COMMENTS AND ADDENDA

The Comments and Addenda section is for short communications which are not of such urgency as to justify publication in Physical Review Letters and are not appropriate for regular Articles. It includes only the following types of communications: (1) comments on papers previously published in The Physical Review or Physical Review Letters; (2) addenda to papers previously published in The Physical Review or Physical Review Letters, in which the additional information can be presented without the need for writing a complete article. Manuscripts intended for this section may be accompanied by a brief abstract for information-retrieval purposes. Accepted manuscripts will follow the same publication schedule as articles in this journal, and galleys will be sent to authors.

Reevaluation of L_2-Subshell Coster-Kronig Transition Probability and Fluorescence Yield below $Z=81$*

J. C. McGeorge, S. Mohan, and R. W. Fink
School of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332
(Received 8 March 1971)

Recently published experimental values of the L_2-L_3 total Coster-Kronig and L_2-subshell fluorescence yields for $Z=65$, 70, 73, and 80 have been corrected for the presence of the unresolved L_η $[L_2$-$M_1]$ x-ray line in the L_α $[L_3$-$M_{4,5}]$ x-ray group. It is shown that this appreciable correction does not explain the discrepancy between experiment and theory.

As pointed out in a recent paper by Chen *et al.*,[1] the value of the L_2-L_3 total Coster-Kronig yield f_{23} calculated theoretically disagrees with experimental values by about 35%. Although the theoretical calculations by McGuire[2] and Chen *et al.*[1] are based on quite different wave functions, their results are in rather close agreement with each other. This, together with the fact that six of the seven published experimental values of f_{23} are greater than theory predicts, and that all were measured by the same coincidence method suggests that there may be a systematic error in the experiments.

The experimental technique used[3-8] has been outlined by Rao *et al.*[3] and by Wood *et al.*[4] and consists of taking L x-ray spectra in coincidence with $K\alpha_1$ and $K\alpha_2$ x rays individually. The L x rays were observed in Si(Li) detectors which enable only the L_l, $L\alpha$, $L\beta$, and $L\gamma$ x-ray groups to be resolved in the middle-Z region, while above $Z=80$, the L_η, $[L_2$-$M_1]$ component also can be resolved.

Table I lists the energies of the L_η, $L\alpha$, and $L\beta$ x-ray groups taken from the tables of Bearden[9] for $Z=65$, 70, 73, and 80. It is clear that L_η cannot be resolved from $L\alpha$ x rays at $Z=65$, 70, and 73 with the detectors used in the reported experiments (Table II), since the resolution was not better than 260 eV full width at half-maximum (FWHM) (at 6.4 keV), and L_η may be only partially resolved at $Z=80$. In none of the published coincidence spectra is the L_η x-ray line clearly visible. A small "bulge" on the high-energy side of the $L\alpha$ peak can just be discerned in the L x-ray spectrum given[7] for $Z=73$.

In the notation of Rao *et al.*[3] and Wood *et al.*,[4] the values of f_{23} were derived from the expression

$$f_{23}=\frac{C_{L\alpha(K\alpha_2)}/C_{K\alpha_2}}{C_{L\alpha(K\alpha_1)}/C_{K\alpha_1}}\ , \tag{1}$$

which is based on the assumption that the $L\alpha$ x-ray group contains only L x rays emitted in transitions to the L_3 subshell.

Although the L_η $[L_2$-$M_1]$ x-ray line is only $\approx 3\%$ of the intensity of the L_2-M_4 line, its intensity relative to the $L\alpha$ x-ray intensity in spectra taken in coincidence with $K\alpha_2$ x rays is given by

$$\frac{C_{L_\eta}(K\alpha_2)}{C_{L\alpha(K\alpha_2)}}=\left[\left(\frac{L_\eta}{L_2}\right)\omega_2\,\epsilon_{L_\eta}\right]\Big/\left[\left(\frac{L\alpha}{L_3}\right)f_{23}\,\omega_3\,\epsilon_{L\alpha}\right]\ , \tag{2}$$

where L_η/L_2 is the intensity ratio of the L_η component to all x rays emitted in transitions to the L_2

TABLE I. L x-ray energies in keV at $Z=65$, 70, 73, and 80 (from Ref. 9).

Z	$L\alpha_1[L_3$-$M_5]$	$L_\eta[L_2$-$M_1]$	$L\beta_1[L_2$-$M_4]$
65	6.273	6.284	6.978
70	7.416	7.580	8.402
73	8.146	8.428	9.343
80	9.989	10.651	11.823

TABLE II. Revision of f_{23} and ω_2 values and comparison of f_{23} with theory.

Original values				Theoretical x-ray intensity ratios (from Ref. 10)	
Z	ω_2	f_{23}	Reference	L_η/L_2	$L\alpha/L_3$
65	0.160±0.018	0.090±0.014	5	0.0223	0.818
70	0.182±0.011	0.170±0.009	6	0.0221	0.815
73	0.250±0.013	0.180±0.007	7	0.0220	0.807
80	0.316±0.010	0.190±0.010	8	0.0215	0.785
81	0.319±0.010	0.169±0.010	4		
82	0.363±0.015	0.164±0.016	3		
Revised values				Theoretical values of f_{23}	
Z	ω_2	f_{23}	k (Eq. 3)	Ref. 1	Ref. 2[a]
65	0.165±0.018	0.066±0.014	1.000	0.131	0.138
70	0.188±0.011	0.142±0.009	0.984	0.124[b]	0.130
73	0.257±0.013	0.150±0.007	0.979	0.120[b]	0.126
80	0.319±0.010	0.188±0.010	0.065[c]	0.108	0.124
81	0.319±0.010	0.169±0.010	0.000	0.106[b]	0.116
82	0.363±0.015	0.164±0.016	0.000	0.104[b]	0.110

[a]Linear interpolation between values given for $Z=65$, 74, 79, and 85.

[b]Linear interpolation between values given for $Z=60$, 67, 74, 79, and 83.

[c]Reference 12.

subshell, and $L\alpha/L_3$ is the intensity ratio of the $L\alpha$ component to all x rays emitted in transitions to the L_3 subshell. From Eq. (2) it is apparent that in experiments where the L_η x-ray line is not resolved, a significant correction in f_{23} will be required and will reduce its value.

Assuming that the x-ray efficiencies $\epsilon_{L\alpha} \approx \epsilon_{L_\eta}$, the correct value of f_{23} may be calculated from the formula

$$f_{23} = f_{23}' - \left(\frac{(L_\eta/L_2)(\omega_2/\omega_3)}{(L\alpha/L_3)} \right) k , \tag{3}$$

where f_{23}' is the uncorrected published value and k is the fraction of L x rays included in the $L\alpha$ x-ray peak.

Since the reported values of the L_2-subshell fluorescence yield ω_2 were determined essentially from the relationship

$$\omega_2 = \nu_2 - f_{23}\,\omega_3 , \tag{4}$$

they depend slightly on f_{23}. An iterative procedure starting with the published values of ω_2 was therefore used on Eqs. (3) and (4) to reevaluate f_{23} and ω_2 (see Table II). Theoretical values of the ratios L_η/L_2 and $L\alpha/L_3$ were taken from Scofield,[10] as recent experimental work on relative L x-ray intensities shows reasonably good agreement[11] with the theory in this region of Z.

The value of k in Eq. (3) depends on the detector resolution, the energy separation between the L_η and the $L\alpha$ x-ray peaks (increasing with Z), and the method used to evaluate the $L\alpha$ x-ray intensity. Except for $Z=80$,[12] $k \approx 1$ (see Table II).

It is apparent that while these corrections bring the experimental value of f_{23} at $Z=70$ and 73 into closer agreement with theory, some discrepancy still exists. At $Z=80$, the small correction does not significantly improve the agreement with the results at $Z=81$ and 82 (which probably do not require revision, since L_η was apparently resolved from $L\alpha$), and all three values still lie about 30% higher than theory. The result at $Z=65$ is pushed even further from theory by this correction.

The small corrections to the L_2-subshell fluorescence yield ω_2 are barely significant, and agreement with theory[1] remains satisfactory.

*Work supported in part by the U. S. Atomic Energy Commission.

[1]M. H. Chen, B. Crasemann, and V. O. Kostroun, Phys. Rev. A (to be published).

[2]E. J. McGuire, Phys. Rev. A 3, 587 (1971).

[3]P. V. Rao, R. E. Wood, J. M. Palms, and R. W. Fink, Phys. Rev. 178, 1997 (1969).

[4]R. E. Wood, J. M. Palms, and P. V. Rao, Phys. Rev. 187, 1497 (1969).

[5]J. C. McGeorge, H. U. Freund, and R. W. Fink, Nucl. Phys. A154, 526 (1970).

[6]S. Mohan, H. U. Freund, R. W. Fink, and P. V. Rao, Phys. Rev. C 1, 254 (1970).

[7]S. Mohan, R. W. Fink, R. E. Wood, J. M. Palms, and P. V. Rao, Z. Physik 239, 423 (1970).

[8]J. M. Palms, R. E. Wood, P. V. Rao, and V. O. Kostroun, Phys. Rev. C 2, 592 (1970).

[9]J. A. Bearden, Rev. Mod. Phys. 39, 78 (1967).

[10]J. H. Scofield, Phys. Rev. 179, 9 (1969).

[11]P. V. Rao, J. M. Palms, R. E. Wood, Phys. Rev. A (to be published).

[12]P. V. Rao, J. M. Palms, and R. E. Wood (private communication).