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Spectra of Highly Ionized Atoms of Tokamak Interest

by

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SPECTRA OF HIGHLY IONIZED ATOMS OF TOKAMAK INTEREST

by

Robert D. Cowan

ABSTRACT

The general nature of the change in energy level structures along an isoelectronic sequence is reviewed, with particular emphasis on relativistic effects and changes in coupling conditions. The accuracy of computed wavelengths is checked by comparison with experimental data on inner-shell (x-ray) transitions in singly ionized atoms. Relativistic effects can be extremely important for $\Delta n = 0$ transitions, but are taken into account fairly accurately by the approximate relativistic methods used. Computed ionization energies are given for important ions of Cr, Fe, Ni, Kr, Mo, Xe, W, and Au. Computed wavelengths and oscillator strengths are given for resonance lines of most of these elements in the simple isoelectronic sequences of neutral Li, Be, Na, Mg, K, Ni, Cu, and Zn, and more detailed electric- and magnetic-dipole spectra are given for ions of greatest importance.

I. INTRODUCTION

Tokamak discharges usually contain appreciable concentrations of impurity atoms sputtered from the vacuum-vessel wall or from current-aperture limiters. Heavy-element impurities such as Cr, Fe, Ni, Mo, W, etc., are only partially stripped at the discharge temperatures (0.1 to 10 keV) and are rather strong sources of line radiation, thus providing a potentially serious energy loss mechanism. Estimates of the loss rate can be made^{1,2} if the impurity density and degree of ionization are known. Diagnostic measurement of these last two quantities requires knowledge of various fundamental properties of the ions of interest. We here discuss the calculation of wavelengths and transition probabilities, and give approximate numerical values for transitions of particular diagnostic interest.

II. CALCULATIONAL METHOD

All calculations reported here were carried out using the well-known Slater-Condon theory of atomic structure (which includes both Coulomb and spin-orbit interactions), as described by the author³ or summarized briefly in Appendix A of Ref. 1; configuration interactions within a complex were included when appropriate. The required one-electron radial wavefunctions were obtained by self-consistent-field solution of differential equations of the Hartree-Fock (HF) type for each electron configuration involved.

Relativistic effects are very important for the $\Delta n = 0$ transitions of particular interest here. For moderate Z , it is sufficient to simply add first-order-perturbation energy corrections to the HF values of the configuration center-of-gravity energy E_{av} ; this procedure (using the HX potential for the evaluation of the relativistic corrections⁴) will be referred to as HF + r. For high Z , this approach is inadequate because of relativistic modifications in the radial wavefunctions. The most accurate known method of calculating relativistic radial wavefunctions is the Dirac-Hartree-Fock (DHF) method.⁵⁻⁷ However, this method is very time-consuming, and introduces serious complications into the calculation of energy levels and spectra for multi-valence-electron configurations.⁸ For these reasons, we here use the much simpler HFR method.⁸ This approach introduces the Pauli approximation mass-velocity and Darwin relativistic terms (but not the j -dependent spin-orbit term) into the HF radial differential equations; the major relativistic effects are thereby incorporated into the radial wavefunctions, while still making it possible to retain a completely nonrelativistic formalism for the calculation of energy levels and spectra. The accuracy of HFR calculations is comparable to that of DHF calculations for all ionization stages likely to be producible in the foreseeable future.

III. ISOELECTRONIC-SEQUENCE SYSTEMATICS

Before discussing detailed results for specific cases, it is instructive to examine qualitatively the Z dependence of atomic properties along an isoelectronic sequence (fixed number of electrons N). For this purpose we do not need the elaborate Z -expansion theory,⁹ but shall only use expressions akin to the semi-empirical formula¹⁰

$$E_{n\ell} = - \frac{(Z^*)^2}{n^2} = - \frac{(Z-S)^2}{n^2} = - \frac{(Z_c + p)^2}{n^2} \quad \text{Ry} \quad (1)$$

for the binding energy of an electron in the subshell $n\ell$. The effective nuclear charge

$$Z^* = Z - S = Z_c + p, \quad (2)$$

where

$$Z_c = Z - (N - 1), \quad (3)$$

is equal to the actual nuclear charge minus the effective screening charge S of the other $N - 1$ electrons. The screening defect (or penetration)

$$p = Z - Z_c - S = (N - 1) - S \quad (4)$$

is the amount by which the $N - 1$ core electrons fail to perfectly shield the electron $n\ell$ from the nucleus. Evidently p and S are functions of $n\ell$: p tends to zero with increasing n and ℓ (i.e., with decreasing penetration of the ion core by the electron $n\ell$).

The utility of the expression (1) arises from the empirical observation^{10,11} that values of the screening constant σ inferred from experimental binding energies are approximately independent of Z , especially at large Z . This fact is semi-obvious from the concept of screening, but added insight may be obtained as follows.

For very large Z , the nuclear field becomes much stronger than the inter-electronic fields, and so the one-electron radial wavefunctions $r^{-1}P_{n\ell}(r)$ must be approximately hydrogenic in form:

$$P_{n\ell}^Z(r) = Z^{1/2} P_{n\ell}^H(Zr); \quad (5)$$

i.e., the radial extent of the orbitals scales as Z^{-1} . Electron-nuclear Coulomb energies $\langle -Ze^2/r \rangle$ therefore scale approximately as Z^2 . Kinetic energies scale as r^{-2} and thus also go as Z^2 . Electron-electron Coulomb energies, on the other hand, go only as r^{-1} and hence scale as Z . Of course, screening effects cause the radial wavefunctions to be nonhydrogenic in form and so contributions from

the various terms of the Hamiltonian do not scale in precisely the above manner. Examples are given in Figs. 1-3 for HF kinetic, electron-nuclear, and electron-electron contributions to one-electron binding energies. The various contributions can be represented fairly accurately in the form

$$\left. \begin{aligned} E_{\text{kin}}^{n\ell} &\propto (Z - S_1)^2, \\ E_{\text{en}}^{n\ell} &\propto -Z(Z - S_2), \\ E_{\text{ee}}^{n\ell, n'\ell'} &\propto (Z - S_3) \end{aligned} \right\} \quad (6)$$

Fig. 1. Hartree-Fock values (circles) of the square root of the kinetic energy of a 1s and a 2p electron in the isoelectronic sequence $\text{N I } 1s^2 2s^2 2p^3$. The solid curves are straight lines drawn (by eye) to best fit the computed points; their x-intercepts are the values of S indicated on the figure.

Fig. 2. Similar to Fig. 1, except expectation values of $\langle r^{-1} \rangle$. Computed values for 2p lie only slightly below those for 2s, and could not be drawn separately on the scale of the figure.

Fig. 3. Similar to Fig. 1, except electron-electron Coulomb energies for 1s and 2p electrons.

The sum of these contributions includes a constant term as well as terms in Z^2 and Z . The expression (1) includes all three of these terms, though not with independent coefficients of the two lower order terms. It should be noted that the term linear in Z -- and hence the constant S -- represents not only the zero-order electron-electron interactions (direct screening effects), but also first-order corrections to the hydrogenic kinetic and electron-nuclear energies (indirect screening effects).

The above discussion has been entirely nonrelativistic, and relativistic corrections have yet to be added to the binding energy (1). The mass-velocity term is proportional to the expectation value of $[c_i - V_i(r)]^2$, where V_i and c_i are the potential energy function and eigenvalue for the orbital $n_i l_i$, and the Darwin term goes as V_i/r^2 . Thus from the previous discussion we may expect both terms to increase as the fourth power of Z , or approximately

$$E_{rel}^{nl} \propto (Z - S)^4, \quad (7)$$

where S has roughly the same value as in (1). At very high Z , where relativistic modifications of the radial wavefunctions become appreciable, the relativistic contributions increase faster even than given by (7).

IV. ENERGY LEVEL STRUCTURES

At intermediate Z , where relativistic effects are not yet too important, the basic nature of the level structure of an ion follows directly from (1). For two configurations that differ only in the excitation of one electron to a shell of different n , the energy difference between the configurations is

$$E_{n_2 l_2} - E_{n_1 l_1} = \frac{(Z - S_1)^2}{n_1^2} - \frac{(Z - S_2)^2}{n_2^2} \quad (8)$$

This difference increases quadratically with Z , and thus remains roughly constant on the scale of the ionization energy. On the other hand, the energy difference between two configurations involving no change in n is

$$\begin{aligned} E_{n l_2} - E_{n l_1} &= \frac{(Z - S_1)^2 - (Z - S_2)^2}{n^2} \\ &= \frac{2(S_2 - S_1)}{n^2} \left[Z - \frac{1}{2}(S_2 + S_1) \right] \quad (9) \end{aligned}$$

This increases only linearly with Z , and thus decreases rapidly relative to $\Delta n \neq 0$ excitation energies. Thus with increasing Z , the level structure tends to become hydrogen-like, with the energy depending strongly on n but only weakly on l .

An example is given in Fig. 4, which shows center-of-gravity energies for some of the low-lying configurations of the N I isoelectronic sequence. Energies are plotted relative to the ionization limit $1s^2 2s^2 2p^2$, and have been scaled as $(Z - N + 1)^{-2}$; i.e., assuming $S = N - 1$, or zero penetration p . Consider first the solid curves, representing configurations formed by adding an electron $n\ell$ to the ion-core ground configuration. For large n and ℓ (3d and 4f) the curves are essentially horizontal straight lines, as would be expected for nonpenetrating electrons for which $S = N - 1$ is indeed appropriate at low Z and which do not

suffer appreciable relativistic effects at high Z . The semi-hydrogenic level structure at intermediate and high Z is quite clear. At low Z , there are large departures from hydrogenic behavior, because of sizeable core penetration by the s and p electrons -- especially, of course, by the $2p$ electron; in particular, it may be noted that in $N\ I$ the $4s$ configuration lies (slightly) below $3d$. In addition, a slight relativistic depression of the $3s$ configuration may be noted at large Z ; relativistic effects are too small for larger n or ℓ to be seen on the scale of the figure.

The dashed curves in Fig. 4 represent configurations derived from the ground configuration by excitation of one or both of the $2s$ electrons to the $2p$ subshell. At moderate to high Z , the (Z_c^{-2}) -scaled excitation energies are hydrogenically small, but at low Z they become very large because of the large changes in nuclear screening; at the lowest Z , they even lie above the ionization limit. Above $Z \cong 30$, the decrease in the relativistic energy upon promoting an electron from $2s$ to $2p$ results in pronounced increases in the (scaled) excitation energies.

Energy-level structures within a configuration are determined mainly by the electron-electron Coulomb radial integrals $F^k(i,j)$ and $G^k(i,j)$, and by the spin-orbit radial integrals ζ_i , where i and j indicate partially filled subshells $n_i \ell_i$ and $n_j \ell_j$. As indicated previously, the Coulomb energies scale linearly with Z , or approximately

$$F^k, G^k \propto Z - S \quad . \quad (10)$$

However, the spin-orbit integral scales as v^i/r^2 , and thus approximately¹²

$$\zeta_i \propto (Z - S)^4 \quad ; \quad (11)$$

at very high Z where relativistic effects on the wavefunctions become significant, ζ_i may increase even faster than Z^4 . At low Z where Coulomb interactions dominate, energy spreads within a configuration decrease as $(Z - S)^{-1}$ relative to the ionization energy or to $\Delta n \neq 0$ excitation energies, but are essentially constant relative to $\Delta n = 0$ excitation energies. Numerous empirical examples of the latter relation are given by Edlén,^{11,10} and a theoretical example is shown in Fig. 5 (for $Z < 20$). At large Z , the spin-orbit interactions dominate, increasing as

Fig. 4. Theoretical (HFR) center-of-gravity energies of low configurations of the N I isoelectronic sequence, relative to the center-of-gravity ionization limit $1s^2 2s^2 2p^2$.

Fig. 5. Theoretical energy levels of the complex $2s^2 2p^3 + 2p^5$ in the N I isoelectronic sequence, plotted relative to the center of gravity of $2s^2 2p^3$; dashed curves, HF plus relativistic center-of-gravity energy corrections (HF + r); solid curves, HFR. Configuration-interaction perturbations are too small to be seen on the scale of the figure.

they do faster than anything except the relativistic contribution (7) to configuration centers of gravity. As a consequence, coupling conditions change rapidly from nearly pure LS at low Z to nearly pure jj at high Z ; the dividing line between more nearly LS and more nearly jj coupling occurs at about $Z = 30$ in the $2s^2 2p^3$ example in Fig. 5.

It may be noted that the configurations $2s^2 2p^3$ and $2p^5$ would overlap beyond about $Z = 54$ were it not for the strong relativistic increase in the center-of-gravity energy of $2p^5$, which begins to become important at about $Z = 15$. Relativistic effects on the radial wavefunctions themselves do not become significant until $Z = 35$ or so.

Fig. 6. Theoretical (HFR) energy levels of the $n = 2$ complexes of the N I isoelectronic sequence (solid curves, odd parity; dashed curves, even parity). Note that the Pauli exclusion principle allows at most two equivalent p electrons with $j = 1/2$ and a maximum of four such electrons with $j = 3/2$; thus jj limits with all five j values equal $1/2$ or $3/2$ are not possible.

The transition to pure jj coupling is shown even more clearly in Fig. 6,¹³ where energies have been scaled to make the distance from lowest level of $s^2 p^3$ to highest level of p^5 unity for all Z . Levels of the even-parity configuration sp^4 have also been added. At high Z , energies approach the relativistic hydrogenic limit, depending primarily on j and only secondarily on ℓ . It should be noted that the details of this approach to the hydrogenic limit are completely unverified experimentally. In spite of the great progress made during recent years in the analysis of spectra of highly ionized ions, the N I sequence is known only as far as Fe XX (and $2p^5 2p^0$ only as far as Cr XVIII).¹⁴ It is doubtful that experimental values of the $n = 2$ levels will be available beyond $Z = 50$ for many years to come.

The N I sequence is of course relatively simple. Energy structures rapidly become vastly more complicated in detail for sequences involving $n = 3, 4, \dots$ ground-configuration electrons.¹¹ The basic features are, however, much the same, except that the relativistic $n\ell j$ limit is never closely approached for other than

Fig. 7. Theoretical values of configuration-interaction radial Coulomb integrals for the interactions $2s^2 2p^3 + 2p^5$ and $2s^2 2p^2 3s + 2s^2 2p^2 4s$ in the N I isoelectronic sequence. Circles HF, dashed curves HFR.

s and p electrons (as shown by the high-Z values of x-ray-determined inner-shell energy levels)¹⁵ because of the small values of ζ_{nl} for $l > 1$.

V. CONFIGURATION INTERACTIONS

Like all electron-electron Coulomb energies, configuration-interaction Coulomb radial integrals may be expected to scale linearly with Z:

$$R^k(l_1 l_2, l_3 l_4) \propto (Z - S) ; \quad (12)$$

examples are given in Fig. 7. (Sizeable departures from this behavior may occur when there is strong cancellation between positive and negative contributions to the radial integral; however, R^k is then usually so small that configuration interactions are unimportant.)

For an interaction between two configurations belonging to different complexes,* the energy difference between the interacting levels varies from (8) like

* A complex consists of all configurations of given parity that can be formed using a single set of values $\{n\}$ of the principal quantum numbers, varying only the angular momenta $\{l\}$.

$(Z - S)^2$ -- S here being a weighted average of S_1 and S_2 . The magnitude of the energy perturbation then varies like

$$\Delta E \propto \frac{(R^k)^2}{E^2 - E^1} \propto \frac{(Z - S)^2}{(Z - S)^2} = \text{constant}. \quad (13)$$

The ratio of the perturbation to the energy spread among levels of a configuration therefore decreases, from (10) and (11), with increasing Z . Thus interactions between complexes tend to be unimportant in highly ionized atoms.

For interactions between two configurations of the same complex, energy perturbations are seen from (9) to vary as

$$\Delta E \propto \frac{(R^k)^2}{E^2 - E^1} \propto \frac{(Z - S)^2}{(Z - S)} = (Z - S). \quad (14)$$

The ratio of this to the energy spread within a configuration (where determined mainly by Coulomb interactions) is constant. Thus the importance of intra-complex interactions is roughly independent of Z , except for very high Z where relativistic effects (7) and (11) dominate. In general, interactions within a complex should be included in all numerical calculations (though in the $N I 2s^2 2p^3 + 2p^5$ sequence, energy perturbations are too small to be seen on the scale of Figs. 5 and 6).

VI. RADIATIVE TRANSITIONS

Electric multipole oscillator strengths and transition probabilities are proportional to the square of a reduced radial multipole integral for the jumping electron:

$$M^2 \equiv \left\langle n_i l_i \parallel r^t \parallel n_j l_j \right\rangle^2 \propto (Z - S)^{-2t}. \quad (15)$$

For electric dipole transitions ($t = 1$) with $\Delta n \neq 0$ at moderate Z ,

$$f \propto (\Delta E) M^2 \propto (Z - S)^2 (Z - S)^{-2} = \text{constant} \quad (16)$$

and

$$A \propto (\Delta E)^3 M^2 \propto (Z - S)^4 . \quad (17)$$

For $\Delta n = 0$ transitions,

$$f \propto (Z - S)(Z - S)^{-2} \propto (Z - S)^{-1} \quad (18)$$

and

$$A \propto (Z - S)^3 (Z - S)^{-2} \propto (Z - S) . \quad (19)$$

These simple scalings are illustrative only, and frequently are grossly inaccurate for several reasons:

(1) At high Z , relativistic effects (7) may greatly alter the variation of ΔE with Z (especially for $\Delta n = 0$ transitions, where the nonrelativistic contribution to ΔE is small); at still higher Z , relativistic modifications of the radial wavefunctions will change the Z dependence of M^2 .

(2) At low or moderate Z , there may be serious cancellation between positive and negative contributions to M ; this may greatly modify the Z dependence (15).

(3) The above discussion concerns primarily transition-array summed values of $\bar{f}$ and A . Changes with Z in the angular factors omitted from (16)-(19) may greatly alter the partition of f and A among the various lines of the array; for example, transitions that are spin forbidden under good LS-coupling conditions at low Z may become strongly allowed at high Z where S is no longer a good quantum number.

VII. ACCURACY OF WAVELENGTH CALCULATIONS

The calculation of energy levels involves theoretical values of the following quantities: (1) The center-of-gravity energy E_{av} of a configuration; (2) Coulomb radial integrals F^k and G^k , and spin-orbit radial integrals ζ , which determine level separations from E_{av} in the single-configuration approximation; and (3) Coulomb integrals R^k , which determine energy perturbations among levels of different configurations. On the basis of a great deal of experience comparing calculations with experimental data for elements up to $Z \approx 50$ and ionization stages from

about VIII to XXX, the following statements can be made: (1) Binding energies (i.e., values of E_{av} relative to the appropriate ionization limit) are accurate to about 0.1 to 0.2% for 1s electrons and to about 0.2 to 0.5% for other electrons; (2) Values of C computed by the Blume-Watson method¹⁶ using HFR wavefunctions are accurate to about 1 to 5% for ground-configuration p electrons and to 2-10% for other electrons (see Ref. 8 and Table I below); (3) Values of F^k and G^k , scaled down by a factor of about 0.85 to 0.90 to allow for correlation effects (i.e., weak configuration-interaction perturbations from distant configurations) are accurate to 5 or 10%; (4) Values of R^k are rather uncertain, but seem to require scale factors of about 0.6 for the $n = 2$ complex and about 0.6 to 0.8 for higher n . (All results given in the present report were computed using scale factors of 0.88 for F^k and G^k , and 0.6 for R^k . These factors were chosen to give optimum agreement between calculated and experimental energy levels for Fe X-XXII.¹⁷ A value of 0.7 or 0.8 for R^k would probably have been more appropriate for most cases in heavier elements, and configuration-interaction effects have been correspondingly underestimated.)

Accuracies of computed wavelengths follow from the above remarks:

For $\Delta n \neq 0$ transitions, the major contribution to the transition energy arises from ΔE_{av} , which in most cases of interest is a sizeable fraction of the ionization energy. Wavelengths are thus accurate to about 0.1 to 0.5%, though wavelength differences among lines of a transition array exhibit the 5 to 10% uncertainty in the Coulomb-splitting parameters (except for one-valence-electron configurations where only spin-orbit parameters are involved).

For $\Delta n = 0$ transitions, ΔE_{av} is a much smaller fraction of the ionization energy because of cancellation of the hydrogenic 2^2 term, and is correspondingly less accurate. Coulomb splittings and configuration interactions may be comparable with ΔE_{av} , and relativistic contributions (of uncertain accuracy) may also be important. Uncertainties in absolute wavelength as well as in wavelength differences may be 2 to 10%.

For forbidden transitions (usually intra-configuration magnetic-dipole transitions), wavelength uncertainties will be even greater -- 5 to 10% -- unless they depend mainly on spin-orbit parameters (closely jj coupled conditions, or intra-LS-term transitions under good LS coupling conditions) in which case they will be 2 to 5%. Uncertainties of this magnitude are embarrassingly large, but it is very difficult to make them appreciably smaller. It must be recognized that the transition energies in question may be only about 1% of the ionization energy, so that

a 10% uncertainty represents only 0.1% of the ionization energy, and perhaps 0.01 to 0.001% of the total electronic binding energy of the ion.

A. Comparison With X-ray Transitions

A better feel for the accuracy of computed wavelengths can be obtained by comparing calculations with known experimental values. Some comparisons of this sort will be given in Secs. IX and XII. However, very few experimental data are available for very highly ionized atoms of elements heavier than nickel; consequently, few direct checks are possible on the calculational accuracy of the very large spin-orbit splittings and relativistic effects on binding energies. Fortunately, indirect checks are possible in the case of simple one-valence-electron ions through characteristic (one-hole) x-ray transitions, which are known^{15,18} for atoms of all Z .

For example, photoelectric or electron-collisional ejection of, say, a 3s electron from a tungsten atom leaves a singly ionized atom in the M_I (single-3s-hole) x-ray level. This hole may be filled by a $3p_{3/2}$ electron, leaving a singly ionized atom in the M_{III} (single- $3p_{3/2}$ -hole) x-ray level; the transition may be accompanied by emission of a photon of energy $E(M_I) - E(M_{III})$. Comparison of the theoretically computed value of this energy difference for an isolated singly ionized atom with the experimental x-ray value¹⁵ provides (if we ignore solid-state effects usually present in x-ray measurements) some estimate of the probable accuracy of the theoretical 3s - $3p_{3/2}$ valence-electron transition energy in Na-like W 63+.

A numerical example is shown in the upper portion of Fig. 8 for the Ni I (or, rather, Zn III) isoelectronic-sequence transition $3d^{10} - 3d^9 4p$ and the somewhat analogous x-ray transition $M_{IV,V} - M_{II,III}$ (3d hole to 4p hole). The quantity ΔE_{av} is the difference in $(2J + 1)$ -weighted average energies of all levels of the two configurations, as given theoretically directly by the spherical-average HF (or HFR) calculations, and by explicit averaging of the experimental levels. The plot is given in the form of a Moseley diagram -- $(\Delta E_{av})^{1/2}$ vs. Z -- because for a $\Delta n \neq 0$ transition this should from (8) give a nearly straight-line relationship. For the Ni I sequence, experimental data are available as far as tungsten.¹⁹ Relativistic effects on ΔE_{av} are small (less than 5% even at $_{82}\text{Pb}$), and the difference between HF + r and HFR is too small to plot. Provided relativistic corrections are included, the theoretical values agree with experiment to within the experimental uncertainties of 0.1 to 1% for both the Ni I-sequence and x-ray transitions.

The lower portion of Fig. 8 shows similar comparisons for the sequence Cu I $3d^{10}4s - 3d^{10}4p$ and the x-ray transition $N_I N_{II,III}$ (4s hole to 4p hole). The Moseley diagrams (solid and dashed curves) are S-shaped because at low atomic number it is ΔE_{av} (not $\sqrt{\Delta E_{av}}$) that increases linearly with Z [Eq. (9)], and because for high atomic number the relativistic contribution is both large and positive. (In the $3d - 4p$ transition, the relativistic contribution was negative because the upper level had the smaller l , and suffered the greater relativistic depression in spite of its greater n .) Available data²⁰ for the Cu I sequence extend to only marginally high enough Z (≈ 54) to indicate that HFR gives more accurate results than HF + r. For the x-ray transition, however, HFR values definitely agree much better with experiment -- within 3% from $Z = 50$ to $Z = 74$ -- and so a similar result may be inferred for the Cu I sequence. (The poor agreement between theory and experiment for Br II $4s^2 4p^4 - 4s 4p^5$, which is not really an x-ray transition at all, is due to a very strong $4s 4p^5 + 4s^2 4p^3 4d$ configuration interaction that was neglected in the present calculation. The poor agreement for Mo II $4s^2 4p^5 4d^6 - 4s 4p^6 4d^6$ may similarly be due to a neglected $4s 4p^6 4d^6 + 4s^2 4p^4 4d^7$ interaction, or to solid-state effects on the x-ray transition.)

For the $3s - 3p$ transitions shown in Fig. 9, the relativistic contribution to ΔE_{av} represents over 70% of the total at $Z = 79$. Experimental data for the Na I sequence²¹ at present extend only to Mo XXXII, where there is no appreciable difference between HFR and HF + r. However, the x-ray data show HFR to be much more accurate than HF + r above $Z \approx 55$. Above $Z \approx 70$ even HFR becomes inaccurate, but this is apparently an indication of difficulties in calculating inner-shell transitions; for the Na I-sequence valence-shell transitions, the HFR results agree well with the DHF values.

For $2s - 2p$ transitions in the Li I isoelectronic sequence, relativistic effects become astronomical, accounting for about 90% of ΔE_{av} by $Z = 79$ (see Fig. 11 below).

For one-electron spectra such as those of the Cu I, Na I, and Li I sequences, the calculation of wavelengths of individual spectrum lines involves, in addition to ΔE_{av} , only spin-orbit parameter values (Coulomb configuration interactions being negligible because of the Coulomb selection rule $LSJ = L'S'J'$ and the considerations of Sec. V). The accuracy of computed values of ζ_{nl} may be estimated from the results given in Table I, where "experimental" values of ζ have been inferred from experimental energy levels and the theoretical relation

Fig. 8. Comparison of optical (valence-shell) and x-ray (inner-shell, singly ionized-atom) transition energies. Top: the $\Delta n = 1$ $3d - 4p$ transition, which in the Ni I isoelectronic sequence is $3d^{10} - 3d^9 4p$; bottom: the $\Delta n = 0$ $4s - 4p$ transition, which in the Cu I sequence is $3d^{10} 4s - 3d^{10} 4p$. All curves represent theoretical single-configuration Hartree-Fock results, either without (HF) or with (HF + r) relativistic perturbation energy corrections, or including approximate relativistic effects in the radial wavefunctions (HFR). The triangles and circles represent experimental values; the squares are DHF theoretical values.

Fig. 9. Comparison of $\Delta n = 0$ $3s - 3p$ transitions for x-ray levels and for the Na I $2p^6 3s - 2p^6 3p$ isoelectronic sequence. Note that unlike the Ni I and Cu I cases, the x-ray transition here has an energy greater than the optical transition. The triangles and circles represent experimental values; the squares are DHF results.

$$|E^{nlj_+} - E^{nlj_-}| = \frac{1}{2}(2l + 1)\zeta_{nl} \quad , \quad (20)$$

where $j_{\pm} = l \pm \frac{1}{2}$. It may be seen that relativistic effects are significant even at $Z = 30$, that HFR values are always considerably better than HF, and that errors in HFR values are usually in the range 2 to 5%.

In summary, the HFR method is not significantly inferior to DHF in the accuracy of calculation of ΔE_{av} and ζ_1 for cases of Tokamak interest. For configurations involving more than one electron outside of closed subshells, the HFR method is much simpler than DHF, and accuracies are limited in either approach by uncertainties in the appropriate scaling factors needed for the Coulomb-interaction integrals F^k , G^k , and R^k .

VIII. IONIZATION ENERGIES

The most probable degree of ionization of atoms in a plasma can be estimated roughly if the ionization energies are known. Under conditions of local thermal equilibrium, a rough rule of thumb is that the predominant ion stages will be those having an ionization energy equal to five or ten times kT_e . In Tokamak plasmas, electron densities are low enough that conditions lie closer to coronal equilibrium, and discharge times may be too short to ionize even to these conditions; consequently, the predominant stages are those having ionization energies more like one to three times kT_e .

Experimental ionization energies (in some cases interpolated or extrapolated) are given by Moore²² for low ionization stages of all elements, and by Reader and Sugar¹⁷ for all stages of iron; extrapolations based on self-consistent-field calculations are given by Kelly, et al.^{23,24} for all ions of elements up through krypton. Rough theoretical values of accuracy ($\pm 5\%$) adequate for present purposes are given for all ionization stages of all elements by Carlson, et al.²⁵

More accurate ionization energies (± 0.1 to 1%) are given in Table II for ions of Tokamak interest in simple isoelectronic sequences, and in Table III for many ions of a few of these elements. Values for tungsten and gold will be given in Table VI. In all cases, the value quoted is the true first ionization energy, from the ground level of the indicated ion to the ground level of the next higher ionization stage. The method, as outlined in Sec. II, consisted of first performing an HFR calculation for the ground configuration of each of the two ions. This gave radial wavefunctions for each configuration, and also the zero-order center-of-gravity ionization energy of the first ion, ΔE_{av} , including relativistic effects, and also including a rough correlation-energy correction.⁴ The ground level of each ion was then computed by calculating and diagonalizing energy

matrices for each ion, including (except in very complex cases) important configuration interactions -- e.g., for Be I-like ions $2s^2 + 2p^2$, and for Mg I-like ions $3s^2 + 3p^2 + 3d^2$. (Addition of configuration interactions of course necessitated additional MFR calculations for the excited configurations.)

Ionization energies for isoelectronic sequences having simple ground configurations are shown graphically in Fig. 10. The figure shows that in Tokamak plasmas reaching a temperature of 1 or 2 keV, aluminum will be ionized down to the 1s shell, iron to about the 2s subshell, molybdenum to 3s, xenon into the 3d subshell, and tungsten to about 4s or 4p.

IX. RESONANCE LINES OF SIMPLE ISOELECTRONIC SEQUENCES

Of particular interest for diagnostic purposes are resonance lines in isoelectronic sequences with very simple ground configurations; these lines, being both intense and few in number, should be most easily detectable and identifiable. Computed wavelengths for sequences and elements of interest are given in Table IV. Experimental values, where known, provide both an indication of the theoretical accuracy and a means of estimating corrected wavelengths for the heavier elements.

Table IV also gives computed (absorption) oscillator strengths and (emission) transition probability rates. Estimated accuracies are ± 10 to 20% for the one-electron configurations where intermediate-coupling and configuration-interaction effects are nil or unimportant, and perhaps $\pm 50\%$ for the stronger lines of the two-electron-configuration cases. In all cases, f and A were computed using the theoretical wavelengths; where λ is known, f and A can be corrected to the experimental wavelength using the relations $f \propto \lambda^{-1}$ and $A \propto \lambda^{-3}$.

As an illustration of the magnitude of relativistic effects, theoretical oscillator strengths for the Li I sequence are shown in Fig. 11. For the $\Delta n = 0$ transition, the relativistic contribution to the transition energy becomes significant by $Z = 15$ and represents 90% of the total by $Z = 80$, but relativistic effects on the radial wavefunctions are negligible till $Z \approx 65$. For the $\Delta n \neq 0$ transition, both effects appear by about $Z = 30$.

X. SPECTRA OF MOLYBDENUM IONS

From the ionization energies in Table III it may be inferred that molybdenum atoms in kilovolt plasmas will be at least twenty times ionized. Nothing is known experimentally about the spectra of such ions except for the three lines of Mo XXXI and XXXII given in Table IV. As a guide to further experimental work,

Fig. 10. Ionization energies for some isoelectronic sequences with simple ground configurations. Ionization energies for ions with ground configurations ns are greater than the values shown for ns^2 by amounts decreasing from about 15% at the lowest Z plotted to 1 to 3% at the highest Z plotted.

Fig. 11. Multiplet oscillator strengths, $f(s_{1/2} - p_{1/2}) + f(s_{1/2} - p_{3/2})$, for resonance transitions in the Li I isoelectronic sequence.⁸ Solid curves, HF; dashed curves, HF + r; dotted curves, HFR; circles, DHF (length approximation) from L. Armstrong, Jr., W. R. Fielder, and D. L. Lin, Phys. Rev. A 14, 1114 (1976).

theoretical wavelengths and oscillator strengths are given in Table V for the strongest lines of Mo XXV - XXXVIII. Although wavelengths are generally quoted to four significant figures in order to give wavelength differences for closely spaced lines of an array to at least a couple of figures, it must be remembered that both absolute wavelengths and wavelength differences cannot in most cases be expected to be accurate to better than a few percent (Sec. VII).

There is obviously a profusion of strong lines (not to mention the omitted weaker ones), which cover much the same wavelength range from one ion to the next. This, coupled with the 2 to 5% wavelength uncertainties, implies that the tabulated wavelengths will not be very helpful unless the ionization stage giving rise to each observed line can be ascertained experimentally. [It may be noted that the wavelengths of the strong $3p - 3d$ lines tend to increase with increasing ionization stage. This has been noted also in the case of iron spectra.²⁶]

XI. SPECTRA OF TUNGSTEN AND GOLD IONS

Some experimental data are available on tungsten spectra as far as W VII²⁷ and on gold spectra to Au III;²⁸ thereafter, essentially nothing is known except for a single line¹⁹ in Ni I-like W XLVII and Au LII. Although theoretical predictions of the W and Au lines of principal Tokamak interest have already been listed in Table IV, the experimental difficulties involved in the unambiguous experimental identification of these (and other) spectrum lines are so great that it seems worthwhile presenting a somewhat detailed theoretical survey for all ionization stages.

The situation for tungsten is summarized in Table VI for ground configurations and some of the lower excited configurations. The indicated ground configuration may not always be correct up to about the eighteenth spectrum because of the difficulty of accurately calculating the binding energy of a 4f electron in this range; however, relative positions of low-lying configurations should be correct to one or two electron volts, and this does not appreciably affect the overall picture.

Spectra will be almost hopelessly complex all the way from W IX or X to W XXVII, owing to the presence throughout this range of low-lying configurations involving a partially filled 4f subshell. In the lower ionization stages, this is due to near equality of 4f and 5p binding energies,²⁷ and in the vicinity of W XVII there is near equality of 4f and 5s energies, as illustrated in Fig. 12. W XXVIII and XXIX (ground configurations $4d^{10}4f$ and $4d^{10}$, respectively) should involve relatively simple transition arrays, but in any actual light source (including Tokamaks) these will almost surely be overlapped by the much more complex spectra of neighboring ions.^{29,30}

By about W XXXVIII or XXXIX (ground configurations $4p^64d$ and $4p^6$), one begins to reach spectra simple enough that there is some hope of identifying experimentally observed spectrum lines. However, it may be seen from Fig. 13 that in the neighborhood of 50 to 60 Å 4s - 4p, 4p - 4d, and 4d - 4f arrays all overlap, and nothing may be very feasible in this spectral region. Indeed, laser-produced spectra of tungsten (and tantalum) expected to involve about the 39th ionization stage showed intense continua in the vicinity of 50 to 60 Å,³⁰ and spectra produced by ORMAK (which has gold plated vacuum-vessel walls and a tungsten limiter) show three continua in the interval 40 to 60 Å.³¹ Although discrete spectrum lines were observed superimposed on the continua,^{30,31} it may prove more feasible to work in the spectral regions above 60 Å and below 20 Å.

Fig. 12. Theoretical configuration-average binding energies of electrons in the ground (or low-excited) configurations of tungsten ions from the seventh to fiftieth spectrum (VII to L), as measured approximately by the HFR eigenvalue ϵ^{nl} and Koopmans' theorem.

Computed wavelengths and transition probabilities for the strong spectrum lines ($f > 0.1$) of the simpler spectra of W XXXVIII to LXIV and Au XLIII to LII are given in Tables VII and VIII, respectively. As in Table V for molybdenum, many more significant figures are given than are justified by the absolute calculational accuracy, but the tables suffice at least to indicate the difficulties involved in the identification of experimental lines.

XII. FORBIDDEN TRANSITIONS

For diagnostic purposes, it would be very valuable to be able to determine ion temperatures T_i by measuring Doppler widths of spectrum lines emitted by high- Z impurity ions. Adequate spectral intensity and resolution for such measurements is obtainable only at relatively long wavelengths ($\lambda > 800 \text{ \AA}$, and preferably $\lambda > 1100 \text{ \AA}$). At the temperatures of interest ($T_e \approx 0.5$ to 5 keV), the degree of ionization is so high that such wavelengths usually arise only from intra-configuration (and hence electric-dipole-forbidden) transitions. Intensity requirements limit consideration to forbidden transitions that:

- (1) Originate from metastable levels (levels of the ground and low-excited configurations that cannot decay by rapid electric dipole transitions);

Fig. 13. Approximate spectral regions within which strong spectrum lines ($f > 0.1$) of the indicated tungsten transition arrays are computed to lie.

(2) Originate from levels that cannot decay by many different paths, or by a much more probable path than the one in question;

(3) Have transition probability rates A that are not small compared with collisional excitation and deexcitation rates (hence $A \geq 10^3$ to 10^5 s^{-1} for plasmas of interest here). In addition,

(4) The electron configurations involved must not contain so many metastable levels that the number of atoms in any one level is a small fraction of the total.

Item (4) probably eliminates interest in ions with ground configurations d^w ($2 < w < 8$) and f^w ($2 < w < 12$). The same might be thought true of the (large- J) metastable levels of $3p^w 3d$ and $4p^w 4d$, which (for $2 < w < 5$) are fairly numerous; however, the higher energy metastable levels tend to decay an order of magnitude faster than the lower levels, and so the latter at least are probably well populated.

Experimental energy level structures are now well enough known for iron ions¹⁷ (from wavelength measurements on electric-dipole-allowed lines) to predict wavelengths for most forbidden transitions of interest. However, a good deal less is known for chromium and nickel, and essentially nothing for higher Z ions of interest here. No experimental data whatever exist for transition probabilities of forbidden lines of the type of interest here for atoms (of any element) that are more than once or twice ionized. Hence we must rely almost entirely on theoretical calculations to obtain the desired atomic properties.

Calculations were carried out by the methods described in Sec. II. Configuration interactions of the types $ns^2 + np^2$, $nsnp + npnd$ ($n > 2$), $nsn'd + npn'p$, etc., were generally included where appropriate; these were frequently of considerable importance in the calculation of wavelengths (energy perturbations being as large as 10 or 15 kK), but wavefunction mixing was seldom greater than 1% and so was usually of little importance in the calculation of transition probabilities.

Tables IX-XV give computed wavelengths (in vacuum) and transition probabilities for Fe, Cr and Ni, Kr, Mo, Xe, W, and Au, respectively. Experimental wavelengths (in air, for $\lambda > 2000 \text{ \AA}$) and other theoretical values of A for iron^{32,33} are included in Table IX for comparison. In general, all M1 transitions omitted from the tables have either $\lambda < 750 \text{ \AA}$, or $A_{M1} < 500 \text{ s}^{-1}$, or a transition probability less than one tenth of ΣA .

The theoretical calculation of magnetic-dipole (M1) line strengths is of relatively high accuracy in that no radial transition integrals are involved.

Under nearly pure LS coupling conditions, the strength of a transition between two levels of a single LS term involves only an angular integral, which is known exactly; the only uncertainty in calculating transition probabilities then arises from the fact that $A_{M1} \propto \lambda^{-3}$, which means an uncertainty of about 10 or 20% if the experimental wavelength is unknown. When departures from LS coupling are appreciable, additional errors arise from uncertainties in the intermediate-coupling wavefunctions (i.e., uncertainties in the values of the eigenvector components); this is especially true of transitions between levels belonging to (nominally) different LS terms, which owe their very existence to intermediate-coupling mixings. Even taking into account the greater wavelength uncertainties in these cases, errors are probably no greater than a factor two (appreciably less if the wavelength becomes known experimentally) except for weak lines of no interest here.

Electric-quadrupole (E2) transition probabilities are less accurate than for M1 transitions because they involve the square of a radial quadrupole integral and because $A_{E2} \propto \lambda^{-5}$. However, these transitions appear to be too weak to be of any interest for present purposes. E2 transition probabilities were computed in most cases, and it was found that where a transition is both M1 and E2 allowed, the probability of the latter is never greater than 2 or 3% of the former (except for lines with $\lambda < 200 \text{ \AA}$) and is usually much less. Values of A_{E2} have therefore mostly been omitted from the present tables in the interest of brevity; an exception is the $A_0 - A_2$ transition in np^2 configurations, which at high Z overshadows the otherwise-useable $A_1 - A_2$ magnetic-dipole transitions. Correspondingly, values of ΣA in Tables XI to XV include only M1 decays, except where the E2 transition of np^2 is included.

By and large, Tables IX-XV indicate that for nearly every ion of elements up to xenon there are forbidden lines available that are potentially useful for Doppler-width measurements. However, for tungsten and gold the opposite is true: Practically none of the higher ionization stages presents a useable line. Some short-wavelength M1 lines are listed, partly to emphasize the absence of lines with $\lambda > 800 \text{ \AA}$, and partly because these lines may be comparable in intensity with the E1 lines of Tables VII-VIII and may therefore be useful for ion-stage identification purposes.

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TABLE I
SPIN-ORBIT PARAMETER VALUES (kK)

	ζ_{4p} (Cu I $3d^{10}4p$ seq.)				ζ_{4p} (x-ray)		
	HF	HFR	DHF ^a	Exp	HF	HFR	Exp ^f
35Br	4.37	4.59		5.05^b	2.54	2.67	3.2
36Kr	5.68	5.99		6.52^c			3.58^b
42Mo	18.70	20.09	20.77	20.93^d	11.50	12.43	$\sim 16.^g$
50Sn	55.75	61.92			35.65	39.83	$\sim 48.^g$
54Xe	86.34	97.74		98.71^d			$\sim 54.^g$
74W	441.9	567.0	543.2		284.9	373.5	356.
79Au	607.1	810.2	768.1				529.
82Pb	725.8	993.6			482.0	673.7	642.

	ζ_{3p} (Na I $2p^63p$ seq.)				ζ_{3p} (x-ray)		
	HF	HFR	DHF ^a	Exp	HF	HFR	Exp ^f
26Fe	13.18	13.53	13.92	13.99^e		7.87	
29Cu	22.91	23.70		24.25^e			
36Kr	65.23	68.87	69.1	69.0^d	39.88	42.18	48.
42Mo	133.6	144.1	143.3	$140.^d$	87.65	94.67	94.
54Xe	414.3	472.1	462.		296.3	338.0	333.
66Dy	998.	1222.	1171.				894.
74W	1636.	2122.	2005.		1265.	1645.	1580.
79Au	2165.	2925.	2739.		1693.	2295.	2177.

TABLE I (cont)

	ζ_{2p} (Li I $1s^2 2p$ seq.)				ζ_{2p} (x-ray)		
	<u>HF</u>	<u>HFR</u>	<u>DHF^a</u>	<u>Exp</u>	<u>HF</u>	<u>HFR</u>	<u>Exp^f</u>
6^C	0.0686			0.0718			
8^O	0.346			0.355			
10^{Ne}	1.083			1.100			
14^{Si}	5.38	5.42		5.59			
18^{Ar}	16.81	17.03		17.0			
26^{Fe}	83.8	86.2		85.8	63.6	65.3	70.
42^{Mo}	638.	689.	675.		529.	569.	564.
54^{Xe}	1813.	2067.			1554.	1763.	1729.
74^{W}	6633.	8578.	8069		5899.	7572.	7190.
79^{Au}	8669.	11663.			7759.	10353.	9759.
82^{Pb}	10100.	13933.					

^aJ. B. Mann, private communication, except 2p values from L. Armstrong, Jr., W. R. Fielder, and D. L. Lin, Phys. Rev. A 14, 1114-1128 (1976) and 3p values up to Xe from Yong-Ki Kim, private communication.

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TABLE II
IONIZATION ENERGIES (eV)

Li I sequence, $1s^2 2s^2 S_{1/2} - 1s^2 1S_0$

	<u>Calc</u>	<u>Exp</u>	<u>Ref.</u> ^a
¹⁰ Ne VIII	239.8	239.1	M
¹⁸ Ar XVI	919.	918.	M
²⁶ Fe XXIV	2047.	2024. ± 3	RS
³⁶ Kr XXXIV	4112.	~4105.	KP
⁴² Mo XL	5713.		
⁵⁴ Xe LII	9813.		
⁷⁴ W LXXII	19680.		
⁷⁹ Au LXXVII	22850.		

Be I sequence, $2s^2 1S_0 - 2s^2 S_{1/2}$

¹⁰ Ne VII	205.6	207.3	M
¹⁸ Ar XV	853.	854.8	M
²⁶ Fe XXIII	1947.	~1950.	RS
³⁶ Kr XXXIII	3968.	~3912.	KP
⁴² Mo XXXIX	5546.		
⁵⁴ Xe LI	9582.		
⁷⁴ W LXXI	19370.		
⁷⁹ Au LXXVI	22530.		

TABLE II (cont)

Na I sequence, $2p^6 3s^2 S_{1/2} - 2p^6 1S_0$

	<u>Calc</u>	<u>Exp</u>	<u>Ref.^a</u>
$^{18}\text{Ar VIII}$	143.6	143.5	M
$^{26}\text{Fe XVI}$	489.4	489.3	RS
$^{36}\text{Kr XXVI}$	1205.	~1206.	KP
$^{42}\text{Mo XXXII}$	1791.		
$^{54}\text{Xe XLIV}$	3334.		
$^{74}\text{W LXIV}$	7137.		
$^{79}\text{Au LXIX}$	8365.		

Mg I sequence, $3s^2 1S_0 - 3s^2 S_{1/2}$

$^{18}\text{Ar VII}$	123.5	124.3	M
$^{26}\text{Fe XV}$	454.5	$457. \pm 2$	RS
$^{36}\text{Kr XXV}$	1152.	~1151.	KP
$^{42}\text{Mo XXXI}$	1726.		
$^{54}\text{Xe XLIII}$	3245.		
$^{74}\text{W LXIII}$	7004.		
$^{79}\text{Au LXVIII}$	8220.		

TABLE II (cont)

K I (Sc III) sequence, $3p^6 3d^2 D_{3/2} - 3p^6 1S_0$

	<u>Calc</u>	<u>Exp</u>	<u>Ref.</u> ^a
$^{26}\text{Fe VIII}$	151.0	151.1	RS
$^{36}\text{Kr XVIII}$	641.	642.	KP
$^{42}\text{Mo XXIV}$	1083.		
$^{54}\text{Xe XXXVI}$	2302.		
$^{74}\text{W LVI}$	5347.		
$^{79}\text{Au LXI}$	6312.		
$^{82}\text{Pb LXIV}$	6931.		

Ni I sequence, $3d^{10} 1S_0 - 3d^9 2D_{5/2}$

$^{36}\text{Kr IX}$	232.4	230.9	M
$^{42}\text{Mo XV}$	543.		
$^{54}\text{Xe XXVII}$	1495.		
$^{74}\text{W XLVII}$	4055.		
$^{79}\text{Au LII}$	4884.		
$^{82}\text{Pb LV}$	5418.		

TABLE II (cont)

Cu I sequence, $3d^{10}4s^2s_{1/2} - 3d^{10}1s_0$

	Calc	Exp	Ref. ^a
$^{36}\text{Kr VIII}$	125.4	126.	M
$^{42}\text{Mo XIV}$	302.1		
$^{50}\text{Sn XXII}$	642.		
$^{54}\text{Xe XXVI}$	857.		
$^{74}\text{W XLVI}$	2415.		
$^{79}\text{Au LI}$	2941.		
$^{82}\text{Pb LIV}$	3286.		

Zn I sequence, $3d^{10}4s^21s_0 - 3d^{10}4s^2s_{1/2}$

$^{36}\text{Kr VII}$	108.2	111.0	M
$^{42}\text{Mo XIII}$	278.0		
$^{50}\text{Sn XXI}$	609.		
$^{54}\text{Xe XXV}$	819.		
$^{74}\text{W XLV}$	2354.		
$^{79}\text{Au L}$	2874.		
$^{82}\text{Pb LIII}$	3215.		

^aExperimental data from M: C. E. Moore, Ref. 22.

RS: J. Reader and J. Sugar, Ref. 17.

KP: R. L. Kelly and L. J. Palumbo, Ref. 24.

TABLE III
IONIZATION ENERGIES (eV)

Ground Config.	Fe		Ni	Kr	Mo	Xe	
	Cr	Calc Exp ^a					
4d						XVIII	434.8
4p ⁶						XIX	549.
4p ⁵						XX	583.
4p ⁴						XXI	618.
4p ³						XXII	651.
4p ²						XXIII	701.
4p						XXIV	737.
4s ²				VII 108.1	XIII 278.0	XXV	819.
4s				VIII 125.4	XIV 302.1	XXVI	857.
3d ¹⁰				IX 232.4	XV 542.8	XXVII	1495.
3d ²				XVII 591.	XXIII 1020.	XXXV	2211.
3d				XVIII 641.	XXIV 1083.	XXXVI	2302.
3p ⁶		IX 231.8 233.6	XI 317.5	XIX 786.	XXV 1264.	XXXVII	2554.
3p ⁵		X 261.5 262.1	XII 351.4	XX 833.	XXVI 1323.	XXXVIII	2639.
3p ⁴		XI 290.7 290.3	XIII 384.9	XXI 884.	XXVII 1387.	XXXIX	2728.
3p ³	X 241.4	XII 326.8 330.8	XIV 424.3	XXII 936.	XXVIII 1449.	XL	2812.
3p ²	XI 269.3	XIII 359.2 361.0	XV 461.5	XXIII 997.	XXIX 1535.	XLI	2979.
3p	XII 297.6	XIV 391.5 392.2	XVI 497.9	XXIV 1050.	XXX 1601.	XLII	3071.
3s ²	XIII 353.0	XV 454.5 457. ± 3	XVII 569.	XXV 1152.	XXXI 1726.	XLIII	3245.
3s	XIV 384.3	XVI 489.4 489.3	XVIII 607.	XXVI 1205.	XXXII 1791.	XLIV	3334.
2p ⁶	XV 1011.	XVII 1261. 1266. ± 3	XIX 1540.	XXVII 2926.	XXXIII 4257.	XLV	7665.
2p ⁵	XVI 1097.	XVIII 1358. 1358.	XX 1646.	XXVIII 3070.	XXXIV 4430.	XLVI	7893.
2p ⁴	XVII 1189.	XIX 1460. 1456.	XXI 1759.	XXIX 3227.	XXXV 4617.	XLVII	8143.
2p ³	XVIII 1294.	XX 1573. 1582.	XXII 1880.	XXX 3381.	XXXVI 4798.	XLVIII	8381.
2p ²	XIX 1397.	XXI 1690. 1689.	XXIII 2012.	XXXI 3594.	XXXVII 5099.	IL	8987.
2p	XX 1498.	XXII 1800. 1799.	XXIV 2134.	XXXII 3760.	XXXVIII 5296.	L	9257.
2s ²	XXI 1631.	XXIII 1947. 1950.	XXV 2292.	XXXIII 3366.	XXXIX 5546.	LI	9582.
2s	XXII 1723.	XXIV 2047. 2024. ± 3	XXVI 2401.	XXXIV 4112.	XL 5716.	LII	9813.
1s ²	XXIII 7488.	XXV 8836. 8828.	XXVII 10300.	XXXV 17310.	XL1 23840.	LIII	40245.
1s	XXIV 7897.	XXVI 9280. 9278.	XXVIII 10780.	XXXVI 17940.	XLII 24570.	LIV	41211.

^aReader and Sugar, Ref. 17; most values are actually isoelectronic extrapolations.

TABLE IV

WAVELENGTHS, ABSORPTION OSCILLATOR STRENGTHS, AND EMISSION
TRANSITION PROBABILITIES FOR SIMPLE ISOELECTRONIC SEQUENCES

Li I sequence: $2s^2 S_{1/2} - 2p^2 P_{3/2, 1/2}$

Z	Ion		λ (Å)		f		A (s^{-1}) ^a		λ_{exp} (Ref) ^b		
10	Ne	VIII	770.	780.	0.103	0.0510	5.81(8)	5.59(8)	770.	780.	KP
18	Ar	XVI	356.	392.	0.058	0.0262	1.51(9)	1.14(9)	352.	388.	KP
26	Fe	XXIV	195.	260.	0.047	0.0176	4.15(9)	1.74(9)	192.	255.	RS
36	Kr	XXXIV	92.0	180.	0.049	0.0127	1.95(10)	2.61(9)			
42	Mo	XL	58.7	150.	0.056	0.0109	5.35(10)	3.24(9)			
54	Xe	LII	24.9	110.	0.076	0.0086	4.08(11)	4.74(9)			
74	W	LXXII	6.99	69.1	0.134	0.0068	9.15(12)	9.45(9)			
79	Au	LXXVII	5.24	62.3	0.153	0.0065	1.87(13)	1.10(10)			

Be I sequence: $2s^2 1S_0 - 2s2p^1 P_1, ^3P_1$ or $\left(\frac{1}{2} \frac{3}{2}\right)_1, \left(\frac{1}{2} \frac{1}{2}\right)_1$

10	Ne	VII	497.	1007.	0.413	0.0000	3.73(9)	1.76(4)	465.	~895.	KP
18	Ar	XV	241.	471.	0.216	0.0003	8.30(9)	3.08(6)	221.	~431.	KP
26	Fe	XXIII	145.	292.	0.159	0.0021	1.69(10)	5.43(7)	133.	264.	K,W
36	Kr	XXXIII	77.5	188.	0.138	0.0066	5.13(10)	4.20(8)			
42	Mo	XXXIX	52.2	152.	0.141	0.0088	1.15(11)	8.43(8)			
54	Xe	LI	23.8	114.	0.169	0.0099	6.60(11)	1.69(9)			
74	W	LXXI	6.89	68.2	0.278	0.0102	1.30(13)	4.87(9)			
79	Au	LXXVI	5.18	61.4	0.315	0.0100	2.61(13)	5.87(9)			

TABLE IV (cont)

Na I sequence: $3s^2 S_{1/2} - 3p^2 P_{3/2, 1/2}$

<u>Z</u>	<u>Ion</u>		<u>λ (Å)</u>		<u>f</u>		<u>A (s⁻¹)^a</u>		<u>λ_{exp} (Ref)^b</u>		
18	Ar	VIII	701.	713.	0.400	0.197	2.72(9)	2.58(9)	700.	714.	KP
26	Fe	XVI	337.	361.	0.269	0.126	7.93(9)	6.40(9)	335.	361.	RS
36	Kr	XXVI	180.	221.	0.212	0.087	2.19(10)	1.18(10)	180.	221.	H
42	Mo	XXXII	129.	178.	0.202	0.073	4.08(10)	1.53(10)	129.	177.	H
54	Xe	XLIV	66.5	126.	0.213	0.057	1.61(11)	2.38(10)			
74	W	LXIV	22.6	80.0	0.293	0.041	1.92(12)	4.32(10)			
79	Au	LXIX	17.3	72.2	0.325	0.039	3.60(12)	4.99(10)			

Mg I sequence: $3s^2 {}^1S_0 - 3s3p {}^1P_1, {}^3P_1$ or $(\frac{1}{2} \frac{3}{2})_1, (\frac{1}{2} \frac{1}{2})_1$

18	Ar	VII	594.	928.	1.309	0.0003	8.23(9)	6.47(5)	586.	883.?	KP
26	Fe	XV	290.	433.	0.850	0.0035	2.25(10)	4.17(7)	284.	417.	RS
36	Kr	XXV	162.	250.	0.619	0.0199	5.23(10)	7.07(8)	159.		H
42	Mo	XXXI	119.	197.	0.550	0.0345	8.67(10)	1.99(9)	117.		H
54	Xe	XLIII	63.7	134.	0.507	0.0551	2.78(11)	6.80(9)			
74	W	LXIII	22.2	83.7	0.625	0.0596	2.81(12)	1.89(10)			
79	Au	LXVIII	17.1	75.4	0.684	0.0586	5.17(12)	2.29(10)			

TABLE IV (cont)

K I sequence: $3d^2 4p^2 \text{ } ^2D_{3/2, 5/2} - 4p^2 \text{ } ^2P_{3/2, 1/2}$

Z	Ion	λ (Å)			f			A (s^{-1}) ^a			λ_{exp} (Ref) ^b	
26	Fe VIII	192.9	193.5	194.0	0.0120	0.072	0.060	2.15(9)	1.91(10)	2.11(10)		
36	Kr XVIII	44.03	44.34	44.53	0.0071	0.043	0.035	2.45(10)	2.16(11)	2.37(11)		
42	Mo XXIV	26.01	26.26	26.42	0.0061	0.036	0.030	5.98(10)	5.23(11)	5.70(11)		
54	Xe XXXVI	12.24	12.45	12.58	0.0052	0.031	0.025	2.31(11)	1.97(12)	2.12(12)		
74	W LVI	5.27	5.45	5.59	0.0051	0.030	0.024	1.24(12)	1.00(13)	1.04(13)		
79	Au LXI	4.46	4.64	4.79	0.0053	0.031	0.025	1.78(12)	1.42(13)	1.44(13)		
82	Pb LXIV	4.06	4.24	4.39	0.0054	0.031	0.025	2.19(12)	1.73(13)	1.73(13)		

Ni I sequence: $3d^{10} 1s_0 - 3d^9 4p^3 \text{ } ^1D_1, ^1P_1, ^3P_1$ or $(\frac{3}{2} \frac{3}{2})_1, (\frac{5}{2} \frac{3}{2})_1, (\frac{3}{2} \frac{1}{2})_1$

35	Br VIII	140.3	141.1	143.7	0.146	0.475	0.096	1.65(10)	5.30(10)	5.91(8)	138.9	139.8	~142.5	KP
36	Kr IX	115.8	116.5	118.4	0.138	0.470	0.005	2.28(10)	7.69(10)	7.55(8)	115.0	115.7	117.7	KP
42	Mo XV	50.01	50.53	50.97	0.092	0.428	0.000	8.21(10)	3.73(11)	4.62(6)	49.90	50.44	50.92	A
50	Sn XXI	24.22	24.60	24.78	0.056	0.349	0.031	2.14(11)	1.28(12)	1.13(11)	24.21	24.60	24.79	B
54	Xe XXVII	18.32	18.66	18.82	0.047	0.307	0.056	3.10(11)	1.96(12)	3.54(11)				
74	W XLVII	6.75	7.01	7.17	0.031	0.228	0.104	1.49(12)	1.03(13)	4.48(12)		7.08		B
79	Au LII	5.60	5.84	6.01	0.030	0.226	0.108	2.11(12)	1.47(13)	6.63(12)		5.93		B
82	Pb LV	5.04	5.28	5.45	0.030	0.226	0.110	2.59(12)	1.81(13)	8.23(12)				

Cu I sequence: $3d^{10} 4s^2 \text{ } ^2S_{1/2} - 3d^{10} 4p^2 \text{ } ^2P_{3/2, 1/2}$

35	Br VII	745.	786.		0.61	0.289		3.66(9)	3.12(9)		736.1	779.6		KP
36	Kr VII	659.	700.		0.59	0.280		4.57(9)	3.81(9)		651.6	695.9		KP
42	Mo XIV	376.	425.		0.53	0.233		1.24(10)	8.63(9)		373.6	423.6		H, R
50	Sn XX	220.	276.		0.48	0.191		3.31(10)	1.67(10)					
54	Xe XXVI	174.3	234.1		0.47	0.175		5.16(10)	2.13(10)		173.9	234.2		H
74	W XLVI	61.2	127.5		0.52	0.125		4.63(11)	5.12(10)					
79	Au LI	47.7	113.3		0.55	0.116		8.12(11)	6.05(10)					
82	Pb LIV	41.0	105.6		0.58	0.112		1.14(12)	6.71(10)					

TABLE IV (cont)

Zn I sequence: $3d^{10}4s^2\ ^1S_0 \sim 3d^{10}4s4p\ ^1P_1, ^3P_1$ or $\left(\frac{1}{2}\frac{3}{2}\right)_1, \left(\frac{1}{2}\frac{1}{2}\right)_1$

Z	Ion		λ (Å)		f		A (s ⁻¹) ^a		λ_{exp}		(Ref) ^b
35	Br	VI	669.	1010.	1.91	0.004	9.49(9)	9.00(6)	661.1	939.6	KP
36	Kr	VII	592.	882.	1.85	0.006	1.17(10)	1.68(7)	585.4	793.4?	KP
42	Mo	XIII	345.	499.	1.57	0.026	2.93(10)	2.28(8)	340.9		H,R
50	Sn	XXI	207.	309.	1.32	0.073	6.85(10)	1.65(9)			
54	Xe	XXV	166.1	258.	1.24	0.098	1.00(11)	3.27(9)	164.5		H
74	W	XLV	60.2	135.0	1.16	0.159	7.11(11)	1.94(10)			
79	Au	L	47.1	119.4	1.20	0.161	1.21(12)	2.51(10)			
82	Pb	LIII	40.6	111.1	1.24	0.161	1.67(12)	2.90(10)			

^aNumbers in parentheses represent powers of ten.

^bA: E. Alexander, et al., Ref. 19.
 B: P. G. Burkhalter, et al., Ref. 19.
 H: E. Hinnov, Ref. 20.
 K: S. O. Kastner, W. M. Neupert, and M. Swartz, *Astrophys. J.* 191, 261 (1974).
 KP: R. L. Kelly and L. J. Palumbo, Ref. 24.
 R: J. Reader, private communication.
 RS: J. Reader and J. Sugar, Ref. 17.
 W: K. G. Widing, *Astrophys. J.* 197, L33 (1975).

TABLE V

STRONG ELECTRIC DIPOLE TRANSITIONS IN MOLYBDENUM XXV TO XXXVIII^a

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
MO 25	3P6	--	MO 25	3P5 3D				
0.0	0.0	¹ S	920.2	1.0	A	106.68	.020	2.15E+07
0.0	0.0		1087.9	1.0	H	91.92	.128	3.36E+10
0.0	0.0		1345.0	1.0	C	74.46	1.688	6.77E+11
0.0	0.0					SUM F=	1.814	
MO 26	3S2 3P5	--	MO 26 3S 3P6	+	MO 26 3S2 3P4 3D			
-65.0	1.5	² P	788.6	.5	+A	117.45	.025	2.39E+10
-65.0	1.5		1182.3	.5	F	80.43	.241	4.97E+11
-65.0	1.5		1192.3	1.5	F	79.66	.152	1.59E+11
-65.0	1.5		1239.4	2.5	G	76.78	.736	5.55E+11
-65.0	1.5		1250.9	1.5	G	76.11	.255	2.95E+11
-65.0	1.5					SUM F=	1.570	
126.1	.5	² P	788.6	.5	+A	150.95	.031	9.19E+09
126.1	.5		1305.3	.5	F	84.80	.378	3.51E+11
126.1	.5		1415.8	1.5	H	77.53	.910	5.05E+11
126.1	.5					SUM F=	1.513	
MO 27	3S2 3P4	--	MO 27 3S 3P5	+	MO 27 3S2 3P3 3D			
-141.6	2.0	$\left(\frac{3}{2} \frac{3}{2}\right)$	666.9	2.0	+A	125.05	.041	1.78E+10
-141.6	2.0		1058.1	2.0	F	83.34	.110	1.25E+11
-141.6	2.0		1062.1	2.0	G	83.26	.115	1.11E+11
-141.6	2.0		1089.3	1.0	G	81.22	.132	2.23E+11
-141.6	2.0		1090.5	3.0	F	81.15	.201	1.46E+11
-141.6	2.0		1099.9	2.0	H	80.53	.088	9.05E+10
-141.6	2.0		1129.8	3.0	G	76.64	.291	2.24E+11
-141.6	2.0					SUM F=	1.356	
-79.2	0.0	$\left(\frac{3}{2} \frac{3}{2}\right)$	720.8	1.0	A	125.01	.023	3.24E+09
-79.2	0.0		1089.3	1.0	G	85.58	.219	6.65E+10
-79.2	0.0		1126.6	1.0	H	82.94	.227	7.34E+10
-79.2	0.0		1182.5	1.0	I	79.26	.631	2.23E+11
-79.2	0.0					SUM F=	1.318	
36.1	1.0	$\left(\frac{3}{2} \frac{1}{2}\right)$	666.9	2.0	+A	150.53	.032	5.15E+09
36.1	1.0		1182.1	2.0	I	87.26	.311	1.63E+11
36.1	1.0		1224.8	0.0	E	84.13	.136	3.80E+11
36.1	1.0		1246.3	1.0	J	82.63	.262	2.56E+11
36.1	1.0		1303.8	2.0	K	78.88	.208	1.34E+11
36.1	1.0					SUM F=	1.280	

TABLE V (CONT)

F1(KM)	J1	F2(KM)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
77.3	2.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	1126.6	1.0 M	95.31	.138	1.64E+11
77.3	2.0	1182.1	2.0 I	91.52	.283	6.73E+12
77.3	2.0	1303.5	2.0 K	81.54	.179	1.84E+11
77.3	2.0	1316.6	3.0 I	80.69	.583	4.27E+11
77.3	2.0			SUM F = 1.309		
284.9	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	1420.6	1.0 M	87.70	1.047	3.02E+11
284.9	0.0			SUM F = 1.260		
40 2A 3S2 3P3	--	40 2A 3S 3P4	+	40 2A 3S2 3P2 30		
-203.4	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	535.8	2.5 +A	135.27	.033	8.02E+09
-203.4	1.5	919.4	2.5 E	89.06	.078	4.49E+10
-203.4	1.5	955.2	1.5 F	86.31	.246	2.20E+11
-203.4	1.5	971.3	2.5 F	85.13	.258	1.57E+11
-203.4	1.5	986.2	.5 D	84.37	.123	2.33E+11
-203.4	1.5	1056.7	2.5 G	79.56	.114	8.26E+10
-203.4	1.5			SUM F = 1.141		
-43.3	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	535.8	2.5 +A	172.66	.028	4.14E+09
-43.3	1.5	759.2	1.5 +C	124.61	.066	2.83E+10
-43.3	1.5	1056.7	2.5 G	92.41	.212	1.14E+11
-43.3	1.5	1126.6	.5 G	85.46	.191	1.84E+11
-43.3	1.5	1129.8	1.5 I	85.24	.185	1.69E+11
-43.3	1.5	1134.1	2.5 M	84.57	.190	1.24E+11
-43.3	1.5			SUM F = 1.104		
.0	2.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	798.6	2.5 +C	125.23	.037	1.58E+10
.0	2.5	992.7	1.5 G	109.73	.107	1.26E+11
.0	2.5	1139.1	2.5 M	87.79	.154	1.33E+11
.0	2.5	1193.1	3.5 E	83.62	.025	3.03E+11
.0	2.5			SUM F = 1.119		
52.0	.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	642.9	.5 +A	169.23	.019	4.47E+09
52.0	.5	1035.6	1.5 M	101.67	.041	2.94E+10
52.0	.5	1098.6	.5 F	95.55	.157	1.37E+11
52.0	.5	1129.8	1.5 I	92.79	.200	3.47E+10
52.0	.5	1212.7	1.5 J	86.15	.307	1.38E+11
52.0	.5	1282.3	1.5 K	81.28	.192	9.67E+10
52.0	.5			SUM F = 1.065		
211.9	1.5 $\left(\frac{3}{2} \frac{3}{2} \frac{3}{2}\right)$	798.6	2.5 +C	170.45	.025	3.80E+09
211.9	1.5	1202.4	.5 M	97.23	.180	2.54E+11
211.9	1.5	1282.3	1.5 K	93.42	.161	1.23E+11
211.9	1.5	1300.5	2.5 J	91.86	.462	2.43E+11
211.9	1.5			SUM F = 1.022		

TABLE V (CONT)

F1(KM)	J1	F2(KM)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
MO 20 352 3P2	--	MO 20 35 3P3	+	MO 20 352 3P 3D		
-265.3	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	562.1	1.0 *A	120.87	.285	3.12E+10
-265.3	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	841.9	1.0 *C	90.32	.287	5.63E+10
-265.3	0.0	886.5	1.0 0	86.83	.505	1.44E+11
-265.3	0.0			SUM F=	.967	
-94.3	1.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	759.1	1.0 *B	116.40	.084	4.11E+10
-94.3	1.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	878.3	2.0 E	102.29	.175	6.71E+10
-94.3	1.0	1027.2	2.0 G	86.77	.168	8.54E+10
-94.3	1.0	1029.6	1.0 E	88.58	.154	1.31E+11
-94.3	1.0			SUM F=	.920	
-64.7	2.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	671.4	2.0 0	115.47	.083	4.10E+10
-64.7	2.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	841.9	1.0 *C	110.37	.127	1.10E+11
-64.7	2.0	1027.2	2.0 G	91.50	.146	1.10E+11
-64.7	2.0	1050.5	3.0 C	89.67	.274	1.63E+11
-64.7	2.0			SUM F=	.928	
125.6	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	666.4	3.0 *A	104.11	.226	3.68E+09
125.6	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	1062.5	1.0 F	104.52	.134	1.37E+11
125.6	2.0	1093.5	2.0 H	103.35	.227	1.42E+11
125.6	2.0	1161.6	3.0 0	96.54	.305	1.50E+11
125.6	2.0			SUM F=	.868	
202.3	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	759.1	1.0 *H	179.50	.018	1.22E+09
202.3	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	1186.3	1.0 G	101.42	.680	1.47E+11
202.3	0.0			SUM F=	.819	
MO 30 352 3P	--	MO 30 35 3P2	+	MO 30 352 3D		
-143.6	.5 2P	672.9	1.5 *B	122.40	.152	3.36E+10
-143.6	.5	723.4	.5 *B	115.31	.226	1.13E+11
-143.6	.5	924.1	1.5 C	93.64	.291	1.11E+11
-143.6	.5			SUM F=	.774	
62.4	1.5 2P	770.3	2.5 *B	141.25	.257	8.35E+09
62.4	1.5	972.9	1.5 0	109.83	.224	1.24E+11
62.4	1.5	994.4	2.5 C	107.29	.251	9.69E+10
62.4	1.5			SUM F=	.713	
MO 31 352	--	MO 31 35 3P				
-10.6	0.0 1S	407.9	1.0 *A	196.07	.035	1.94E+09
-10.6	0.0	831.6	1.0 *B	118.74	.552	8.67E+10
-10.6	0.0			SUM F=	.585	

TABLE V (CONT)

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
MO 32 3S		--	MO 32 3P					
0.0	.5 ² S		561.1	.5	A	178.22	.073	1.53E+10
0.0	.5		777.3	1.5	A	128.65	.202	4.08E+10
0.0	.5					SUM F =	.275	
MO 34 2S2 2P5		--	MO 34 2S 2P6					
-300.7	1.5 ² P		2350.0	.5	A	37.73	.048	4.49E+11
601.3	.5		2350.0	.5	A	57.19	.032	6.45E+10
MO 35 2S2 2P4		--	MO 35 2S 2P5					
-648.6	2.0 ($\frac{3}{2} \frac{3}{2}$)		1729.4	2.0	A	42.05	.047	1.75E+11
-648.6	2.0 ($\frac{3}{2} \frac{2}{2}$)		1983.7	1.0	A	37.99	.041	3.13E+11
-461.7	0.0 "		1983.7	1.0	A	40.69	.076	1.02E+11
229.7	1.0 ($\frac{3}{2} \frac{1}{2}$)		1729.4	2.0	A	66.68	.022	1.99E+10
229.7	1.0 ($\frac{2}{2} \frac{2}{2}$)		2607.3	0.0	A	41.36	.029	3.34E+11
340.2	2.0 "		2864.6	1.0	B	39.61	.061	4.35E+11
1295.6	0.0 ($\frac{1}{2} \frac{1}{2}$)		2864.6	1.0	B	63.73	.046	2.52E+10
MO 36 2S2 2P3		--	MO 36 2S 2P4					
-946.2	1.5 ($\frac{1}{2} \frac{1}{2} \frac{3}{2}$)		1107.2	2.5	A	48.70	.022	4.15E+10
-946.2	1.5 ($\frac{2}{2} \frac{2}{2} \frac{2}{2}$)		1437.3	.5	A	41.95	.021	1.62E+11
-946.2	1.5		1455.6	1.5	A	41.63	.069	2.66E+11
-128.4	1.5 ($\frac{1}{2} \frac{3}{2} \frac{3}{2}$)		1107.2	2.5	A	80.93	.016	1.08E+10
-128.4	1.5 ($\frac{2}{2} \frac{2}{2} \frac{2}{2}$)		2056.9	1.5	B	45.76	.050	1.60E+11
-128.4	1.5		2403.6	.5	B	39.49	.032	2.77E+11
.0	2.5 ($\frac{1}{2} \frac{3}{2} \frac{3}{2}$)		2243.4	2.5	B	44.58	.040	1.49E+11
.0	2.5 ($\frac{2}{2} \frac{2}{2} \frac{2}{2}$)		2497.8	1.5	C	40.00	.057	3.58E+11
148.6	.5 ($\frac{1}{2} \frac{3}{2} \frac{3}{2}$)		2403.6	.5	B	44.33	.037	1.27E+11
148.6	.5 ($\frac{2}{2} \frac{2}{2} \frac{2}{2}$)		2497.8	1.5	C	42.56	.044	8.12E+10
979.9	1.5 ($\frac{3}{2} \frac{3}{2} \frac{3}{2}$)		2243.4	2.5	B	79.15	.018	1.29E+10
979.9	1.5 ($\frac{2}{2} \frac{2}{2} \frac{2}{2}$)		3349.4	.5	C	42.20	.052	3.92E+11

TABLE V (CONT)

E1(KK)	J1	E2(KK)	J2	LAMBDA(A)	f	A(SEC-1)
-----	---	-----	---	-----	---	-----
MO 37 2S2 2P2 -- MO 37 2S 2P3						
-1271.3	2.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	938.5	1.0 A	45.26	.137	1.48E+11
-411.1	1.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	1422.1	2.0 B	54.55	.020	3.87E+10
-411.6	1.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	1863.1	1.0 B	43.97	.063	2.17E+11
-309.8	2.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	1623.0	3.0 A	51.74	.018	3.12E+10
-309.8	2.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	1943.9	2.0 C	44.37	.060	2.33E+11
-309.8	2.0	1972.0	1.0 C	43.81	.040	2.31E+11
617.5	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	2602.0	2.0 D	48.20	.050	1.44E+11
617.5	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	2991.0	1.0 D	42.12	.047	2.02E+11
829.7	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	1972.8	1.0 C	47.42	.019	5.38E+09
829.7	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	2991.0	1.0 D	46.25	.081	8.44E+10
MO 3A 2S2 2P -- MO 3A 2S 2P2						
-677.4	.5 ² P	1381.7	1.5 B	48.56	.083	1.17E+11
-677.4	.5	1424.8	.5 B	48.03	.062	1.78E+11
313.4	1.5 ² P	2044.4	2.5 B	57.78	.021	2.82E+10
313.4	1.5	2426.1	.5 C	47.33	.024	1.40E+11
313.4	1.5	2449.1	1.5 C	46.82	.078	2.38E+11

^a(1) E1 and E2 are the lower and upper level energies in kilo-kaysers (units of 1000 cm⁻¹), and J1 and J2 are the corresponding total angular momenta. The jj-coupling quantum numbers for the lower levels of p⁴ refer to the two p-electron holes. The upper levels are usually very impure in either the LS- or the jj-coupling representation; they have simply been designated by A, B, C, D, ... in the order of increasing energy for each value of J. Asterisks denote levels that clearly belong to the configuration sp^{w+1}.

(2) LAMBDA, F, and A are the wavelength in Angströms, the absorption oscillator strength f, and the emission transition probability per second. Omitted lines all have f < 0.1; for n = 2 transitions, all omitted lines have f < 0.015.

TABLE VI
GROUND LEVEL AND ENERGY RANGE OF LOW CONFIGURATIONS
OF TUNGSTEN IONS, AND IONIZATION ENERGIES FOR TUNGSTEN AND GOLD (ELECTRON VOLTS)

W Ion	Ground Configuration		Low Excited Configurations		I. E.	
					W	Au
	<u>Kr + 4d¹⁰5s² + :</u>					
I	5p ⁶ 4f ¹⁴ 5d ⁴ 6s ²					
⋮						
VII	4f ¹⁴ 5p ⁶ 1s ₀	(0 - 0)			120.0 ^a	
VIII	4f ¹³ 5p ⁶ 2F _{7/2}	(0 - 2.2)	f ¹⁴ p ⁵ (1.2 - 12.2)		139.8	
IX	4f ¹⁴ 5p ⁴ 3p ₂	(0 - 25.3)	f ¹³ p ⁵ (1.6 - 17.0); f ¹² p ⁶ (8.0 - 22.3)		158.2	
X	4f ¹⁴ 5p ³ 4s _{3/2}	(0 - 24.7)	f ¹³ p ⁴ (3.6 - 33.0); f ¹² p ⁵ (12.8 - 41.3)		177.0	
XI	4f ¹⁴ 5p ² 3p ₀	(0 - 27.9)	f ¹³ p ³ (6.6 - 37.4); f ¹² p ⁴ (17.9 - 62.6)		207.0	
XII	4f ¹³ 5p ² (⁷ / ₂ , 3p ₀) _{7/2}	(0 - 30.7)	f ¹⁴ p(2.7 - 15.0); f ¹² p ³ (12.6 - 59.1)		231.3	
	<u>Kr + 4d¹⁰ + :</u>					
XIII	5s ² 4f ¹⁴ 1s ₀	(0 - 0)	s ² f ¹³ p(1.3 - 18.8); s ² f ¹² p ² (6.8 - 55.1); sf ¹⁴ p(28 - 49)		256.3	
XIV	5s ² 4f ¹³ 2F _{7/2}	(0 - 2.3)	s ² f ¹² p(8.1 - 39.2); sf ¹⁴ (23.8)		288.8	
XV	5s ² 4f ¹² 3H ₆	(0 - 15.4)	s ² f ¹¹ p(16.5 - 56.1); sf ¹³ (17.0 - 19.9); f ¹⁴ (38.7)		323.6	
XVI	5s ² 4f ¹¹ 4I _{15/2}	(0 - 21.3)	sf ¹² (8.9 - 25.0); f ¹³ (24.0 - 26.4); s ² f ¹⁰ p(27.5 - 83.1)		360.0	
XVII	5s4f ¹¹ 5I ₈	(0 - 22.7)	s ² f ¹⁰ (1.8 - 38.8); f ¹² (7.5 - 22.9)		386.8	
XVIII	4f ¹¹ 4I _{15/2}	(0 - 21.7)	sf ¹⁰ (3.1 - 41.4)		419.1	
XIX	4f ¹⁰ 5I ₈	(0 - 37.6)				
⋮	<u>Kr + :</u>					
XXIV	4d ¹⁰ 4f ⁵ 6H _{5/2}				3420.7	
XXV	4d ¹⁰ 4f ⁴ 5I ₄	(0 - 44.3)	f ³ 5s(96 - 125); f ² s ² (205 - 226)		733.	
XXVI	4d ¹⁰ 4f ³ 4I _{9/2}	(0 - 27.6)	f ² s(113 - 134); fs ² (235 - 239)		783.	
XXVII	4d ¹⁰ 4f ² 3H ₄	(0 - 21.3)	fs(127 - 131); d ⁹ f ³ (194 - 274)		832.	

TABLE VI (cont.)

W Ion	Ground Configuration		Low Excited Configurations		I. E.	
					W	Au
XXVIII	$4d^{10}4f^2F_{5/2}$	(0 - 3.8)	$d^9f^2(192 - 259); d^{10}5d(282 - 288)$		881.	1195.
XXIX	$4d^{10}iS_0$	(0 - 0)	$d^9f(191 - 253); d^95p(398 - 445)$		1129.	1476.
XXX	$4d^9^2D_{5/2}$	(0 - 16.5)	$d^8f(191 - 267); 4p^54d^{10}(192 - 277)$		1177.	1529.
XXXI	$4d^8^3F_4$	(0 - 43.2)	}		8191.	10448.
...						
XXXVI	$4d^3^4F_{3/2}$					
XXXVII	$4d^2^3F_2$	(0 - 49.8)	$4d4f(207 - 250)$		1566.	1969.
XXXVIII	$4d^2D_{3/2}$	(0 - 19.3)	$4p^54d^2(148 - 298); 4f(212 - 217); 5p(550 - 590)$		1620.	2028.
XXXIX	$4p^6^1S_0$	(0 - 0)	$4p^54d(146 - 270); 4p^55s(670 - 767)$		1827.	2257.
XL	$4p^5^2P_{3/2}$	(0 - 97.0)	$4s4p^6(209); 4p^44d(148 - 370)$		1881.	2316.
XLI	$4p^4\left(\frac{3}{2}\frac{3}{2}\right)_2$	(0 - 192)	$4s4p^5(202 - 312); 4p^34d(151 - 396)$		1938.	2380.
XLII	$4p^3\left(\frac{1}{2}\frac{1}{2}\frac{3}{2}\right)_{3/2}$	(0 - 200)	$4s4p^4(194 - 411); 4p^24d(152 - 393)$		1993.	2489.
XLIII	$4p^2\left(\frac{1}{2}\frac{1}{2}\right)_0$	(0 - 209)	$4s4p^3(192 - 416); 4p4d(248 - 389)$		2148.	2594.
XLIV	$4p^2P_{1/2}$	(0 - 102)	$4s4p^2(95.6 - 313); 4d(260 - 279)$		2209.	2711.
XLV	$4s^2^1S_0$	(0 - 0)	$4s4p(85.0 - 206); 4p^2(195 - 409)$		2354.	2874.
XLVI	$4s^2S_{1/2}$	(0 - 0)	$4p(97.2 - 203)$		2415.	2941.
XLVII	$3d^{10}^1S_0$	(0 - 0)	$3d^94p(1659 - 1838); 3d^94f(2082 - 2182)$		4055.	4884.
XLVIII	$3d^9^2F_{7/2}$		}		32200.	
...						
LIV	$3d^3$					
LV	$3d^2\left(\frac{3}{2}\frac{3}{2}\right)_2$	(0 - 186)			5208.	
LVI	$3d^2D_{3/2}$	(0 - 80)	$3p^53d^2(239 - 794)$		5347.	

TABLE VI (cont)

W Ion	Ground Configuration		Low Excited Configurations		I. E.	
					W	Au
LVII	$3p^6 1S_0$	(0 - 0)	$3p^5 3d(223 - 684)$		5715.	
LVIII	$3p^5 2p_{3/2}$	(0 - 369)	$3s3p^6(567); 3p^4 3d(220 - 1054)$		5838.	
LIX	$3p^4 \left(\frac{3}{2} \frac{3}{2}\right)_2$	(0 - 753)	$3s3p^5(553 - 945); 3p^3 3d(219 - 1096)$		5968.	
LX	$3p^3 \left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)_{3/2}$	(0 - 755)	$3s3p^4(536 - 1322); 3p^2 3d(214 - 1086)$		6091.	
LXI	$3p^2 \left(\frac{1}{2} \frac{1}{2}\right)_0$	(0 - 775)	$3s3p^3(535 - 1336); 3p 3d(576 - 1080)$		6596.	
LXII	$3p^2 p_{1/2}$	(0 - 385)	$3s3p^2(160 - 953); 3d(597 - 679)$			

^aExperimental value 122.0 eV (Ref. 27).

TABLE VII

STRONG ELECTRIC DIPOLE TRANSITIONS IN TUNGSTEN XXXVIII TO LXIV^a

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
W 38 4P6 4D		--	W 38 4P5 4D2					
-93.5	1.5	² D	1432.6	1.5	L	65.52	.353	5.48E+11
-93.5	1.5		1467.5	2.5	F	64.06	.829	8.99E+11
-93.5	1.5		1470.1	.5	C	63.95	.075	2.45E+11
-93.5	1.5		1523.1	.5	D	62.63	.202	6.88E+11
-93.5	1.5		1914.7	2.5	H	49.79	.372	6.68E+11
-93.5	1.5		2049.5	.5	E	46.66	.326	2.06E+12
-93.5	1.5		2497.8	1.5	I	45.63	1.138	3.64E+12
-93.5	1.5					SUM F =	3.453	
62.4	2.5	² D	1556.6	3.5	F	66.92	.298	3.33E+11
62.4	2.5		1624.8	1.5	G	64.04	.296	7.22E+11
62.4	2.5		1630.2	2.5	G	63.78	.516	8.46E+11
62.4	2.5		2180.6	3.5	H	47.21	.444	9.98E+11
62.4	2.5		2205.8	2.5	J	46.66	.932	2.06E+12
62.4	2.5		2210.6	3.5	I	46.55	.411	9.49E+11
62.4	2.5		2218.5	1.5	J	46.38	.329	1.53E+12
62.4	2.5		2229.9	1.5	K	46.14	.222	1.04E+12
62.4	2.5					SUM F =	3.554	
W 38 4P6 4D		--	W 38 4P6 4F		+ W 38 4P6 5P	+ W 38 4P6 5F		
-93.5	1.5	² D	1614.7	2.5	A	58.54	.430	5.58E+11
-93.5	1.5		4343.6	.5	A	22.54	.082	2.16E+12
-93.5	1.5		5984.4	2.5	B	16.45	.381	6.26E+12
-93.5	1.5					SUM F =	.911	
62.4	2.5	² D	1655.9	3.5	A	62.75	.382	4.85E+11
62.4	2.5		4662.6	1.5	A	21.74	.102	2.16E+12
62.4	2.5		6003.6	3.5	B	16.83	.355	6.27E+12
62.4	2.5					SUM F =	.875	
W 39 4P6		--	W 39 4P5 4D		+ W 39 4P5 5S	+ W 39 4P5 5D		
0.0	0.0	¹ S	1213.0	1.0	A	82.44	.011	3.46E+09
0.0	0.0		1546.7	1.0	B	64.65	1.371	7.29E+11
0.0	0.0		2106.9	1.0	C	46.58	2.519	2.58E+12
0.0	0.0		5414.4	1.0	D	18.47	.434	2.03E+12
0.0	0.0		6187.5	1.0	E	16.16	.266	2.27E+12
0.0	0.0		6717.4	1.0	F	14.89	.017	1.67E+11
0.0	0.0		6797.4	1.0	G	14.71	.627	6.44E+12
0.0	0.0		7513.0	1.0	H	13.31	.363	4.55E+12
0.0	0.0					SUM F =	5.607	

TABLE VII (CONT)

E1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
W 40 4S2 4P5	--	W 40 4S 4P6	+	W 40 4S2 4P4 4D		
-265.3	1.5 ² P	1241.7	1.5 C	66.35	.312	4.73E+11
-265.3	1.5	1268.0	2.5 C	65.22	.609	6.37E+11
-265.3	1.5	1422.0	.5 *C	59.26	.282	7.64E+11
-265.3	1.5	1859.1	.5 E	47.07	.421	2.53E+12
-265.3	1.5	1874.4	1.5 E	46.73	.487	1.44E+12
-265.3	1.5	1882.1	2.5 E	46.57	1.103	2.26E+12
-265.3	1.5	1892.3	1.5 F	46.35	.194	6.73E+11
-265.3	1.5			SUM F = 3.452		
517.1	.5 ² P	1422.0	.5 *C	116.50	.078	4.26E+10
517.1	.5	2076.0	1.5 G	64.15	.975	7.90E+11
517.1	.5	2112.3	.5 F	62.69	.812	1.38E+12
517.1	.5	2642.9	1.5 H	47.00	1.222	1.84E+12
517.1	.5			SUM F = 3.104		
W 41 4S2 4P4	--	W 41 4S 4P5	+	W 41 4S2 4P3 4D		
-545.3	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	871.2	2.0 B	70.60	.267	8.97E+10
-545.3	2.0	959.2	3.0 B	60.47	.454	4.89E+11
-545.3	2.0	1086.5	2.0 *C	61.28	.257	4.57E+11
-545.3	2.0	1186.0	1.0 *C	57.76	.145	4.85E+11
-545.3	2.0	1518.8	2.0 E	48.45	.048	1.36E+11
-545.3	2.0	1575.7	3.0 D	47.15	.198	4.25E+11
-545.3	2.0	1585.0	2.0 F	46.94	.616	1.86E+12
-545.3	2.0	1586.2	1.0 E	46.91	.377	1.90E+12
-545.3	2.0	1599.3	3.0 E	46.63	.729	1.64E+12
-545.3	2.0			SUM F = 3.063		
-475.1	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	984.3	1.0 B	68.52	.505	2.39E+11
-475.1	0.0	1186.0	1.0 *C	60.20	.460	2.88E+11
-475.1	0.0	1586.2	1.0 E	48.51	.064	6.08E+10
-475.1	0.0	1643.4	1.0 F	47.20	.511	5.10E+11
-475.1	0.0	1655.6	1.0 G	46.93	1.311	1.32E+12
-475.1	0.0	1774.1	1.0 H	44.46	.174	1.96E+11
-475.1	0.0			SUM F = 3.083		
231.9	1.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	1086.5	2.0 *C	117.01	.067	1.96E+10
231.9	1.0	1762.0	2.0 H	65.36	.317	2.97E+11
231.9	1.0	1774.1	1.0 H	64.84	.353	5.60E+11
231.9	1.0	1815.1	2.0 I	63.16	.652	6.54E+11
231.9	1.0	1889.2	0.0 *D	60.34	.150	8.22E+11
231.9	1.0	2322.0	0.0 E	47.84	.215	1.88E+12
231.9	1.0	2348.0	1.0 J	47.26	.421	1.26E+12
231.9	1.0	2381.6	2.0 J	46.52	.412	7.62E+11
231.9	1.0			SUM F = 2.713		

TABLE VII (CONT)

F1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
267.5	2.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	1086.5	2.0 *C	122.10	.034	1.50E+10
267.5	2.0	1186.0	1.0 *C	108.68	.044	4.10E+10
267.5	2.0	1762.0	2.0 H	66.91	.163	2.42E+11
267.5	2.0	1801.7	3.0 G	65.18	.597	6.69E+11
267.5	2.0	1815.1	2.0 I	64.62	.288	4.61E+11
267.5	2.0	1967.3	1.0 *I	56.83	.373	1.20E+12
267.5	2.0	2348.0	1.0 J	48.07	.077	3.71E+11
267.5	2.0	2379.3	3.0 H	47.35	.795	1.69E+12
267.5	2.0	2381.6	2.0 J	47.30	.257	7.66E+11
267.5	2.0			SUM F =	2.720	
1071.9	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	1967.3	1.0 *I	111.67	.154	2.74E+10
1071.9	0.0	2652.6	1.0 K	63.26	2.217	1.23E+12
1071.9	0.0			SUM F =	2.371	
W 42 4S2 4P3 -- W 42 4S 4P4 + W 42 4S2 4P2 40						
-806.1	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	629.1	2.5 A	69.68	.174	1.59E+11
-806.1	1.5	759.8	2.5 *B	63.86	.247	2.25E+11
-806.1	1.5	875.0	.5 *A	59.40	.087	3.27E+11
-806.1	1.5	892.8	1.5 *B	58.86	.340	6.55E+11
-600.1	1.5	1316.8	2.5 D	47.11	.836	1.68E+12
-806.1	1.5	1317.4	1.5 D	47.09	.632	1.04E+12
-806.1	1.5	1334.5	.5 C	46.72	.297	1.82E+12
-806.1	1.5			SUM F =	2.734	
-52.1	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	759.8	2.5 *B	123.17	.062	1.82E+10
-52.1	1.5	1374.9	1.5 E	70.08	.059	7.96E+10
-52.1	1.5	1488.6	2.5 F	64.91	.679	7.16E+11
-52.1	1.5	1567.1	1.5 *G	61.74	.330	5.70E+11
-52.1	1.5	1707.6	.5 *E	56.83	.141	5.80E+11
-52.1	1.5	2061.2	1.5 I	47.32	.381	1.13E+12
-52.1	1.5	2074.5	.5 F	47.02	.239	1.44E+12
-52.1	1.5	2074.7	2.5 H	47.02	.311	6.25E+11
-52.1	1.5			SUM F =	2.373	
-8.5	2.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	759.8	2.5 *B	132.16	.020	1.13E+10
-8.5	2.5	892.8	1.5 *B	110.95	.052	4.22E+10
-8.5	2.5	1394.6	2.5 E	71.27	.361	8.06E+10
-8.5	2.5	1400.6	3.5 C	66.71	.452	5.08E+11
-8.5	2.5	1629.5	2.5 *G	61.05	.335	5.99E+11
-8.5	2.5	1721.1	1.5 *H	57.82	.286	8.56E+11
-8.5	2.5	2061.2	1.5 I	48.32	.487	3.72E+11
-8.5	2.5	2074.7	2.5 H	48.00	.279	8.08E+11
-8.5	2.5	2098.2	3.5 D	47.47	.642	1.43E+12
-8.5	2.5			SUM F =	2.390	

TABLE VII (CONT)

E1(KK)	J1	E2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
46.4	.5 ($\frac{1}{2} \frac{3}{2} \frac{3}{2}$)	875.7	.5 *A	120.69	.082	3.74E+10
46.4	.5 ($\frac{1}{2} \frac{3}{2} \frac{3}{2}$)	1505.1	1.5 F	68.56	.342	2.43E+11
46.4	.5	1512.8	.5 U	68.20	.234	3.35E+11
46.4	.5	1707.6	.5 *E	60.20	.349	6.42E+11
46.4	.5	1721.1	1.5 *H	59.71	.314	2.94E+11
46.4	.5	2061.2	1.5 I	49.63	.093	1.26E+11
46.4	.5	2155.0	1.5 J	47.42	.888	1.32E+12
46.4	.5			SUM F = 2.392		
807.5	1.5 ($\frac{3}{2} \frac{3}{2} \frac{3}{2}$)	1629.5	2.5 *G	121.65	.074	2.22E+10
807.5	1.5 ($\frac{3}{2} \frac{3}{2} \frac{3}{2}$)	1721.1	1.5 *H	109.45	.051	2.84E+10
807.5	1.5	2329.0	1.5 K	65.72	.491	7.58E+11
807.5	1.5	2364.8	2.5 J	64.21	.975	1.05E+12
807.5	1.5	2528.9	.5 *H	58.77	.384	1.46E+12
807.5	1.5			SUM F = 2.041		
W 43 4S2 4P2 -- W 43 4S 4P3 + W 43 4S2 4P 4D						
-1276.9	0.0 ($\frac{1}{2} \frac{1}{2}$)	593.9	1.0 *A	59.65	.731	4.54E+11
-1276.9	0.0 ($\frac{1}{2} \frac{1}{2}$)	1043.6	1.0 B	47.16	1.780	1.79E+12
-1276.9	0.0			SUM F = 2.520		
-300.4	1.0 ($\frac{1}{2} \frac{3}{2}$)	471.2	2.0 *A	129.59	.073	1.75E+10
-300.4	1.0 ($\frac{1}{2} \frac{3}{2}$)	1134.1	2.0 C	69.71	.150	1.31E+11
-300.4	1.0	1238.4	2.0 *U	64.98	.463	4.39E+11
-300.4	1.0	1343.3	2.0 *A	60.80	.068	3.60E+11
-300.4	1.0	1395.8	1.0 *C	58.95	.307	5.89E+11
-300.4	1.0	1421.6	1.0 *U	58.07	.143	2.84E+11
-300.4	1.0	1798.5	2.0 F	47.64	.392	6.90E+11
-300.4	1.0	1816.8	0.0 B	47.23	.147	1.32E+12
-300.4	1.0	1820.7	1.0 E	47.14	.388	1.10E+12
-300.4	1.0			SUM F = 2.147		
-265.7	2.0 ($\frac{1}{2} \frac{3}{2}$)	1153.1	3.0 A	70.48	.191	1.83E+11
-265.7	2.0 ($\frac{1}{2} \frac{3}{2}$)	1298.4	3.0 *B	63.92	.200	2.38E+11
-265.7	2.0	1418.2	2.0 *E	59.30	.440	8.31E+11
-265.7	2.0	1421.6	1.0 *D	59.27	.226	7.16E+11
-265.7	2.0	1798.5	2.0 F	48.44	.294	8.36E+11
-265.7	2.0	1825.1	3.0 L	47.83	.633	1.32E+12
-265.7	2.0			SUM F = 2.204		
534.2	2.0 ($\frac{3}{2} \frac{3}{2}$)	1208.9	3.0 *B	130.78	.069	1.95E+10
534.2	2.0 ($\frac{3}{2} \frac{3}{2}$)	1932.7	2.0 G	71.51	.084	1.10E+11
534.2	2.0	2045.7	3.0 U	60.16	.752	8.19E+11
534.2	2.0	2158.7	2.0 *H	61.56	.485	8.53E+11
534.2	2.0	2271.3	1.0 *G	57.57	.296	9.92E+11
534.2	2.0			SUM F = 1.848		

TABLE VI (CONT)

E1(KK)	J1	E2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
604.2	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	1395.8	1.0 *C	126.32	.068	1.22E+10
604.2	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	1421.6	1.0 *D	122.33	.079	1.16E+10
604.2	0.0	2060.6	1.0 F	66.66	.745	3.51E+11
604.2	0.0	2271.3	1.0 *G	59.98	.882	5.44E+11
604.2	0.0			SUM F = 1.798		
W 44 4S2 4F -- W 44 4S 4F2 + W 44 4S2 4D						
-555.1	.5 ² P	214.3	.5 *A	129.97	.290	3.54E+10
-555.1	.5	1126.6	1.5 *B	60.18	.515	4.75E+11
-555.1	.5	1115.8	.5 *B	59.85	.422	7.87E+11
-555.1	.5	1538.1	1.5 C	47.77	.887	1.30E+12
-555.1	.5			SUM F = 1.918		
272.3	1.5 ² P	1006.8	2.5 *A	136.15	.075	1.81E+10
272.3	1.5	1106.6	1.5 *B	119.84	.048	2.25E+10
272.3	1.5	1692.6	2.5 B	70.41	.230	2.06E+11
272.3	1.5	1820.1	2.5 *C	64.61	.391	4.17E+11
272.3	1.5	1941.0	.5 *C	59.93	.150	5.92E+11
272.3	1.5	1966.3	1.5 *D	59.03	.609	1.17E+12
272.3	1.5			SUM F = 1.567		
W 44 4S2 4F -- W 44 4S2 5S + W 44 4S2 5D						
-555.1	.5 ² P	6259.7	.5 A	14.67	.128	3.97E+12
-555.1	.5	7615.5	1.5 A	12.24	.221	4.93E+12
272.3	1.5 ² P	6258.4	.5 A	16.71	.113	5.38E+12
272.3	1.5	7615.5	1.5 A	13.62	.020	7.15E+11
272.3	1.5	7697.7	2.5 A	13.47	.161	4.43E+12
W 45 4S2 -- W 45 4S 4F + W 45 4S 5P						
-6.0	0.0 ¹ S	734.6	1.0 A	135.02	.150	1.94E+10
-6.0	0.0	1654.9	1.0 B	60.21	1.159	7.11E+11
-6.0	0.0	8038.7	1.0 C	12.43	.110	1.59E+12
-6.0	0.0	8435.0	1.0 D	11.85	.257	4.07E+12
-6.0	0.0			SUM F = 1.686		
W 46 3D12 4S -- W 46 3D12 4F + W 46 3D12 5P						
0.0	.5 ² S	784.2	.5 A	127.52	.125	5.11E+10
0.0	.5	1634.7	1.5 A	61.17	.520	4.63E+11
0.0	.5	8186.8	.5 B	12.21	.060	2.69E+12
0.0	.5	8586.4	1.5 B	11.65	.126	3.10E+12
0.0	.5			SUM F = .830		

TABLE VII (CONT)

F1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SCF=1)
-----	---	-----	---	-----	---	-----
W 47 3012		-- W 47 302 4P	+ W 47 302 4F			
0.0 0.0 ^{1S}		13952.1 1.0 A	} 4P	7.17	.115 ^b	4.09E+12 ^b
0.0 0.0		14269.4 1.0 B		7.01	.255 ^b	1.15E+13 ^b
0.0 0.0		14694.3 1.0 C		6.75	.235 ^b	1.70E+12 ^b
0.0 0.0		16818.0 1.2 D	} 4F	5.95	.001	7.80E+10
0.0 0.0		17045.4 1.0 E		5.87	.2043	1.35E+14
0.0 0.0		17597.9 1.0 F		5.68	5.002	4.12E+14
W 56 3P6 3D		-- W 56 3P5 3D2				
-386.0 1.5 ^{2D}		2533.6 1.5 E		34.25	.144	8.22E+11
-386.0 1.5		2591.5 2.5 E		33.58	.281	1.11E+12
-386.0 1.5		2634.9 .5 C		33.10	.096	1.17E+12
-386.0 1.5		4822.9 1.5 H		19.29	.361	6.52E+12
-386.0 1.5				SUM F = 1.268		
257.4 2.5 ^{2D}		3294.5 3.5 F		35.25	.093	3.70E+11
257.4 2.5		3239.7 2.5 G		33.53	.272	1.20E+12
257.4 2.5		3247.8 1.5 G		33.40	.108	9.66E+11
257.4 2.5		5382.1 2.5 J		19.51	.248	4.34E+12
257.4 2.5		5401.7 3.5 H		19.40	.216	3.65E+12
257.4 2.5		5442.2 1.5 J		19.20	.160	4.31E+12
257.4 2.5				SUM F = 1.145		
W 57 3P6		-- W 57 3P5 3D				
0.0 0.0 ^{1S}		1884.6 1.0 A		53.06	.009	7.32E+29
0.0 0.0		2864.0 1.0 B		34.92	.091	8.95E+11
0.0 0.0		5077.8 1.0 C		19.09	.712	4.06E+12
W 58 352 3P5		-- W 58 3S 3P6	+ W 58 352 3P4 3D			
-991.2 1.5 ^{2P}		1748.8 1.5 C		36.50	.105	5.24E+11
-991.2 1.5		1794.6 2.5 C		35.90	.220	7.59E+11
-991.2 1.5		4048.7 2.5 E		19.64	.325	3.67E+12
-991.2 1.5		4061.9 1.5 E		19.79	.212	3.58E+12
-991.2 1.5		4070.0 .5 E		19.76	.213	7.29E+12
-991.2 1.5				SUM F = 1.181		
1982.5 .5 ^{2P}		3584.1 .5 *C		62.44	.027	4.64E+10
1982.5 .5		4793.1 1.5 G		35.58	.332	8.74E+11
1982.5 .5		4844.0 .5 F		34.95	.231	1.26E+12
1982.5 .5		6983.9 1.5 H		19.99	.346	2.89E+12
1982.5 .5				SUM F = .950		

TABLE VII (CONT)

F1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
W 59 3S2 3P4 --		W 59 3S 3P5 +		W 59 3S2 3P3 3D		
-2025.6	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	648.1	3.0 D	37.40	.160	5.45E+11
-2025.6	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	2438.5	2.0 *C	22.40	.087	1.16E+12
-2025.6	2.0	2956.7	3.0 D	20.07	.285	3.37E+12
-2025.6	2.0	2981.3	2.0 F	19.97	.253	4.22E+12
-2025.6	2.0	3019.0	1.0 E	19.82	.218	6.16E+12
-2025.6	2.0			SUM F =	1.155	
-1879.5	0.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	721.2	1.0 H	38.45	.199	3.00E+11
-1879.5	2.0 $\left(\frac{3}{2} \frac{3}{2}\right)$	2689.4	1.0 D	21.80	.082	3.81E+11
-1879.5	0.0	3118.5	1.0 F	20.01	.772	4.29E+12
-1879.5	0.0			SUM F =	1.132	
945.7	1.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	2438.5	2.0 *C	66.99	.029	2.60E+10
945.7	1.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	3655.9	2.0 H	36.40	.143	4.21E+11
945.7	1.0	3671.0	1.0 H	36.00	.096	4.76E+11
945.7	1.0	3737.3	2.0 Y	35.82	.144	4.49E+11
945.7	1.0	5882.2	0.0 E	28.26	.119	5.78E+12
945.7	1.0	5931.2	1.0 J	20.06	.106	2.76E+12
945.7	1.0	5960.4	2.0 J	19.94	.130	1.31E+12
945.7	1.0			SUM F =	.924	
1022.8	2.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	3732.7	3.0 G	36.90	.205	7.19E+11
1022.8	2.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	3737.3	2.0 I	36.60	.100	4.89E+11
1022.8	2.0	5596.6	1.0 *I	21.86	.134	3.11E+12
1022.8	2.0	5937.7	3.0 H	20.35	.231	2.60E+12
1022.8	2.0			SUM F =	.931	
4046.2	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	5596.6	1.0 I	64.50	.068	3.62E+10
4046.2	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	6813.8	1.0 K	36.13	.620	1.00E+12
4046.2	0.0			SUM F =	.688	
W 60 3S2 3P3 --		W 60 3S 3P4 +		W 60 3S2 3P2 3D		
-3029.0	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	-517.0	2.5 A	39.81	.091	2.50E+11
-3029.0	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	1901.3	2.5 U	20.28	.318	3.44E+12
-3029.0	1.5	1946.6	1.5 U	20.10	.381	6.29E+12
-3029.0	1.5	1960.5	.5 C	20.04	.135	4.40E+12
-3029.0	1.5			SUM F =	1.130	
-05.4	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	2561.8	2.5 F	37.03	.185	5.79E+11
-05.4	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	4298.2	1.5 *G	22.76	.112	1.45E+12
-05.4	1.5	4652.3	2.5 H	20.21	.112	1.22E+12
-05.4	1.5	4660.5	1.5 I	20.18	.163	2.68E+12
-05.4	1.5	4883.5	.5 F	20.08	.152	5.03E+12
-05.4	1.5			SUM F =	.911	

TABLE VII (CONT)

F1(KK)	J1	E2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
.0	2.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	2427.4	2.5 E	41.20	.030	1.17E+11
.0	2.5	2561.8	2.5 F	39.00	.027	1.18E+11
.0	2.5	2591.3	3.5 C	38.59	.151	5.07E+11
.0	2.5	4448.9	2.5 *G	22.48	.111	1.46E+12
.0	2.5	4618.9	1.5 *H	21.65	.098	2.09E+12
.0	2.5	4852.3	2.5 H	20.61	.133	2.09E+12
.0	2.5	4860.5	1.5 I	20.57	.098	2.30E+12
.0	2.5	4864.9	3.5 D	20.56	.205	2.42E+12
.0	2.5			SUM F=	.920	
110.4	.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	1552.1	.5 *A	69.37	.033	4.55E+10
110.4	.5	2640.1	1.5 F	39.53	.133	2.84E+11
110.4	.5	2660.0	.5 D	39.22	.093	4.02E+11
110.4	.5	4673.7	.5 *E	22.26	.101	1.35E+12
110.4	.5	4618.9	1.5 *H	22.18	.058	3.91E+11
110.4	.5	4860.5	1.5 I	21.05	.071	5.38E+11
110.4	.5	5014.3	1.5 J	20.39	.309	2.90E+12
110.4	.5			SUM F=	.845	
3058.7	1.5 $\left(\frac{3}{2} \frac{3}{2} \frac{3}{2}\right)$	5673.5	1.5 K	38.24	.132	6.04E+11
3058.7	1.5	5726.5	2.5 J	37.48	.275	8.70E+11
3058.7	1.5	7633.6	.5 *H	21.86	.182	5.08E+12
3058.7	1.5			SUM F=	.676	
W 61 352 3P2 -- W 61 35 3P3 + W 61 352 3P 30						
-4073.3	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	473.0	1.0 *A	22.00	.224	1.73E+12
-4073.3	0.0	839.2	1.0 B	20.36	.895	4.80E+12
-4073.3	0.0			SUM F=	1.119	
-1085.9	1.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	239.6	2.0 *A	75.44	.028	1.94E+10
-1085.9	1.0	1392.0	2.0 C	40.36	.110	2.92E+11
-1085.9	1.0	3143.3	2.0 *D	23.65	.084	6.00E+11
-1085.9	1.0	3517.8	1.0 *C	21.72	.125	1.77E+12
-1085.9	1.0	3574.5	1.0 *D	21.46	.052	7.58E+11
-1085.9	1.0	3609.6	2.0 F	20.43	.162	1.55E+12
-1085.9	1.0	3827.4	0.0 B	20.35	.071	3.43E+12
-1085.9	1.0	3832.8	1.0 E	20.33	.219	3.54E+12
-1085.9	1.0			SUM F=	.900	
-1010.1	2.0 $\left(\frac{1}{2} \frac{3}{2}\right)$	1411.2	3.0 A	41.30	.064	2.35E+11
-1010.1	2.0	3374.9	3.0 *B	23.18	.051	4.56E+11
-1010.1	2.0	3524.0	2.0 *E	22.06	.114	1.56E+12
-1010.1	2.0	3574.5	1.0 *D	21.81	.119	2.79E+12
-1010.1	2.0	3829.6	2.0 F	20.75	.243	3.76E+12
-1010.1	2.0	3813.9	3.0 C	20.73	.221	2.45E+12
-1010.1	2.0			SUM F=	.906	

TABLE VII (CONT)

E1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
2027.5	2.0	$\left(\frac{3}{2} \frac{3}{2}\right)$	4412.5	2.0	G	41.93	.052	1.96E+11
2027.5	2.0		4574.2	3.0	D	39.27	.199	6.10E+11
2027.5	2.0		6443.7	2.0	*H	22.60	.181	2.35E+12
2027.5	2.0		6774.8	1.0	*H	21.38	.168	4.78E+12
2027.5	2.0					SUM F =	.675	
2176.7	0.0	$\left(\frac{3}{2} \frac{3}{2}\right)$	4542.9	1.0	F	48.61	.240	3.30E+11
2178.7	0.0		6774.8	1.0	*H	22.09	.339	1.55E+12
2178.7	0.0					SUM F =	.654	
W 62 3S2 3P -- W 62 3S 3P2 + W 62 3S2 3D								
-2080.0	.5	2P	2423.3	1.5	*B	22.21	.158	1.07E+12
-2080.0	.5		2456.7	.5	*B	22.04	.222	3.05E+12
-2080.0	.5		2731.9	1.5	C	20.78	.484	3.73E+12
-2080.0	.5					SUM F =	.900	
1028.8	1.5	2P	3398.9	2.5	B	42.19	.113	2.83E+11
1028.8	1.5		5271.3	2.5	*C	23.57	.090	7.17E+11
1028.8	1.5		5554.6	.5	*C	22.10	.084	2.30E+12
1028.8	1.5		5608.1	1.5	*E	21.80	.321	4.49E+12
1028.8	1.5					SUM F =	.674	
W 63 3S2 -- W 63 3S 3P								
-11.7	0.0	1S	1182.3	1.0	A	83.75	.059	1.89E+10
-11.7	0.0		4483.9	1.0	B	22.24	.625	2.81E+12
-11.7	0.0					SUM F =	.685	
W 64 3S -- W 64 3P								
0.0	.5	2S	1250.7	.5	A	79.96	.041	4.31E+10
0.0	.5		4433.5	1.5	A	22.56	.293	1.92E+12
0.0	.5					SUM F =	.334	

^aSee footnote to Table V.

^bOscillator strengths and transition probabilities differ from the values in Table IV because of the inclusion here of configuration interaction with 3d⁹4f.

TABLE VIII
STRONG ELECTRIC DIPOLE TRANSITIONS IN GOLD XLIII TO LTI^a

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
AU 43 4P6 4D -- AU 43 4P5 4D2								
-134.4	1.5	² D	1611.6	1.5	E	57.27	.392	7.96E+11
-134.4	1.5		1646.4	2.5	E	56.16	.822	1.10E+12
-134.4	1.5		1667.3	.5	L	55.50	.245	1.70E+12
-134.4	1.5		2339.2	2.5	M	40.43	.300	8.40E+11
-134.4	1.5		2485.7	.5	E	38.17	.291	2.60E+12
-134.4	1.5		2525.8	1.5	M	37.50	.932	4.40E+12
-134.4	1.5		2555.8	1.5	I	37.17	.178	8.60E+11
-134.4	1.5					SUM F =	3.296	
89.6	2.5	² D	1791.9	3.5	F	58.75	.299	4.33E+11
89.6	2.5		1871.4	1.5	G	56.14	.313	9.92E+11
89.6	2.5		1880.6	2.5	G	55.83	.565	1.21E+12
89.6	2.5		2696.3	3.5	H	38.36	.762	2.58E+12
89.6	2.5		2703.9	2.5	J	38.25	.817	3.73E+12
89.6	2.5		2725.4	1.5	J	37.94	.494	3.43E+12
89.6	2.5		2761.2	3.5	I	37.43	.055	1.95E+11
89.6	2.5		2790.1	1.5	K	37.03	.005	3.68E+10
89.6	2.5					SUM F =	3.416	
AU 43 4P6 4D -- AU 43 4P6 4F + AU 43 4P6 5P + AU 43 4P6 5F								
-134.4	1.5	² D	1817.7	2.5	A	51.23	.393	6.60E+11
-134.4	1.5		5355.6	.5	A	18.21	.080	3.22E+12
-134.4	1.5		7335.4	2.5	B	13.30	.423	1.05E+13
-134.4	1.5					SUM F =	.913	
89.6	2.5	² D	1880.6	3.5	A	55.85	.343	5.50E+11
89.6	2.5		5825.3	1.5	A	17.43	.100	3.30E+12
89.6	2.5		7364.8	3.5	B	13.75	.392	1.04E+13
89.6	2.5					SUM F =	.872	
AU 44 4P6 -- AU 44 4P5 4D + AU 44 4P5 5S + AU 44 4P5 5D								
0.0	0.0	¹ S	1341.8	1.0	A	74.53	.017	6.76E+09
0.0	0.0		1764.4	1.0	B	56.68	1.448	1.00E+12
0.0	0.0		2621.0	1.0	C	38.15	2.271	3.47E+12
0.0	0.0		6548.5	1.0	D	15.27	.449	4.28E+12
0.0	0.0		7664.6	1.0	E	13.05	.281	3.67E+12
0.0	0.0		8135.3	1.0	F	12.29	.028	4.10E+11
0.0	0.0		8246.8	1.0	G	12.13	.664	1.00E+13
0.0	0.0		9275.7	1.0	H	10.78	.397	7.59E+12
0.0	0.0					SUM F =	5.555	

TABLE VIII (CONT)

F1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
AU 45	4S2 4P5	--	AU 45	4S 4P6	+	AU 45	4S2 4P4 4D	
-380.4	1.5 ² P		1338.0	1.5 C		58.19	.324	6.37E+11
-380.4	1.5		1368.3	2.5 C		57.19	.644	8.75E+11
-380.4	1.5		1759.8	.5 *C		46.72	.194	1.19E+12
-380.4	1.5		2226.4	.5 E		38.36	.419	3.79E+12
-380.4	1.5		2243.5	1.5 E		38.11	.634	2.91E+12
-380.4	1.5		2243.9	2.5 E		38.11	1.023	3.15E+12
-380.4	1.5		2523.2	1.5 G		34.48	.016	8.81E+10
-380.4	1.5					SUM F =	3.359	
746.9	.5 ² P		1759.8	.5 *C		98.72	.076	5.25E+10
746.9	.5		2523.2	1.5 G		56.39	1.006	1.05E+12
746.9	.5		2553.5	.5 F		55.35	.755	1.64E+12
746.9	.5		3347.2	1.5 H		38.46	1.095	2.47E+12
746.9	.5					SUM F =	2.944	
AU 46	4S2 4P4	--	AU 46	4S 4P5	+	AU 46	4S2 4P3 4D	
-772.5	2.0 ($\frac{3}{2} \frac{3}{2}$)		846.0	2.0 B		61.78	.108	1.89E+11
-772.5	2.0 ($\frac{3}{2} \frac{3}{2}$)		936.0	3.0 B		58.53	.494	6.87E+11
-772.5	2.0		1300.8	2.0 *C		48.23	.251	7.20E+11
-772.5	2.0		1416.1	1.0 *C		45.69	.175	9.30E+11
-772.5	2.0		1763.5	2.0 E		39.43	.047	2.00E+11
-772.5	2.0		1835.3	2.0 F		36.35	.628	2.85E+12
-772.5	2.0		1837.6	3.0 D		38.31	.852	2.76E+12
-772.5	2.0		1840.8	1.0 E		38.27	.416	3.16E+12
-772.5	2.0		1886.9	3.0 E		37.60	.043	1.44E+11
-772.5	2.0					SUM F =	3.134	
-699.0	0.0 ($\frac{3}{2} \frac{3}{2}$)		465.6	1.0 B		60.07	.590	3.64E+11
-699.0	0.0 ($\frac{3}{2} \frac{3}{2}$)		1416.1	1.0 *C		47.28	.421	4.18E+11
-699.0	0.0		1840.8	1.0 E		39.57	.085	1.22E+11
-699.0	0.0		1900.8	1.0 F		38.33	1.844	2.79E+12
-699.0	0.0		1961.4	1.0 G		37.58	.020	3.11E+10
-699.0	0.0		2004.1	1.0 H		35.80	.073	1.26E+11
-699.0	0.0					SUM F =	3.090	
352.1	1.0 ($\frac{3}{2} \frac{1}{2}$)		1300.8	2.0 *C		105.41	.074	2.66E+10
352.1	1.0 ($\frac{3}{2} \frac{1}{2}$)		2085.2	2.0 H		57.70	.351	4.22E+11
352.1	1.0		2094.1	1.0 H		57.41	.326	6.59E+11
352.1	1.0		2137.6	2.0 I		56.01	.606	7.75E+11
352.1	1.0		2407.8	0.0 *D		47.72	.154	1.36E+12
352.1	1.0		2912.9	0.0 E		39.05	.224	2.94E+12
352.1	1.0		2943.5	1.0 J		38.59	.414	1.86E+12
352.1	1.0		2975.2	2.0 J		38.12	.446	1.12E+12
352.1	1.0					SUM F =	2.706	

TABLE VIII (CON)

E1(KK)	J1	E2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
391.4	2.0 $\left(\frac{3}{2} \frac{1}{2}\right)$	1300.8	2.0 *C	109.96	.038	2.12E+10
391.4	2.0	1416.1	1.0 *C	97.59	.050	5.86E+10
391.4	2.0	2085.2	2.0 H	59.04	.150	2.88E+11
391.4	2.0	2130.2	3.0 G	57.51	.650	9.36E+11
391.4	2.0	2137.6	2.0 I	57.27	.276	5.61E+11
391.4	2.0	2532.2	1.0 *I	46.71	.361	1.84E+12
391.4	2.0	2943.3	1.0 J	39.19	.086	6.20E+11
391.4	2.0	2949.9	3.0 H	38.78	.751	2.38E+12
391.4	2.0	2975.2	2.0 J	38.72	.241	1.07E+12
391.4	2.0			SUM F = 2.722		
1543.1	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	2532.2	1.0 *I	101.11	.171	3.71E+10
1543.1	0.0 $\left(\frac{1}{2} \frac{1}{2}\right)$	3326.8	1.0 K	56.06	2.106	1.49E+12
1543.1	0.0			SUM F = 2.277		
AU 47 4S2 4P3 -- AU 47 4S 4P0 + AU 47 4S2 4P2 4D						
-1151.3	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	488.0	2.5 A	61.00	.265	3.16E+11
-1151.3	1.5 $\left(\frac{1}{2} \frac{1}{2} \frac{3}{2}\right)$	852.6	2.5 *B	49.90	.148	2.64E+11
-1151.3	1.5	988.3	.5 *A	46.74	.102	6.23E+11
-1151.3	1.5	1007.1	1.5 *B	46.53	.368	1.14E+12
-1151.3	1.5	1450.0	2.5 D	38.44	.873	2.63E+12
-1151.3	1.5	1452.8	1.5 D	38.40	.685	3.10E+12
-1151.3	1.5	1469.9	.5 C	36.15	.302	2.77E+12
-1151.3	1.5			SUM F = 2.850		
-48.4	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	852.6	2.5 *B	111.00	.269	2.48E+10
-48.4	1.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	1580.2	1.5 E	61.40	.117	2.76E+11
-48.4	1.5	1688.8	2.5 F	57.57	.655	8.79E+11
-48.4	1.5	2000.4	1.5 *G	46.81	.309	8.60E+11
-48.4	1.5	2165.4	.5 *E	45.17	.178	1.16E+12
-48.4	1.5	2538.0	1.5 I	38.66	.398	1.78E+12
-48.4	1.5	2553.5	2.5 H	36.43	.316	9.51E+11
-48.4	1.5	2556.1	.5 F	38.40	.255	2.30E+12
-48.4	1.5			SUM F = 2.451		
.0	2.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	852.6	2.5 *B	117.29	.034	1.63E+10
.0	2.5 $\left(\frac{1}{2} \frac{3}{2} \frac{3}{2}\right)$	1007.1	1.5 *B	99.50	.057	5.79E+10
.0	2.5	1597.6	2.5 E	62.60	.093	1.58E+11
.0	2.5	1697.5	3.5 C	58.91	.490	7.00E+11
.0	2.5	2076.1	2.5 *G	48.17	.305	8.78E+11
.0	2.5	2181.5	1.5 *H	45.64	.311	1.08E+12
.0	2.5	2538.0	1.5 I	39.40	.094	6.25E+11
.0	2.5	2553.5	2.5 H	39.16	.284	1.24E+12
.0	2.5	2574.6	3.5 D	38.80	.647	2.14E+12
.0	2.5			SUM F = 2.468		

TABLE VII (CONT)

F1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
55.8	.5 $(\frac{1}{2} \frac{3}{2} \frac{3}{2})$	988.3	.5 *A	107.23	.090	5.24E+10
55.8	.5	1715.6	1.5 F	60.25	.419	3.85E+11
55.8	.5	1724.9	.5 D	59.91	.281	5.23E+11
55.8	.5	2165.4	.5 *E	47.40	.278	8.20E+11
55.8	.5	2181.5	1.5 *H	47.04	.293	4.42E+11
55.8	.5	2538.4	1.5 I	40.29	.097	2.00E+11
55.8	.5	2640.3	1.5 J	38.60	.001	2.01E+12
55.8	.5			SUM F =	2.415	
1166.6	1.5 $(\frac{3}{2} \frac{3}{2} \frac{3}{2})$	2076.1	2.5 *G	109.95	.078	2.88E+10
1166.6	1.5	2181.5	1.5 *H	98.54	.053	3.62E+10
1166.6	1.5	2883.7	1.5 K	58.24	.454	8.93E+11
1166.6	1.5	2922.2	2.5 J	56.96	.955	1.31E+12
1166.6	1.5	3328.4	.5 *H	46.69	.390	2.39E+12
1166.6	1.5			SUM F =	2.021	
AU 48	4S2 4P2 --	AU 48	4S 4P3 +	AU 48	4S2 4P 4D	
-1548.3	0.0 $(\frac{1}{2} \frac{1}{2})$	587.7	1.0 *A	46.82	.768	7.79E+11
-1548.3	0.0	1057.2	1.0 B	38.38	1.831	2.76E+12
-1548.3	0.0			SUM F =	2.590	
-421.3	1.0 $(\frac{1}{2} \frac{3}{2})$	453.4	2.0 *A	114.32	.071	2.19E+10
-421.3	1.0	1230.7	2.0 C	60.53	.351	3.83E+11
-421.3	1.0	1546.0	2.0 *D	50.83	.246	3.81E+11
-421.3	1.0	1681.6	0.0 *A	47.55	.071	6.24E+11
-421.3	1.0	1741.7	1.0 *C	46.23	.328	1.03E+12
-421.3	1.0	1765.0	1.0 *D	45.74	.134	4.27E+11
-421.3	1.0	2160.2	2.0 F	36.70	.394	1.05E+12
-421.3	1.0	2179.3	0.0 B	38.45	.151	2.04E+12
-421.3	1.0	2185.6	1.0 E	38.36	.396	1.80E+12
-421.3	1.0			SUM F =	2.195	
-383.0	2.0 $(\frac{1}{2} \frac{3}{2})$	1241.2	3.0 A	61.57	.258	3.24E+11
-383.0	2.0	1026.7	3.0 *B	49.76	.147	2.82E+11
-383.0	2.0	1763.1	2.0 *E	46.60	.442	1.30E+12
-383.0	2.0	1765.0	1.0 *D	46.55	.230	1.18E+12
-383.0	2.0	2160.2	2.0 F	39.32	.307	1.32E+12
-383.0	2.0	2187.6	3.0 C	38.90	.610	1.95E+12
-383.0	2.0			SUM F =	2.213	
769.9	2.0 $(\frac{3}{2} \frac{3}{2})$	1626.7	3.0 *B	116.70	.069	2.42E+10
769.9	2.0	2373.4	2.0 G	62.36	.143	2.45E+11
769.9	2.0	2482.2	3.0 D	58.40	.704	9.83E+11
769.9	2.0	2836.2	2.0 *H	48.40	.414	1.18E+12
769.9	2.0	2968.1	1.0 *G	45.40	.318	1.71E+12
769.9	2.0			SUM F =	1.791	

TABLE VIII (CONT)

F1(KK)	J1	F2(KK)	J2	LAMBDA(A)	F	A(SEC-1)
-----	---	-----	---	-----	---	-----
846.6	0.0 $(\frac{3}{2} \frac{3}{2})$	1741.7	1.0 *C	111.72	.087	1.55F+10
846.6	0.0 $(\frac{3}{2} \frac{3}{2})$	1765.0	1.0 *D	108.88	.079	1.47F+10
846.6	0.0	2504.1	1.0 F	60.33	.818	4.99F+11
846.6	0.0	2966.1	1.0 *G	47.14	.752	7.52F+11
846.6	0.0			SUM F = 1.747		
AU 49 4S2 4P -- AU 49 4S 4P2 + AU 49 4S2 4D						
-794.0	.5 ² P	77.9	.5 *A	114.69	.091	4.62F+12
-794.0	.5	1332.0	1.5 *B	47.04	.543	8.19F+11
-794.0	.5	1339.1	.5 *B	46.88	.432	1.31F+12
-794.0	.5	1781.9	1.5 C	38.82	.911	2.02E+12
-794.0	.5			SUM F = 1.981		
391.7	1.5 ² P	1222.8	2.5 *A	120.32	.074	2.27F+10
391.7	1.5	1332.0	1.5 *B	106.34	.050	2.95F+10
391.7	1.5	2020.0	2.5 B	61.41	.359	4.24E+11
391.7	1.5	2375.8	2.5 *C	50.40	.235	4.12E+11
391.7	1.5	2521.5	.5 *C	46.95	.163	2.87E+11
391.7	1.5	2548.3	1.5 *D	46.37	.624	1.94F+12
391.7	1.5			SUM F = 1.564		
AU 50 4S2 -- AU 50 4S 4P						
-6.0	0.0 ¹ S	831.1	1.0 A	119.45	.161	2.51F+10
-6.0	0.0	2116.8	1.0 B	47.11	1.204	1.21E+12
AU 51 3D10 4S -- AU 51 3D10 4P + AU 51 3D10 5P						
0.0	.5 ² S	882.6	.5 A	113.30	.116	6.04F+10
0.0	.5	2097.9	1.5 A	47.67	.553	8.12E+11
0.0	.5	9896.4	.5 B	10.10	.058	3.78E+12
0.0	.5	10470.8	1.5 B	9.55	.123	4.48F+12
AU 52 3D10 -- AU 52 3D9 4P + AU 52 3D9 4F						
0.0	0.0 ¹ S	16646.4	1.0 A	6.01	.119 ^b	7.35E+12 ^b
0.0	0.0	17125.1	1.0 B	5.84	.252 ^b	1.65E+13 ^b
0.0	0.0	17867.3	1.0 C	5.60	.034 ^b	2.43E+12 ^b
0.0	0.0	19980.6	1.0 D	5.00	.000	8.57E+09
0.0	0.0	20264.4	1.0 E	4.93	2.514	2.30E+14
0.0	0.0	20985.5	1.0 F	4.77	5.717	5.60E+14

a,^b See footnotes to Table VII.

TABLE IX
MAGNETIC DIPOLE TRANSITIONS IN IRON IONS^a

Configuration	Transition	λ_{exp}^b (Å)	λ_{calc} (Å)	A_{M1} (s ⁻¹)	
				this work	other ^b
[Fe XIII] 3p ²	³ P ₁ - ¹ D ₂	2580.	2581.	6.88(1)	6.9(1)
	³ P ₂ - ¹ D ₂	3388.5	3387.	8.34(1)	8.4(1)
	³ P ₁ - ¹ S ₀	1213.0	1272.	9.96(2)	1.15(3)
[Fe XIV] 3p	² P _{1/2} - ² P _{3/2}	5303.4	5406.	5.72(1)	6.03(1)
[Fe XV] 3s3p	³ P ₁ - ³ P ₂	7058.6	7312.	3.44(1)	3.77(1)
[Fe XVII] 2p ⁵ 3s	¹ P ₁ - ³ P ₀		1131.	1.65(4)	
[Fe XVIII] 2p ⁵	² P _{3/2} - ² P _{1/2}	974.8	971.	1.98(4)	1.92(4)
[Fe XIX] 2p ⁴	³ P ₂ - ³ P ₁	1118.4	1118.	1.44(4)	
	³ P ₀ - ³ P ₁	7080.	5885.	6.96(1)	
	³ P ₂ - ¹ D ₂	~589.	617.	1.69(4)	
	³ P ₁ - ¹ D ₂	~1244.	1378.	5.69(2)	
	³ P ₁ - ¹ S ₀	~422.	437.	1.39(5)	
	⁴ S _{3/2} - ² D _{3/2}	~779.	791.	1.45(4)	

TABLE IX (cont)

	$4S_{3/2} - 2D_{5/2}$	~603.	603.	1.41(3)
	$2D_{3/2} - 2D_{5/2}$	2670.	2544.	4.88(2)
	$4S_{3/2} - 2P_{1/2}$	~400.	403.	3.12(4)
	$2D_{3/2} - 2P_{1/2}$	822.	823.	5.35(3)
	$4S_{3/2} - 2P_{3/2}$	~319.	319.	2.73(4)
	$2D_{3/2} - 2P_{3/2}$	541.	534.	4.68(4)
	$2D_{5/2} - 2P_{3/2}$	679.	676.	1.21(4)
	$2P_{1/2} - 2P_{3/2}$	1580.	1523.	1.85(3)
[Fe XXI] $2p^2$	$3P_0 - 3P_1$	1354.	1329.	6.93(3)
	$3P_1 - 3P_2$	2304.	2282.	8.29(2)
	$3P_1 - 1D_2$		600.	1.71(4)
	$3P_2 - 1D_2$		814.	1.49(4)
	$3P_1 - 1S_0$		341.	1.35(5)
[Fe XXII] $2p$	$2P_{1/2} - 2P_{3/2}$	845.	830.	1.58(4)

TABLE IX (cont)

^aTransitions not listed for the indicated configurations have $A_{M1} < 50 \text{ s}^{-1}$ or have upper levels that are not metastable.

^bFrom Refs. 17 and 32, except [Fe XVIII] and [Fe XXII] from Doschek and Feldman, Ref. 33.

TABLE X
MAGNETIC DIPOLE TRANSITIONS IN CHROMIUM AND NICKEL IONS^a

Configuration	Transition	Cr			Ni		
		λ (Å)	A_{M1} (s ⁻¹)		λ (Å)	A_{M1} (s ⁻¹)	
$3p^2$	$^3P_1 - ^1D_2$	[XI] 3150.	2.02(1)		[XV] 2100.	2.13(2)	
	$^3P_2 - ^1D_2$	3943.	2.95(1)		2841.	2.20(2)	
	$^3P_1 - ^1S_0$	1501.	3.65(2)		1081.	2.43(3)	
$3p$	$^2P_{1/2} - ^2P_{3/2}$	[XII] 8367.	1.54(1)		[XVI] 3652.	1.85(2)	
$3s3p$	$^3P_1 - ^3P_2$	[XIII] 11396.	9.1 (0)		[XVII] 4886.	1.15(2)	
$2p^5 3s$	$^1P_1 - ^3P_0$	[XV] 1709.	5.16(3)		[XIX] 781.	4.76(4)	
$2p^5$	$^2P_{3/2} - ^2P_{1/2}$	[XVI] 1407. ^b	6.49(3) ^b		[XX] 691. ^c	5.48(4) ^c	
$2p^4$	$^3P_2 - ^3P_1$	[XVII] 1662.	4.51(3)		[XXI] 776.	4.16(4)	
	$^3P_0 - ^3P_1$	26415.	0.8 (0)		2494.	8.27(2)	

TABLE X (cont)

Configuration	Transition	Cr		Ni	
		λ (Å)	A_{M1} (s^{-1})	λ (Å)	A_{M1} (s^{-1})
$2p^3$	$^3P_2 - ^1D_2$	781.	6.42(3)	486.	4.22(4)
	$^3P_1 - ^1D_2$	1471.	3.48(2)	1298.	8.55(2)
	$^3P_1 - ^1S_0$	510.	5.84(4)	368.	3.15(5)
	$^4S_{3/2} - ^2D_{3/2}$	[XVIII] 877.	5.20(3)	[XXII] 682.	3.80(4)
	$^4S_{3/2} - ^2D_{5/2}$	712.	3.50(2)	500.	5.01(3)
	$^2D_{3/2} - ^2D_{5/2}$	3787.	1.58(2)	1872.	1.14(3)
	$^4S_{3/2} - ^2P_{1/2}$	465.	1.22(4)	345.	7.52(4)
	$^2D_{3/2} - ^2P_{1/2}$	991.	3.04(3)	697.	7.76(3)
	$^4S_{3/2} - ^2P_{3/2}$	392.	1.52(4)	255.	4.18(4)

TABLE X (cont)

Configuration	Transition	Cr		Ni	
		λ (Å)	A_{M1} (s^{-1})	λ (Å)	A_{M1} (s^{-1})
$2p^2$	$^2D_{3/2} - ^2P_{3/2}$	710.	1.60(4)	408.	1.26(5)
	$^2P_{1/2} - ^2P_{3/2}$	2499.	4.44(2)	986.	6.44(3)
	$^3P_0 - ^3P_1$	[XIX] 2057.	1.92(3)	[XXIII] 893.	2.22(4)
	$^3P_1 - ^3P_2$	2835.	4.79(2)	1918.	1.25(3)
	$^3P_1 - ^1D_2$	758.	6.03(3)	472.	4.49(4)
	$^3P_2 - ^1D_2$	1035.	5.73(3)	625.	3.77(4)
$2p$	$^3P_1 - ^1S_0$	405.	5.96(4)	286.	2.92(5)
	$^2P_{1/2} - ^2P_{3/2}$	[XX] 1184.	5.44(3)	[XXIV] 598.	4.23(4)

^aSee footnote a to Table IX.

^bDoschek and Feldman, Ref. 33, give $\lambda_{\text{exp}} = 1412 \text{ Å}$ and $A_{M1} = 6.34(3) s^{-1}$.

^cDoschek and Feldman give $\lambda_{\text{exp}} = 695 \text{ Å}$ and $A_{M1} = 5.32(4) s^{-1}$.

TABLE XI

MAGNETIC DIPOLE TRANSITIONS IN KRYPTON XVIII TO XXXII^a

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
KR 18 3P6 3D -- KR 18 3P6 3D								
-9.4	1.5	A	0.3	2.5	A	6382.11	.000	4.17E+01
KR 19 3P5 3D -- KR 19 3P5 3D								
760.2	3.0	A	845.7	2.0	C	1166.43	.000	5.97E+03
777.7	2.0	B	845.7	2.0	C	1470.43	.000	1.77E+03
			845.7	2.0	C		SUM A=	8.71E+03
752.2	2.0	A	866.7	2.0	D	858.75	.000	4.30E+03
777.7	2.0	B	866.7	2.0	D	1209.58	.000	1.42E+03
808.1	3.0	B	866.7	2.0	D	1649.72	.000	1.85E+03
			866.7	2.0	D		SUM A=	0.40E+03
759.2	4.0	A	877.3	3.0	C	846.99	.000	1.03E+04
808.1	3.0	B	877.3	3.0	C	1404.37	.000	2.21E+03
			877.3	3.0	C		SUM A=	1.44E+04
KR 20 3P5 -- KR 20 3P5								
-29.2	1.5	A	58.4	.5	A	1141.74	.000	1.21E+04
KR 20 3P4 3D -- KR 20 3P4 3D								
709.4	4.5	A	783.1	3.5	C	1356.48	.000	3.98E+03
718.8	3.5	B	783.1	3.5	C	1553.62	.000	1.27E+03
			783.1	3.5	C		SUM A=	7.69E+03
718.8	3.5	B	806.6	3.5	D	9138.64	.000	2.78E+03
			806.6	3.5	D		SUM A=	6.78E+03
709.4	4.5	A	816.2	4.5	B	936.83	.000	6.01E+03
			816.2	4.5	B		SUM A=	7.52E+03
KR 21 3P4 -- KR 21 3P4								
-72.2	2.0	A	6.8	1.0	A	1265.64	.000	9.24E+03
			6.8	1.0	A		SUM A=	9.74E+03
-72.2	2.0	A	42.2	2.0	B	874.52	.000	8.39E+03
			42.2	2.0	B		SUM A=	8.49E+03

TABLE XT (CONT)

F1(KK)	J1				F2(KK)	J2			LAMBDA(A)	F	A(SEC=1)
-----	---				-----	---			-----	---	-----
KR 21	3P3	3D	--		KR 21	3P3	3D				
641.5	4.0	A			731.0	4.0	B		1117.87	.000	4.47E+03
					731.0	4.0	B			SUM A=	5.00E+03
628.9	3.0	A			749.1	4.0	C		832.29	.000	1.17E+03
641.5	4.0	A			749.1	4.0	C		929.75	.000	1.61E+03
					749.1	4.0	C			SUM A=	3.06E+03
641.5	4.0	A			761.9	4.0	D		830.97	.000	1.22E+03
					761.9	4.0	D			SUM A=	1.93E+03
641.5	4.0	A			765.1	5.0	A		809.90	.000	1.11E+03
731.0	4.0	B			765.1	5.0	A		2941.01	.000	4.17E+02
					765.1	5.0	A			SUM A=	1.54E+03
KR 22	3P3		--		KR 22	3P3					
-107.1	1.5	A			-29.2	1.5	B		1284.57	.000	7.95E+03
-107.1	1.5	A			.0	2.5	A		934.10	.000	1.29E+03
					.0	2.5	A			SUM A=	1.07E+03
.0	2.5	A			107.2	1.5	C		932.43	.000	5.40E+03
					107.2	1.5	C			SUM A=	3.69E+04
KR 22	3P2	3D	--		KR 22	3P2	3D				
706.3	4.5	A			811.2	4.5	B		952.66	.000	6.62E+03
					811.2	4.5	B			SUM A=	1.42E+04
KR 23	3P2		--		KR 23	3P2					
-127.9	0.0	A			-58.2	1.0	A		1434.25	.000	5.19E+03
					-58.2	1.0	A			SUM A=	5.19E+03
-58.2	1.0	A			58.5	2.0	B		857.28	.000	8.87E+03
-32.4	2.0	A			58.5	2.0	B		1106.46	.000	7.34E+03
					58.5	2.0	B			SUM A=	1.63E+04
KR 23	3P	3D	--		KR 23	3P	3D				
686.8	3.0	A			751.9	4.0	A		1537.10	.000	5.02E+03

TABLE XI (CONT)

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
KR 24	3S2 3P	--	KR 24	3S2 3P				
-70.8	.5 A		26.7	1.5 A		1025.63	.000	8.37E+03
KR 25	3S 3P	--	KR 25	3S 3P				
589.6	1.0 A		467.4	2.0 A		1285.57	.000	6.06E+03
KR 28	2P5	--	KR 28	2P5				
-154.6	1.5 A		371.2	0.5 A		221.51	.000	1.67E+05
KR 29	2P4	--	KR 29	2P4				
-339.9	2.0 A		184.7	2.0 B		190.67	.000	1.23E+06
84.1	1.0 A		184.7	2.0 B		1045.85	.000	2.68E+03
			184.7	2.0 B			SUM A =	1.03E+06
KR 30	2P3	--	KR 30	2P3				
-496.6	1.5 A		.4	2.5 A		203.82	.000	2.47E+05
-101.9	1.5 B		.0	2.5 A		981.43	.000	5.96E+03
			.0	2.5 A			SUM A =	2.53E+05
KR 31	2P2	--	KR 31	2P2				
-646.1	.0 A		-157.3	2.0 A	E2	204.59	.000	2.91E+02
-238.9	1.0 A		-157.3	2.0 A		1225.51	.000	3.46E+03
			-157.3	2.0 A			SUM A =	3.75E+03
KR 32	2S2 2P	--	KR 32	2S2 2P				
-352.2	0.5 A		152.1	1.5 A		108.28	.000	1.16E+06

^aSee footnote to Table V for significance of the level designations A, B, C, D, ...

TABLE XII

MAGNETIC DIPOLE TRANSITIONS IN MOLYBDENUM XVI TO XXXVII

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
MO 16	3D9	--	MO 16	3D9				
-10.8	2.5	A	16.2	1.5	A	3712.32	.000	3.18E+02
MO 24	3D	--	MO 24	3D				
-22.4	1.5	A	14.9	2.5	A	2681.91	.000	5.62E+02
MO 25	3P5 3D	--	MO 25	3P5 3D				
920.2	1.0	A	959.1	2.0	A	2569.73	.000	7.33E+02
920.2	1.0	A	988.9	2.0	B	1454.55	.000	4.58E+02
956.5	3.0	A	988.9	2.0	B	3088.26	.000	2.96E+02
			988.9	2.0	B			SUM A= 9.15E+02
956.5	3.0	A	1030.5	3.0	B	1552.54	.000	8.65E+02
959.1	2.0	A	1030.5	3.0	B	1400.76	.000	1.84E+03
			1030.5	3.0	B			SUM A= 2.81E+03
1087.9	1.0	B	1179.0	2.0	D	1098.67	.000	1.04E+04
			1179.0	2.0	D			SUM A= 0.40E+04
MO 26	3P5	--	MO 26	3P5				
-63.0	1.5	A	126.1	.5	A	528.75	.000	1.22E+05
MO 26	3P4 3D	--	MO 26	3P4 3D				
842.8	3.5	A	881.0	4.5	A	2619.87	.000	4.20E+02
968.1	2.5	B	1044.4	3.5	C	1310.59	.000	5.94E+03
			1044.4	3.5	C			SUM A= 8.37E+04
MO 27	3P4	--	MO 27	3P4				
-79.2	0.0	A	36.1	1.0	A	867.63	.000	1.40E+04
			36.1	1.0	A			SUM A= 1.13E+05

TABLE XII (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
MO 27	SP3 3D	--	MO 27	SP3 3D				
752.2	3.0 A		785.5	4.0 A		3000.85	.000	6.01E+02
868.1	3.0 B		940.3	4.0 B		1279.21	.000	6.95E+03
			946.3	4.0 B			SUM A=	5.59E+04
868.1	3.0 B		988.3	4.0 D		832.08	.000	3.87E+05
920.2	3.0 C		988.3	4.0 D		1468.03	.000	1.61E+03
			984.3	4.0 D			SUM A=	1.17E+04
946.3	4.0 B		999.3	5.0 A		1887.29	.000	1.97E+05
			999.3	5.0 A			SUM A=	1.82E+04
MO 28	SP2 3D	--	MO 28	SP2 3D				
853.7	3.5 A		904.4	4.5 A		1972.27	.000	2.44E+05
			974.4	4.5 A			SUM A=	2.46E+05
984.3	3.5 C		1095.0	4.5 B		903.04	.000	1.52E+04
			1095.0	4.5 B			SUM A=	1.28E+05
MO 29	SP2	--	MO 29	SP2				
-265.3	0.0 A		-99.3	1.0 A		602.43	.000	6.52E+04
-265.3	.0 A		-64.7	2.0 A	EP	408.51	.000	1.10E+02
-99.3	1.0 A		-64.7	2.0 A		2889.99	.000	2.67E+02
			-64.7	2.0 A			SUM A=	3.77E+02
MO 29	SP 3D	--	MO 29	SP 3D				
853.0	3.0 B		1000.2	4.0 A		679.17	.000	5.35E+04
			1070.2	4.0 A			SUM A=	5.69E+04
MO 30	SS2 3P	--	MO 30	SS2 3P				
-143.8	.5 A		62.4	1.5 A		484.97	.000	7.92E+04
MO 31	SS 3P	--	MO 31	SS 3P				
497.4	1.0 A		671.7	2.0 A		575.33	.000	6.41E+04

TABLE XVI (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
MO 34	2P5	--	MO 34	2P5				
-300.7	1.5	A	631.3	.5	A	110.87	.0000	1.33E+47
MO 35	2P4	--	MO 35	2P4				
-946.2	1.5	A	.0	2.5	A	195.64	.0000	2.17E+40
-128.4	1.5	"	.0	2.5	A	778.81	.0000	1.79E+44
			.0	2.5	A		SUM A=	2.10E+40
MO 36	2P3	--	MO 36	2P3				
-648.0	2.0	A	344.2	2.0	B	131.13	.0000	7.65E+06
229.7	1.0	A	344.2	2.0	B	904.85	.0000	4.84E+05
			344.2	2.0	B		SUM A=	7.65E+06
MO 37	2P2	--	MO 37	2P2				
-1271.3	.0	A	-309.8	2.0	A	E2 104.00	.0000	4.67E+23
-411.0	1.0	A	-309.8	2.0	A	988.35	.0000	5.79E+03
			-309.8	2.0	A		SUM A=	1.04E+24
MO 38	2P	--	MO 38	2P				
-677.4	.5	A	513.4	1.5	A	100.93	.0000	8.77E+06

TABLE XIII

MAGNETIC DIPOLE TRANSITIONS IN XENON XVIII TO XLII

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
XE 18 4P6 4D -- XE 18 4P6 4D								
-15.5	1.5	A	9.0	2.5	A	4450.37	.000	1.23F+02
XE 19 4P5 4D -- XE 19 4P5 4D								
677.7	3.0	A	723.6	3.0	B	2326.84	.000	1.89F+02
674.1	2.0	A	720.6	3.0	B	2409.77	.000	3.96F+02
			720.6	3.0	B			SUM A= 5.95F+02
677.7	3.0	A	796.5	2.0	C	843.05	.000	2.08F+04
674.1	2.0	A	796.5	2.0	C	853.70	.000	5.18E+03
690.5	2.0	B	796.5	2.0	C	1002.23	.000	2.22E+03
			796.5	2.0	C			SUM A= 2.99E+04
696.5	2.0	B	822.4	2.0	D	794.53	.000	1.03F+04
720.6	3.0	B	822.4	2.0	D	983.07	.000	7.85E+03
760.4	1.0	B	822.4	2.0	D	1012.90	.000	3.27E+03
			822.4	2.0	D			SUM A= 2.81E+04
XE 20 4P5 -- XE 20 4P5								
-54.7	1.5	A	71.4	.5	A	792.66	.000	3.65F+04
XE 21 4P4 -- XE 21 4P4								
-124.5	2.0	A	15.9	1.0	A	832.60	.000	3.00E+04
-60.7	2.0	A	15.9	1.0	A	1210.30	.000	4.94E+03
			15.9	1.0	A			SUM A= 3.50E+04
15.9	1.0	A	177.5	0.0	B	619.82	.000	1.17E+05
XE 22 4P3 -- XE 22 4P3								
-145.3	1.5	A	-34.7	1.5	B	920.57	.000	2.80E+04
-145.3	1.5	A	-9.6	2.5	A	747.83	.000	5.40E+03
			-9.6	2.5	A			SUM A= 5.49E+03
-9.6	2.5	A	132.0	1.5	C	706.10	.000	1.32E+04
22.0	.5	A	132.0	1.5	C	908.96	.000	7.20E+03
			132.0	1.5	C			SUM A= 8.38E+04

TABLE XIII (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC=1)
-----	---		-----	---		-----	---	-----
XE 23	4P2	--	XE 23	4P2				
-182.6	0.0	A	-69.2	1.0	A	881.89	.000	2.76E+04
-69.2	1.0	A	79.7	2.0	B	671.38	.000	2.45E+04
-49.1	2.0	A	79.7	2.0	B	776.16	.000	2.15E+04
XE 24	4S2 4P	--	XE 24	4S2 4P				
-99.6	.5	A	39.8	1.5	A	717.47	.000	2.45E+04
XE 25	4S 4P	--	XE 25	4S 4P				
382.8	1.0	A	532.3	2.0	A	836.99	.000	2.45E+04
XE 28	3D9	--	XE 28	3D9				
-44.1	2.5	A	66.1	1.5	A	927.62	.000	2.17E+04
XE 29	3D8	--	XE 29	3D8				
-122.1	4.0	A	-19.0	3.0	A	970.50	.000	2.66E+04
			-19.0	3.0	A		SUM A=	2.75E+04
-78.3	2.0	A	23.2	2.0	B	984.81	.000	1.49E+04
			23.2	2.0	B		SUM A=	1.61E+04
-78.3	2.0	A	47.0	1.0	A	797.95	.000	1.52E+04
			47.0	1.0	A		SUM A=	1.67E+04
23.2	2.0	B	120.3	2.0	C	1030.09	.000	1.12E+04
			120.3	2.0	C		SUM A=	5.42E+04
XE 35	3D2	--	XE 35	3D2				
-191.2	2.0	A	-72.2	3.0	A	839.90	.000	3.54E+04
-89.8	.0	A	-0.7	1.0	A	1122.08	.000	1.05E+04
			-0.7	1.0	A		SUM A=	1.32E+04
-72.2	3.0	A	-11.9	4.0	A	1658.60	.000	2.51E+03
-11.9	4.0	A	96.8	4.0	B	920.56	.000	1.07E+04
			96.8	4.0	B		SUM A=	5.35E+04

TABLE XIII (CONT)

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
XE 37	SP5 SD	--	XE 37	SP5 SD				
1335.7	1.0 A		1359.4	2.0 A		1861.45	.000	1.40E+03
			1359.4	2.0 A			SUM A=	1.43E+03
1344.4	3.0 A		1408.5	4.0 A		960.47	.000	1.36E+04
1359.4	2.0 A		1471.2	2.0 A		894.74	.000	8.02E+03
			1471.2	2.0 A			SUM A=	3.74E+04
XE 38	SP5	--	XE 38	SP5				
-238.9	1.5 A		491.1	.5 A		156.27	.000	4.73E+06
XE 38	SP4 SD	--	XE 38	SP4 SD				
1030.4	1.5 A		1065.9	.5 A		2821.86	.000	1.15E+03
1030.4	1.5 A		1168.9	1.5 A		722.03	.000	7.34E+03
1049.7	2.5 A		1168.9	1.5 A		838.96	.000	9.17E+02
1065.9	.5 A		1168.9	1.5 A		970.31	.000	2.40E+03
			1168.9	1.5 A			SUM A=	1.07E+04
1049.7	2.5 A		1184.2	3.5 A		743.82	.000	1.75E+04
1082.2	3.5 A		1184.2	3.5 A		981.19	.000	5.91E+03
			1184.2	3.5 A			SUM A=	2.34E+04
1082.2	3.5 A		1197.0	0.5 A		871.55	.000	1.83E+04
XE 40	SP2 SD	--	XE 40	SP2 SD				
1208.2	3.5 A		1362.2	4.5 A		609.43	.000	4.51E+04
1297.9	3.5 A		1362.2	4.5 A		1554.54	.000	1.18E+03
			1362.2	4.5 A			SUM A=	4.63E+04
XE 41	SP2	--	XE 41	SP2				
-895.6	.0 A		-230.2	2.0 A	E2	150.41	.000	1.41E+04
-279.9	1.0 A		-232.2	2.0 A		2010.97	.000	6.46E+02
			-230.2	2.0 A			SUM A=	1.48E+04
XE 42	SP2 SP	--	XE 42	SP2 SP				
-469.6	.5 A		213.4	1.5 A		146.40	.000	2.88E+06

TABLE XIV
MAGNETIC DIPOLE TRANSITIONS IN TUNGSTEN XXVIII TO LXII

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
W 28 4D1/2 4F	--		W 28 4D1/2 4F					
-17.3	2.5	A	13.7	3.5	A	3294.71	.000	3.25E+02
W 30 4D9	--		W 30 4D9					
-53.4	2.5	A	40.0	1.5	A	749.63	.000	3.86E+04
W 31 4D8	--		W 31 4D8					
-125.9	4.0	A	2.5	3.0	A	779.90	.000	4.89E+04
-100.6	2.0	A	28.5	2.0	B	774.35	.000	2.95E+04
-47.3	0.0	A	42.6	1.0	A	1138.03	.000	7.02E+03
			40.0	1.0	A			SUM A= 3.29E+04
28.5	2.0	B	151.9	2.0	C	610.28	.000	1.87E+04
			151.9	2.0	C			SUM A= 8.79E+04
W 37 4D2	--		W 37 4D2					
-199.3	2.0	A	-56.7	3.0	A	701.09	.000	5.65E+04
-56.7	3.0	A	-16.7	4.0	A	2502.04	.000	4.61E+02
-137.3	0.0	A	-16.7	1.0	A	828.71	.000	2.33E+04
			-16.7	1.0	A			SUM A= 2.73E+04
-16.7	4.0	A	111.2	4.0	B	781.68	.000	1.62E+04
			111.2	4.0	B			SUM A= 7.83E+04
W 38 4P6 4D	--		W 38 4P6 4D					
-93.5	1.5	A	62.4	2.5	A	641.40	.000	4.11E+04

TABLE XIV (CONT)

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
W 38 4P5 402	--		W 38 4P5 402					
1143.8	3.5	A	1264.2	4.5	A	830.25	.0000	3.62E+04
1264.2	4.5	A	1296.0	5.5	A	3150.38	.0000	3.01E+02
1143.8	3.5	A	1352.1	4.5	B	480.02	.0000	3.31E+03
1264.2	4.5	A	1352.1	4.5	B	1137.91	.0000	3.18E+02
1267.4	5.5	B	1352.1	4.5	B	1179.94	.0000	1.95E+03
			1352.1	4.5	B			SUM A= 5.81E+03
1296.0	5.5	A	1423.2	5.5	B	785.78	.0000	1.58E+04
			1423.2	5.5	B			SUM A= 6.29E+04
1332.2	3.5	B	1457.3	4.5	C	799.43	.0000	4.41E+02
			1457.3	4.5	C			SUM A= 8.74E+04
W 39 4P5 40	--		W 39 4P5 40					
1213.6	1.0	A	1244.8	2.0	A	3149.20	.0000	2.81E+02
			1244.8	2.0	A			SUM A= 2.86E+02
1236.2	3.0	A	1367.4	4.0	A	761.68	.0000	2.64E+04
1244.8	2.0	A	1383.4	2.0	B	721.52	.0000	1.31E+04
			1383.4	2.0	B			SUM A= 4.77E+04
W 40 4P5	--		W 40 4P5					
-265.3	1.5	A	517.1	.5	A	127.61	.0000	8.65E+06
W 40 4P4 40	--		W 40 4P4 40					
966.1	3.5	A	1103.3	4.5	A	726.80	.0000	3.04E+04
W 41 4P3 40	--		W 41 4P3 40					
700.4	3.0	A	646.2	4.0	A	685.78	.0000	3.82E+04

TABLE XIV (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
W 43	4P2	--	W 43	4P2				
-1076.9	.0 A		-265.7	2.0 A	E2	123.27	.000	2.05E+05
-300.4	1.0 A		-245.7	2.0 A		2875.59	.000	2.07E+02
			-265.7	2.0 A			SUM A=	2.05E+05
W 44	4S2 4P	--	W 44	4S2 4P				
-555.1	.5 A		272.3	1.5 A		120.86	.000	5.11E+06
W 45	4S 4P	--	W 45	4S 4P				
734.6	1.0 A		1519.1	2.0 A		127.47	.000	4.94E+06
W 48	3D2	--	W 48	3D2				
-220.9	2.5 A		331.4	1.5 A		181.05	.000	2.74E+06
W 49	3D8	--	W 49	3D8				
48.5	3.0 A		118.3	2.0 B		1431.09	.000	3.78E+03
			118.3	2.0 B			SUM A=	2.20E+06
48.5	3.0 A		160.2	4.0 B		895.03	.000	3.92E+03
			160.2	4.0 B			SUM A=	1.13E+06
W 55	3D2	--	W 55	3D2				
-194.1	3.0 A		-86.8	4.0 A		931.78	.000	7.21E+03
W 56	3P6 3D	--	W 56	3P6 3D				
-386.0	1.5 A		257.4	2.5 A		155.42	.000	2.89E+06
W 57	3P5 3D	--	W 57	3P5 3D				
1884.6	1.0 A		1943.9	2.0 A		1684.32	.000	1.86E+03
			1943.9	2.0 A			SUM A=	2.00E+03

TABLE XIV (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
W 58 3P5		--	W 58 3P5					
-991.2	1.5 A		1982.5	.5 A		33.63	.000	4.75E+08
W 58 3P4 3D		--	W 58 3P4 3D					
835.0	2.5 A		862.4	3.5 A		3661.00	.000	1.44E+92
W 61 3P2		--	W 61 3P2					
-4073.3	.0 A		-1010.1	2.0 A	E2	32.64	.000	6.82E+06
-1085.9	1.0 A		-1010.1	2.0 A		1318.98	.000	2.07E+05
			-1010.1	2.0 A			SUM A=	6.82E+06
W 62 3S2 3P		--	W 62 3S2 3P					
-2080.0	.5 A		1028.8	1.5 A		32.17	.000	2.71E+08

TABLE XV

MAGNETIC DIPOLE TRANSITIONS IN GOLD XXXV TO LXIII

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
AU 35 4D9		--	AU 35 4D9					
-78.0	2.5 A		117.0	1.5 A		512.91	.000	1.20E+05
AU 36 4D8		--	AU 36 4D8					
-149.5	2.0 A		41.5	2.0 B		523.67	.000	9.42E+04
12.1	3.0 A		41.5	2.0 B		3399.46	.000	2.94E+02
			41.5	2.0 B			SUM A=	9.45E+04
12.1	3.0 A		60.8	4.0 B		2050.25	.000	3.01E+02
			60.8	4.0 B			SUM A=	5.11E+04

TABLE XV (CONT)

F1(KK)	J1		F2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
AU 42	4D2	--	AU 42	4D2				
-72.8	3.0	A	-27.6	4.0	A	2208.57	.000	5.86E+02
AU 43	4P6 4D	--	AU 43	4P6 4D				
-134.4	1.5	A	89.0	2.5	A	406.33	.000	1.22E+05
AU 43	4P5 4D2	--	AU 43	4P5 4D2				
1418.2	4.5	A	1454.7	5.5	A	2743.50	.000	3.95E+02
1233.8	3.5	A	1516.7	4.5	B	353.46	.000	9.20E+03
1418.2	4.5	A	1516.7	4.5	B	1015.36	.000	3.88E+02
1423.5	3.5	B	1516.7	4.5	B	1072.91	.000	2.20E+03
			1516.7	4.5	B		SUM A=	1.20E+04
AU 44	4P5 4D	--	AU 44	4P5 4D				
1341.8	1.0	A	1374.1	2.0	A	3095.88	.000	2.96E+02
			1374.1	2.0	A		SUM A=	3.04E+02
AU 45	4P5	--	AU 45	4P5				
-380.4	1.5	A	746.9	.5	A	80.71	.000	2.59E+07
AU 45	4P4 4D	--	AU 45	4P4 4D				
978.0	3.5	A	1181.7	4.5	A	490.83	.000	9.78E+04
AU 48	4P2	--	AU 48	4P2				
-1548.3	.0	A	-383.0	2.0	A	E2 85.81	.000	8.77E+05
-421.3	1.0	A	-383.0	2.0	A	2609.25	.000	2.72E+02
			-383.0	2.0	A		SUM A=	8.77E+05
AU 49	4S2 4P	--	AU 49	4S2 4P				
-794.0	.5	A	391.7	1.5	A	84.34	.000	1.50E+07

TABLE XV (CONT)

E1(KK)	J1		E2(KK)	J2		LAMBDA(A)	F	A(SEC-1)
-----	---		-----	---		-----	---	-----
AU 50	4S 4P	--	AU 50	4S 4P				
831.1	1.0 A		1969.7	2.0 A		87.63	.000	1.47E+07
AU 53	3D9	--	AU 53	3D9				
-304.9	2.5 A		457.3	1.5 A		131.19	.000	7.24E+06
AU 54	3D8	--	AU 54	3D8				
85.4	3.0 A		161.9	2.0 B		1307.13	.000	4.78E+03
			161.9	2.0 b				SUM A= 5.82E+06
85.4	3.0 A		206.1	4.0 B		828.79	.000	5.32E+03
			206.1	4.0 b				SUM A= 2.85E+06
AU 60	3D2	--	AU 60	3D2				
-1079.2	2.0 A		-162.4	2.0 B		109.07	.000	5.05E+06
-246.1	3.0 A		-162.4	2.0 b		1194.66	.000	4.72E+03
			-162.4	2.0 b				SUM A= 5.06E+06
-246.1	3.0 A		-128.4	4.0 A		849.54	.000	8.83E+03
AU 61	3P6 3D	--	AU 61	3P6 3D				
-526.8	1.5 A		351.2	2.5 A		113.60	.000	7.34E+06
AU 62	3P5 3D	--	AU 62	3P5 3D				
1987.2	1.0 A		2047.3	2.0 A		1665.55	.000	1.04E+03
			2047.3	2.0 A				SUM A= 2.12E+03
AU 63	3P5	--	AU 63	3P5				
-1372.6	1.5 A		2745.1	.5 A		24.29	.000	1.26E+09
AU 63	3P4 3D	--	AU 63	3P4 3D				
552.1	2.5 A		577.7	3.5 A		3896.48	.000	1.17E+02