A Review, Bibliography, and Tabulation of *K*, *L*, and Higher Atomic Shell X-Ray Fluorescence Yields

J.H. Hubbell[a]
Ionizing Radiation Division, Physics Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899-0001

P.N. Trehan, Nirmal Singh, and B. Chand
Departments of Physics and Biophysics, Panjab University, Chandigarh 160014, India

D. Mehta
Physics and Astrophysics Department, University of Delhi, Delhi 110007, India

and

M.L. Garg, R.R. Garg, Surinder Singh, and S. Puri
Departments of Physics and Biophysics, Panjab University, Chandigarh 160014, India

Received February 1, 1994; revised manuscript received March 5, 1994

The measured *K*, *L*, and higher atomic shell x-ray fluorescence yield data, covering the period 1978 to 1993, following the major previous compilations by Bambynek *et al.* (1972) and Krause (1979), are reviewed. An annotated bibliography of x-ray fluorescence yield measurements, analyses, fits and tables 1978–1993 is presented. Comparisons of the fluorescence yields ω_K, ϖ_L, and ϖ_M, based on measurements, and on theoretical models, are presented. Values of ω_K, ϖ_L, and ϖ_M, fitted to standard empirical parametric formulations, are presented. In addition, selected well-characterized measured ω_K, ϖ_L, and ϖ_M results restricted to the period 1978–1993 are listed. These selected measured values are fitted by least squares to polynomials in Z of the form $\Sigma_n a_n Z^n$ and compared with theoretical and with earlier fitted values. A section on application of fluorescence yield data to computations of x-ray energy-absorption coefficients is included.

Key words: Auger effect; energy-absorption coefficient; fluorescence yield; ionization; photon; radiationless transitions; vacancies; x-ray.

Contents

---

[a] Present address 11830 Rocking Horse Rd., Rockville, MD 20852.

Reprints available from ACS; see Reprints List at back of issue.

0047-2689/94/23(2)/339/26/$12.00

1. Introduction: Definitions, History

Values of the fluorescence yield $\omega_i(Z)$, where i represents a given atomic electron shell or subshell, of an atom with atomic number Z, are required in a variety of applications including, for example, atomic physics studies, x-ray fluorescence (XRF) surface chemical analysis, and dosimetric computations for health physics, cancer therapy, and industrial irradiation processing. The focus of this work is on fluorescence yield information for the latter application, in particular the computation of the photon energy-absorption coefficient μ_{en}/ρ.

An excellent description of the fluorescence yield has been given by Compton and Allison (35Co01), briefly paraphrased as follows. When an inner shell atomic electron is ejected from an atom as a result of a collision process involving a photon or other incoming projectile, a vacancy is thus created in that electron's pre-collision subshell.

For incoming photons, such processes could be the photoelectric effect, Compton collisions, and triplet production (electron-positron pair production in the field of the atomic electrons, by photons with energy in excess of 2.04 MeV). Associated with this inner-shell vacancy is an excess of energy above the atom's ground state.

Deexcitation of the (many-electron) atom then occurs through a cascade of radiative and (mostly) radiationless events and, unless electrons are captured from the outside, the atom ends up in a multiply ionized state as discussed, e.g., by Krause *et al.* (71Kr01), rather than returning to the ground state of the neutral atom. A statistical (probabilistic) analysis of this complex series of events has been attempted by Jacobs and Rozsnyai (86Ja01). However, in many applications, the atom is assumed to return to its ground state, including filling the vacancy, by one of two modes.

In one mode a fluorescence (or characteristic) x-ray is emitted[b] from the atom, with photon energy equal to the difference between the vacancy-site inner-shell energy level and the energy level of the particular outer shell which happens to supply the electron to fill the vacancy. In the other mode, no fluorescence x-ray is emitted, but instead the excess energy is used to eject an outer-shell electron from the atom, in addition to the ejected electron causing the original vacancy. This second ejected electron is known as an Auger electron, after the cloud chamber confirmation and explanation by Auger (25Au01, 25Au02) of earlier conjectures by Sadler (09Sa01) and Barkla (17Ba01) and observations by Wilson (23Wi01, 23Wi02).

In simplest terms, the fluorescence yield $\omega_i(Z)$ is

$$\omega_i(Z) = \frac{f_i(Z)}{v_i(Z)} \qquad (1)$$

where $f_i(Z)$ is the average number of fluorescence (characteristic) x-rays emitted as a result of $v_i(Z)$ vacancies created in the i^{th} shell or subshell. In reality the situation is quite complex due to the multiplicity of transitions of varying likelihood involving the participating inner and outer subshells, the details of which are described in the extensive reviews by, e.g., Fink *et al.* (66Fi01, 74Fi01, 91Fi01), Bambynek *et al.* (72Ba01), Krause (79Kr01), Mitchell and Barfoot (81Mi01), and Cohen (87Co01). This work is an annex to, and not a replacement of, these earlier major reviews.

Compton and Allison (35Co01) and some later authors, e.g., Tertian and Claisse (82Te01) consider the Auger effect a two stage process, in which the characteristic x-ray is first emitted but then reabsorbed by an outer electron shell in a photoeffect type process. However, this two-stage picture is not in keeping with present-day understanding [Åberg and Howat (82Å01)]. Already, Wentzel (27We01) showed that the Auger effect is explained by *Fermi's Golden Rule #2* (50Fe01) [actually Wentzel's, although ascribed by Fermi to Schiff (49Sc01)] of perturbation theory.

The energy that is released when the primary vacancy is filled by an electron from a higher orbit is transferred to the *Auger* electron by a virtual photon—there is no real intermediate state. This is consistent with the picture given by other authors such as Burhop (52Bu01, 72Bu01), and by N. A. Dyson (73Dy01) who contends that the Auger effect must be a one stage process because of strong lines (such as $K \rightarrow L_1$ transition) in the Auger spectra which are forbidden in radiative transitions. A unified theory of the Auger effect and autoionization as resonance scattering has been developed by Åberg and Howat (82Åb01).

The annotated bibliography in this work combines an automated search of Physics Abstracts with a manual search, and focuses on the time period 1978–1993 following the Krause (79Kr01) 1979 review article. Additional text references are listed separately following the annotated bibliography.

2. Application of Fluorescence Yield Data in Computing Mass Energy-absorption Coefficients

The mass energy-absorption coefficient μ_{en}/ρ (cm^2/g or m^2/kg, where 1 cm^2/g = 0.1 m^2/kg), a key parameter in computations of energy deposited in media subjected to photon irradiation, is defined see, e.g., R. T. Berger (61Be01), Hubbell (77Hu01), Hubbell (82Hu01), Higgins *et al.* (92Hi01), and Seltzer (93Se01) as

$$\mu_{en}/\rho = (\mu/\rho)f \qquad (2)$$

In this expression, f is the average fraction of the incident photon energy E_0 which does not leave the site of the primary collision in the form of secondary photon radiation (fluorescence, Compton scattered photons, annihilation radiation, bremsstrahlung, etc.) but goes into kinetic energy of particles, particularly electrons, for dissipation locally in the medium via collision losses as ionization and excitation. Here μ/ρ is the total mass attenuation coefficient see, e.g., Hubbell (69Hu01) for a given incident photon energy E_0 in a given substance:

---

[b] Here and in what follows, we make the implicit assumption that excitation occurs well above threshold, so that excitation and deexcitation can be treated as distinct processes between which complete relaxation takes place. Also, the x-ray will not be characteristic, but a satellite, if the excitation process produces multiple vacancies through accompanying shake, which can happen with considerable probability [Åberg (67Åb01); Schaphorst (93Sc01) and references therein].

$$\mu/\rho = \sigma_{\text{incoh}}/\rho + \sigma_{\text{coh}}/\rho + \tau/\rho + \kappa_n/\rho + \kappa_e/\rho + \sigma_{\text{ph.n.}}/\rho \tag{3}$$

in which the significant interaction components are incoherent (Compton) scattering σ_{incoh}/ρ, coherent (Rayleigh) scattering σ_{coh}/ρ, atomic photoeffect τ/ρ, electron-positron pair production in the field of the atomic nucleus κ_n/ρ, pair production in the field of the atomic electrons (triplet production) κ_e/ρ, and photonuclear interactions (e.g., (γ,n), $(\gamma,2n)$, (γ,p), (γ,fiss), etc.) $\sigma_{\text{ph.n.}}/\rho$.

In Eqs. (2), (3), and (4) the units of μ/ρ and μ_{en}/ρ have been customarily cm^2/g, as well as all of the terms on the right-hand side of Eq. (3) (e.g., σ_{incoh}/ρ in cm^2/g). However, the preferred units for this quantities (μ/ρ, μ_{en}/ρ etc.) are in the SI base units m^2/kg (where 1 m^2/kg = 10 cm^2/g) as in the tables of Hubbell (82Hu01) and in ICRU Report 44 (89Ic01).

For computational purposes Eq. (2), using the information on the individual processes indicated in Eq. (3), becomes:

$$\mu_{en}/\rho = (\mu/\rho)f = (\sigma_{\text{incoh}}/\rho)f_{\text{incoh}} + (\tau/\rho)f_\tau + (\kappa_n/\rho)f_{\kappa_n} + (\kappa_e/\rho)f_{\kappa_e} + (\sigma_{\text{ph.n.}}/\rho)f_{\sigma_{\text{ph.n.}}} \tag{4}$$

in which the σ_{coh}/ρ term in Eq. (3) is omitted because the coherent scattering process deposits negligible energy at the collision site. Also, in existing μ_{en}/ρ tables, the photonuclear term $(\sigma_{\text{ph.n.}}/\rho)f_{\sigma_{\text{ph.n.}}}$ has been ignored. In Eq. (4) the energy-absorption weighting fractions f_{incoh}, f_τ, f_{κ_n}, and f_{κ_e} follow the f definition in Eq. (2), each for the individual interaction process indicated.

Although the incoherent scattering σ_{incoh}/ρ and triplet production κ_e/ρ processes produce vacancies in the atomic electron subshells, resulting in the emission of either fluorescence photons or Auger electrons, existing tables ignore fluorescence emission (in effect, set $\omega_i = 0$) for these processes in which the subshell distribution of vacancy creation is not well known. An example of one of the few available vacancy cascade studies mentioning this effect (Compton ionization) is the work on Kr by Krause and Carlson (67Kr01). Computational procedures for evaluating f_{incoh} and f_κ (treating κ_n and κ_e alike), ignoring fluorescence, are given, e.g., by Hubbell (77Hu01) and by Higgins *et al.* (92Hi01). However, a treatment incorporating the full cascade is now available in newer and more detailed calculations by Seltzer (93Se01).

For the atomic photoeffect term $(\tau/\rho)f_\tau$, Hubbell (77Hu01) calculated f_τ using the formulation by R. T. Berger (61Be01), modified as suggested by Carlsson (71Ca01) to include additional fluorescence cascade effects. For each atomic electron shell group i, where i signifies $K, L, M, \ldots$, a photoeffect energy-absorption fraction f_{τ_i} was calculated for each incident photon energy E_0 and element Z as

$$f_{\tau_i}(E_0,Z) = \left(1-\frac{\eta_i}{E_0}\right)\cdot[1-G_{\text{br}}(E_0-\eta_i)] + \frac{\eta_i}{E_0}\left(1 - \frac{\omega_i E_i}{\eta_i} - N_{i,\,i+1}\,\frac{\omega_{i+1}\,E_{i+1}}{\eta_1}\right) \tag{5}$$

in which η_i is the mean absorption-edge energy of the i-shell, $G_{\text{br}}(E_0\text{-}\eta_i)$ is the bremsstrahlung yield see, e.g., Berger and Seltzer (83Be01) and ICRU (84Ic01) for the photoelectron of energy $E_0 - \eta_i$, ω_i is the i-shell fluorescence yield, E_i is the i-shell fluorescence x-ray mean energy, and $N_{i,\,i+1}$ is the average number of vacancies created in the $(i + 1)$-shell per primary i-shell vacancy.

For μ_{en}/ρ in mixtures, where the bremsstrahlung yield $G_{\text{br}}(E_0\text{-}\eta_i)$ is a function of the matrix rather than the atom suffering the primary collision, further refinements in the computations have been proposed by Attix (84At01), and have been implemented by Seltzer (93Se01).

Since the K fluorescence x-rays predominate over the L x-rays, and L x-rays over M x-rays, etc., both in photon energy and yield, particularly for low-Z elements, the approximation f'_τ for the photoeffect energy-absorption fraction f_τ has sometimes been used, e.g., by R. T. Berger (61Be01), in computing μ_{en}/ρ:

For E_0 above the K edge:

$$(\tau/\rho)f'_\tau \approx (\tau_K/\rho)\left(1 - \frac{\omega_K\bar{E}_K}{E_0}\right) + (\tau_L/\rho) + (\tau_M/\rho) + \ldots \tag{6}$$

which reduces to

$$f'_\tau \approx 1 - \frac{(\tau_K/\rho)}{(\tau/\rho)}\left(\frac{\omega_K\bar{E}_K}{E_0}\right) . \tag{7}$$

For E_0 between the K and L edge:

$$(\tau/\rho)f'_\tau \approx (\tau_L/\rho)\left(1 - \frac{\varpi_L\bar{E}_L}{E_0}\right) + (\tau_M/\rho) + \ldots \tag{8}$$

or

$$f'_\tau \approx 1 - \frac{(\tau_L/\rho)}{(\tau/\rho)}\left(\frac{\varpi_L\bar{E}_L}{E_0}\right) . \tag{9}$$

and similarly between the L and M edges:

$$f'_\tau \approx 1 - \frac{(\tau_M/\rho)}{(\tau/\rho)}\left(\frac{\varpi_M\bar{E}_M}{E_0}\right) \tag{10}$$

with further ad hoc approximations within the L and M multiple-edge regions.

3. *K*-Shell Fluorescence Yield ω_K

The bulk of the fluorescence yield measurements reported in the literature have been for the K shell, and this trend has continued through the 1978–1993 period, as indicated in the annotated bibliography in Sec. 11 in this report. A semi-empirical fitting formula for ω_K, introduced by Burhop (55Bu01), has become established in the literature, of the form

$$\left(\frac{\omega_K}{1-\omega_K}\right)^{1/4} = C_0 + C_1Z + C_2Z^2 + C_3Z^3 = \sum_{i=0}^{3} C_iZ^i \tag{11}$$

which can be rewritten

$$\omega_K = \frac{\left[\sum_{i=0}^{3} C_iZ^i\right]^4}{1 + \left[\sum_{i=0}^{3} C_iZ^i\right]^4} . \tag{12}$$

This same fitting formula, with different sets of C_i coefficients, has been applied to average L-shell fluorescence yields ϖ_L, as will be seen in Sec. 4 following.

Bambynek *et al.* (72Ba01), in their 1972 review article (the most comprehensive and widely quoted fluorescence yield reference to date), have fitted their collection of "selected 'most reliable' experimental values," listed in their Table III.IV with parameters for Eq. (12), above, of values:

$$\begin{aligned} C_0 &= 0.015 \pm 0.010 \\ C_1 &= 0.0327 \pm 0.0005 \\ C_2 &= 0 \\ C_3 &= -(0.64 \pm 0.07) \times 10^{-6} \ . \end{aligned} \tag{13}$$

In Table 1 of this work, ω_K values for $3 \leqslant Z \leqslant 110$, matching the range of the Krause (79Kr01) table, generated from the above Eqs. (12) and (13), are given in the first ω_K column, and are compared with measured values (averaged when more than one measurement per element is given) in the next column.

In a subsequent review, Krause (79Kr01) incorporated additional new data in a revised evaluation, and presented a table of ω_K *adopted values* for all elements $5 \leqslant Z \leqslant 110$, but did not provide a corresponding parametric fit or fits. These 1979 Krause adopted values are included in Table 1 of this work, also percent differences of these adopted values from the 1972 Bambynek *et al.* (72Ba01) fit.

In 1984 Bambynek (84Ba01) presented a further reevaluation of ω_K, incorporating about 100 new measurements subsequent to the 1972 Bambynek *et al.* (72Ba01) evaluation. Using a stepwise regression analysis with 119 selected ω_K measurements, Bambynek fitted his new evaluation to the form in Eq. (12) above, with parameters C_i now:

$$\begin{aligned} C_0 &= 0.0370 \pm 0.0052 \\ C_1 &= 0.03112 \pm 0.00044 \\ C_2 &= (5.44 \pm 0.11) \times 10^{-5} \\ C_3 &= -(1.250 \pm 0.070) \times 10^{-6} \ . \end{aligned} \tag{14}$$

This revised fit was used to generate the ω_K values in the next to the last column in Table 1 for all elements $3 \leqslant Z \leqslant 110$.

For $35 \leqslant Z \leqslant 107$ the 1984 values differ from the 1972 values by less than 1%. For $3 \leqslant Z \leqslant 34$ the new values exceed the old by more than 1%, and for $3 \leqslant Z \leqslant 11$ by more than 10%. However, in the range $3 \leqslant Z \leqslant 11$ ω_K is small, ranging from 2.928×10^{-4} for $Z = 3$ to 0.02133 for $Z = 11$. Since ω_K enters the computations of photon energy-absorption coefficients μ_{en}/ρ approximately as $[1 - \omega_K(\bar{E}_K/E_0)]$, see Eq. (6), where $\bar{E}_K/E_0 < 1$, these differences, even the 78.5% at $Z = 3$, result in less than 1% differences in μ_{en}/ρ for all elements $3 \leqslant Z \leqslant 100$.

The fitting formula Eq. (12), rewritten from Eq. (11), with the 1984 Bambynek (84Ba01) parameters in Eq. (14) is the ω_K evaluation which was used in the Higgins *et al.* (92Hi01) and Seltzer (93Se01) μ_{en}/ρ computations, and the numerical values are repeated for convenience in the summary Table 8 for $3 \leqslant Z \leqslant 100$. However a new polynomial fit to weighted averages of more-recent well-characterized measured data for $11 \leqslant Z \leqslant 99$ is described in Sec. 7 and presented in Table 4 of this work, with coefficients given in Table 7, and is here recommended for future applications as discussed in Sec. 8.

4. L-Shell Average Fluorescence Yield ϖ_L

The status of fluorescence yield data for the L subshells L_1, L_2, and L_3, and particularly for the average yield ϖ_L, is well summarized in the recent reviews by Cohen (87Co01) and by Jitschin (90Ji01). Jitschin summarizes and discusses measurements of ω_{L1}, ω_{L2} and ω_{L3}, also Coster-Kronig and Auger yields, over the time period 1980–1990. Jitschin classifies the measurement methods as (a) crystal spectrometer, (b) $K_\alpha - L_\alpha$ coincidence, and (c) synchrotron photoionization. In his summary table Jitschin (90Ji01) also includes two earlier papers by Campbell *et al.* (74Ca01, 75Mc02) which report $e^- - L$-x-ray coincidence measurements in Pb of ω_{L1} and the Coster-Kronig yields f_{12} and f_{13}.

For the atomic photoeffect process, the average L-shell fluorescence yield ϖ_L is defined (see, for example Krause in 78Kr01, 79Kr01) as

$$\varpi_L = (\sigma_{L1}\nu_1 + \sigma_{L2}\nu_2 + \sigma_{L3}\omega_3)/\sigma_L \tag{15}$$

in which σ_{L1}, σ_{L2}, σ_{L3} and σ_L are the L_1, L_2 and L_3 individual L-subshell and total L-shell photoeffect cross sections (e.g., from Scofield 73Sc01). ν_1, ν_2 and ω_3 are the effective subshell fluorescence yields which are discussed and defined in more detail by Krause in (80Kr01), who has also pointed out the generally weak dependence of the average L fluorescence yield on the initial vacancy distribution (93Kr01).

On the other hand, there are circumstances in which the L fluorescence yield can depend critically on the vacancy distribution among the three L subshells, which can have quite different effective fluorescence yields. Where Coster-Kronig channels are open, the vacancies in the more tightly bound subshells will predominantly *bubble up* to the L_3 ($2p_{3/2}$) subshell before the next step in the cascade takes place. However, some Coster-Kronig transitions are energetically cut off in certain regions of the periodic table [Chen *et al.* (71Ch01), Crasemann *et al.* (71Cr01), Chen *et al.* (77Ch01)]. Then the vacancy distribution among the subshells can make a big difference, and it in turn depends critically on the mode of excitation. Thus, what is the *average* yield in one experiment can be very different from the *average* yield in another experiment if the excitation mechanisms (and energies) are different in the two. In this work, photoionization substantially above threshold, rather than, for example, collisions with charged particles, or decays of radioactive atoms (see, e.g., 75Ra01), is assumed to be the excitation mechanism.

Cohen (87Co01) presents, besides tables and standard-form fits (Eq. (12)) of the ϖ_L values given by Bambynek *et al.* (72Ba01) and by Mitchell and Barfoot (81Mi01), new theoretical values of ϖ_L calculated using the ECPSSR (*E*nergy loss, *C*oulomb deflection, *P*erturbed *S*tationary *S*tate, *R*elativistic effects) theory of Brandt and Lapicki (79Br01) and the resulting L-shell ionization cross sections computed by Cohen and Harrigan (85Co02).

Cohen's (87Co01) fitting parameters for ϖ_L in Eq. (12) are:
Bambynek *et al.* (72Ba01), ϖ_L, $23 \leq Z \leq 96$:

$$C_0 = 0.238209 \\ C_1 = -0.00216099 \\ C_2 = 1.85156 \times 10^{-4} \\ C_3 = -7.47647 \times 10^{-7} \quad (16)$$

Mitchell and Barfoot (81Mi01), ϖ_L, $23 \leq Z \leq 92$:

$$C_0 = 0.326968 \\ C_1 = -0.00242879 \\ C_2 = 1.71660 \times 10^{-4} \\ C_3 = -6.96583 \times 10^{-7} \quad (17)$$

Cohen (87Co01), ϖ_L, ECPSSR, $30 \leq Z \leq 96$:

$$C_0 = 0.177650 \\ C_1 = 0.00298937 \\ C_2 = 8.91297 \times 10^{-5} \\ C_3 = -2.67184 \times 10^{-7} \quad (18)$$

Numerical values generated from these fits are compared with the tables presented by Cohen (87Co01), in Table 2 of this work.

The Cohen ECPSSR fit, using the above Eq. (18) parameters, was extended to lower Z's, down to $Z = 3$, the first element with an L-shell electron, under the assumption that electrons external to the atom could participate in the fluorescence process. The ϖ_L values computed from the fit for the lowest Z's appeared too high, exceeding the ω_K values. However, the Mitchell and Barfoot (81Mi01) table actually extends down to $Z = 12$, based on results in a thesis by Hoffmann (78Ho01).

A log-log plot of the Mitchell-Barfoot-Hoffmann values was found to be linear over the range $12 \leq Z \leq 50$ except for two anomalously low points for $Z = 17$ and 18, perhaps due to round-off in the two-digit table. Using the slope of this log-log linear plot, and normalizing from 0.024 to the 3-digit 0.0242 ECPSSR Cohen-fit value at $Z = 37$ a fit is here presented:

For ϖ_L, $11 \leq Z \leq 36$:

$$\varpi_L = 1.9390 \times 10^{-8} \times Z^{3.8874} \quad (19)$$

In the summary Table 8 from (89Hu01), the values of ϖ_L were generated using Eq. (19) for $11 \leq Z \leq 36$, and Eq. (12) with the Cohen (87Co01) ECPSSR fit parameters in the above Eq. (18) for $37 \leq Z \leq 100$, and these ϖ_L values were used in the Higgins *et al.* (92Hi01) and Seltzer (93Se01) μ_{en}/ρ computations. However, a new polynomial fit to weighted averages of 1983–1993 evaluated measured data for $26 \leq Z \leq 92$ is described in Sec. 7 with numerical values presented in Table 5 of this work and coefficients given in Table 7, and is here recommended for future ϖ_L applications for $Z \geq 26$, as discussed in Sec. 8.

5. *M*-Shell Average Fluorescence Yield ϖ_M

An extended-range table of M-shell average fluorescence yield values ϖ_M, suitable for systematic computations of mass energy-absorption coefficients μ_{en}/ρ, was not found in the literature, so this work has undertaken to provide recommended ϖ_M fits and tables.

Burhop (55Bu01) fitted the ϖ_M Lay (34La01) and Jaffe (54Ja01) data available in 1955 by a formula

$$\varpi_M = 1.7 \times 10^{-9} (Z\text{-}13)^4 \quad (20)$$

Subsequent measurements by Jopson *et al.* (65Jo01), corrected by Bambynek *et al.* (72Ba01) for a 20% correction from double M-shell vacancies to convert ω_{LM} into ϖ_M data, and by Konstantinov and Sazonova (68Ko01), by Hribar *et al.* (82Hr01), and by Shatendra *et al.* (84Sh01) are shown in Table 3. The average difference of all three measurements 1934–1984 from the Burhop (55Bu01) Eq. (20) values is a factor 0.758, with no significant trend as a function of Z over this limited high-Z range $76 \leq Z \leq 92$.

Hence a recommended fit has been proposed (89Hu01):

$$\varpi_M = 0.758 \times 1.7 \times 10^{-9} (Z\text{-}13)^4 \\ = 1.29 \times 10^{-9} (Z\text{-}13)^4 \quad (21)$$

from which numerical values are given in the last column in Table 3, and for the range $19 \leq Z \leq 100$ in the summary Table 8.

Also shown in Table 3, for comparison, are some theoretical ϖ_M values derived from Chen *et al.* (80Ch02) and given by Sarkar *et al.* (81Sa01). The Chen *et al.* (80Ch02) values listed were obtained from their theoretical ω_{M_4} and ω_{M_5} values using a recipe quoted by McGuire (72Mc01) from Jopson *et al.* (65Jo01):

$$\varpi_M \approx \varpi_{LM} \approx 0.4\ \omega_{M_4} + 0.6\ \omega_{M_5} \quad (22)$$

The Sarkar *et al.* (81Sa01) values listed in Table 3 were also derived from the Chen *et al.* (80Ch02) theoretical ω_{M_i} subshell values, but by Sarkar *et al.* using the relation

$$\varpi_M = \sum_{i=1}^{5} \frac{1}{18} N_{M_i}\, \omega_{M_i} \quad (23)$$

in which N_{M_i} are the numbers of electrons in each M_i subshell.

Equation (21), used in generating the ϖ_M values listed in the summary Table 8 for $19 \leq Z \leq 100$, could be further refined by including additional ω_{M_i} subshell measurements by Karttunen *et al.* (71Ka01) and by Baker *et al.* (74Ba01), perhaps combined using Eq. (23) above.

In the present work, a further ϖ_M analysis has been undertaken, incorporating more-recent measurements $64 \leq Z \leq 92$ up through 1993 as described in Sec. 7, with the results given in Table 6 including values generated from a new polynomial fit.

6. *N*- and Higher-Shell Average Fluorescence Yields

No N-shell or higher shell measurements were found in the literature. For the N shell, the best source of ϖ_N data, if required, is probably the theoretical work of McGuire (74Mc01), which provides ω_{N_1}, ω_{N_2}, and ω_{N_3} values for 25 elements over the range $38 \leq Z \leq 103$, and ω_{N_4}, ω_{N_5}, and $\omega_{N_{6,7}}$ values for 20 elements over the range $50 \leq Z \leq 103$. For average ϖ_N values, this information would need to be combined using an expression analogous to either Eq. (22) or (23) above.

As a cautionary note on the McGuire (74Mc01) results, Chantler (93Ch01) has pointed out to the authors a comment in a paper by Ohno and Wendin (85Oh01) that, although the McGuire results (75Mc01) have become a standard reference, an extensive comparison by Fuggle and Alvarado (80Fu01) of experimental core-hole linewidths in the N shell with Mcguire's calculations (74Mc01) revealed large differences between theory and experiment for Coster-Kronig type of transitions. However, good agreement is found over extensive ranges of the periodic table, hence the McGuire (74Mc01) results are here recommended for the N shell until replaced by improved systematic calculations and tabulations.

7. A Further Analysis and Fits Using 1978–1993 Measured Data

In this section we present a new analysis, using selected x-ray production (XRP) cross section and fluorescence yield measurements for the K-, L- and M-shells by both photons and charged particles from the period 1978–1993 (including also one 1977 paper). For those works in which the XRP cross sections were given, the fluorescence yields were obtained from the cross section values using the relation

$$\omega_{K/L/M} = \frac{\sigma^{x}_{K/L/M}}{\sigma_{K/L/M}} \tag{24}$$

where $\sigma^{x}_{K/L/M}$ denotes the total measured x-ray production cross section and $\sigma_{K/L/M}$ is the K-, L- or M-shell ionization cross section, respectively. We used the values of the ionization cross sections given by Scofield (73Sc01) and by Cohen (85Co02) for photons and protons, respectively.

$\sigma^{x}_{K/L/M}$ measured x-ray production cross sections were evaluated by adding the (K_α and K_β) XRP cross sections for K x-rays, (L_l, L_α, L_β and L_γ) XRP cross sections for the L x-rays, and in the case of M x-rays, since different components were not resolved, therefore the total M XRP cross sections were directly obtained. The fluorescence yield data for the K, L and M shells thus derived from XRP measurements according to Eq. (24) are presented in column 2 of the Tables 4, 5, and 6, respectively. The uncertainties shown are quoted from the originating authors.

In the cases where the XRP cross sections were reported at more than one incident energy of the exciting particle (photons, charged particles), the values of the i^{th} shell fluorescence yields, ω_i (i = K, L, M), for an element were obtained by taking the weighted average of the ω_j values available at different incident energies, using the expression

$$\omega_i = W \sum_j \left[\frac{\omega_j}{(\Delta\omega_j)^2} \right], \quad W = \frac{1}{\sum_j (\Delta\omega_j)^{-2}} \tag{25}$$

where ω_j denotes the j^{th} experimentally deduced fluorescence yield and ($\Delta\omega_j$) represents the quoted uncertainty in the j^{th} experimental value. These weighted-average ω_i values are listed in column 3 of the Tables 4, 5, and 6.

The averaged (for each Z) experimental values of fluorescence yields were least squares fitted to polynomials in Z of the form

$$\omega_i = \sum_{n=0} a_n Z^n \quad . \tag{26}$$

Precaution was taken to avoid any undesirable oscillations in the regions between the calculated points. The values of the fitting coefficients a_n and the atomic-number ranges of validity of the polynomials are given in Table 7. The fitted values are presented in column 4 of the Tables 4, 5, and 6.

The theoretical average L shell fluorescence yields based on the RDHS (relativistic Dirac-Hartree-Slater) model, ϖ_L(RDHS), were taken from Puri *et al.* (93Pu04). In this reference the L_i subshell fluorescence (ω_i, i = 1,2,3) and Coster-Kronig (f_{ij}) yields have been evaluated using RDHS model based radiative and non-radiative transition rates from Scofield (74Sc01) and Chen *et al.* (79Ch02), respectively. The cutoffs and onsets of different Coster-Kronig transitions have been properly considered in these calculations. The ϖ_L values were further evaluated using these calculated ω_i and f_{ij} values.

In the case of the M shell, theoretical data (72Mc01, 80Ch02, 83Ch01) on ω_i(i=1,2,3,4,5), f_{ij}, and the super Coster-Kronig transition probabilities S_{ij} are available for a limited number of elements in the atomic-number region of interest. The values of these parameters for intermediate elements were obtained using spline interpolation. The interpolated values were used in the present calculations of theoretical average M shell fluorescence yields. As a word of caution, Krause (93Kr01) points out that there are inherent limitations in the single particle calculations for M and N shell parameters such as the early calculations by McGuire (72Mc01) and by Chen *et al.* (80Ch02, 83Ch01). These limitations are discussed by Karim and Crasemann (85Ka01) in their calculations of L-shell Coster-Kronig transition rates for Ar, including the effects of final-state channel mixing.

8. General Discussion

The values of K shell fluorescence yields ω_K generated from the polynomial fitting of the experimental data, using Eq. (26) and the K shell coefficients a_n in Table 7, are compared in Table 4 with the semi-empirical values of Krause (79Kr01) and with the values listed in the earlier report by Hubbell (89Hu01) generated from the 1984 Bambynek fit (84Ba01). The latter three data sets are seen to be in general agreement within the uncertainties indicated in the experimental-value column, which range from the order of 10% for $Z = 11$ to the order of 1% for $Z = 80$ and above.

The present fitted values of the average L shell fluorescence yields, ϖ_L(fit), are compared with the ϖ_L(RDHS) (93Pu04) and ϖ_L(ECPSSR) (87Co01) values, and also with the 1989 Hubbell listing (89Hu01), in Table 5. The ϖ_L(RDHS) (93Pu04) values are higher than the ϖ_L (ECPSSR) (87Co01) by up to 12% in the atomic-number region $32 \leqslant Z \leqslant 77$ and up to 21% for elements with $Z < 32$. These two sets are in good agreement with each other for elements with $Z > 77$. It is clear from Table 5 that the ϖ_L(fit) values are in good agreement with the ϖ_L(RDHS) (93Pu04) values for the elements in the region $28 \leqslant Z \leqslant 92$. For the elements with $48 \leqslant Z \leqslant 77$, the fitted values are higher than the ϖ_L(ECPSSR) (87Co01) by up to 20% whereas outside this atomic-number region the two sets are in agreement with each other. In our polynomial fitting in this work, we omitted the here-listed experimental ϖ_L values in the region $40 \leqslant Z \leqslant 53$ from Singh *et al*. (83Si02) because of the large deviations from the other available but limited data. As further measured data become available, this omission may be reconsidered in future fitting attempts.

The fitted average *M* shell fluorescence yields ϖ_M(fit) and the two sets of theoretical values ϖ_M (Chen) (80Ch02, 83Ch01) and ϖ_M (McGuire) (72Mc01), also the 1989 Hubbell fit (89Hu01), are compared in Table 6. The two sets of theoretical values of ϖ_M agree with each other for the elements with $70 \leqslant Z \leqslant 92$ except for $Z = 90$ where the ϖ_M (Chen) is lower than the ϖ_M (McGuire) value by 20%. Above $Z = 90$, the theoretical data based on AHS ([non-relativistic] approximate Herman Skillman) calculations of McGuire (72Mc01) are not available.

Below $Z = 70$, RDHS model (80Ch02, 83Ch01) based data for the *M* shell on ω_i ($i = 1,2,3,4,5$), f_{ij} and S_{ij} are not available. From Table 6 we note that the fitted values ofϖ_M for the elements in the region $64 \leqslant Z \leqslant 92$ agree with both the sets of theoretical values except for $Z = 90$, where the ϖ_M(fit) value is closer to the ϖ_M (McGuire) value. The ϖ_M(fit) values for the elements in the region $64 \leqslant Z \leqslant 92$ are found to be as much as 22% higher than the Burhop-formula (55Bu01) fitted 1989 values of Hubbell (89Hu01) which are included in this comparison since they have been used as input data to some practical applications including the recent μ_{en}/ρ calculations by Higgins *et al*. (92Hi01) and Seltzer (93Se01).

We note from the above discussion that:

(a) The present ω_K(fit) values in Table 4 are in good agreement with the semi-empirical values of Krause (79Kr01) and are well supported by the RDHS model based values of Chen (80Ch01) over the atomic-number region $17 \leqslant Z \leqslant 80$. The 1989 Hubbell (89Hu01) ω_K values generally agree with the present fitted values within the stated experimental uncertainties, in many cases falling between the experimental values and the present fitted values.

(b) The present ϖ_L(fit) values in Table 5 are best explained by the ϖ_L(RDHS) (93Pu01) values over the atomic number region $28 \leqslant Z \leqslant 92$. The earlier Hubbell ϖ_L listings (89Hu01), generated from the Cohen (87Co01) standard-form parametric fit [Eq. (12), using Eq. (18) parameters, $Z = 37$ to 100, Eq. (19) for $Z = 3$ to 36] to his ECPSSR model results, deviate from the present polynomial fit in the region $46 \leqslant Z \leqslant 53$ by amounts ranging from 10% to 18% (for $Z = 52$); however, the listed independent measurements differ by similar amounts, as much as 24% for $Z = 49$, as discussed above.

(c) The present ϖ_M(fit) values in Table 6 are seen to be in good agreement with both the Chen (80Ch02, 83Ch01) and the McGuire (72Mc01) theoretical values in the atomic number region $64 \leqslant Z \leqslant 92$. The 1989 Hubbell (89Hu01) ϖ_M values, although systematically lower than the present work for $Z \geqslant 70$, are seen to be in reasonable agreement for $Z < 70$, and could be used to extend the present fitted values down to $Z = 13$ in applications where this *Z* range is needed.

In view of these observations, the authors recommend the use of the polynomial fitted values [Eq. (26), using the coefficients given in Table 7] of the *K*-, *L*- and *M*-shell fluorescence yields for various applications. Nevertheless, the 1989 Hubbell (89Hu01) values in Table 8, along with their generating functions, are still included in this paper for applications where these extended ranges are required.

9. Tables 1 to 8: $\omega_K, \varpi_L, \varpi_M$, Analyses and Fits

TABLE 1. ω_K: Comparison of earlier fits, tables, $3 \leq Z \leq 110$

Z	Bambynek *et al.*, 1972 fit[a]	Bambynek *et al.*, 1972 most rel. exper.	% Diffs. exper. from 1972 fit	Krause 1979 adopted table	% Diffs. 1979 adopted from 1972 fit	Bambynek 1984 fit[a]	% Diffs. 1984 fit to 1972 fit
3 Li	[1.64(−4)][a]					[2.928(−4)][a]	78.5%
4 Be	[4.51(−4)][a]					[6.929(−4)][a]	53.6
5 B	[.00101][a]			.0017	68.3%	[.001409][a]	39.5
6 C	[.00198][a]			.0028	41.4	.002575	30.1
7 N	[.00351][a]			.0052	48.1	.004349	23.9
8 O	[.00579][a]			.0083	43.4	.006909	19.3
9 F	[.00902][a]			.013	44.1	.01045	15.9
10 Ne	[.0134][a]			.018	34.3	.01519	13.4
11 Na	[.0192][a]			.023	19.8	.02133	11.1
12 Mg	[.0265][a]			.030	13.3	.02911	9.8
13 Al	.0357	.0380	6.4%	.039	9.2	.03872	8.5
14 Si	.0469	.043	−8.3	.050	6.6	.05037	7.4
15 P	.0603	.060	−.5	.063	4.5	.06422	6.5
16 S	.0760	.082	7.9	.078	2.6	.08038	5.8
17 Cl	.0941	.0955	1.5	.097	3.1	.09892	5.1
18 Ar	.115	.122	6.1	.118	2.6	.1199	4.3
19 K	.138			.140	1.4	.1432	3.8
20 Ca	.163			.163	0	.1687	3.5
21 Sc	.190	.190	0	.188	−1.1	.1962	3.3
22 Ti	.219	.221	.9	.214	−2.3	.2256	3.0
23 V	.249	.253	1.6	.243	−2.4	.2564	3.0
24 Cr	.281	.283	.7	.275	−2.1	.2885	2.7
25 Mn	.314	.313	−.3	.308	−1.9	.3213	2.3
26 Fe	.347	.342	−1.4	.340	−2.0	.3546	2.2
27 Co	.381	.366	−3.9	.373	−2.1	.3880	1.8
28 Ni	.414			.406	−1.9	.4212	1.7
29 Cu	.446	.443	−.7	.440	−1.3	.4538	1.7
30 Zn	.479			.474	−1.0	.4857	1.4
31 Ga	.510	.528	3.5	.507	−.6	.5166	1.3
32 Ge	.540	.554	2.6	.535	−.9	.5464	1.2
33 As	.568	.589	3.6	.562	−1.1	.5748	1.2
34 Se	.596			.589	−1.2	.6019	1.0
35 Br	.622			.618	−.6	.6275	.9
36 Kr	.646	.660	2.2	.643	−.5	.6517	.9
37 Rb	.669	.669	0	.667	−.3	.6744	.8
38 Sr	.691	.702	1.6	.690	−.1	.6956	.7
39 Y	.711			.710	−.1	.7155	.6
40 Zr	.730			.730	0	.7340	.5
41 Nb	.747			.747	0	.7512	.6
42 Mo	.764			.765	.1	.7672	.4
43 Te	.779			.780	.1	.7821	.4
44 Ru	.793			.794	.1	.7958	.4
45 Rh	.806			.808	.2	.8086	.3
46 Pd	.818			.820	.2	.8204	.3
47 Ag	.830	.843	.5	.831	.1	.8313	.2
48 Cd	.840			.843	.4	.8415	.2
49 In	.850			.853	.4	.8508	.1
50 Sn	.859			.862	.3	.8595	.1
51 Sb	.867			.870	.3	.8676	.1
52 Te	.875	.857	−2.1	.877	.2	.8750	0
53 I	.882			.884	.2	.8819	0
54 Xe	.888	.894	.7	.891	.3	.8883	0
55 Cs	.895	.889	−.7	.897	.2	.8942	−.1
56 Ba	.900			.902	.2	.8997	0
57 La	.906			.907	.1	.9047	−.1
58 Ce	.911			.912	.1	.9096	−.2
59 Pr	.915			.917	.2	.9140	−.1
60 Nd	.920			.921	.1	.9181	−.2
61 Pm	.924			.925	.1	.9220	−.2
62 Sm	.927			.929	.2	.9255	−.2

TABLE 1. ω_K: Comparison of earlier fits, tables, $3 \leq Z \leq 110$ — Continued

Z	Bambynek *et al.*, 1972 fit[a]	Bambynek *et al.*, 1972 most rel. exper.	% Diffs. exper. from 1972 fit	Krause 1979 adopted table	% Diffs. 1979 adopted from 1972 fit	Bambynek 1984 fit[a]	% Diffs. 1984 fit to 1972 fit
63 Eu	.931	.925	−.6	.932	.1	.9289	−.2
64 Gd	.934			.935	.1	.9320	−.2
65 Tb	.937			.938	.1	.9349	−.2
66 Dy	.940	.943	.3	.941	.1	.9376	−.2
67 Ho	.943			.944	.1	.9401	−.2
68 Er	.945			.947	.2	.9425	−.3
69 Tm	.947			.949	.2	.9447	−.2
70 Yb	.950			.951	.1	.9467	−.3
71 Lu	.952			.953	.1	.9487	−.3
72 Hf	.954			.955	.1	.9505	−.4
73 Ta	.956			.957	.1	.9522	−.4
74 W	.957			.958	.1	.9538	−.3
75 Re	.959			.959	0	.9553	−.4
76 Os	.960			.961	.1	.9567	−.3
77 Ir	.962			.962	0	.9580	−.4
78 Pt	.963	.967	.4	.963	0	.9592	−.4
79 Au	.964			.964	0	.9604	−.4
80 Hg	.966	.958	−.8	.965	−.1	.9615	−.5
81 Tl	.967			.966	−.1	.9625	−.5
82 Pb	.968	.972	.4	.967	−.1	.9634	−.5
83 Bi	.968			.968	0	.9643	−.4
84 Po	.970			.968	−.2	.9652	−.5
85 At	.971			.969	−.2	.9659	−.5
86 Rn	.972			.969	−.3	.9667	−.5
87 Fr	.972			.970	−.2	.9674	−.5
88 Ra	.973			.970	−.3	.9680	−.5
89 Ac	.974			.971	−.3	.9686	−.6
90 Th	.975			.971	−.4	.9691	−.6
91 Pa	.975			.972	−.3	.9696	−.6
92 U	.976	.970	−.6	.972	−.4	.9701	−.6
93 Np	[.977][a]			.973	−.4	.9706	−.7
94 Pu	[.977][a]			.973	−.4	.9710	−.6
95 Am	[.978][a]			.974	−.4	.9713	−.7
96 Cm	[.978][a]			.974	−.4	.9717	−.6
97 Bk	[.979][a]			.975	−.4	.9720	−.7
98 Cf	[.979][a]			.975	−.4	.9722	−.7
99 Es	[.980][a]			.975	−.5	.9725	−.8
100 Fm	[.980][a]			.976	−.4	[.9727][a]	−.7
101 Md	[.980][a]			.976	−.4	[.9729][a]	−.7
102 No	[.981][a]			.976	−.5	[.9730][a]	−.8
103 Lw	[.981][a]			.977	−.4	[.9732][a]	−.8
104	[.981][a]			.977	−.4	[.9732][a]	−.8
105	[.982][a]			.977	−.5	[.9733][a]	−.9
106	[.982][a]			.978	−.4	[.9733][a]	−.9
107	[.982][a]			.978	−.4	[.9734][a]	−.9
108	[.983][a]			.978	−.5	[.9733][a]	−1.0
109	[.983][a]			.978	−.5	[.9733][a]	−1.0
110	[.983][a]			.979	−.4	[.9732][a]	−1.0

---

[a] Values in square brackets [ ] are outside the regions of validity of the fits by Bambynek *et al.* (72Ba01) and by Bambynek (84Ba01). These unjustified extrapolations, using the fits, are included only to provide non-zero numerical data where required in some applications.

TABLE 2. Summary and analysis of Cohen (87Co01) ϖ_L review, fits, and tabulations, including ECPSSR (Energy loss, Coulomb deflection, Perturbed Stationary State, Relativistic effects)

Z	Bambynek *et al.*, 1972 ϖ_L table	Bambynek *et al.*, 1972 ϖ_L fit	% diff. fit from table	Mitchell & Barfoot 1981 ϖ_L table	Mitchell & Barfoot 1981 ϖ_L fit	% Diff. fit from table	Cohen 1987 ECPSSR ϖ_L table	Cohen 1987 ECPSSR ϖ_L fit	% Diff. fit from table
23 V	.00235	.00588	+150.2%	.0038	.0154	+305.%			
24 Cr									
25 Mn	.00295	.00685	132.2	.0052	.0170	+227.			
26 Fe									
27 Co									
28 Ni				.0081	.0201	+148.	.0092	.0111	+20.7%
29 Cu	.0056	.00951	69.8	.0093	.0213	129.	.0105	.0121	15.2
30 Zn				.011	.0226	105.	.0117	.0132	12.8
31 Ga	.0064	.0113	76.6	.012	.0240	100.	.0131	.0145	10.7
32 Ge				.014	.0255	82.1	.0145	.0158	9.0
33 As				.015	.0271	80.7	.0161	.0172	6.8
34 Se				.017	.0289	70.0	.0177	.0188	6.2
35 Br				.019	.0308	62.1	.0198	.0204	3.0
36 Kr				.022	.0329	49.5	.0219	.0222	1.4
37 Rb	.010	.0192	92.0	.024	.0351	46.3	.0241	.0242	.42
38 Sr				.027	.0375	38.9	.0262	.0263	.38
39 Y	.0315	.0229	−27.3	.030	.0401	33.7	.0288	.0285	−1.0
40 Zr				.033	.0428	29.7	.0313	.0309	−6.4
41 Nb				.036	.0458	27.2	.0344	.0335	−2.6
42 Mo				.040	.0489	22.3	.0374	.0363	−2.9
43 Tc				.043	.0522	21.4	.0406	.0393	−3.2
44 Ru				.047	.0558	18.7	.0438	.0425	−3.0
45 Rh				.052	.0596	14.6	.0471	.0459	−2.5
46 Pd				.056	.0637	13.8	.0503	.0495	−1.6
47 Ag	.0518	.0458	−11.6	.061	.0679	11.3	.0544	.0534	−1.8
48 Cd				.066	.0726	10.0	.0584	.0575	−1.5
49 In				.071	.0774	9.0	.0629	.0618	−1.7
50 Sn				.077	.0825	7.1	.0673	.0665	−1.2
51 Sb				.082	.0879	7.2	.0724	.0714	−1.4
52 Te				.089	.0936	5.2	.0774	.0765	−1.2
53 I				.096	.0996	3.8	.0828	.0820	−.97
54 Xe	.107	.0804	−24.9	.102	.106	3.9	.0882	.0877	−.57
55 Cs	.089	.0867	−2.6	.110	.113	2.7	.102	.0938	−8.04
56 Ba	.093	.0934	+.43	.117	.119	1.7	.101	.100	−.99
57 La	.101	.101	0	.125	.127	1.6	.108	.107	−.93
58 Ce				.133	.134	.75	.115	.114	−.87
59 Pr	.123	.116	5.7	.141	.142	.71	.123	.121	−1.63
60 Nd	.131	.124	−5.3	.150	.150	0	.130	.129	−.77
61 Pm				.158	.159	.63	.138	.137	−.73
62 Sm				.168	.168	0	.145	.145	0
63 Eu	.142	.151	+ 6.3	.177	.177	0	.154	.153	−.65
64 Gd				.187	.187	0	.162	.163	−.62
65 Tb	.194	.172	−11.3	.197	.196	−.51	.172	.172	0
66 Dy	.14	.182	+30.0	.207	.206	−.48	.181	.182	−.55
67 Ho				.217	.217	0	.191	.192	−.52
68 Er				.228	.227	−.44	.201	.202	−.50
69 Tm				.239	.238	−.42	.210	.212	+0.95
70 Yb				.250	.249	−.40	.220	.223	1.36
71 Lu				.261	.261	0	.231	.234	1.30
72 Hf				.272	.272	0	.242	.245	1.24
73 Ta	.225	.266	+18.2	.284	.284	0	.255	.257	.78
74 W				.296	.296	0	.267	.269	.75
75 Re				.308	.308	0	.280	.281	.36
76 Os				.320	.320	0	.293	.293	0
77 Ir	.30	.320	6.7	.332	.332	0	.305	.305	0
78 Pt	.32	.334	4.4	.344	.344	0	.318	.318	0
79 Au	.398	.348	−12.6	.356	.357	+ .28	.332	.331	−.30
80 Hg	.38	.362	−4.7	.369	.369	0	.345	.343	−.58
81 Tl	.43	.376	−12.6	.381	.382	+ .26	.359	.356	−.84
82 Pb	.36	.390	8.3	.393	.394	.25	.372	.369	−.81
83 Bi	.40	.403	.7	.406	.406	0	.385	.382	−.78

TABLE 2. Summary and analysis of Cohen (87Co01) ϖ_L review, fits, and tabulations, including ECPSSR (Energy loss, Coulomb deflection, Perturbed Stationary State, Relativistic effects) — Continued

Z	Bambynek *et al.*, 1972 ϖ_L table	Bambynek *et al.*, 1972 ϖ_L fit	% diff. fit from table	Mitchell & Barfoot 1981 ϖ_L table	Mitchell & Barfoot 1981 ϖ_L fit	% Diff. fit from table	Cohen 1987 ECPSSR ϖ_L table	Cohen 1987 ECPSSR ϖ_L fit	% Diff. fit from table
84 Po							.398	.395	−.75
85 At							.411	.409	−.49
86 Rn							.423	.422	−.24
87 Fr							.436	.435	−.23
88 Ra	.451	.472	4.6				.448	.448	0
89 Ac							.461	.461	0
90 Th	.488	.498	2.0				.475	.474	−.21
91 Pa	.51	.511	.2				.487	.486	−.21
92 U	.51	.524	2.7	.515	.514	−.19	.499	.499	0
93 Np	.575	.537	−6.6				.510	.511	+.20
94 Pu	.581	.549	−5.5				.522	.524	.38
95 Am							.535	.536	19
96 Cm	.531	.572	+ 7.7				.547	.548	18
97 Bk								.560	
98 Cf								.572	
99 Es								.583	
100 Fm								.595	

TABLE 3. Earlier (89Hu01) analysis of ϖ_M data

	Measurements						Theory		Fit
Z	Lay 1934	Jaffe 1954	Jopson *et al.* 1965	Konstantinov & Sazonova 1968	Hribar *et al.* 1982	Shatendra *et al.* 1984	Chen *et al.* (McGuire recipe)	Sarkar *et al.* 1981 (derived Chen 1980)	Burhop 1955 formula, renormal.
64 Gd								.0072	.0087
66 Dy								.0095	.0102
67 Ho								.0110	.0110
70 Yb							.0128	.0154	.0136
72 Hf								.0190	.0156
73 Ta								.0209	.0167
74 W							.0194	.0220	.0179
76 Os			.013±.003						.0203
78 Pt								.0257	.0230
79 Au			.024±.005	.023±.001		.025±.004		.0268	.0245
80 Hg							.0274		.0260
82 Pb			.026±.005	.029±.002	.032±.003	.028±.004			.0292
83 Bi		.037±007	.030±.006	.035±.002			.0318		.0310
88 Ra							.0400		.0408
90 Th						.044±.004			.0453
92 U	.06					.051±.005	.0470		.0502
96 Cm							.0520		.0612
100 Fm							.0578		.0739

TABLE 4. *K*-shell fluorescence yields for the elements 11 ≤ Z ≤ 99

Z	ω_K(Exp.)[a]	Ref.	Average values	This work Fitted values	Krause 79Kr01	89Hu01 84Ba01
11 Na	0.021±0.002	88Ra01	–	0.021	0.023	0.0213
12 Mg	0.027±0.003	88Ra01	–	0.026	0.030	0.0291
13 Al	0.034±0.003 0.027±0.005 0.030±0.003	88Ra01 81Ku01	0.033±0.039	0.0387	0.039	0.0387
14 Si	0.048±0.005 [0.0481±0.0014][a]	88Ra01 87Br01	–	0.043	0.050	0.0504
16 S	0.070±0.008	88Ra01	–	0.071	0.078	0.0804
17 Cl	0.089±0.009 [0.101±0.004][a]	88Ra01 78Es01	–	0.089	0.097	0.0989
19 K	0.134±0.020 0.131±0.003 [0.144±0.004]	88Ra01 81Bh01 93So01	0.132±0.003	0.132	0.140	0.143
20 Ca	0.151±0.003 0.156±0.005 0.127±0.013 [0.164±0.004][a]	85Ga02 81Bh01 81Ku01 93So01	0.151±0.002	0.147	0.163	0.169
21 Sc	0.211±0.006	90Si02	–	0.183	0.188	0.196
22 Ti	0.205±0.005 0.216±0.008	85Ga02 81Bh01	0.208±0.004	0.218	0.214	0.226
23 V	0.249±0.006 0.252±0.020	87Ku01 81Ku01	0.249±0.005	0.253	0.243	0.256
24 Cr	0.281±0.006 [0.2901±0.0025][a]	90Si02 78Ma01	–	0.286	0.275	0.289
25 Mn	0.321±0.007 0.310±0.023 [0.312±0.003][a] [0.340±0.017][a] [0.283±0.002][a] [0.28 ±0.02][a]	87Ku01 81Ku01 89Ko01 88Ge01 82Sm01 81Gu01	0.320±0.007	0.319	0.308	0.321
26 Fe	0.336±0.006 0.335±0.011 0.350±0.019 [0.352±0.004][a]	90Si02 81Bh01 92Pi01 92So01	0.336±0.005	0.351	0.340	0.355
27 Co	0.368±0.007	87Ku01	–	0.382	0.373	0.388
28 Ni	0.418±0.011 0.394±0.016	90Si02 81Ar02	0.410±0.009	0.412	0.406	0.421
29 Cu	0.448±0.010 0.441±0.018 0.440±0.018 0.425±0.021 [0.452±0.003][a]	85Ga02 81Ar02 81Bh01 92Pi01 94So01	0.442±0.007	0.441	0.440	0.454
30 Zn	0.482±0.009 0.490±0.020 0.478±0.018 0.471±0.025	85Ga02 81Ar02 81Bh01 92Pi01	0.481±0.007	0.469	0.474	0.486
31 Ga	0.543±0.011	90Si02	–	0.496	0.507	0.517

TABLE 4. *K*-shell fluorescence yields for the elements 11 ≤ Z ≤ 99 — Continued

Z	ω_K(Exp.)[a]	Ref.	Average values	This work Fitted values	Krause 79Kr01	89Hu01 84Ba01
32 Ge	0.529±0.010	85Ga02	0.539±0.009	0.523	0.535	0.546
	0.538±0.029	92Pi01				
	0.549±0.011	84Ca01				
	[0.532±0.016][a]	87Br01				
33 As	0.590±0.024	81Ar02	0.581±0.017	0.549	0.562	0.575
	0.579±0.025	88Si01				
	0.574±0.029	84Si01				
34 Se	0.591±0.011	85Ga02	0.580±0.009	0.574	0.589	0.602
	0.537±0.022	81Ar02				
35 Br	0.586±0.011	87Ku01	0.586±0.009	0.598	0.618	0.628
	0.586±0.023	81Ar02				
	[0.626±0.012][a]	78Es01				
36 Kr	0.660±0.007	86Ko01	–	0.621	0.643	0.652
37 Rb	0.635±0.013	87Ku01	–	0.643	0.667	0.674
	[0.673±0.008][a]	78Th01				
38 Sr	0.687±0.023	90Si02	0.690±0.02	0.665	0.690	0.696
	0.697±0.034	81Bh01				
39 Y	0.668±0.030	85Ga02	–	0.685	0.710	0.716
40 Zr	0.700±0.028	81Ar02	0.708±0.23	0.705	0.730	0.734
	0.725±0.039	81Bh01				
41 Nb	0.722±0.044	90Si02	0.733±0.25	0.724	0.747	0.751
	0.738±0.030	81Ar02				
42 Mo	0.746±0.041	87Al01	0.773±0.009	0.742	0.765	0.767
	0.740±0.01	87Ku01				
	0.804±0.032	81Ar02				
	0.758±0.043	92Pi01				
	0.792±0.013	91Ca01				
45 Rh	0.829±0.058	90Si02	–	0.792	0.808	0.809
46 Pd	0.846±0.059	90Si02	–	0.807	0.820	0.820
47 Ag	0.843±0.046	87Al01	0.828±0.004	0.822	0.831	0.831
	0.856±0.025	85Ga02				
	0.857±0.034	81Ar02				
	0.861±0.072	81Bh01				
	0.826±0.005	80Ta02				
	[0.84±0.02][a]	79Pl01				
	[0.847±0.013][a]	89Eg01				
48 Cd	0.874±0.048	87Al01	0.854±0.012	0.836	0.843	0.842
	0.856±0.075	81Bh01				
	0.853±0.013	91Ca01				
49 In	0.900±0.049	87Al01	0.844±0.004	0.848	0.853	0.851
	0.864±0.025	87Ku01				
	0.849±0.036	81Ar02				
	0.843±0.005	80Ta02				
50 Sn	0.854±0.047	87Al01	0.874±0.011	0.861	0.862	0.860
	0.872±0.025	85Ga02				
	0.890±0.036	81Ar02				
	0.874±0.013	91Ca01				

TABLE 4. K-shell fluorescence yields for the elements $11 \leqslant Z \leqslant 99$ — Continued

Z	ω_K(Exp.)[a]	Ref.	Average values	This work Fitted values	Krause 79Kr01	89Hu01 84Ba01
51 Sb	0.896±0.049	87Al01	0.872±0.022	0.872	0.870	0.868
	0.866±0.025	87Ku01				
52 Te	0.823±0.073	90Si02	–	0.883	0.877	0.875
53 I	0.846±0.024	87Ku01	0.841±0.019	0.894	0.884	0.882
	0.831±0.033	81Ar02				
54 Xe	0.889±0.010	77Hr01	–	0.903	0.891	0.888
55 Cs	0.902±0.026	87Ku01	0.898±0.013	0.912	0.897	0.894
	0.899±0.015	88Si01				
	0.896±0.016	83Si01				
	[0.904±0.018][a]	89Eg01				
56 Ba	0.920±0.051	87Al01	0.931±0.024	0.920	0.902	0.900
	0.934±0.027	85Ga02				
57 La	0.913±0.050	87Al01	–	0.928	0.907	0.905
59 Pr	0.930±0.023	88Si01	–	0.941	0.917	0.914
60 Nd	[0.917±0.020][a]	79Ch02	–			0.918
61 Pm	[0.918±0.017][a]	89Eg01	–			0.922
62 Sm	[0.913±0.028][a]	85Se02	–			0.923
63 Eu	0.957±0.030	88Si01	0.939±0.16	0.962	0.932	0.929
	0.933±0.019	85Si01				
66 Dy	0.975±0.027	88Si01	–	0.972	0.941	0.938
69 Tm	0.983±0.028	88Si01	–	0.979	0.949	0.945
70 Yb	[0.954±0.023][a]	89Eg01	–			0.947
71 Lu	0.951±0.030	88Si01	–	0.981	0.953	0.949
73 Ta	0.955±0.011	88Si01	–	0.983	0.957	0.952
80 Hg	0.980±0.009	88Si01	–	0.980	0.965	0.962
93 Np	0.972±0.003	79Ah01	–	0.969	0.973	0.971
94 Pu	0.972±0.003	79Ah01	–	0.969	0.973	0.971
96 Cm	0.971±0.006	79Ah01	–	0.971	0.974	0.972
97 Bk	[0.971±0.006][a]	79Ah01	–			0.972
98 Cf	0.973±0.004	79Ah01	–	0.974	0.975	0.972
	[0.976±0.005][a]	77Fr01				
99 Es	0.972±0.004	79Ah01	–	0.976	0.975	0.973

[a] Values in square brackets [ ] have been added in proof at the suggestion of W. Bambynek, and have not been included in the average values in column 4 nor in the fitting to obtain column 5.

TABLE 5. Average L-shell fluorescence yields for the elements $26 \leqslant Z \leqslant 92$

Average L-Shell fluorescence yieldsϖ_L							
Z	Experimental values	Ref.	Average values	This work fitted values	RHDS 93Pu04	ECPSSR 87Co01	Hubbell 89Hu01
26 Fe	0.0063±0.0010	91Mc01	–	0.0064	0.0052	0.0063	0.00614
28 Ni	0.0091±0.0014 0.0083±0.0016	91Mc01 85Du01	0.0087±0.001	0.0088	0.0085	0.0092	0.00819
29 Cu	0.0105±0.001 6.0098±0.0019	91Mc01 85Du01	0.0102±0.0012	0.0100	0.0100	0.0105	0.00939
30 Zn	0.0117±0.0018	91Mc01	–	0.0113	0.0103	0.0117	0.0107
31 Ga	0.0129±0.0019	91Mc01	–	0.0128	0.0121	0.0131	0.0122
32 Ge	0.0139±0.0021	91Mc01	0.0140±0.0016	0.0141	0.0140	0.0145	0.0138
33 As	0.0156±0.0023	85Du01	–	0.0156	0.0160	0.0161	0.0155
36 Kr	0.0210±0.002	79Sp01	–	0.0211	0.0209	0.0219	0.0218
37 Rb	0.0186±0.0028	85Du01	–	0.0232	0.0234	0.0241	0.0242
38 Sr	0.0213±0.0032	85Du01	–	0.0256	0.0260	0.0262	0.0263
39 Y	0.0246±0.0036	80Se01	0.0245±0.0024	0.0282	0.0288	0.0288	0.0285
40 Zr	0.0330±0.0049 0.0282±0.0014	85Du01 83Si02	–	0.0310	0.0318	0.0313	0.0319
41 Nb	0.037±0.003 0.029±0.0014	92Ga01 83Si02	–	0.0342	0.0361	0.0344	0.0335
42 Mo	0.0380±0.003 0.0316±0.0016	92Ga01 83Si02	0.0380±0.0029	0.0376	0.0396	0.0374	0.0363
45 Rh	0.051±0.005	92Ga01	–	0.0499	0.0517	0.0471	0.0459
46 Pd	0.054±0.005 0.039±0.007	92Ga01 85Du01	0.0498±0.0040	0.0547	0.0557	0.0503	0.0495
47 Ag	0.057±0.005 0.0556±0.002	92Ga01 883Si02	–	0.0599	0.0599	0.0544	0.0534
48 Cd	0.066±0.005 0.0569±0.002	92Ga01 883Si02	–	0.0656	0.0652	0.0584	0.0575
49 In	0.075±0.005 0.0571±0.0029	92Ga01 83Si02	–	0.0717	0.0705	0.0629	0.0618
50 Sn	0.079±0.006 0.081±0.012	92Ga01 80Se01	–	0.0782	0.0757	0.0673	0.0665
51 Sb	0.083±0.006	92Ga01	–	0.0852	0.0813	0.0724	0.0714
52 Te	0.093±0.007	92Ga01	–	0.0934	0.0873	0.0774	0.0765
53 I	0.077±0.004	83Si02	–	0.096	0.092	0.083	0.082
56 Ba	0.110±0.003	90Si01	–	0.110	0.114	0.101	0.100
57 La	0.118±0.003 0.108±0.008	90Si01 90Ma02	0.117±0.003	0.116	0.121	0.108	0.107
58 Ce	0.121±0.004 0.108±0.008	90Si01 90Ma02	0.120±0.004	0.123	0.129	0.115	0.114

TABLE 5. Average L-shell fluorescence yields for the elements $26 \leqslant Z \leqslant 92$ — Continued

Average L-Shell fluorescence yieldsϖ_L							
Z	Experimental values	Ref.	Average values	This work fitted values	RHDS 93Pu04	ECPSSR 87Co01	Hubbell 89Hu01
59 Pr	0.132±0.004 0.127±0.009	90Si01 90Ma02	0.131±0.003	0.130	0.138	0.123	0.121
60 Nd	0.143±0.004 0.131±0.009	90Si01 90Ma02	0.141±0.003	0.138	0.146	0.130	0.129
62 Sm	0.161±0.005 0.149±0.010 0.144±0.005	90Si01 90Ma02 92St01	0.152±0.003	0.155	0.164	0.145	0.145
63 Eu	0.164±0.005 0.148±0.010	90Si01 90Ma02	0.161±0.004	0.165	0.173	0.154	0.153
64 Gd	0.184±0.005 0.165±0.010	90Si01 90Ma02	0.180±0.004	0.174	0.184	0.162	0.163
65 Tb	0.192±0.006 0.168±0.010	90Si01 90Ma02	0.186±0.005	0.184	0.194	0.172	0.172
66 Dy	0.199±0.006 0.175±0.010	90Si01 90Ma02	0.192±0.005	0.194	0.204	0.181	0.182
67 Ho	0.217±0.006 0.193±0.010 0.267±0.010	90Si01 90Ma02 86Bh01	0.222±0.004	0.205	0.214	0.191	0.192
68 Er	0.223±0.007 0.205±0.010	90Si01 90Ma02	0.217±0.006	0.215	0.223	0.201	0.202
69 Tm	0.228±0.007	90Si01	–	0.226	0.231	0.210	0.212
70 Yb	0.239±0.007 0.228±0.010	90Si01 90Ma02	0.235±0.006	0.236	0.241	0.220	0.223
71 Lu	0.246±0.007 0.235±0.010	90Si01 90Ma02	0.242±0.006	0.247	0.252	0.231	0.234
72 Hf	0.255±0.007	90Si01	–	0.258	0.264	0.242	0.245
73 Ta	0.274±0.008 0.254±0.012 20.273±0.008 0.316±0.013 0.280±0.020	90Si01 90Ma0 85Sh01 86Bh01 85Si02	0.267±0.005	0.269	0.277	0.255	0.257
74 W	0.285±0.008 0.272±0.013 0.296±0.021 0.290±0.020	90Si01 90Ma02 85Sh01 85Si02	0.283±0.006	0.280	0.290	0.267	0.269
75 Re	0.286±0.008	90Si01	–	0.292	0.301	0.280	0.281
77 Ir	0.326±0.010	90Si01	–	0.314	0.322	0.305	0.305
78 Pt	0.328±0.010	90Si01	–	0.326	0.332	0.318	0.318
79 Au	0.330±0.010 0.338±0.016 0.336±0.023 0.345±0.014 0.360±0.020	90Si01 90Ma02 85Sh01 86Bh01 85Si02	0.338±0.007	0.337	0.342	0.332	0.331

TABLE 5. Average L-shell fluorescence yields for the elements $26 \leq Z \leq 92$ — Continued

Average L-Shell fluorescence yields ϖ_L							
Z	Experimental values	Ref.	Average values	This work fitted values	RHDS 93Pu04	ECPSSR 87Co01	Hubbell 89Hu01
80 Hg	0.346±0.017	90Ma02	0.349±0.010	0.348	0.352	0.345	0.343
	0.323±0.020	85Sh01					
	0.380±0.020	85Si02					
81 Tl	0.354±0.010	90Si01	0.356±0.007	0.360	0.363	0.359	0.356
	0.349±0.017	90Ma02					
	0.337±0.023	85Sh01					
	0.365±0.015	86Bh01					
	0.390±0.030	85Si02					
82 Pb	0.374±0.010	790Si01	0.376±0.008	0.371	0.374	0.372	0.369
	0.361±0.018	90Ma02					
	0.391±0.027	85Sh01					
	0.395±0.019	86Bh01					
	0.380±0.030	85Si02					
	0.401±0.00	81Ko01					
83 Bi	0.374±0.010	90Si01	0.328±0.007	0.383	0.385	0.385	0.382
	0.367±0.017	90Ma02					
	0.410±0.023	85Sh01					
	0.411±0.015	86Bh01					
90 Th	0.473±0.010	90Si01	0.464±0.018	0.468	0.470	0.475	0.474
	0.407±0.017	85Sh01					
	0.456±0.023	86Bh01					
	0.490±0.015	85Si02					
92 U	0.489±0.010	90Si01	0.500±0.019	0.495	0.492	0.499	0.499
	0.609±0.042	85Sh01					
	0.492±0.025	86Bh01					
	0.600±0.040	85Si02					

TABLE 6. Average M-shell fluorescence yields for the elements 71 ≤ Z ≤ 92

			Average M-Shell fluorescence yields ϖ_M				
Z	Experimental values	Ref.	Average values	This work fitted values	Chen 80Ch02 83Ch01	McGuire 72Mc01	Hubbell 89Hu01
71 Lu	0.0154±0.0015	93Pu01		−0.0156	0.0172	0.0160	0.0146
72 Hf	0.0176±0.0017	93Pu01		0.0173	0.0183	0.0186	0.0156
73 Ta	0.0190±0.0019	93Pu01		0.0189	0.0193	0.0208	0.0167
77 Ir	0.0276±0.0022	93Pu01		0.0257	0.0240	0.0236	0.0216
78 Pt	0.0285±0.0023	93Pu01		0.0274	0.0254	0.0247	0.0230
79 Au	0.0264±0.0021 0.0300±0.0024	90Ma01 93Pu01	0.0279±0.0015	0.0292	0.0268	0.0270	0.0245
81 Tl	0.0332±0.0020	91Ga01	–	0.0328	0.0298	0.0305	0.0275
82 Pb	0.0362±0.0024 0.0311±0.0025 0.0334±0.0027	91Ga01 90Ma01 93Pu01	0.0336±0.0014	0.0346	0.0313	0.0320	0.0292
83 Bi	0.0384±0.0020 0.0356±0.0025	91Ga01 93Pu01	0.0373±0.0015	0.0365	0.329	0.0334	0.0310
90 Th	0.0525±0.0036 0.0537±0.0037 0.0512±0.0035	91Ga01 90Ma01 93Pu01	0.0524±0.002	0.0501	0.0451	0.0543	0.0453
92 U	0.0539±0.0037 0.0535±0.003 0.0514±0.0031	91Ga01 790Ma01 93Pu01	0.0527±0.0019	0.0541	0.0491	–	0.0502

TABLE 7. *K*-, *L*-, and *M*-shell fluorescence yields fitted to the polynomials $\sum_n a_n Z^n$ as a function of atomic number (Z)

Parameter	Range of *Z*	Fitting coefficient				
		a_0	a_1	a_2	a_3	a_4
ω_K	11–19	1.4340×10^{-1}	-2.5606×10^{-2}	1.3163×10^{-3}	–	–
	20–99	-7.6388×10^{-1}	5.4070×10^{-2}	-4.0544×10^{-4}	-1.4348×10^{-6}	-1.8252×10^{-8}
ϖ_L	26–51	-9.2521×10^{-2}	8.7531×10^{-3}	-2.8087×10^{-4}	3.4823×10^{-6}	
	52–92	4.2193	-2.3520×10^{-1}	4.7911×10^{-3}	-4.1549×10^{-5}	-1.3564×10^{-7}
ϖ_M	71–92	-4.587×10^{-2}	1.208×10^{-4}	1.051×10^{-5}	–	–

TABLE 8. Fluorescence yield values ω_K, ϖ_L, and ϖ_M for $3 \leq Z \leq 100$, generated from the Bambynek (84Ba01), Cohen (87Co01) and Burhop (55Bu01) fitting functions extended and modified (in part) by Hubbell (89Hu01)

TABLE 8. Fluorescence yield values ω_K, ϖ_L, and ϖ_M for $3 \leq Z \leq 100$, generated from the Bambynek (84Ba01), Cohen (87Co01) and Burhop (55Bu01) fitting functions extended and modified (in part) by Hubbell (89Hu01) — Continued

Z	ω_K	ϖ_L	ϖ_M
3 Li	2.928(−4)		
4 Be	6.929(−4)		
5 B	.001409		
6 C	.002575		
7 N	.004349		
8 O	.006909		
9 F	.01045		
10 Ne	.01519		
11 Na	.02133	2.17(−4)	
12 Mg	.02911	3.04(−4)	
13 Al	.03872	4.15(−4)	
14 Si	.05037	5.53(−4)	
15 P	.06422	7.24(−4)	
16 S	.08038	9.30(−4)	
17 Cl	.09892	.00118	
18 Ar	.1199	.00147	
19 K	.1432	.00181	1.67(−6)
20 Ca	.1687	.00221	3.10(−6)
21 Sc	.1962	.00268	5.28(−6)
22 Ti	.2256	.00321	8.46(−6)
23 V	.2564	.00381	1.29(−5)
24 Cr	.2885	.00450	1.89(−5)
25 Mn	.3213	.00527	2.67(−5)
26 Fe	.3546	.00614	3.68(−5)
27 Co	.3880	.00711	4.96(−5)
28 Ni	.4212	.00819	6.53(−5)
29 Cu	.4538	.00939	8.45(−5)
30 Zn	.4857	.0107	1.08(−4)
31 Ga	.5166	.0122	1.35(−4)
32 Ge	.5464	.0138	1.68(−4)
33 As	.5748	.0155	2.06(−4)
34 Se	.6019	.0174	2.51(−4)
35 Br	.6275	.0195	3.02(−4)
36 Kr	.6517	.0218	3.61(−4)
37 Rb	.6744	.0242	4.28(−4)
38 Sr	.6956	.0263	5.04(−4)
39 Y	.7155	.0285	5.90(−4)
40 Zr	.7340	.0309	6.86(−4)
41 Nb	.7512	.0335	7.93(−4)
42 Mo	.7672	.0363	9.12(−4)
43 Tc	.7821	.0393	.00104
44 Ru	.7958	.0425	.00119
45 Rh	.8086	.0459	.00135
46 Pd	.8204	.0495	.00153
47 Ag	.8313	.0534	.00172
48 Cd	.8415	.0575	.00193
49 In	.8508	.0618	.00217
50 Sn	.8595	.0665	.00242
51 Sb	.8676	.0714	.00269
52 Te	.8750	.0765	.00298
53 I	.8819	.0820	.00330
54 Xe	.8883	.0877	.00365
55 Cs	.8942	.0938	.00401
56 Ba	.8997	.100	.00441
57 La	.9049	.107	.00484
58 Ce	.9096	.114	.00529
59 Pr	.9140	.121	.00578
60 Nd	.9181	.129	.00629
61 Pm	.9220	.137	.00685
62 Sm	.9255	.145	.00744
63 Eu	.9289	.153	.00806
64 Gd	.9320	.163	.00873
65 Tb	.9349	.172	.00943
66 Dy	.9376	.182	.0102
67 Ho	.9401	.192	.0110
68 Er	.9425	.202	.0118
69 Tm	.9447	.212	.0127
70 Yb	.9467	.223	.0136
71 Lu	.9487	.234	.0146
72 Hf	.9505	.245	.0156
73 Ta	.9522	.257	.0167
74 W	.9538	.269	.0179
75 Re	.9553	.281	.0191
76 Os	.9567	.293	.0203
77 Ir	.9580	.305	.0216
78 Pt	.9592	.318	.0230
79 Au	.9604	.331	.0245
80 Hg	.9615	.343	.0260
81 Tl	.9625	.356	.0275
82 Pb	.9634	.369	.0292
83 Bi	.9643	.382	.0310
84 Po	.9652	.395	.0328
85 At	.9659	.409	.0347
86 Rn	.9667	.422	.0366
87 Fr	.9674	.435	.0387
88 Ra	.9680	.448	.0408
89 Ac	.9686	.461	.0430
90 Th	.9691	.474	.0453
91 Pa	.9696	.486	.0477
92 U	.9701	.499	.0502
93 Np	.9706	.511	.0528
94 Pu	.9710	.524	.0555
95 Am	.9713	.536	.0583
96 Cm	.9717	.548	.0612
97 Bk	.9720	.560	.0642
98 Cf	.9722	.572	.0673
99 Es	.9725	.583	.0706
100 Fm	.9727	.595	.0739

10. Acknowledgment

The contribution to this work by JHH (U.S.-side Principal Investigator, and NIST contractor) was supported by the NIST Standard Reference Data Program.

Acknowledgment is also made for support, in part, from the U.S.-India Foundation, for the work performed at the Panjab University.

The authors thank Walter Bambynek, Dale Hoppes, Chris Chantler, Bernd Crasemann, Manfred Krause and K. N. Stoev for reading the manuscript and providing valuable suggestions and additional material.

11. Annotated Bibliography of X-ray Fluorescence Yield Measurements, Analysis, Fits, and Tables 1978–1993

77Fr01 Freedman, M. S., Ahmad, I., Porter, F. T., Sjoblom, R. K., Barnes, R. F., Lerner, J. and Field, P. R., Phys. Rev. C **15**, 760–776 (1977). Two-Quasiparticle States in ^{25}0Cf Populated by Electron Capture Decay of 8.6-h ^{25}0Es Isomer (*K*: Cf).

77Hr01 Hribar, M., Kodre, A. and Pahor, J., Zeitschrift f. Physik A **280**, 227–229 (1977), The Determination of the *K*-Shell Fluorescence Yield of Xenon by the Use of the Proportional Counter Method (*K*: Xe).

78Al01 Allawadhi, K. L., Arora, S. K., and Sood, B. S., Natl. Acad. Sci. Lett. (India) **1**, 109–111 (1978), Average *L* Shell Fluorescence Yields Following *K* to *L* Transfer of Vacancies in Some High Z Elements (*L*: high Z).

78Do01 Doyle, B. L., Schiebel, U., McDonald, J. R., and Ellsworth, L. D., Phys. Rev. A **17**, 523–528 (1978), Charge-State Dependence of the Mean *K*-Shell Fluorescence Yields of Si^{q}+ Ions (*K*: Si ions).

78Ga01 Gardner, R. K. and Gray, t. J., At. Data Nucl. Data Tables **21**, 515–536 (1978). Cross Sections for *K*-Shell Ionization, X-Ray Production, or Auger-Electron by Ion Impact (*K*: theor. ionization cross sections, x-ray production cross sections).

78Es01 Espenschied., P. and Hoffmann, K.-W., Z. Physik A **289**, 37–40 (1978). The *K*-Fluorescence Yield of Chlorine and Bromine (*K*: Cl. Br).

78Ke01 Keith, H. D. and Loomis, T. C., X-Ray Spectrom. **7**, 217–224 (1978), Measurement of *K*-Shell Fluorescence Yield and K_α/K_ω Intensity Ratio forNickel (*K*: Ni).

78Ko01 Kochery, I. P., PhD. Thesis, Emory University, Atlanta, USA (1978). Inner Shell Ionization in the Electron-Capture Decay of ^{113}Sn and ^{181}W. (*L*: ω_1, f_{12}, f_{13}: Ta).

78Ma01 Magnier, P., Bouchard, J., Blondel, M, Perolat, J. P. and Vatin, R., Z.Physik A **284**, 389–397 (1978). Precise Measurement of the XK Emission Rate Following the Electron-Capture Decay of ^{54}Mn – Fluorescence Yield ω_K of Cr (*K*: Cr).

78Me01 Meyer, B., Richter, G., Cleff, B. and Santo, R., Jahresbericht 1978, p. 9–15, Institut für Kernphysik, Universität Münster, Germany. Wirkungsquerschnitte für *L*-Unterschalen-Ionisierung durch Protonen (*L*: ω_1, ω_2, ω_3: Cd, Te, Ce, W).

78Ta01 Tanis, J. A. and Shafroth, S. M., Phys. Letters A **67**, 124–125 (1978). Projectile Fluorescence Yields in Heavy Ion Collisions (*K*: Cu).

78Th01 Thomas, D.J., Z. Physik A **289**, 51–58 (1978). The Electron Capture Decay of ^{85}Sr – Measurements of the *K* X-Ray Emission Probability, Half-Life, and Decay Scheme (*K*: Mn).

79Ah01 Ahmad, I., Z. Phys. A (Germany) **290**, 1–5 (1979). Precision Measurement of *K*-Shell Fluorescence Yields in Actinide Elements (*K*: Np, Pu, Cm, Bk, Cf, Es).

79Ch01 Chen, M. H., Laiman, E., Crasemann, B., Aoyagi, M., and Mark, H., Phys. Rev. A (USA), **19**, 2253–2259 (1979). Relativistic *L*-Shell Auger and Coster-Kronig Rates and Fluorescence Yields (Theor.: L$_1$, L$_3$: Hg, U, Cm; L$_2$: Yb, W, Hg, Ra, Th, U, Cm).

79Ch02 Chrobaczek, D. and Hammer, J. M., Spring Meeting of the Nuclear Physics Society, DPG, March 26–30, 1979, Gent, Belgium. Determination of the *K*-Shell Fluorescence Yield of Neodymium (*K*: Nd).

79Hr01 Hribar, M., Kodre, A., and Pahor, J., Fizika (Yugoslavia) **11**, 109–115 (1979), The Study of the *L*-shell Fluorescence Yields of Tin and Antimony (L: Sn, Sb).

79In01 Indira, P. A., Unus, I. J., Lee, S. R. and Venugopala Rao, P., Z. Physik A **290**, 245–249 (1979). L$_1$ Subshell Yields at $Z = 73$ from the Electron Capture Decay of ^{181}W (*L*: ω_1, f_{12}, f_{13}: Ta).

79In02 Indira, P. A., Unus, I. J., Venugopala Rao, P. and Fink, R. W., J.Phys. B **12**, 1351–1356 (1979). *L* X-Ray Yields from Double-Vacancy States in Indium (*L*: x-ray yields from *LL*-, *LX*-vacancy states: In).

79Kr01 Krause, M. O., J. Phys. and Chem. Ref. Data (USA), **8**, 307–327 (1979), Atomic Radiative and Radiationless Yields for *K* and *L* Shells. (Review, Tables: *K*: $5 \leq Z \leq 110$; *L*: $12 \leq Z \leq 110$).

79La01 Langenberg, A. and Van Eck, J., J. Phys. B (GB) **12**, 1331–1350 (1979), An Evaluation of *K*-Shell Fluorescence Yields; Observation of Outer-Shell Effects (Review, fit: K: $3 \leq Z \leq 98$).

79Lu01 Luz, N., Sackmann. S. and Lutz, H. O., J. Phys. B **12**, 1973–1993 (1979). Impact-Parameter Dependence of *K*-Shell Excitation in Slow Ion-Atom Collisions (*K*: N-, O-, Ne-, Na-, Mg-ions).

79Pl01 Plch, J., Dryák, P., Zeradicka, J., Schönfeld, E. and Szörényi, Czech. J. Phys. B **29**, 1071–1083 (1979). Revision of the ^{109}Cd Data (*K*: Ag).

79Sp01 Spiler, F. and Hribar, M., Fizika (Yugoslavia) **11**, 117–120 (1979), The New Determination of the *L*-Shell Fluorescence Yield of Krypton (*L*: Kr).

79Tu01 Tunnell, T. W., Can, C., and Bhalla, C. P., IEEE Trans. Nucl. Sci. (USA) **NS-26**, Pt. 2, 1124–1126 (1979), Theoretical Lifetimes and Fluorescence Yields for Multiply-Ionized Fluorine (Theor.: *K*: *F* ions).

80Bi01 Bissinger, G., Joyce, J. M., Tanis, J. A., and Varghese, S. L., Phys. Lett. A, **77A**, 156–158 (1980) Statistical Scaling of C and O *K*-Shell Fluorescence Yields (*K*: C in CH_4, C_2H_2, C_2H_4, C_2H_4, CO_2, CF_4; O in O_2, CO, CO_2, H_2O).

80Ch01 Chen, M. H., Crasemann, B., and Mark, H., Phys. Rev. A (USA) **21**, 436–441 (1980). Relativistic *K*-Shell Auger Rates, Level Widths, and Fluorescence Yields (Theor.: *K*: 25 elements $18 \leq Z \leq 96$).

80Ch02 Chen, M. H., Crasemann, B., and Mark, H., Phys. Rev. A (USA) **21**, 449–453 (1980), Relativistic *M*-Shell Radiationless Transitions (Theor.: *M*: 8 elements $70 \leq Z \leq 100$).

80Gn01 Gnade, B. E., Braga, R. A., and Fink, R. W., Phys. Rev. C (USA) **21**, 2025–2032 (1980), $L_{2,3}$-Subshell X-Ray Fluorescence and Coster-Kronig Yields at $Z = 64$ and 67 (L$_2$, L$_3$: Gd, Ho).

80Kr01 Krause, M. O., Phys. Rev. A (USA) **22**, 1958–1961 (1980) Average *L*-Shell Fluorescence, Auger, and Electron Yields (Review: *L*: $40 \leq Z \leq 100$).

80Ma01 Marques, M. I., Martins, M. C., and Ferreira, J. G., Port. Phys (Portugal) **11**, 9–12 (1980), The L_1 Subshell Fluorescence Yield of Tl (L$_1$: Tl).

80Ni01 Nigam, A. N. and Napalia, R., Proc. Natl. Acad. Sci. India, Sec. A, **50**, 137–144 (1980), Screening Effects in Emission of Satellites in *L*- and *M*- X-Ray Spectra (Screening effects: *L*, *M*).

80Se01 Sera, K., Ishii, K., Yamadera, A., Kuwako, A., Kamiya, M., Sebata, M., Morita, S. and Chu, T. C., Phys. Rev. A **22**, 2536–2549 (1980), *L*- and *M*-Shell Ionization Cross Sections for 3–40-MeV-Proton Bombardments (X-ray production cross sections: *L*: Y, Sn; *M*: Au, Bi).

80Ta01 Takasaki, M. and Shima, K., Physica B and C (Netherlands) **101** C, 420–422 (1980), Ne *K*-Shell Fluorescence Yield in Collisions Between Ne-Atoms and Ne-Ions at 0.6- 2.3 MeV (*K*: Ne atoms, ions).

80Ta02 Takiue, M. and Ishikawa, H., Nucl. Instr. Meth. (Netherlands) **173**, 391–394 (1980), *K*-Fluorescence Yields of Ag and In (*K*: Ag, In).

80Ta03 Tanis, J. A., Jacobs, W. W., and Shafroth S. M., Phys. Rev. A (USA) **22**, 483–495 (1980). Systematics of Target and Projectile *K*-X-Ray Production and Radiative Electron Capture for 20–80-MeV Cl^{q}+ Ions Incident on 25–200-μg/cm^2 Cu Targets (*K*: Cl ions).

80Tu01 Tunnell, T. W., Bhalla, C. P. and Can, C., Phys. Letters A **75**, 195–196 (1980). Theoretical Lifetimes and Fluorescence Yields for $1s2p\ ^3P$ Levels (Theor. L: $2 < Z < 50$).

81Ar01 Arora, S. K., Allawadhi, K. L., and Sood, B. S., J. Phys. Soc. Jpn. (Japan) **50**, 251–254 (1981), Measurement of L_3-Shell Fluorescence Yields in Pb, Th and U (L_3: Pb, Th, U).

81Ar02 Arora, S. K., Allawadhi, K. L., and Sood, B. S., Physica B&C (Netherlands) **111** C, 71–75 (1981), Measurement of K-Shell Fluorescence Yields in Elements $28 \leqslant Z \leqslant 53$ (K: Ni, Cu, As, Zn, Se, Br, Zr, Nb, Mo, Ag, In, Sn, I).

81Bh01 Bhan, C., Chaturvedi, S.N. and Nath, N., X-Ray Spectrom. **10**, 128–130 (1981), Measurement of K X-Ray Fluorescence Cross - Sections (K XRF cross sections: K, Ca, Ti, Fe, Cu, Zn, Sr, Zr, Ag, Cd).

81Ch01 Chen, M. H., Crasemann, B., and Mark, H., Phys. Rev. A (USA) **24**, 177–182 (1981), Widths and Fluorescence Yields of Atomic L-Shell Vacancy States (Theor.: L_1: $18 \leqslant Z \leqslant 100$; L_2: $25 \leqslant Z \leqslant 94$; L_3: $18 \leqslant Z \leqslant 92$).

81Ch02 Chen, M. H., Crasemann, B., Karim, K.R. and Mark, H., Phys. Rev. A **24**, 1845–1851 (1981). Relativistic Auger and X-Ray Deexcitation Rates of Highly Stripped Atoms (Theor.: Transition probabilities for Li-, N-, F-, K-, Co-like ions, up to $Z = 92$).

81Ch03 Chen, M. H., Crasemann, B. and Mark, H., Phys. Rev. A **24**, 1852–1861 (1981). Relativistic Auger and X-Ray Emission Rates of the 1s2s2p Configurationof Li-Like Ions (Theor.: x-ray emission rates of Li-like ions for $13 < Z < 92$).

81Fi01 Fink, R. W. and Venugopala Rao, P., in J. W. Robinson (ed.) Handbook of Spectroscopy, Vol. **3** (CRC Press, Boca Raton, USA, 1981), p. 125–139. Tables of Experimental Values of X-Ray Fluorescence and Coster-Kronig Yields for the K-, L-, and M-Shells (ω_K (Exp): Li, Be, B, C, N, F, Ne, Al -Es; ω_K(fit): Al − Cf; L: ω_1(Exp): Ag − Cm; ω_2(Exp): Pd − Cf; ω_3(Exp): Ag − Cm; ω_3(fit): Pd − Cf; f_{12}, f_{13},f_{23}: La − Cm; ω_L: V − Cm; ω_M: Os, Au, Pb, Bi, U, Np, Cm).

81Gn01 Gnade, B. E., Braga, R. A. and Fink, R. W., Phys. Rev. C **23**, 580 (1981). Erratum: L_{23}-Subshell X-Ray Fluorescence and Coster-Kronig Yields at Z =64 and 67 (L: ω_2, f_{23}, ω_2, ω_3: Gd, Ho).

81Gu01 Gurov, G. A., Danilin, L. D., Korochkin, A. M. and Tachilovskii, G. P., Prikl. Tadern. Spektrosk. [Applied Nuclear Spectroscopy] **10**, 250–254 (1981). ^{55}Fe Half-Life and Fluorescence Yield (K: Mn).

81Ko01 Kodre, A., Hribar, M., Ajlec, B., and Pahor, J., Z. Phys. A (Germany) **303**, 23–26 (1981), L-Shell Fluorescence Yields of Lead (L, L_1, L_2, L_3: Pb).

81Ku01 Kuhn, U., Genz, H., Löw, W., Richter, A, and Müller, H.-W., Z. Phys. A (Germany) **300**, 103–104 (1981). Measurement of the K-Shell Fluorescence Yield of $_{13}$Al, $_{20}$Ca, $_{23}$V, and $_{25}$Mn for Vacancies Produced by the Relativistic Electron Impact (K: Al, Ca, V, Mn).

81Ku02 Kurup, M. B., Prasad, K. G., and Sharma, R. P., Nucl. Instr. Meth. Phys. Res. (Netherlands) **188**, 223–231 (1981), X-Ray Yields by Low Energy Heavy Ion Excitation in Alkali Halide Solid Targets (K: Cl, ion energy dependence).

81Ma01 Markevich, D., and Budick, B., J. Phys. B (GB) **14**, 1553–1563 (1981). Fluorescence Yields for the Rhodium L Shell (L, L_1, L_2, L_3: Rh).

81Mi01 Mitchell, I. V., and Barfoot, K. M., Nucl. Sci. Applic. (Harwood, U.K.) **1**, 99–162 (1981), Particle Induced X-Ray Emission Analysis Application to Analytical Problems (Review, tabulations: K: $5 \leqslant Z \leqslant 92$; L: $12 \leqslant Z \leqslant 92$; M: $82 \leqslant Z \leqslant 92$).

81Pe01 Petrini, D., J. Phys. B (GB) **14**, 3839–3847 (1981), Theoretical Auger Rates and Fluorescence Yields for some Excited Single K-Vacancy Terms for Boron II (Theor.: K: B ions).

81Ro01 Rozet, J. P. and Chetioui, A., J. Phys. B (GB) **14**, 73–89 (1981), Non-immediate L-Shell Equilibrium of Fast Heavy Projectiles in Solid Targets: Influence on K X-Ray Yield Variation with Target Thickness (K: Kr ions).

81Sa01 Sarkar, M., Mommsen, H., Sarter, W., and Schurkes, P., J. Phys. B (GB) **14**, 3163–3172 (1981), M-Shell X-Ray Production Cross Sections in the Proton Energy Range 250–400 keV (M: Gd, Dy, Ho, Yb, Hf, Ta, W, Pt, Au).

81Tu01 Tunnell, T. W. and Bhalla, C. P., Phys. Letters A **86**, 13–16 (1981). Average Satellite and Hypersatellite Fluorescence Yields (Theor: $\omega(n)$ for n = 0–6, and N, O, F, Ne, Si).

82Hr01Hribar, M., Kodre, A., and Pahor, J., Physica B&C (Netherlands) **115** C 132–136 (1982), A Study of the M-Shell Fluorescence Yields of Lead (M: Pb).

82Kr01 Kricke, C. and Brenn, R., Nucl. Instr. Meth. Phys. Res. (Netherlands) **202**, 107–111 (1982), Fluorescence Yield of the $2^4\ P^o_{5/2}$ State of Lithium-like Neon (K: Ne ions).

82Sm01 Smith, D. E., Nucl. Instr. Meth. **200**, 283–287 (1982). International Comparison of Activity Measurements of a Solution of ^{55}Fe (K: MN).

82Ta01 Tan, M., Braga, R. A., Fink, R. W., and Venugopala Rao, P., Phys. Scr. (Sweden) **25**, 536–542 (1982), X-Ray Fluorescence Yields and Coster-Kronig Transition Probabilities of the L_1, L_2, and L_3 Subshells of Pb (L_1, L_2, and L_3: Pb).

82Tu01 Tunnell, T. W., Can, C., and Bhalla, C. P., J. Quant. Spectrosc. and Radiat. Transfer (GB) **27**, 405–416 (1982), Theoretical Transition Energies, Lifetimes and Fluorescence Yields of Multiply Ionized Silicon (Theor.: K, L_1, L_2, L_3, M_1: Si ions).

83Ar01 Arndt, E. and Hartmann, E., Phys. Lett. A (Netherlands) **95A**, 146–147 (1983), Deexcitation Rates and Fluorescence Yields of Highly Stripped Atoms (K: Pb ions).

83Ar02 Artamonova, K. P., Valiev, F. F., Grigor'ev, E. P., Zolotavin, A. V., Sergeev, V. O., and Tulina, T. A., Ukr. Fiz. Zh. (USSR) **28**, 1447–1450, (1983), Fluorescence and Auger Electron Yields for L-Subshells in Gd Decay (L_1, L_2, L_3: Gd).

83Bh01 Bhalla, C. P., IEEE Trans. Nucl. Sci. (USA) **NS-30**, 1093–1096 (1983), Lifetimes and Fluorescence Yields of States Produced in Heavy Ion-Atom Collisions (Theor.: heavy ions: L: $2 \leqslant Z \leqslant 50$).

83Bh02 Bhalla, C. P., IEEE Trans. Nucl. Sci. (USA) **NS-30**, 1097–1099 (1983), Theoretical X-Ray Transition Energies and Fluorescence Yields for Multiply-Ionized Oxygen (Theor.: K: O ions).

83Ca01 Can, C. and Bhalla, C. P., IEEE Trans. Nucl. Sci. (USA) **NS-30**, 1090–1092 (1983), Theoretical Lifetimes, X-Ray Transition Energies and Fluorescence Yields for Double K Vacancy Configurations of Multiply-Ionized Fluorine (Theor.: K: F ions).

83Ch01 Chen, M. H., Crasemann, B. and Mark, H., Phys. Rev. A **27**, 2989–2994 (1983), Radiationless Transitions to Atomic $M_{1,2,3}$ Shells: Results of Relativistic Theory. (Theor.: $M_{1,2,3}$: Ho, Yb, W, Pt, Hg, At, Ra, Th, U, Am).

83Ka01 Karazija, R., Litov. Fiz. Sb. (USSR) **23**, 6–16 (1983), Trans in: Sov. Phys.-Collect. (USA) **23**, 1–9 (1983), Approximate Invariance of Auger and Radiative Level Widths and the Fluorescence Yield (Theor.: effect of inner unfilled shells).

83Ni01 Nicolaides. C. A.. Komninos. Y.. and Beck. D. R.. Phys. Rev. A (USA) **27**, 3044–3052 (1983), K-Shell Binding Energy of Be and Its Fluorescence Yield (K: Be).

83Si01 Singh, K., Singh, G., Sharma, R. K., and Sahota, H. S., Phys. Rev. C (USA) **28**, 2115–2117 (1983), K-Shell Fluorescence Yield of Cs (K: Cs).

83Si02 Singh, N., Mittal, R., Allawadhi, K. L., and Sood, B. S., Physica B&C (Netherlands) **123** C, 115–120 (1983), Measurement of the Average L-Shell Fluorescence Yields in Elements $40 \leqslant Z \leqslant 53$ (L: Zr, Nb, Mo, Ag, Cd, In, Sn, I).

84Av01 Avaldi, L., Mitchell, I. V., and Eschbach, H. L., Nucl. Instr. Meth. Phys. Res. Sect. B (Netherlands), **231** (B3), 21–26 (1984), Beam Interactions with Materials and Atoms Precise X-Ray-Production Cross Sec. Measurement of Medium-Z Elements by Protons (K: Cu, Br).

84Ba01 Bambynek, W., X-84 Proc. X-Ray and Inner-Shell Processes in Atoms, Molecules and Solids, Leipzig Aug. 20–23, 1984, edited by A. Meisel (VEB Druckerei; Thomas Münzer, Langensalza 1984) post-deadline Paper P-1. A New Evaluation of K-Shell Fluorescence Yields (Fit: K: $5 \leqslant Z \leqslant 100$).

84Be01 Benka, O., Nucl. Instr. Meth. Phys. Res. Sect. B (Netherlands), **232** (B4), 279–282 (1984), The Influence of Multiple Ionization upon Fluorescence Yield (Theor.: K: $9 \leqslant Z \leqslant 25$).

84Bh01 Bhalla, C.P. and Tunnell, T. W., J. Quant Spectrosc. Radiat. Transfer. **32**, 141–158 (1984). Theoretical Lifetimes, Transition Energies, Fluorescence Yields, and Nonradiative Branching Ratios for Highly Excited States of Li-Like Argon (Theor.: *K*: Ar).

84Ca01 Campbell, J. L., McGhee, P. L., Gingerich, R. R., Ollerhead, R. W. and Maxwell, J. A., Phys. Rev. A **30**, 161–169 (1984). New Approach to Measurement of the L_2-L_3 Coster-Kronig Transition Probability in Heavy Atoms ($L\ f_{23}$: Pb).

84Ca02 Casnati, E., Tartari, A., Baraldi, C., and Napoli, G., J. Phys. B (GB) **17**, 2413–2419 (1984), Experimental *K*-Shell Fluorescence Yield of Monocrystalline Germanium (*K*: Ge).

84Dr01 Dryak, P., Egorov, Yu. S., Nodovesov, V. G., Plch, J. and Shyukin, G.E., 34th Annual Conf. Nucl. Spectroscopy and Structure of Nuclei, Alma Ata, 1984, p. 540 (*L*: ω_1, ω_2, ω_3: U).

84Sh01 Shatendra, K., Allawadhi, K. L., and Sood, B.S., Physica B&C (Netherlands) **124** C, 279–281 (1984), Measurement of Average *M*-Shell Fluorescence Yields in Some High *Z* Elements (*M*: Au, Pb, Th, U).

84Sh02 Shatendra, K., Allawadhi, K. L., and Sood, B. S., Indian J. Phys. Part A **58A**, 366–367 (1984), Measurement of Average *M*-Shell Fluorescence Yields in Gold and Uranium (*M*: Au, U).

84Si01 Singh, K. and Sahota, H. S., J. Phys. G (GB) **10**, 241–245 (1984), A New Method of Measuring the *K*-Shell Fluorescence Yield of As (*K*: As).

84Si02 Singh, K., Singh, G., Sharma, R. K., and Sahota, H. S., Indian J. Phys. Part A **58A**, 491–492 (1984), The *K*-Shell Fluorescence Yield of Cs (*K*: Cs).

85Co01 Combet Farnoux, F., Electronic and Atomic Collisions. 14th International Conference on the Physics of Electronic and Atomic Collisions. Abstracts of Contributed Papers 546 (1985), Coggiola, M. J., Huestis, D. L., Saxon, R. P. (Eds.), *K* Fluorescence Yields, Auger and X-Ray Decay Rates for Multiply Ionized Atoms (*K*: ions).

85Cr01 Crasemann, B., High-Energy Ion-Atom Collisions. Berenyi, D., Hock, G. (Eds.) Proceedings of the 2nd Workshop on High-Energy Ion-Atom Collision Processes, 27–28 Aug 1984, Debrecen, Hungary, Publ: Akademiai Kiado, Budapest, Hungary, 199–221 (1985), Fluorescence Yields and X-Ray Production from Atomic Inner Shells (Review, tabulations: *K*: $18 \leqslant Z \leqslant 96$; L_1: $18 \leqslant Z \leqslant 100$; L_2: $25 \leqslant Z \leqslant 94$; L_3: $18 \leqslant Z \leqslant 92$; $M_{1,2,3}$: $67 \leqslant Z \leqslant 95$; M_4,5: $70 \leqslant Z \leqslant 100$).

85Di01 von Dincklage, R.-D. and Hay, H. J., Z. Physik A **321**, 375–380 (1985). Atomic L-Subshell Yields from the Electron Capture Decays of ^{157}Tb and ^{158}Tb (L $f_1$2, $f_1$3, $f_2$3, ω_1, ω_2, ω_1, ω_2, ω_3: Gd).

85Du01 Duggan, J. L., Kocur, P. M., Price, J. L., McDaniel, F. D., Mehta, R. and Lapicki, G., Phys. Rev. A **32**, 2088–2092 (1985), *L*-Shell X-Ray Production Cross Sections of Ni, Cu, Ge, As, Rb, Sr, Y, Zr, and Pd by (0.25–2.5)-MeV Protons (*L* XRF cross sections: Ni, Cu, Ge, As, Rb, Sr, Y, Zr, Pd).

85Ga01 Garg, M. L., Kumar, S., Mehta, D., Verma, H. R., Mangal, P. C., and Trehan, P. N., J. Phys B **18**, 4529–4538 (1985), Measurement of Photon-Induced *L* X-Ray Fluorescence Cross Sections for Ta, W, Au, Tl and Bi in the 15–60 keV Energy Range (*L* XRF cross sections: Ta, W, Au, Tl, Bi).

85Ga02 Garg, M. L., Mehta, D., Kumar, S., Mangal, P. C. and Trehan, P. N., X-Ray Spectrom. **14**, 165–169 (1985), Energy Dependence of Photon-Induced K_α and K_ω X-Ray Fluorescence Cross Sections for Some Elements with $20 \leqslant Z \leqslant 56$ (K XRF cross sections: Ca, Ti, Cu, Zn, Ge, Se, Y, Ag, Sn, Ba).

85Ha01 Hallak, A. B., Saleh, N. S., and Shabaro, K. M., Appl. Phys. Commun. (USA) **5**, 241–251 (1985–86), Measurement of *K*- and *L* X-Ray Fluorescence Yield (K_α: S, Cd, K, Ca, Ti, V, Cr, Co, Ni, Cu, Zn, Br, Sr, Nb, Mo, Ba, La, Eu, Gd; L_3: Mo, Ag, Cd, Sn, I, Cs, Ba, La, Sm, Dy, Tm, Lu, W, Pb, Bi).

85Ha02 Hanke, W., Wernisch, J., and Pohn, C., X-Ray Spectrom. **14**, 43–47 (1985), Fluorescence Yields, ω_K ($12 \leqslant Z \leqslant 42$) and ω_{L_3} ($38 \leqslant Z \leqslant 79$), from a Comparison of Literature and Experiments (SEM), (Fits: *K*: $12 \leqslant Z \leqslant 42$; L_3: $30 \leqslant Z \leqslant 79$).

85Ji01 Jitschin, W., Materlik, G., Werner, U., and Funke, P., J. Phys. B (GB) **18**, 1139–1153 (1985), Coster-Kronig and Fluorescence Yields of Au L Subshells Derived from Photoionisation Measurements (L_1, L_2, L_3: Au).

85Ka01 Karim, K. R., Phys. Rev. A **32**, 2747–2750 (1985). Hartree-Fock Calculation of Transition Rates for Atoms with Multiple Open Shells of the Same Symmetry and the Same Occupation Number(Theor.: *K*).

85Ma01 Marques, M. I., Martins, M. C., and Ferreira, J. G., Phys. Scr. (Sweden) **32**, 107–110 (1985), L_1 Subshell Yields of Pt and Hg (L_1: Pt, Hg).

85Se01 Sergienko, V. A., Vorontsovskii, A. V., and Naim, M. A., Bull. Acad. Sci. USSR, Phys. Ser. (USA) **49**, 112–116 (1985), Investigation of the Spectrum of LX and KX-Quanta During the Decay of ^{203}Hg and Determination of the Yields of *L*- and *K*-Fluorescence for Tl Atoms (*K*, *L*: Tl).

85Se02 Sergienko, V. A., Vorontsovskii, A. V. and Naim, M. A., Bull. Acad.Sci., USSR, Phys. Ser. **49** (5), 51–54 (1985), [Izv. Akad.... Nauk, SSSR, Ser. Fiz. **49**, 891–894 (1985)] Study of *XL*- and *XK*-Radiation on ^{152}Eu Decay (*K*: Sm; LX emission ratios: Sm).

85Sh01 Shatendra, K., Allawadhi, K. L. and Sood, B. S., Phys. Rev. A **31**, 2918–2921 (1985), Measurement of L_l, L_α, L_ω, and L_ω X-Ray Production Cross Sections in Some High-*Z* Elements by 60 keV Photons (*L* XRF cross sections: Ta, W, Au, Hg, Tl, Pb, Bi, Th, U).

85Si01 Singh, K., Grewal, B. S., and Sahota, H. S., J. Phys. G (GB) **11**, 399–405 (1985), Determination of the P_K Values to the 172, 103, and 97 keV Levels and the Fluorescence Yields ω_K of Eu after Electron Capture by ^{153}Gd (*K*: Eu).

85Si02 Singh, I., Mittal, R., Allawadhi, K. L., and Sood, B. S., Physica B&C (Netherlands) **132** C, 119–121 (1985), Measurement of Average *L*-Shell Fluorescence Yields in Elements $73 \leqslant Z \leqslant 92$) (*L*: Ta, W, Au, Hg, Tl, Pb, Bi, Th, U).

85Ve01 Verma, H. R., Pal, D., Garg, M. L. and Trehan, P. N., J. Phys. B **18**, 1133–1138 (1985). Photon-Induced *L*-Shell X-Ray Intensity Ratios for W(74) and Hg(80) in the Energy Range $17 \leqslant E \leqslant 47$ keV (*L* subshell ratios: W, Hg).

86Ar01 Arvanitis, D., Dobler, U., Wenzel, L., Baberschke, K., and Stöhr, J., J. Phys. Colloq. (France) **47**, 173–178 (1986), A New Technique for Submonolayer NEXAFS, Fluorescence Yield at the Carbon *K*-Edge (*K*: C at *K*-edge).

86Bh01 Bhan, C., Chaturvedi, S. N., and Nath, N., X-Ray Spectrom. **15**, 217–219 (1986), Fluorescence Cross Sections for L Shell X-Ray Lines (*L* XRF cross sections: Ho, Ta, Au, Tl, Pb, Bi, Th, U).

86Ch01 Chen, M. H. and Crasemann, B., Phys. Rev. A **34**, 87–92 (1986). Relativistic Calculation of Atomic *N*-Shell Ionization by Protons (Theor.: *N*: Bi).

86Ga01 Garg, M. L., Mehta, D., Verma, H. R., Singh, N., Mangal, P. C. and Trehan, P. N., J. Phys. B **19**, 1615–1622 (1986), Measurement of *L* X-Ray Fluorescence Cross Sections and Relative Intensities for Ho, Er and Yb in the Energy Range 11–41 keV (*L* XRF cross sections: Ho, Er, Yb).

86Ka01 Karim, K. S., Bhalla, C. P. and Tunnell, T. W., J. Quant. Spectrosc.Radiat. Transfer **36**, 505–513 (1986). Theoretical X-Ray and Auger Transition Rates, X-Ray Wavelengths, Auger-Electron Energies, Fluorescence Yields and Nonradiative Branching Ratios of Doubly Excited Helium-Like Neon (Theor.: *K*: He-like Ne ions).

86Ka02 Karim, K. S. and Bhalla, C. P., Phys. Rev. A **34**, 4743–4750 (1986). Dielectronic Satellite Spectra of Hydrogenlike Chromium (Theor.: *K*: H-like Cr ions).

86Ko01 Kodre, A., Hribar, M., and Glavic, D., Z. Phys. D (Germany) **3**, 173–176 (1986), The Auger-Raman Effect and the *K*-Shell Fluorescence Yield of Krypton (*K*: Kr).

86Ph01 Phillips, R. A. and Larkins, F. P., Austral. J. Phys. **39**, 717–730(1986). X-Ray Emission Spectra of Some Carbon-Containing Molecules (*K*: C).

86Ra01 Rao, N. V., Rao, B. S., Suryanarayana, C., Reddy, S. B., Satyaranarayana, G., and Sastry, D. L., Port. Phys. (Portugal) **17**, 35–48 (1986), Measurement on *K* X-Ray Fluorescence Yield Ratios in the Region of $55 \leqslant Z \leqslant 82$) (Ratios: *K*: $55 \leqslant Z \leqslant 82$).

86Ro01 Rosato, E., Nucl. Instr. Meth. Phys. Res. (Netherlands) **B15**, 591–594 (1986), *L*-Subshell Fluorescence Yield and Coster-Kronig Transition Probabilities Near $Z = 50$ (L_1: Sn).

86Sa01 Saleh, N. S., Hallak, A. B., and Amer, M. M., Appl. Phys. Communications **6**, 153–164 (1986), Measurement of *K* and *L* X-Ray Fluorescence Cross Sections (*K* XRF cross sections: S, Cl, K, Ca, Ti, V, Cr, Co, Ni, Cu, Zn, Br, Sr, Nb, Mo; *L* XRF cross sections: Mo, Ag, Cd, Sn, I, Cs, Ba, La, Sm, Dy, Tm, Lu, W, Re, Pb, Bi, Th, U).

86Sc01 Schönfeldt, W. A., Mokler, P. H., Hoffmann, D.H.H., and Warczak, A., Z. Phys. D **4**, 161–176 (1986), Resonant Electron Transfer and L-Shell Excitation at 3.6 MeV/u ${}_{62}\mathrm{Sm}^{q+} \rightarrow$ Xe Collisions, $q = 34-52$ (Theor.: L_3: Sm ions).

86Si01 Singh, N., Mittal, R., Singh, B., Allawadhi, K. L. and Sood, B. S., Phys. Rev. A **34**, 3459–3462 (1986). Measurement of L_l, L_α, L_ω, and L_ω X-Ray Production cross sections in Some High-*Z* Elements by 18-, 26-, 33-, and 44-keV Photons (*L* XRF cross sections: Ta, W, Au, Hg, Tl, Pb, Bi, Th, U).

87Al01 Al-Nasr, I. A., Jabr, I. J., Al-Saleh, K. A., and Saleh, N. S., Appl. Phys. A (Germany) **A43**, 71–73 (1987), Measurement of K_α Cross Sections and Fluorescence Yields for Elements in the Range $42 \leqslant Z \leqslant 57$ Using Radioisotope X-Ray Fluorescence (*K*: Mo, Ag, Cd, In, Sn, Sb, Ba, La).

87Au01 Auerhammer, J., Genz, H., and Richter, A., J. Phys. Colloq. (France) **48**, 621–624 (1987), Measurements of is *L*-Subshell Fluorescence Yields for Light Elements (L_1, L_2, L_3: Ni, Cu, Ge, Kr, Sr, Mo, Ag).

87Bh01 Bhalla, R. P., McDaniel, F. D., and Lapicki, G., Nucl. Instr. Meth. B **24/25**, 180–183 (1987) Carbon *K*-Shell X-Ray and Auger-Electron Cross Sections and Fluorescence Yields in Benzene Bombarded by 0.6 to 2.0 MeV Protons (*K*: C).

87Br01 Brunner, G., J. Phys. B **20**, 4983–4991 (1987). *K*-Shell Fluorescence Yields of Silicon and Germanium by Detector Escapes (*K*: Si, Ge).

87Ca01 Campbell, J. L., and McGhee, P. L., J. Phys. Colloq. (France) **48**, 597–600 (1987). *L* Subshell Fluorescence and Coster-Kronig Yields for $Z = 78$, 80, 81, and 82 (L_1, L_2, L_3: Pt, Au, Hg, Tl, Pb).

87Ch01 Charlton, D. E., Pomplun, E., and Booz, J., Radiat. Res. (USA) **111**, 553–564 (1987), Some Consequences of the Auger Effect: Fluorescence Yield, Charge Potential, and Energy Imparted (Review, for dosimetry applications).

87Co01 Cohen, D. D., Nucl. Instr. Meth. B **22**, 55–58 (1987). Average *L* Shell Fluorescence Yields (Review, Tables, fits: *L*: $23 \leqslant Z \leqslant 96$).

87Co02 Combet Farnoux, F., J. Phys. Colloq. (France) **48**, 199–202 (1987). Multiplet Effects on *K* Fluorescence Yields of Multiply-Charged Ions (*K*: Al ions).

87Fi01 Fischer, D. A., Zaera, F., and Gland, J. L., J. Phys. Colloq. (France) **48**, 1097–1100 (1987), Fluorescence Yield Near Edge Structure (FYNES): A Novel Technique for In Situ Surface Chemistry (*K*: near-edge structure: C, S).

87Ga01 Garg, M. L., Garg, R. R. and Malmqvist, K. G., J. Phys. B **20**, 3705–3714 (1987), Measurements of *L* X-Ray Fluorescence Cross Sections in Rare-Earth Elements (*L* XRF cross sections: Nd, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu).

87Hr01 Hribar, M., Kodre, A., and Glavic, D., J. Phys. Colloq. (France) **48**, 625–628 (1987), Fluorescence Yield of Double *K* Vacancies in Krypton (Double *K* vacancy: Kr).

87Ku01 Kumar, S., Singh, S., Mehta, D., Singh, N., Mangal, P. C., and Trehan, P. N., X-Ray Spectrometry **16**, 203–206 (1987). Measurement of *K* X-Ray Fluorescence Cross-Sections for Some Elements with $23 \leqslant Z \leqslant 55$ in the Energy Range 8–60 keV (*K* XRF cross sections: V, Mn, Co, Br, Rb, Mo, In, Sb, I, Cs).

87Lo01 Lorenz, M. and Hartmann, E., J. Phys. B, At. Mol. Phys. (UK) **20**, 6189–6195 (1987). Effect of *L*-Shell Spectator Vacancy on X-Ray Fluorescence Yields and Relative Intensities (L_1, L_2, L_3: In, Pb).

87Ph01 Phillips, W. R., Rehm, K. E., Henning, W., Ahmad, I., Schiffer, J. P., Glagola, B., and Wang, T. F., J. Phys. Colloq. (France) **48**, 311–313 (1987), *K*-Shell Fluorescence Yields in Highly Stripped Fe Atoms (*K*: Fe ions).

87Sa01 Saleh, N. S. and Al-Saleh, K. A., Phys. Stat. Sol. (A) **102**, 619–623 (1987), Measurement of *K*-Shell X-Ray Cross Sections of Selected Elements from Ti to Zn for Incident Protons (*K* XRF cross sections: Ti, Cr, Fe, Ni, Zn).

87Sa02 Saleh, N. S. and Al-Saleh, K. A., Appl. Radiat. Isotopes **38**, 975–977 (1987), Measurement of Photon-Induced $K_{\alpha 1}$ and $K_{\beta 1}$ X-Ray Fluorescence Cross-Sections for Some Elements with $73 \leqslant Z \leqslant 82$ (K XRF cross sections: Ta, W, Re, Os, Ir, Pt, Au, Hg, Pb).

87Si01 Singh, S., Garg, M. L., Mehta, D., Verma, H. R., Singh, N., Mangal, P. C., and Trehan, P. N., J. Phys. B **20**, 941–947 (1987). Measurements of Photon-Induced *L* X-Ray Fluorescence Cross Sections and Relative Intensities for Ba, Ce and Nd at 15.2, 17.8, 22.6 and 25.8 keV (*L* XRF cross sections: Ba, Ce, Nd).

87Si02 Singh, S., Mehta, D., Garg, M. L., Kumar, S., Singh, N., Mangal, P. C., and Trehan, P. N., J. Phys. B **20**, 3325–3333 (1987), Measurement of Photon-Induced *L* X-Ray Fluorescence Cross Sections and Relative Intensities for Tm, Lu, Th, and U in the Energy Range 15–60 keV (*L* XRF cross sections: Tm, Lu, Th, U).

87Si03 Singh, S., Mehta, D., Garg, M. L., Kumar, Singh, N., Mangal, P. C., and Trehan, P. N., J. Phys B **20**, 5345–5353 (1987), Measurement of L X-Ray Fluorescence Cross Sections and Relative Intensities for Elements $56 \leqslant Z \leqslant 66$ in the Energy Range 11–41 keV (L XRF cross sections: Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy).

87Si04 Singh, N., Mittal, R., Allawadhi, K. L. and Sood, B. S., J. Phys. B **20**, 5639–5645 (1987), Measurement of $L_{\ell+\alpha}$, L_β and L_γ X-Ray Production Cross Sections in Some Rare-Earth Elements by 10, 18, 26 and 33 keV Photons (*L* XRF cross sections: Nd, Sm, Eu, Gd, Dy, Er, Yb, Lu).

87We01 Werner, U. and Jitschin, W., J. Phys. Colloq. (France) **48**, 559–562 (1987). Radiative, Auger, and Coster-Kronig Yields Obtained by the Synchrotron Photoionization Technique (L_1, L_2, L_3: $72 \leqslant Z \leqslant 82$: Measurements described but results not presented).

87Xu01 Xu, J. Q. and Rosato, E., J. Phys. Colloq. (France) **48**, 661–664 (1987). Relative Intensities of Diagram and Satellite *L*-X-Rays for Elements $37 \leqslant Z \leqslant 56$ (Analysis: L_1: $37 \leqslant Z \leqslant 56$).

88Au01 Auerhammer, J., Genz, H., and Richter, A., Z. Phys. D, At. Mol. Clusters (West Germany) **7**, 301–307 (1988), Measurements of L-Subshell Fluorescence Yields for Light and Medium Heavy Elements ($28 \leqslant Z \leqslant 47$) ($L_1$, L_2, L_3: Ni, Cu, Ge, Kr, Sr, Mo, Ag).

88Ch01 Chen, M. H. and Crasemann, B., At. Data Nucl. Data Tables (USA) **38**, 381–424 (1988). *K*-Shell Auger and Radiative Transitions in the Boron Isoelectronic Sequence (Theory: Tables: *K*: C, N, O, F, Ne, Mg, Si, S, Ar, Ca, Ti, Fe, Zn, Kr, Mo, Ag, Xe).

88Ge01 Geidelman, A. M., Egorov, Yu. S., Kuzmenko, N. K., Nedovesov, V. G., Chechev, V. P. and Shyukin, G. E., Proceedings of the International Conference on Nuclear Data for Science and Technology, May 30-June 3, 1988, Mito, Japan, edited by S. Igarasi (JAERI, Tokyo, 1988), p. 909–910. Measurements and Evaluation of Nuclear and Atomic Data of the Applied Radionuclides (*K*: Mn).

88Ha01 Hartmann, E., J. Phys. B, At. Mol. Opt. Phys. (UK) **21**, 1173–1182 (1988), X-Ray Fluorescence Yields for Light Emitter Atoms: Carbon (Theor.: *K*: *C*).

88Ha02 Hartmann, E. and Der, R., J. Phys. B **21**, 1751–1760 (1988), X-Ray Fluorescence Yields for Light Emitter Atoms: Fluorine (Theor.: *K*: F).

88Ka01 Karim, K. R. and Bhalla, C. P., Phys. Scripta **38**, 795–801 (1988). Auger and Radiative Deexcitation Rates and Energies of $3\ell 3\ell'$ States of Helium-Like Argon and Silicon (Theor.: *K*: He-like Ar, Si ions).

88Mc01 McGhee, P. L. and Campbell, J. L., J. Phys. B, At. Mol. Opt. Phys. (UK) **21**, 2295–2309 (1988), Measurement of Coster-Kronig and Fluorescence Yields of the L_2 and L_3 Subshells of Heavy Atoms (L_2, L_3: Pt, Hg, Tl, Pb, U, Cm).

88Mi01 Miyagawa, Y., Nakamura, S., and Miyagawa, S., Nucl. Instr. Meth. B **30**, 115–122 (1988), Analytical Formulas for Ionization Cross Sections and Coster-Kronig Corrected Fluorescence Yields of the L_1, L_2, and L_3 Subshells (Fits: L_1, L_2, L_3: $40 \leqslant Z \leqslant 92$).

88Mo01 Mohan, H., Singh, P. S., Singh, D., Verma, H. R., and Khurana, C. S., Indian J. Phys. A (India) **62A**, 680–684 (1988), Average *L*-Shell Fluorescence Yield Measurements in Sn and Te by Proton Bombardment (*L*: Sn, Te).

88Ni01 Nilsen, J., At. Data Nucl. Data Tables **38**, 339–379 (1988). Dielectronic Satellite Spectra for Helium-Like Ions (Theor.: *K*: Ne8+ – Xe52+).

88Ra01 Rani, A., Koshal, R. K., Chaturvedi, S. N., and Nath, N., X-Ray Spectrom. **17**, 53–54 (1988). Photon-Excited *K* X-Ray Fluorescence Cross-Sec. Measurements for Some Low-Z Elements (*K* (relative to Ca): Na, Mg, Al, Si, S, Cl, K).

88Sa01 Sahota, H. S., Singh, R., and Sidhu, N.P.S., X-Ray Spectrom. **17**, 99–101 (1988). Average *L* Shell Fluorescence Yields from *L* Shell Vacancies in Radionuclides (*L*: Pr, Sm, Tb, Dy, Tm, Bi, U, Np, Pu).

88Sa02 Saleh, N. S., J. Radioanal. Nucl. Chem., Articles, **122**, 193–206 (1988). Photon and Proton Induced X-Ray Cross Sections for Some Elements (*K* XRF cross sections: Y, Zr, Nb, Mo, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, Ba, La; *L* XRF cross sections: Ta, W, Re, Pt, Au, Tl, Pb, Bi).

88Si01 Sidhu, N.P.S., Grewal, B. S., and Sahota, H. S., X-Ray Spectrom. (UK) **17**, 29–31 (1988), *K*-Shell Fluorescence Yields of Some Elements from Nuclear Decay Parameters (*K*: As, Cs, Pr, Eu, Dy, Tm, Lu, Ta, Hg).

88Ta01 Tan, M., Braga, R. A., Fink, R. W., and Venugopala Rao, P., Phys. Scripta (Sweden) **37**, 62–65 (1988), $L_{2,3}$ Subshell X-Ray Fluorescence Yields and Coster-Kronig Transition Probabilities of Nd and Yb (L_2, L_3: Nd, Yb).

88We01 Werner, U. and Jitschin, W., Phys. Rev. A, **38**, 4009–4018 (1988), *L*-Vacancy Decay in Heavy Elements ($72 \leqslant Z \leqslant 82$) by the Synchrotron Photoionization Method (L_1, L_2, L_3: Hf, W, Ir, Pt, Au, Pb).

88Wh01 Whitfield, S. B., Armen, G. B., Carr, R., Levin, J. C. and Crasemann, B., Phys. Rev. A **37**, 419–425 (1988). Vacancy Multiplication Following Ni *L*-Shell Photoionization (Theor.: *L*: Ni).

88Xu01 Xu, J. Q. and Rosato, E., Nucl. Instr. Meth. B **33**, 297–300 (1988), Decay Rates of 2s Vacancies for the Elements $37 \leqslant Z \leqslant 56$ (Analysis: L_1: $37 \leqslant Z \leqslant 56$).

89Ch01 Chen, M. H., Phys. Rev. A **40**, 2365–2372 (1989). Effects of Relativity and Configuration Interaction on *L*-Shell Auger and Radiative Decays of the Doubly Excited $3\ell3\ell'$ States of Sodium like Ions(-Theor.: *L*: Na-like ions, $18 < Z < 92$).

89Ch02 Chen, M. H., Phys. Rev. A **40**, 2758–2761 (1989). Effective *L*-Shell Fluorescence Yields for Sodium like and Neonlike Low-Lying Autoionizing States (Theor.: *L*: Ne, Na).

89Eg01 Egorov, A. G., Egorov, Yu. S., Nedovesov, V. G., Shyukin, G. E. and Yakolev, K., Nuclear Spectroscopy and Atomic Nucleus Structure, Proc. of the 39th Conf., Tashkent, April 18–21, 1989 (Lo. Nauka, Leningrad,1989), p. 505 (*K*: Ag, Cs, Pm, Yb).

89Ko01 Konstantinov, A. A., Sazonova, T. E., Sepman, S. V., and Frolov, E. A., Metrologia **26**, 205–206 (1989), Determination of the Manganese *K*-Shell Fluorescence Yield from the ^{55}Fe Decay (*K*: Mn).

89Si01 Singh, S., Chand, B., Mehta, D., Kumar, S., Garg, M. L., Singh, N., Mangal, P. C., and Trehan, P. N., J. Phys. B **22**, 1163–1173 (1989). *L* X-Ray Fluorescence Cross Sections and Relative Intensity Measurements for Hf, Re, Ir, Pt and Pb in the Energy Range 15–60 keV (*L* XRF cross sections: Hf, Re, Ir, Pt, Pb).

89Si02 Singh, S., Mehta, D., Kumar, S., Garg, M. L., Singh, N., Mangal, P. C., and Trehan, P. N., X-Ray Spectrom. **18**, 193–198 (1989). Contribution Due to Excitation by Scattered Photons in Measurements of *L* X-Ray Cross Sections (*L* XRF cross sections: Pr, Nd, Sm, Tb, Yb).

89Xu01 Xu, J. Q., Z. Phys. D **13**, 25–27 (1989). New Interpretation of the Ag *L*-Series X-Ray Spectrum (Theor. *L*: Ag).

90Ca01 Catz, A. L. and Meyers, M. F., Phys. Rev. A **41**, 271–276 (1990). Measurement of the L_2-L_3 Coster-Kronig Transition Probability on Nd (Z =60) (*L*: f_{23}: Nd).

90Ka01 Kahlon, K. S., Allawadhi, K. L., Sood, B. S. and Shatendra, K., Pramana **35**, 105–114 (1990). Experimental Investigation of Angular Dependence of Photon Induced *L*-Shell X-Ray Emission Intensity (Angular dependence of *L* x-rays).

90Ma01 Mann, K. S., Singh, N., Mittal, R., Allawadhi, K. L. and Sood, B. S., J. Phys. B **23**, 2497–2504 (1990), *M*-Shell X-Ray Production Cross Sections in Au, Pb, Th and U by 6–12 keV Photons (*M* XRF cross sections: Au, Pb, Th, U).

90Ma02 Mann, K. S., Singh, N., Mittal, R., Allawadhi, K. L. and Sood, B. S., J. Phys. B **23**, 3521–3530 (1990), Measurement of *L* X-Ray Production Cross Sections in Elements $57 \leqslant Z \leqslant 92$ at 22.6 keV (*L* XRF cross sections: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb, Lu, Ta, W, Au, Hg, Tl, Pb, Bi, Th, U).

90Pa01 Pajek, M., Kobzev, A. P., Sandrik, R., Skrypnik, A. V., Ilkhamov, R. A., Khusmurodov, S. H., and Lapicki, G., Phys. Rev. A **42**, 261–272 (1990). *M*-Shell X-Ray Production by 0.6–4.0-MeV Protons in Ter Elements from Hafnium to Thorium (*M* XRF cross sections: Hf, Ta, W, Re, Os, Ir, Pt, Au, Bi, Th).

90Pa02 Pajek, M., Kobzev, A. P., Sandrik, K., Skrypnik, A. V., Ilkhamov, R. A., Khusmurodov, S. H., and Lapicki, G., Phys. Rev. A **42**, 5298–5304 (1990), *M*-Shell X-Ray Production by 0.8–4.0-MeV ^{4}He$^+$ Ions in Ten Elements from Hafnium to Thorium (*M* XRF cross sections: Hf, Ta, W, Re, Os, Ir, Pt, Au, Bi, Th) .

90Pa03 Pajek, M., Kobzev, A. P., Sandrik, R., Skrypnik, A. V., Ilkhamov, R. A., Khusmurodov, S. H., and Lapicki, G., Phys. Rev. A **42**, 6582–6587 (1990), *M*-Shell X-Ray Production by 0.6–3.0-MeV ^{3}He$^+$ Ions in Tantalum, Osmium, Gold, Bismuth, and Thorium (*M* XRF cross sections: Ta, Os, Au, Bi, Th).

90Se01 Sergienkov, V. A. and Shilnikov, O. V., Proc. 40th Annual Conf. Nucl. Spectroscopy and Structure of Nuclei, Leningrad, 1990, p. 233 (*L*: ω_1, ω_2, ω_3: Pb).

90Se02 Sergienkov, V. A. and Shilnikov, O. V., Proc. 40th Annual Conf. Nucl. Spectroscopy and Structure of Nuclei, Leningrad, 1990, p. 234 (*L*: ω_1, ω_2, ω_3: Np).

90Si01 Singh, S., Mehta, D., Garg, R. R., Kumar, S., Garg, M. L., Singh, N., Mangal, P. C., Hubbell, J. H., and Trehan, P. N., Nucl. Instr. Meth. B **51**, 5–10 (1990), Average *L*-Shell Fluorescence Yields for Elements $56 \leqslant Z \leqslant 92$ (*L*: Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Ir, Pt, Au, Tl, Pb, Bi, Th, U).

90Si02 Singh, S., Rani, R., Mehta, D., Singh, N., Mangal, P. C., and Trehan, P. N., X-Ray Spectrom. **19**, 155–158 (1990), *K* X-Ray Fluorescence Cross-Sec. Measurements of Some Elements in the Energy Range 8–47 keV (*K* XRF cross sections: Sc, Cr, Fe, Ni, Ga, Sr, Nb, Rh, Pd, Te).

91Ca01 Casnati, E., Baraldi, C. and Tartari, A., Phys Rev. A **44**, 1699–1704 (1991), Measurement of *K* X-Ray Emission from Mo, Cd, and Sn Stimulated by 59.54-keV Photons (*K* XRF cross sections: Mo, Cd, Sn).

91Ga01 Garg, R. R., Singh, S., Shahi, J. S., Mehta, D., Singh, N., Trehan, P. N., Kumar, S., Garg, M. L., and Mangal, P. C., X-Ray Spectrom. **20**, 91–95 (1991), Measurement of *M*-Shell X-Ray Production Cross-Sections Using 5.96-keV Photons (*M* XRF cross sections: Tl, Pb, Bi, Th, U).

91Mc01 McNeir, M. R., Yu, Y. C., Weathers, D. L., Duggan, J. L., McDaniel, F. D. and Lapicki, G., Phys. Rev. A **44**, 4372–4378 (1991). *L*-Shell X-Ray Production Cross Sections in $_{26}$Fe, $_{28}$Ni, $_{29}$Cu, $_{30}$Zn, $_{31}$Ga, and $_{32}$Ge by 0.5- to 5.0-MeV Protons (*L* XRF cross sections: Fe, Ni, Cu, Zn, Ga, Ge).

91Wi01 Willemsen, M. F. C. and Kuiper, A. E. T., Nucl. Instr. Meth. B **61**, 213–230 (1991), Particle-Induced X-Ray Emission of Light Elements (*K*: N, O, F).

91Xu01 Xu, J. Q., Phys. Rev. A **43**, 4771–4779 (1991). *L*-Subshell Fluorescence Yields for Elements with $73 < Z < 83$ (*L*; ω_1, ω_2, ω_3: Ta, W, Re, Ir, Pt, Au, Hg, Tl, Pb, Bi).

92Da01 Darko, J. B. and Tetteh, G. K., X-Ray Spectrom. **21**, 111–114 (1992), Measurement of Relative Intensities of *L*-Shell X-Rays of Some Heavy Elements Using Cd-109 Radioisotope Source (L_1, L_2, L_3 relative Intensities: Sm, W, Ir, Au, Hg, Pb, U).

92Ga01 Garg, R. R., Puri, S., Singh, S., Mehta, D., Shahi, J. S., Garg, M. L., Singh, N., Mangal, P. C. and Trehan, P. N., Nucl. Instr. Meth. B **72**, 147–152 (1992). Measurements of *L* X-Ray Fluorescence Cross-Sections and Yields for Elements in the Atomic Range $41 \leqslant Z \leqslant 52$ at 5.96 keV (*L*: Nb, Mo, Rh, Pd, Ag, Cd, In, Sn, Sb, Te).

92Pi01 Pious, J. K., Balakrishna, K. M., Lingappa, N. and Siddappa, K., J. Phys. B **25**, 1155–1160 (1992), Total K Fluorescence Yields for Fe, Cu, Zn, Ge and Mo (*K*: Fe, Cu, Zn, Ge, Mo).

92Pu01 Puri, S., Chand, B., Garg, M. L., Singh, N., Hubbell, J. H. and Trehan, P. N., X-Ray Spectrom. **21**, 171–174 (1992), Physical Parameters for *L* X-Ray Production Cross-Sections (*L* XRF cross sections, calc.: *Z* = 56–92).

92So01 Solé (Jover), V. A., Ph.D. Thesis, Universidad Valencia, 1992. Medidas Precisas de Rendimientos de Fluorescencia de la Capa K (*K*: K, Ca, Fe, Cu).

92So02 Solé, V. A., Nucl. Instr. Meth. A **312**, 303–307 (1992). Accurate Measurement of $P_K\omega_K$ in the Decay of ^{59}Co and the *K*-Shell Fluorescence Yield of Iron (*K*: Fe).

92St01 Stotzel, R., Werner, U., Sarkar, M., and Jitschin, W., J. Phys. B **25**, 2295–2307 (1992), Fluorescence, Coster-Kronig and Auger Yields of the $_{62}$Sm L Subshells Measured with the Synchrotron Photoionization Method (*L* subshell ratios: Sm).

92Xu01 Xu, J. Q. and Xu, X. J., J. Phys. B **25**, 695–702 (1992) Pb and Bi *L* X-Ray Relative Intensities for Proton and Helium-Ion Bombardment (L_1, L_2, L_3: Pb, Bi).

93Ma01 Marques, M. I., Martins, M. C., Parente, F. and Ferreira, J. G., J. Phys. B **26**, 1263–1269 (1993). L_1 Fluorescence Yield of Yb and Ir (L1: Yb, Ir).

93Pu01 Puri, S., Mehta, D., Chand, B., Singh, N., Mangal, P. C. and Trehan, P. N., Nucl. Instr. Meth. **B 73**, 319–323 (1993), *M* Shell X-Ray Production Cross-Sections and Fluorescence Yields for the Elements with $71 \leqslant Z \leqslant 92$ Using 5.96 keV Photons (M: Lu, Hf, Ta, Ir, Pt, Au, Pb, Bi, Th, U).

93Pu02 Puri, S., Mehta, D., Chand, B., Singh, N. and Trehan, P. N., Nucl. Instr. Meth. B **73**, 443–446 (1993), Measurement of *K* to *L* Shell Vacancy Transfer Probability for the Elements $37 \leqslant Z \leqslant 42$ (*K-L* vacancy transfer: Rb, Sr, Y, Zr, Nb, Mo).

93Pu03 Puri, S., Mehta, D., Chand, B., Singh, N., Hubbell, J. H. and Trehan, P. N., Nucl. Instr. Meth. B **83**, 21–30 (1993), Production of L_i Sub-Shell and *M* Shell Vacancies Following Inner-Shell Vacancy Production (Theor: *K-L* vacancy transfer: 29 elements $18 \leqslant Z \leqslant 96$; *L-M* vacancy transfer: 25 elements $25 \leqslant Z \leqslant 96$).

93Pu04 Puri, S., Mehta, D., Chand, B., Singh, N. and Trehan, P. N., X-Ray Spectrom. **22**, 358–361 (1993), L Shell Fluorescence Yields and Coster-Kronig Transition Probabilities for the Elements with $25 \leqslant Z \leqslant 96$ (Theor: L_1, L_2, L_3: all elements $25 \leqslant Z \leqslant 96$).

93Ra01 Rao, D. V., Cesareo, R. and Gigante, G. E., Phys. Rev. A **47**, 1087–1092 (1993), *L* X-Ray Fluorescence Cross Sections and Intensity Ratios in Some High-Z Elements Excited by 23.62- and 24.68-keV Photons (*L* x-ray fluorescence cross sections: Pr, Ho, Yb, Au, Pb).

93Ra02 Rao, D. V., Gigante, G. E. and Cesareo, R., Physica Scripta **47**, 765–768 (1993), *L*-Shell X-Ray Intensity Ratios for Au and Pb at Excitation Energies 36.82, 43.95, 48.60, 50.20 and 53.50 keV (*L* subshell ratios: Au, Pb).

93Ra03 Rao, D. V., Cesareo, R. and Gigante, G. E., Nucl. Instr. Meth. B **83**, 31–36 (1993), *L* X-Ray Fluorescence Cross Sections of Heavy Elements Excited by 15.20, 16.02, 23.62 and 24.68 keV Photons (*L* x-ray fluorescence cross sections: La, Ce, Gd, Er, Au).

93So01 Solé, V. A., Denecke, B., Grosse, G. and Bambynek, W., Nucl. Instr. Meth. A **329**, 418–422 (1993). Measurement of the *K*-Shell Fluorescence Yield of Ca and K with a Windowless Si(Li) Detector (*K*: K, Ca).

94So01 Solé, V. A., Denecke, B., Mouchel, D. and Bambynek, W., Appl. Radiat. Isotopes (in press). Measurement of $P_K\omega_K$ in the Decay of ^{65}Zn and the *K*-Shell Fluorescence Yield of Copper (*K*: Cu).

12. Additional Text References

09Sa01 Sadler, C. A., Phil. Mag. (Ser. 6) **18**, 107–132 (1909), Transformations of X-Rays.

17Ba01 Barkla, C. G., Phil. Trans. Roy. Soc. London A **217**, 315–360 (1917), On X-Rays and the Theory of Radiation.

23Wi01 Wilson, C.T.R., Proc. Roy. Soc. (London) A **104**, 1–24, + 12 plates (1923). Investigations on X-Rays and β-Rays by the Cloud Method. Part I. X-Rays.

23Wi02 Wilson, C.T.R., Proc. Roy. Soc. (London) A **104**, 192–212, + 9 plates (1923). Investigations on X-Rays and β-Rays by the Cloud Method. Part II. β-Rays.

25Au01 Auger, P., Compt. Rend. **180**, 65–68 (1925). Sur les rayons β secondaires produits dans un gaz par des rayons *X*.

25Au Auger, P., J. de Physique et le Radium (ser. 6) **6**, 205–208 (1925) Sur l'effet photoélectrique compose.

27We01 Wentzel, G., Z. f. Physik **43**, 524–530 (1927), über strahlungslose Quantensprünge.

34La01 Lay, H., Z. F. Physik **91**, 533–550 (1934), Die Fluoreszenzausbeute des *L*-Gebiets.

35Co01 Compton, A. H., and Allison, S. K., X-Rays in Theory and Experiment, 2nd ed. (Van Nostrand 1935) p. 477–492.

49Sc01 Schiff, L. I., Quantum Mechanics, 1st ed. (McGraw-Hill 1949) p. 193.

50Fe01 Fermi, E., Nuclear Physics (Fermi lecture notes compiled by J. Orear, A. R. Rosenfeld and R. A. Schluter, University of Chicago Press, p.142 (1950).

52Bu01 Burhop, E. H. S., The Auger Effect and other Radiationless Transitions (Cambridge University Press 1952).

54Ja01 Jaffe, A. A., Bull. Res. Coun. Israel **3**, 316–320 (1954); see also Phys. Abstr. **58**, 360 (1955) The *M* X-Ray from Radium *D* and the *M* X-Ray Fluorescence Yield of Bismuth.

55Bu01 Burhop, E.H.S., J. Physique et le Radium **16**, 625–629 (1955) Le rendement de fluorescence.

61Be01 Berger, R. T., Rad. Res. **15**, 1–29 (1961) The X- or Gamma-Ray Energy Absorption or Transfer Coefficient: Tabulations and Discussion.

65Jo01 Jopson, R. C., Mark, H., Swift, C. D., and Williamson, M.A., Phys. Rev. A **137**, 1353–1357 (1965) *M*-Shell Fluorescence Yields of Bismuth, Lead, Gold, and Osmium.

67Åb01 Åberg, T., Phys. Rev. **156**, 35–41 (1967) Theory of X-Ray Satellites.

66Fi01 Fink, R. W., Jopson, R. C., Mark, H., and Swift, D. C., Rev. Mod. Phys. **38**, 513–540 (1966) Atomic Fluorescence Yields.

67Kr01 Krause, M. O. and Carlson, T. A., Phys. Rev. **158**, 18–24 (1967) Vacancy Cascade in the Reorganization of Krypton Ionized in an Inner Shell.

68Ko01 Konstantinov, A. A. and Sazonova, T. E., Bull. Acad. Sci. USSR (Phys. Ser.) **32**, 581–584 (1968); transl. from Izv. Akad. Nauk SSSR (Ser. Fiz.) **32**, 631–635 (1968) Determination of the *M*-Fluorescence Coefficients of Gold, Lead, and Bismuth.

69Hu01 Hubbell, J. H., Report NSRDS-NBS 29 (1969) Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 keV to 100 GeV.

71Ca01 Carlsson, G. A., Health Phys. **20**, 653–655 (1971) A Criticism of Existing Tabulations of Mass Energy Transfer and Mass Energy Absorption Coefficients.

71Ch01 Chen, M. H., Crasemann, B. and Kostroun, V. O., Phys. Rev. A **4**, 1–7 (1971) Theoretical L_2- and L_3-Subshell Fluorescence Yields and L_2-L_3X Coster-Kronig Transition Probabilities.

71Cr01 Crasemann, B., Chen, M. H. and Kostroun, V. O., Phys. Rev. A **4**, 2161-2164 (1971) Auger and Coster-Kronig Transition Probabilities to the Atomic 2s State and Theoretical L_1 Fluorescence Yields.

71Ka01 Karttunen, E., Freund, H. U., and Fink, R. W., Phys. Rev. A **4**, 1695–1705 (1971), *M*-Shell Fluorescence Yields and the $L_1 - L_3$ Radiative Transition at $Z = 93$ and 96 from Am^{241} and Cf^{249} Decays.

71Kr01 Krause, M. O., Carlson, T. A. and Moddeman, W. E., J. de Physique **32**(Colloque C4), C4–139–144 (1971) Manifestation of Atomic Dynamics through the Auger Effect.

72Ba01 Bambynek, W., Crasemann, B., Fink, R. W., Freund, H.-U., Mark, H., Swift, C. D., Price, R. E., and Rao, P. V., Rev. Mod. Phys. **44**, 716–813 (1972); erratum in **46**, 853 (1974) X-Ray Fluorescence Yields, Auger, and Coster-Kronig Transition Probabilities.

72Bu01 Burhop, E. H. S., and Asaad, W. N., in Advances in Atomic and Molecular Physics, D. R. Bates and I. Estermann, Editors, Academic Press, New York and London (1972), Vol. 8, p. 163–284 The Auger Effect (Appendix includes tables of *K*, *L* fluorescence yields).

72Mc01 McGuire, E. J., Phys. Rev. A **5**, 1043–1047 (1972) Atomic *M*-Shell Coster-Kronig, Auger, and Radiative Rates, and Fluorescence Yields for Ca-Th.

73Dy01 Dyson, N. A., X-Rays in Atomic and Nuclear Physics (Longman 1973) p. 78–81.

73Sc01 Scofield, J. H., Lawrence Livermore Laboratory Report UCRL-51326 (1973) Theoretical Photoionization Cross Sections from 1 to 1500 keV.

74Ba01 Baker, K. A., Tolea, F., Fink, R. W., and Pinajian, J. J., Z. Physik**270**, 1–7 (1974) Mean *M*-Subshell Fluorescence Yields at $Z = 88$, 90, 92, and 94.

74Ca01 Campbell, J. L., McNelles, L. A., Geiger, J. S., Graham, R. L. and Merritt, J. S., Canadian J. Phys. **52**, 488–498 (1974) *L* Subshell Fluorescence Yields and Coster-Kronig Transition Rates at $Z = 88$ and 94.

74Fi01 Fink, R. W., and Rao, P. V., in Handbook of Spectroscopy, J. W. Robinson, Editor, CRC Press, Cleveland, Ohio (1974), p. 219–229 Tables of Experimental Values of X-Ray Fluorescence and Coster-Kronig Yields for the *K*-, *L*-, and M-Shells.

74Mc01 McGuire, E. J., Phys. Rev. A **9**, 1840–1851 (1974) Atomic *N*-Shell Coster-Kronig, Auger, and Radiative Rates and Fluorescence Yields for $38 \leq Z \leq 103$.

74Sc01 Scofield, J. H., At. Data Nucl. Data Tables **14**, 121–137 (1974) Relativistic Hartree-Slater Values for *K* and *L* X-Ray Emission Rates.

75Mc01 McGuire, E. J., in Atomic Inner-Shell Processes, B. Crasemann, ed. (Academic Press, N. Y. 1975), Vol. **1**, p. 293–330 Auger and Coster-Kronig Transitions.

75Mc02 McNelles, L. A., Campbell, J. L., Geiger, J. S., Graham, R. L. and Merritt, J. S., Canadian J. Phys. **53**, 1349–1359 (1975) *L* Subshell Fluorescence Yields and Coster-Kronig Transitions at $Z = 70$.

5Ra01 Rao, P. V., in Atomic Inner-Shell Processes, B. Crasemann, ed. (Academic Press, N. Y. 1975), Vol. 2, p. 1–32, Inner-Shell Transition Measurements with Radioactive Atoms.

77Ch01 Chen, M. H., Crasemann, B., Huang, K.-N., Aoyagi, M. and Mark, H., Atomic Data and Nuclear Data Tables **19**, 97–151 (1977) Theoretical *L*-Shell Coster-Kronig Energies $11 < Z < 103$.

77Hu01 Hubbell, J. H., Rad. Res. **70**, 58–81 (1977) Photon Mass Attenuation and Mass Energy-Absorption Coefficients for H, C, N, O, Ar, and Seven Mixtures from 0.1 keV to 20 MeV.

78Ho01 Hoffmann, D.H.H., Ph.D. Thesis D-17, Technische Hochschule Darmstadt (1978), p. 108.

78Kr01 Krause, M. O., Nestor, C. W., Sparks, C. J. and Ricci, E., Oak Ridge National Laboratory Report ORNL-5399 (1978) X-Ray Fluorescence Cross Sections for *K* and *L* X-Rays of the Elements.

79Br01 Brandt, W., and Lapicki, G., Phys. Rev. A **20**, 465–480 (1979) *L*-Shell Coulomb Ionization by Heavy Charged Particles.

79Ch02 Chen, M. H., Crasemann, B. and Mark, H., At. Data Nucl. Data Tables **24**, 13–37 (1979) Relativistic Radiationless Transition Probabilities for Atomic *K*- and *L*-Shells.

80Fu01 Fuggle, J. C. and Alvarado, S. F., Phys. Rev. A **22**, 1615–1624 (1980) Core-Level Lifetimes as Determined by X-Ray Photoelectron SpectroscopyMeasurements.

82Åb01 Åberg, T. and Howat, G., in Corpuscles and Radiation in Matter I, Encyclopedia of Physics, Vol. XXXI, S. Flügge and W. Mehlhorn, eds. (Springer, Berlin, 1982) p. 469–619.

82Hu01 Hubbell, J. H., Int. J. Appl. Rad. Isot. **33**, 1269–1290 (1982). Photon Mass Attenuation and Energy-Absorption Coefficients from 1 keV to 20 MeV.

82Te01 Tertian, R. and Claisse, F., Principles of Quantitative X-Ray Fluorescence Analysis (Heyden 1982) p. 12–14.

83Be01 Berger, M. J. and Seltzer, S. M., Report NBSIR 82–2550-A (Revised edition issued 1983) Stopping Powers and Ranges of Electrons and Positrons (2nd. Ed.).

84At01 Attix, F. H., Phys. Med. Biol. **29**, 869–871 (1984) Energy-Absorption Coefficients for γ-Rays in Compounds or Mixtures.

84Ic01 ICRU Report 37 (1984) (M. J. Berger, Report Committee Chairman) Stopping Powers for Electrons and Positrons.

85Co02 Cohen, D. D. and Harrigan, M., At. Data Nucl. Data Tables **33**, 255–343 (1985) *K*- and *L*-Shell Ionization Cross Sections for Protons and Helium Ions Calculated in the ECPSSR Theory.

85Ka02 Karim, K. A. and Crasemann, B., Phys. Rev. A **31**, 709–713 (1985) Continuum Interaction in Low-Energy Radiationless Transitions.

85Oh01 Ohno, M. and Wendin, G., Phys. Rev. A **31**, 2318–2330 (1985) Many-Electron Theory of X-Ray Photoelectron Spectra: N-Shell Linewidths in the $_{46}$Pd to $_{92}$U Range.

86Ja01 Jacobs, V. L. and Rozsnyai, B. F., Phys. Rev. A **34**, 216–226 (1986) Multiple Ionization and X-Ray Line Emission Resulting from Inner-ShellElectron Ionization.

89Hu01 Hubbell, J. H. NISTIR 89–4144 (1989) Bibliography and Current Status of K, L, and Higher Shell Fluorescence Yields for Computations of Photon Energy-Absorption Coefficients.

89Ic01 ICRU Report 44 (1989) (D. R. White, Report Committee Chairman), Tissue Substitutes in Radiation Dosimetry and Measurement.

90Ji01 Jitschin, W., in AIP Conference Proceedings 215, X-Ray and Inner-Shell Processes, Knoxville, Tenn. 1990, T. A. Carlson, M. O. Krauge, and S. T. Manson, eds. (1990) Progress in Measurements of *L*-Subshell Fluorescence, Coster-Kronig and Auger Yields.

91Fi01 Fink, R. W. and Rao, P. V., in Practical Handbook of Spectroscopy, J. W. Robinson, Editor, CRC Press, Ann Arbor (1991), p. 829–843 Tables of Experimental Values of X-Ray Fluorescence and Coster-Kronig Yields for the *K*-, *L*-, and *M*-Shells (*K*, *L*, *M* compilation: $Z = 3$ (Li) to 99 (Es)).

92Hi01 Higgins, P. D., Attix, F. H., Hubbell, J. H., Seltzer, S. M., Berger, M. J. and Sibata, C. H., NISTIR 4812 (1992), Mass Energy-Transfer and Mass Energy-Absorption Coefficients, including In-Flight Positron Annihilation for Photon Energies 1 keV to 100 MeV.

93Ch01 Chantler, C. T., personal communication (1993).

93Kr01 Krause, M. O., personal communication (1993).

93Sc01 Schaphorst, S. J., Kodre, A. F., Ruscheinski, J., Crasemann, B., Åberg, T., Tulkki, J., Chen, M. H., Azuma, Y. and Brown, G. S., Phys. Rev. A **47**, 1953–1966 (1993), Multielectron Inner-Shell Photoexcitation in Absorption Spectra of Kr: Theory and Experiment.

93Se01 Seltzer, S. M., Radiation Research **136**, 147–170 (1993), Calculation of Photon Mass Energy-Transfer and Mass Energy-Absorption Coefficients.