 | -0.168D 01 | 0.822D-01 | 0.935D 07 |
| | | 5/2 - 5/2 | -0.577D 00 | 0.459D-03 | 0.774D 05 | -0.168D 01 | 0.391D-02 | 0.659D 06 |
| | | 5/2 - 7/2 | -0.577D 00 | 0.918D-02 | 0.116D 07 | -0.168D 01 | 0.782D-01 | 0.988D 07 |
| 5 | 12 | 3/2 - 5/2 | 0.495D 00 | 0.720D-02 | 0.834D 06 | -0.144D 01 | 0.613D-01 | 0.710D 07 |
| | | 5/2 - 5/2 | 0.498D 00 | 0.345D-03 | 0.592D 05 | -0.145D 01 | 0.291D-02 | 0.500D 06 |
| | | 5/2 - 7/2 | 0.498D 00 | 0.690D-02 | 0.888D 06 | -0.145D 01 | 0.583D-01 | 0.751D 07 |
| 6 | 4 | 3/2 - 5/2 | 0.160D 02 | 0.874D 00 | 0.138D 07 | -0.386D 01 | 0.510D-01 | 0.805D 05 |
| | | 5/2 - 5/2 | 0.160D 02 | 0.409D-01 | 0.925D 05 | -0.380D 01 | 0.231D-02 | 0.521D 04 |
| | | 5/2 - 7/2 | 0.160D 02 | 0.818D 00 | 0.139D 07 | -0.380D 01 | 0.461D-01 | 0.782D 05 |
| 6 | 5 | 3/2 - 5/2 | 0.248D 01 | 0.492D-01 | 0.420D 06 | 0.274D 02 | 0.599D 01 | 0.512D 08 |
| | | 5/2 - 5/2 | 0.265D 01 | 0.265D-02 | 0.333D 05 | 0.274D 02 | 0.283D 00 | 0.355D 07 |
| | | 5/2 - 7/2 | 0.266D 01 | 0.531D-01 | 0.500D 06 | 0.274D 02 | 0.566D 01 | 0.533D 08 |
| 6 | 6 | 3/2 - 5/2 | -0.187D 01 | 0.366D-01 | 0.536D 06 | -0.649D 01 | 0.440D 00 | 0.645D 07 |
| | | 5/2 - 5/2 | -0.195D 01 | 0.188D-02 | 0.408D 05 | -0.671D 01 | 0.223D-01 | 0.482D 06 |
| | | 5/2 - 7/2 | -0.195D 01 | 0.377D-01 | 0.613D 06 | -0.671D 01 | 0.445D 00 | 0.723D 07 |
| 6 | 7 | 3/2 - 5/2 | 0.138D 01 | 0.228D-01 | 0.436D 06 | -0.695D 01 | 0.561D 00 | 0.107D 08 |
| | | 5/2 - 5/2 | 0.143D 01 | 0.116D-02 | 0.320D 05 | -0.695D 01 | 0.274D-01 | 0.775D 06 |
| | | 5/2 - 7/2 | 0.143D 01 | 0.232D-01 | 0.492D 06 | -0.696D 01 | 0.547D 00 | 0.116D 08 |
| 6 | 8 | 3/2 - 5/2 | -0.107D 01 | 0.148D-01 | 0.331D 06 | -0.548D 01 | 0.389D 00 | 0.869D 07 |
| | | 5/2 - 5/2 | -0.110D 01 | 0.746D-03 | 0.247D 05 | -0.554D 01 | 0.186D-01 | 0.621D 06 |
| | | 5/2 - 7/2 | -0.111D 01 | 0.149D-01 | 0.371D 06 | -0.554D 01 | 0.375D 00 | 0.932D 07 |
| 6 | 9 | 3/2 - 5/2 | 0.862D 00 | 0.101D-01 | 0.249D 06 | -0.436D 01 | 0.259D 00 | 0.639D 07 |
| | | 5/2 - 5/2 | 0.888D 00 | 0.507D-03 | 0.186D 05 | -0.439D 01 | 0.124D-01 | 0.455D 06 |
| | | 5/2 - 7/2 | 0.889D 00 | 0.102D-01 | 0.279D 06 | -0.439D 01 | 0.248D 00 | 0.682D 07 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 9 | 12 | 5/2 - 3/2 | 0.700D 02 | 0.919D 00 | 0.219D 05 | -0.185D 01 | 0.644D-03 | 0.154D 02 |
| | | 5/2 - 5/2 | 0.689D 02 | 0.646D-01 | 0.106D 04 | -0.184D 01 | 0.461D-04 | 0.756D 00 |
| | | 7/2 - 5/2 | 0.689D 02 | 0.968D 00 | 0.212D 05 | -0.184D 01 | 0.692D-03 | 0.151D 02 |
| 9 | 13 | 5/2 - 3/2 | -0.130D 02 | 0.762D-01 | 0.106D 05 | -0.291D 00 | 0.385D-04 | 0.537D 01 |
| | | 5/2 - 5/2 | -0.130D 02 | 0.553D-02 | 0.519D 03 | -0.276D 00 | 0.249D-05 | 0.234D 00 |
| | | 7/2 - 5/2 | -0.130D 02 | 0.829D-01 | 0.104D 05 | -0.276D 00 | 0.373D-04 | 0.467D 01 |
| 9 | 14 | 5/2 - 3/2 | 0.607D 01 | 0.241D-01 | 0.696D 04 | 0.192D 00 | 0.241D-04 | 0.636D 01 |
| | | 5/2 - 5/2 | 0.613D 01 | 0.176D-02 | 0.341D 03 | 0.203D 00 | 0.192D-05 | 0.373D 00 |
| | | 7/2 - 5/2 | 0.613D 01 | 0.264D-01 | 0.682D 04 | 0.203D 00 | 0.287D-04 | 0.747D 01 |
| 10 | 13 | 5/2 - 3/2 | 0.883D 02 | 0.108D 01 | 0.139D 05 | -0.241D 01 | 0.801D-03 | 0.104D 02 |
| | | 5/2 - 5/2 | 0.869D 02 | 0.756D-01 | 0.671D 03 | -0.240D 01 | 0.575D-04 | 0.510D 00 |
| | | 7/2 - 5/2 | 0.869D 02 | 0.113D 01 | 0.134D 05 | -0.240D 01 | 0.862D-03 | 0.102D 02 |
| 10 | 14 | 5/2 - 3/2 | -0.162D 02 | 0.888D-01 | 0.687D 04 | -0.439D 00 | 0.652D-04 | 0.504D 01 |
| | | 5/2 - 5/2 | -0.163D 02 | 0.645D-02 | 0.336D 03 | -0.421D 00 | 0.429D-05 | 0.224D 00 |
| | | 7/2 - 5/2 | -0.163D 02 | 0.968D-01 | 0.672D 04 | -0.421D 00 | 0.644D-04 | 0.447D 01 |
| 11 | 14 | 5/2 - 3/2 | 0.109D 03 | 0.124D 01 | 0.911D 04 | -0.304D 01 | 0.962D-03 | 0.710D 01 |
| | | 5/2 - 5/2 | 0.107D 03 | 0.968D-01 | 0.440D 03 | -0.302D 01 | 0.691D-04 | 0.351D 00 |
| | | 7/2 - 5/2 | 0.107D 03 | 0.130D 01 | 0.881D 04 | -0.302D 01 | 0.194D-02 | 0.701D 01 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 9 | 5/2 - 3/2 | 0.271D 02 | 0.445D 00 | 0.111D 08 | -0.606D 00 | 0.223D-03 | 0.555D 02 |
| | | 5/2 - 5/2 | 0.266D 02 | 0.312D-01 | 0.533D 04 | -0.600D 00 | 0.156D-04 | 0.270D 01 |
| | | 7/2 - 5/2 | 0.266D 02 | 0.468D 00 | 0.107D 08 | -0.600D 00 | 0.237D-03 | 0.541D 02 |
| 6 | 10 | 5/2 - 3/2 | -0.516D 01 | 0.369D-01 | 0.478D 05 | -0.116D-01 | 0.195D-06 | 0.240D 00 |
| | | 5/2 - 5/2 | -0.518D 01 | 0.266D-02 | 0.232D 04 | -0.517D-02 | 0.265D-08 | 0.231D-02 |
| | | 7/2 - 5/2 | -0.518D 01 | 0.399D-01 | 0.465D 05 | -0.508D-02 | 0.384D-07 | 0.446D-01 |
| 6 | 11 | 5/2 - 3/2 | 0.246D 01 | 0.115D-01 | 0.283D 05 | 0.161D 00 | 0.495D-04 | 0.122D 03 |
| | | 5/2 - 5/2 | 0.248D 01 | 0.836D-03 | 0.138D 04 | 0.166D 00 | 0.374D-05 | 0.615D 01 |
| | | 7/2 - 5/2 | 0.248D 01 | 0.125D-01 | 0.275D 05 | 0.166D 00 | 0.562D-04 | 0.123D 03 |
| 6 | 12 | 5/2 - 3/2 | -0.153D 01 | 0.533D-02 | 0.186D 05 | 0.216D 00 | 0.106D-03 | 0.368D 03 |
| | | 5/2 - 5/2 | -0.155D 01 | 0.388D-03 | 0.904D 03 | 0.219D 00 | 0.776D-05 | 0.181D 02 |
| | | 7/2 - 5/2 | -0.155D 01 | 0.582D-02 | 0.181D 05 | 0.219D 00 | 0.116D-03 | 0.362D 03 |
| 6 | 13 | 5/2 - 3/2 | 0.109D 01 | 0.299D-02 | 0.139D 05 | 0.229D 00 | 0.133D-03 | 0.576D 03 |
| | | 5/2 - 5/2 | 0.110D 01 | 0.218D-03 | 0.633D 03 | 0.231D 00 | 0.967D-05 | 0.281D 02 |
| | | 7/2 - 5/2 | 0.110D 01 | 0.327D-02 | 0.127D 05 | 0.231D 00 | 0.145D-03 | 0.563D 03 |
| 6 | 14 | 5/2 - 3/2 | -0.829D 00 | 0.188D-02 | 0.952D 04 | 0.226D 00 | 0.139D-03 | 0.705D 03 |
| | | 5/2 - 5/2 | -0.837D 00 | 0.137D-03 | 0.463D 03 | 0.227D 00 | 0.101D-04 | 0.341D 02 |
| | | 7/2 - 5/2 | -0.837D 00 | 0.205D-02 | 0.926D 04 | 0.227D 00 | 0.151D-03 | 0.682D 03 |
| 7 | 10 | 5/2 - 3/2 | 0.394D 02 | 0.603D 00 | 0.619D 08 | -0.950D 00 | 0.351D-03 | 0.360D 02 |
| | | 5/2 - 5/2 | 0.387D 02 | 0.423D-01 | 0.298D 04 | -0.942D 00 | 0.250D-04 | 0.176D 01 |
| | | 7/2 - 5/2 | 0.387D 02 | 0.634D 00 | 0.596D 08 | -0.941D 00 | 0.375D-03 | 0.352D 02 |
| 7 | 11 | 5/2 - 3/2 | -0.743D 01 | 0.502D-01 | 0.281D 05 | -0.772D-01 | 0.542D-05 | 0.303D 01 |
| | | 5/2 - 5/2 | -0.746D 01 | 0.363D-02 | 0.137D 04 | -0.681D-01 | 0.303D-06 | 0.114D 00 |
| | | 7/2 - 5/2 | -0.746D 01 | 0.545D-01 | 0.274D 05 | -0.680D-01 | 0.452D-05 | 0.227D 01 |
| 7 | 12 | 5/2 - 3/2 | 0.352D 01 | 0.158D-01 | 0.174D 03 | 0.184D 00 | 0.430D-04 | 0.474D 02 |
| | | 5/2 - 5/2 | 0.355D 01 | 0.115D-02 | 0.846D 03 | 0.190D 00 | 0.333D-05 | 0.243D 01 |
| | | 7/2 - 5/2 | 0.355D 01 | 0.172D-01 | 0.169D 05 | 0.190D 00 | 0.495D-04 | 0.487D 02 |
| 7 | 13 | 5/2 - 3/2 | -0.219D 01 | 0.736D-02 | 0.118D 05 | 0.272D 00 | 0.114D-03 | 0.193D 03 |
| | | 5/2 - 5/2 | -0.221D 01 | 0.536D-03 | 0.576D 03 | 0.276D 00 | 0.842D-05 | 0.905D 01 |
| | | 7/2 - 5/2 | -0.221D 01 | 0.804D-02 | 0.115D 05 | 0.277D 00 | 0.126D-03 | 0.181D 03 |
| 7 | 14 | 5/2 - 3/2 | 0.154D 01 | 0.414D-02 | 0.850D 04 | 0.298D 00 | 0.155D-03 | 0.318D 03 |
| | | 5/2 - 5/2 | 0.156D 01 | 0.302D-03 | 0.414D 03 | 0.302D 00 | 0.113D-04 | 0.155D 02 |
| | | 7/2 - 5/2 | 0.156D 01 | 0.454D-02 | 0.829D 04 | 0.302D 00 | 0.170D-03 | 0.310D 03 |
| 8 | 11 | 5/2 - 3/2 | 0.536D 02 | 0.761D 00 | 0.361D 08 | -0.136D 01 | 0.499D-03 | 0.234D 02 |
| | | 5/2 - 5/2 | 0.528D 02 | 0.534D-01 | 0.174D 04 | -0.136D 01 | 0.352D-04 | 0.115D 01 |
| | | 7/2 - 5/2 | 0.528D 02 | 0.801D 00 | 0.348D 08 | -0.136D 01 | 0.528D-03 | 0.229D 02 |
| 8 | 12 | 5/2 - 3/2 | -0.100D 02 | 0.632D-01 | 0.170D 05 | -0.171D 00 | 0.134D-04 | 0.494D 01 |
| | | 5/2 - 5/2 | -0.101D 02 | 0.459D-02 | 0.828D 03 | -0.159D 00 | 0.114D-05 | 0.206D 00 |
| | | 7/2 - 5/2 | -0.101D 02 | 0.688D-01 | 0.166D 05 | -0.159D 00 | 0.171D-04 | 0.412D 01 |
| 8 | 13 | 5/2 - 3/2 | 0.472D 01 | 0.200D-01 | 0.109D 05 | 0.194D 00 | 0.433D-04 | 0.184D 02 |
| | | 5/2 - 5/2 | 0.477D 01 | 0.146D-02 | 0.530D 03 | 0.203D 00 | 0.263D-05 | 0.958D 00 |
| | | 7/2 - 5/2 | 0.477D 01 | 0.218D-01 | 0.106D 05 | 0.203D 00 | 0.335D-04 | 0.192D 02 |
| 8 | 14 | 5/2 - 3/2 | -0.292D 01 | 0.333D-02 | 0.759D 04 | 0.322D 00 | 0.114D-03 | 0.925D 02 |
| | | 5/2 - 5/2 | -0.295D 01 | 0.682D-03 | 0.371D 03 | 0.328D 00 | 0.843D-05 | 0.459D 01 |
| | | 7/2 - 5/2 | -0.295D 01 | 0.102D-01 | 0.741D 04 | 0.328D 00 | 0.127D-03 | 0.919D 02 |

## APPENDIX 13 : Non-Relativistic Thallium I Oscillator Strengths

THEORETICAL RADIAL MATRIX ELEMENTS, OSCILLATOR STRENGTHS, AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - ms^2S_{1/2}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 7 | 1/2-1/2 | 0.127D 01 | 0.433D-01 | 0.202D 08 | -0.293D 01 | 0.230D 00 | 0.107D 09 |
| | | 3/2-1/2 | 0.210D 01 | 0.437D-01 | 0.393D 08 | -0.201D 01 | 0.761D-01 | 0.354D 08 |
| 6 | 9 | 1/2-1/2 | -0.360D 00 | 0.510D-02 | 0.510D 07 | -0.305D 00 | 0.364D-02 | 0.364D 07 |
| | | 3/2-1/2 | -0.509D 00 | 0.782D-02 | 0.100D 08 | -0.138D 01 | 0.596D-01 | 0.761D 08 |
| 6 | 9 | 1/2-1/2 | 0.195D 00 | 0.166D-02 | 0.206D 07 | 0.106D 01 | 0.484D-01 | 0.607D 08 |
| | | 3/2-1/2 | 0.264D 00 | 0.250D-02 | 0.417D 07 | 0.335D 00 | 0.402D-02 | 0.671D 07 |
| 6 | 10 | 1/2-1/2 | -0.127D 00 | 0.736D-03 | 0.101D 07 | 0.124D 01 | 0.705D-01 | 0.965D 08 |
| | | 3/2-1/2 | -0.173D 00 | 0.114D-02 | 0.214D 07 | 0.102D 01 | 0.393D-01 | 0.737D 08 |
| 7 | 8 | 1/2-1/2 | 0.729D 01 | 0.341D 00 | 0.338D 07 | 0.151D 01 | 0.105D-01 | 0.143D 08 |
| | | 3/2-1/2 | 0.375D 01 | 0.378D 00 | 0.477D 07 | 0.469D 01 | 0.799D-01 | 0.137D 07 |
| 7 | 9 | 1/2-1/2 | -0.143D 01 | 0.201D-01 | 0.109D 07 | -0.319D 01 | 0.323D-01 | 0.501D 07 |
| | | 3/2-1/2 | -0.138D 01 | 0.154D-01 | 0.131D 07 | -0.263D 01 | 0.560D-01 | 0.479D 07 |
| 7 | 10 | 1/2-1/2 | 0.771D 00 | 0.670D-02 | 0.554D 06 | -0.241D 01 | 0.655D-01 | 0.542D 07 |
| | | 3/2-1/2 | 0.703D 00 | 0.606D-02 | 0.694D 06 | -0.261D 01 | 0.699D-01 | 0.757D 07 |
| 8 | 9 | 1/2-1/2 | 0.147D 02 | 0.393D 00 | 0.847D 06 | 0.724D 01 | 0.764D-01 | 0.203D 08 |
| | | 3/2-1/2 | 0.172D 02 | 0.429D 00 | 0.116D 07 | 0.117D 02 | 0.197D 00 | 0.534D 08 |
| 8 | 10 | 1/2-1/2 | -0.274D 01 | 0.293D-01 | 0.307D 06 | -0.267D 01 | 0.283D-01 | 0.291D 08 |
| | | 3/2-1/2 | -0.238D 01 | 0.305D-01 | 0.345D 06 | -0.146D 01 | 0.763D-02 | 0.124D 08 |
| 9 | 10 | 1/2-1/2 | 0.239D 02 | 0.330D 00 | 0.297D 06 | 0.137D 02 | 0.173D 00 | 0.963D 08 |
| | | 3/2-1/2 | 0.277D 02 | 0.372D 00 | 0.412D 06 | 0.193D 02 | 0.277D 00 | 0.199D 08 |

THEORETICAL RADIAL MATRIX ELEMENTS, OSCILLATOR STRENGTHS AND TRANSITION PROBABILITIES, FOR THE SERIES $ns\,^2S_{1/2} - mp\,^2P_{J'}$, CALCULATED FROM WAVE FUNCTIONS GENERATED IN THE COULOMB APPROXIMATION BY BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| N | TRANSITION n | J-J' | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| 7 | 7 | 1/2-1/2 | 0.7270 01 | 0.4110 00 | 0.1620 08 | -0.1690 02 | 0.2230 01 | 0.8790 08 |
| | | 1/2-3/2 | 0.6840 01 | 0.1240 00 | 0.2070 08 | -0.1440 02 | 0.3630 01 | 0.9130 08 |
| 7 | 8 | 1/2-1/2 | -0.5640 00 | 0.1460-01 | 0.2160 07 | -0.2530 01 | 0.9630-01 | 0.1420 08 |
| | | 1/2-3/2 | -0.1350 01 | 0.5660-01 | 0.4400 07 | -0.1550 01 | 0.7450-01 | 0.5790 07 |
| 7 | 9 | 1/2-1/2 | 0.4570 00 | 0.3780-02 | 0.8090 06 | 0.1020 01 | 0.1890-01 | 0.4030 07 |
| | | 1/2-3/2 | 0.6820 00 | 0.1710-01 | 0.1850 07 | 0.1520 01 | 0.8510-01 | 0.9240 07 |
| 8 | 8 | 1/2-1/2 | 0.1460 02 | 0.5660 00 | 0.2590 07 | -0.3230 02 | 0.2800 01 | 0.1230 08 |
| | | 1/2-3/2 | 0.1350 02 | 0.1100 01 | 0.3390 07 | -0.2960 02 | 0.5390 01 | 0.1590 08 |
| 8 | 9 | 1/2-1/2 | -0.1910 01 | 0.2090-01 | 0.4400 06 | -0.8730 01 | 0.4150 00 | 0.1210 07 |
| | | 1/2-3/2 | -0.2570 01 | 0.7770-01 | 0.9760 06 | -0.7940 01 | 0.7430 00 | 0.1330 07 |
| 9 | 9 | 1/2-1/2 | 0.2400 02 | 0.7110 00 | 0.6990 06 | -0.5030 02 | 0.3110 01 | 0.3060 07 |
| | | 1/2-3/2 | 0.2200 02 | 0.1370 01 | 0.8880 06 | -0.4690 02 | 0.6210 01 | 0.4050 07 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES FOR THE SERIES $nd^2D_J - mp^2P_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION BY BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 8 | 3/2-1/2 | 0.192D 01 | 0.135D-01 | 0.720D 06 | 0.255D 01 | 0.345D-01 | 0.127D 07 |
| | | 3/2-3/2 | 0.174D 01 | 0.346D-02 | 0.730D 05 | 0.161D 01 | 0.297D-02 | 0.626D 06 |
| | | 5/2-3/2 | 0.184D 01 | 0.327D-01 | 0.698D 06 | 0.166D 01 | 0.187D-01 | 0.573D 06 |
| 6 | 9 | 3/2-1/2 | -0.797D 00 | 0.331D-02 | 0.483D 06 | -0.109D 00 | 0.997D-04 | 0.908D 04 |
| | | 3/2-3/2 | -0.598D 00 | 0.595D-03 | 0.283D 05 | -0.355D 00 | 0.216D-03 | 0.103D 05 |
| | | 5/2-3/2 | -0.617D 00 | 0.387D-02 | 0.270D 06 | -0.315D 00 | 0.101D-02 | 0.705D 05 |
| 7 | 8 | 3/2-1/2 | 0.566D 01 | 0.768D-01 | 0.575D 06 | 0.346D 01 | 0.281D-01 | 0.216D 06 |
| | | 3/2-3/2 | 0.389D 01 | 0.782D-02 | 0.340D 05 | 0.323D 01 | 0.539D-02 | 0.234D 06 |
| | | 5/2-3/2 | 0.411D 01 | 0.516D-01 | 0.326D 06 | 0.328D 01 | 0.329D-01 | 0.208D 06 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $np^2P_J - md^2D_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ | $R_{IJ}$ | $f_{IJ}$ | $A_{IJ}(sec^{-1})$ |
| 6 | 6 | 1/2-3/2 | 0.199D 01 | 0.290D 00 | 0.126D 09 | 0.363D 01 | 0.962D 00 | 0.413D 09 |
| | | 3/2-3/2 | 0.275D 01 | 0.435D-01 | 0.233D 08 | 0.157D 01 | 0.141D-01 | 0.754D 07 |
| | | 3/2-5/2 | 0.269D 01 | 0.375D 00 | 0.135D 09 | 0.167D 01 | 0.145D 00 | 0.519D 08 |
| 6 | 7 | 1/2-3/2 | -0.102D 01 | 0.881D-01 | 0.518D 08 | 0.307D 01 | 0.800D 00 | 0.471D 08 |
| | | 3/2-3/2 | -0.130D 01 | 0.116D-01 | 0.909D 07 | 0.247D 01 | 0.422D-01 | 0.330D 08 |
| | | 3/2-5/2 | -0.120D 01 | 0.102D 00 | 0.531D 08 | 0.251D 01 | 0.392D 00 | 0.205D 09 |
| 6 | 8 | 1/2-3/2 | 0.660D 00 | 0.394D-01 | 0.262D 08 | 0.236D 01 | 0.504D 00 | 0.335D 08 |
| | | 3/2-3/2 | 0.814D 00 | 0.494D-02 | 0.449D 07 | 0.235D 01 | 0.414D-01 | 0.375D 08 |
| | | 3/2-5/2 | 0.804D 00 | 0.435D-01 | 0.263D 08 | 0.237D 01 | 0.377D 00 | 0.228D 09 |
| 7 | 6 | 1/2-3/2 | 0.915D 01 | 0.332D 00 | 0.424D 06 | 0.190D 02 | 0.144D 01 | 0.184D 07 |
| | | 3/2-3/2 | 0.915D 01 | 0.152D-01 | 0.991D 04 | 0.171D 02 | 0.570D-01 | 0.348D 05 |
| | | 3/2-5/2 | 0.925D 01 | 0.162D 00 | 0.777D 05 | 0.174D 02 | 0.572D 00 | 0.275D 06 |
| 7 | 7 | 1/2-3/2 | 0.394D 01 | 0.246D 00 | 0.507D 07 | -0.716D 01 | 0.815D 00 | 0.168D 08 |
| | | 3/2-3/2 | 0.547D 01 | 0.415D-01 | 0.130D 07 | -0.111D 02 | 0.169D 00 | 0.530D 07 |
| | | 3/2-5/2 | 0.531D 01 | 0.354D 00 | 0.747D 07 | -0.109D 02 | 0.146D 01 | 0.307D 08 |
| 7 | 8 | 1/2-3/2 | -0.199D 01 | 0.946D-01 | 0.312D 07 | -0.161D 01 | 0.554D-01 | 0.204D 07 |
| | | 3/2-3/2 | -0.246D 01 | 0.116D-01 | 0.701D 06 | -0.345D 01 | 0.230D-01 | 0.138D 07 |
| | | 3/2-5/2 | -0.242D 01 | 0.101D 00 | 0.410D 07 | -0.334D 01 | 0.194D 00 | 0.784D 07 |
| 8 | 7 | 1/2-3/2 | 0.195D 02 | 0.495D 00 | 0.683D 05 | 0.290D 02 | 0.110D 01 | 0.151D 06 |
| | | 3/2-3/2 | 0.196D 02 | 0.211D-01 | 0.103D 04 | 0.264D 02 | 0.381D-01 | 0.186D 04 |
| | | 3/2-5/2 | 0.197D 02 | 0.219D 00 | 0.924D 04 | 0.267D 02 | 0.401D 00 | 0.169D 05 |
| 8 | 8 | 1/2-3/2 | 0.592D 01 | 0.234D 00 | 0.854D 06 | -0.191D 02 | 0.245D 01 | 0.892D 07 |
| | | 3/2-3/2 | 0.850D 01 | 0.429D-01 | 0.246D 06 | -0.241D 02 | 0.345D 00 | 0.193D 07 |
| | | 3/2-5/2 | 0.821D 01 | 0.363D 00 | 0.141D 07 | -0.237D 02 | 0.303D 01 | 0.117D 08 |
| 9 | 8 | 1/2-3/2 | 0.326D 02 | 0.628D 00 | 0.178D 05 | 0.413D 02 | 0.101D 01 | 0.286D 05 |
| | | 3/2-3/2 | 0.329D 02 | 0.241D-01 | 0.195D 03 | 0.378D 02 | 0.319D-01 | 0.258D 03 |
| | | 3/2-5/2 | 0.330D 02 | 0.259D 00 | 0.195D 04 | 0.383D 02 | 0.348D 00 | 0.262D 04 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nd^2D_J - mf^2F_{J'}$ CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 6 | 5 | 3/2-5/2 | 0.912D 01 | 0.939D 00 | 0.160D 08 | 0.219D 02 | 0.544D 01 | 0.929D 08 |
| | | 5/2-5/2 | 0.924D 01 | 0.453D-01 | 0.113D 07 | 0.219D 02 | 0.255D 00 | 0.638D 07 |
| 6 | 5 | 5/2-7/2 | 0.924D 01 | 0.906D 00 | 0.170D 08 | 0.219D 02 | 0.511D 01 | 0.956D 08 |
| | | 3/2-5/2 | -0.343D 01 | 0.186D 00 | 0.627D 07 | -0.419D 01 | 0.279D 00 | 0.939D 07 |
| 6 | 6 | 5/2-5/2 | -0.342D 01 | 0.877D-02 | 0.435D 06 | -0.442D 01 | 0.146D-01 | 0.725D 06 |
| | | 5/2-7/2 | -0.342D 01 | 0.175D 00 | 0.652D 07 | -0.442D 01 | 0.292D 00 | 0.109D 08 |
| 7 | 5 | 3/2-5/2 | 0.160D 02 | 0.143D 00 | 0.601D 04 | -0.327D 01 | 0.599D-02 | 0.251D 03 |
| | | 5/2-5/2 | 0.160D 02 | 0.596D-02 | 0.288D 03 | -0.317D 01 | 0.235D-03 | 0.114D 02 |
| 7 | 5 | 5/2-7/2 | 0.160D 02 | 0.119D 00 | 0.432D 04 | -0.317D 01 | 0.471D-02 | 0.171D 03 |
| | | 3/2-5/2 | 0.116D 02 | 0.691D 00 | 0.243D 07 | 0.360D 02 | 0.664D 01 | 0.233D 08 |
| 7 | 6 | 5/2-5/2 | 0.119D 02 | 0.341D-01 | 0.175D 06 | 0.360D 02 | 0.312D 00 | 0.160D 07 |
| | | 5/2-7/2 | 0.119D 02 | 0.682D 00 | 0.263D 07 | 0.360D 02 | 0.623D 01 | 0.240D 08 |
| 8 | 6 | 3/2-5/2 | 0.302D 02 | 0.250D 00 | 0.253D 04 | -0.565D 01 | 0.877D-02 | 0.887D 02 |
| | | 5/2-5/2 | 0.301D 02 | 0.103D-01 | 0.117D 03 | -0.548D 01 | 0.341D-03 | 0.389D 01 |
| 8 | 6 | 5/2-7/2 | 0.301D 02 | 0.206D 00 | 0.176D 04 | -0.548D 01 | 0.681D-02 | 0.583D 02 |

THEORETICAL RADIAL MATRIX ELEMENTS; OSCILLATOR STRENGTHS; AND TRANSITION PROBABILITIES, FOR THE SERIES $nf^2F_{J'} - md^2D_J$, CALCULATED FROM WAVE FUNCTIONS GENERATED BY THE COULOMB APPROXIMATION OF BATES AND DAMGAARD AND BY THE NON-RELATIVISTIC HYDROGENIC APPROXIMATION.

| TRANSITION | | | BATES-DAMGAARD APPROXIMATION | | | NON-RELATIVISTIC HYDROGENIC APPROXIMATION | | |
|---|---|---|---|---|---|---|---|---|
| N | M | J-J' | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ | $R_{ij}$ | $f_{ij}$ | $A_{ij}(sec^{-1})$ |
| 5 | 3 | 5/2-3/2 | 0.274D 01 | 0.215D-01 | 0.119D 06 | 0.189D 00 | 0.102D-03 | 0.564D 03 |
| | | 5/2-5/2 | 0.260D 01 | 0.140D-02 | 0.524D 04 | 0.201D 00 | 0.835D-05 | 0.314D 02 |
| | | 7/2-5/2 | 0.260D 01 | 0.209D-01 | 0.105D 06 | 0.201D 00 | 0.125D-03 | 0.628D 03 |

APPENDIX 14: Eutectic Mixtures

The following table lists the percentage of anhydrous materials (by weight) used in a eutectic mixture with crushed ice formed from distilled water. The eutectic temperatures are taken from Lange's Handbook of Chemistry (11th edition) and the values quoted are the lowest temperature that can be obtained from the mixture of the substance with ice. Temperatures between these lowest possible values and 0°c may be obtained by reducing the percentage of anhydrous material added to the mixture.

| Anhydrous Material | Percentage | Eutectic Temperature °c |
|---|---|---|
| Na Cl | 23.3 | -21.13 |
| $MgCl_2$ | 21.6 | -33.6 |
| K Cl | 19.75 | -11.1 |

APPENDIX 15: Derivation of the Correction Formula for Thermal Transpiration

Consider two volumes containing a gas at low pressure connected by a capillary. Let the temperature and pressure of the gas in volume $V_1$ be $T_1$ and $P_1$ and let the temperature and pressure in volume $V_2$ be $T_2$ and $P_2$. Assume that the cross sectional area of the capillary at $V_1$ is the same as at $V_2$ - let the value of this area be A $cm^2$. The number of molecules striking a unit area of the containing vessel per second is

$$N = \frac{1}{4} n \langle v \rangle$$

where n is the density of molecules in the container and v is the average thermal velocity of the molecules. The rate at which the molecules strike the area of the capillary is equal to the rate at which the molecules leave the volume; this rate is

$$q = nA$$

The rate at which molecules leave the volume $V_1$ is

$$q_1 = \frac{1}{4} n_1 A \langle v_1 \rangle$$

$$= \frac{1}{2} n_1 A \left( \frac{2kT_1}{\pi m} \right)^{1/2}$$

and the rate at which molecules leave the volume $V_2$ is

$$q_2 = \frac{1}{2} n_2 A \left( \frac{2kT_2}{\pi m} \right)^{1/2}$$

The pressure of the gas in the container is given by

$$P = \frac{1}{3} m n \langle v \rangle^2$$

hence, the pressure of gas in volume $V_1$ is

$$P_1 = \frac{1}{3} m n_1 \langle v_1 \rangle^2$$

$$= \frac{4}{3} m n_1 \left( \frac{2kT_1}{\pi m} \right)$$

and the pressure of gas in volume $V_2$ is

$$P_2 = \frac{4}{3} m n_2 \left( \frac{2kT_2}{\pi m} \right)$$

These can be written in the form

$$P_1 = \frac{8}{3} q_1 \frac{m}{A} \langle v_1 \rangle$$

and

$$P_2 = \frac{8}{3} q_1 \frac{m}{A} \langle v_2 \rangle$$

At equilibrium the rate at which molecules leave $V_1$ will be identicle to the rate at which molecules leave $V_2$; that is,

$$q_1 = q_2$$

The equilibrium condition gives

$$\frac{P_1}{P_2} = \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

Therefore, the pressure in the cell is related to the pressure measured at room temperature in the manometer by the formula

$$P_{cell} = \sqrt{\frac{T_{cell}}{T_{room}}} P_{man}$$

where $T_{cell}$ is the temperature of the gas in the cell in degrees Kelvin and $T_{room}$ is the temperature of nitrogen at room temperature in degrees Kelvin; $P_{man}$ is the manometer pressure reading in torr.

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