The Relative Energy of the $L\alpha$ Satellites Excited by Cathode Rays in the Atomic Number Range 47 to 52

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(Received August 3, 1935)

By a photographic method, the measurement of the integrated relative energy of the $L\alpha$ satellites, with respect to their parent $L\alpha_1$ line, has been extended from Ag(47) to Te(52). In this range the satellites decrease rapidly in relative energy with increasing atomic number. This is in substantial agreement with the new theory of Coster and Kronig.

INTRODUCTION

THE purpose of this paper is to report an extension of the measurements of the integrated relative energy for cathode-ray excitation of the $L\alpha$ satellites. The previous work[1] gave integrated relative energies from Zr(40) to Ag(47). The present work extends the measurements to Te(52).

X-ray satellites have been observed to occur within certain well-defined atomic number ranges.[2] The exact manner in which the integrated satellite energy changes with respect to the energy of the parent line, as we pass through the atomic number range of satellite occurrence, is of considerable interest and importance.

EXPERIMENTAL METHOD AND RESULTS

The $L\alpha$ lines of the elements from Ag(47) to Te(52) were recorded on Eastman IV–O Spectroscopic plates with a Siegbahn Vacuum Spectrograph. (A resolving power of about 3000 is attainable with this instrument at $\lambda = 4.0$A.) The Eastman IV–O plates are very fine grained, and, as a precaution further to minimize grain effects, Eastman D–76 Fine Grain Developer was used.

Microphotometric records of the $L\alpha$ lines of Ag(47) and Te(52) are shown in Fig. 1. These records were made by using the oscillation method previously described[3] and are noteworthy for their absence of "grain."

From these microphotometric records, density (intensity) plots were made as in the previous paper.[1] The density-exposure time curves for the wave-length range 4.0–5.4A have recently been studied[4] and a linear region, increasing in extent with increasing wave-length, is found to be present for all wave-lengths studied. The x-ray lines on all plates in the present work were exposed so as to have maximum densities lying within this linear region.

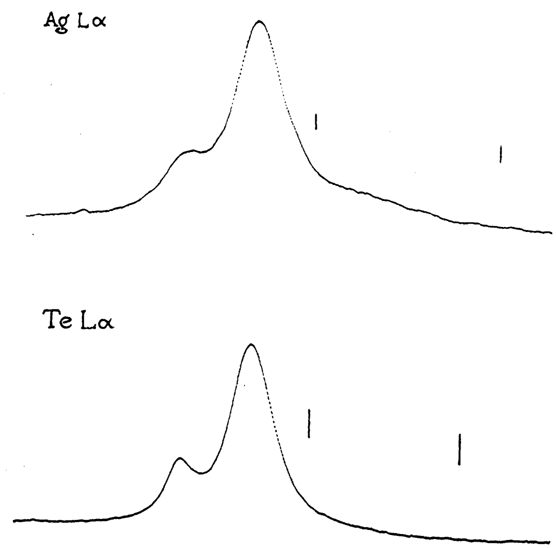

FIG. 1. Microphotometric records of the $L\alpha$ lines of Ag(47) and Te(52), excited by 20 kv electrons. Vertical lines indicate limiting wave-length positions between which satellites have been observed visually.

Fig. 2 shows density (intensity) plots made from microphotometer records. In these density plots the parent line, $L\alpha_1$, has been assumed to have the classical[5] shape and has been fitted with a curve having the proper relative energy, (as measured by areas), with respect to $L\alpha_2$.

[1] F. R. Hirsh, Jr. and F. K. Richtmyer, Phys. Rev. **44**, 955 (1933).
[2] F. K. Richtmyer, J. Frank. Inst. **207**, 353 (1929).
[3] F. K. Richtmyer and F. R. Hirsh, Jr., Rev. Sci. Inst. **4**, 353 (1933).
[4] F. R. Hirsh, Jr., J. Opt. Soc. Am. **25**, 229 (1935).
[5] A. Hoyt, Phys. Rev. **40**, 477 (1932).

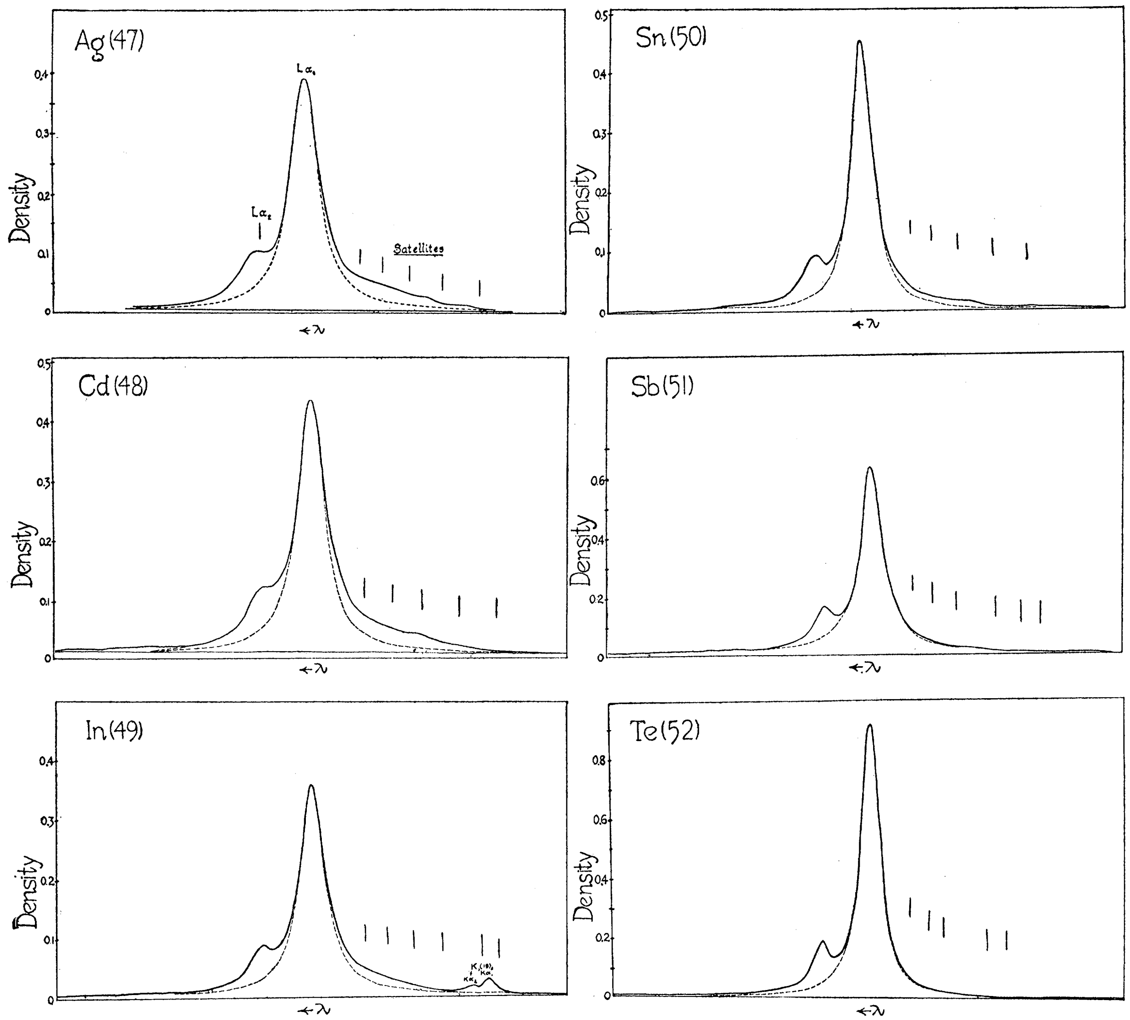

FIG. 2. Density, (intensity), plots of the $L\alpha$ lines of Ag(47) through Te(52) excited by 20 kv electrons. Vertical lines indicate positions at which satellites have been measured visually by others.

This assumption is reasonable since the $L\alpha_1$ line becomes symmetrical as we approach atomic number 52. At Te, (52) where the satellites are extremely faint, the asymmetry of $L\alpha_1$ has nearly vanished and the classical curve is seen to give a good representation of the line shape. All of the area between the classical curve and the short wave-length side of the $L\alpha$ line plot was designated as belonging to the satellite structure. This area divided by the area of $L\alpha_1$ gives the integrated relative energy of the group of satellites as shown in Table I.

The values given in Table I, column I are secured from the density plots in Fig. 2. A second set of spectrograms was made and independently analyzed to check these preliminary results (the data are given in Table I, column II). Both sets of data are plotted as the points surrounded by diamonds and squares in Fig. 3. The crosses are data previously reported.[1]

The full line of Fig. 3 rises to a maximum at atomic number 45, and falls off sharply to small values at atomic number 52. The broken curve[6] for the satellites of $L\beta_2$ shows a maximum at a higher atomic number than the maximum for

[6] A. W. Pearsall, Phys. Rev. **46**, 694 (1934).

the $L\alpha_1$ line curve. It is interesting to note that the $L\beta_2$ line first occurs at a higher atomic number than does $L\alpha_1$. Both the full and dashed curves of Fig. 3 fall off towards atomic number 52 in practically the same manner.

Conclusions

It is shown in Fig. 3 that the satellites of both $L\alpha_1$ and $L\beta_2$ fade out as we approach Te(52) from lower atomic numbers. Both of these parent lines, $L\alpha_1$ and $L\beta_2$, originate from electron transitions ending in the L_{III} shell. The theory, based on the Auger effect, recently advanced by Coster and Kronig[7] explains the disappearance of both the $L\alpha_1$ and $L\beta_2$ satellites near atomic number 52. This theory, furthermore, is in good agreement with other observations made in the Cornell X-Ray Laboratory. (For a discussion of these facts see the article[7] just referred to.)

The theory predicts:

(1) The vanishing of the $L\alpha_1$ and $L\beta_2$ satellites at about atomic number 53.

TABLE I.

ELEMENT	ATOMIC NUMBER	INTEGRATED RELATIVE ENERGY	
		I	II
Ag	47	0.155 *p*	0.330†
Cd	48	0.185	0.200
In	49	0.100	0.120
Sn	50	0.055	0.060
Sb	51	0.010	0.100*
Te	52	0.010	0.010

* High value because of uneven background on plate.
† Value from previous article (see reference 1).
p Dr. L. G. Parratt has very kindly checked with the two-crystal vacuum spectrometer, using a resolving power ~11,000, as obtained with "perfect" calcite crystals. Assuming the parent line is not of the classical shape, and drawing in freehand a "most reasonable" satellite background (foot of the parent line), he finds a total satellite intensity of 7 percent. Assuming the parent line is of the classical shape in an arbitrary region adjacent to the satellites, thus securing the constants and drawing in the background, he finds the value of 11 percent for the total satellite intensity. This is a fairly good check with the photographic value of 15.5 percent as given in Table I, column I. We are both agreed that no satisfactory analytical method of drawing in the parent line under the satellite structure, has been developed as yet. The photographic value of 15.5 is probably a low estimate, since the microphotometer record for Ag $L\alpha$ (see Fig. 1), is slightly lower on the short wave-length side. This would raise the estimate of 15.5 percent (shown as the square at $Z=47$ in Fig. 3), to a point considerably nearer the (full) curve for $L\alpha_1$.

[7] D. Coster and R. De L. Kronig, Physica **2**, 13 (1935).

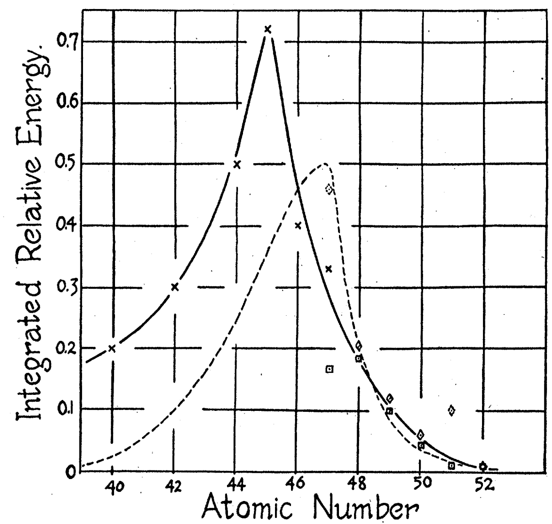

FIG. 3. Integrated relative energies of $L\alpha$ satellites plotted against atomic number. Full line plotted from data given in this article, and in a previous article.[1] Dashed curve is for relative energies of the satellites of $L\beta_2$.[6]

(2) The absence of any enhancement of the intensity of these satellites, due to Auger effects, between atomic numbers 53 and 74.

(3) The reappearance of these satellites above atomic number 74. (For the experimental facts see a recent paper by Kaufman.[8])

A crucial test of this new theory of Coster and Kronig would seem to lie in the comparison of the predicted behavior of the satellites of the lines $L\beta_1$, $L\gamma_1$ and $L\gamma_{2,3}$ according to this new theory, and the experimental facts concerning the satellites of these lines. Further discussion will appear in a later paper.

Acknowledgment

The author wishes to acknowledge Dean Richtmyer's continued interest in this work, and desires to express gratitude for permission to use certain apparatus granted Dean Richtmyer by the Heckscher research council of Cornell University.

[8] S. Kaufman, Phys. Rev. **45**, 385 (1934).