THE EXPLANATION OF THE WIDTH ANOMALY OF THE X-RAY LINE M-ZETA

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ABSTRACT

Kiessig (1938) published data on the widths of the $M\zeta$ line for elements Sr(38) to Ce(58). These data (in Table I) were obtained by measuring microphotometer traces made from carefully exposed photographic plates. They reveal that the width of $M\zeta$ increases rapidly with atomic number in the range $38 \leq Z \leq 52$, but drops greatly between elements 52 and 56. Kiessig observed that the region in which the line width was increasing was the entire fifth period of the periodic table, while the last three elements with their narrower widths were part of the sixth period. This observation tempted him to advance the generalization that the width of $M\zeta$ was small at the beginning of a period and increased to a maximum at the end of a period, but Siegbahn and Magnusson (1934) had previously found that the $M\zeta$ lines of Br(35) and Rb(37) were very narrow. Br and Rb are both near the end of the fourth period. In view of this fact Kiessig decided that the generalization was not valid. He did not advance any other explanation.

TABLE I

Widths of $M\zeta$ in electron volts (after Kiessig)

Element	Width	Element	Width	Element	Width
Sr(38)	1.99	Rh(45)	4.57	Sb(51)	18.5
Zr(40)	2.06	Pd(46)	6.74	Te (52)	18.5
Nb(41)	3.44	Ag(47)	13.6	Ba(56)	7.0
Mo(42)	3.05	Cd(48)	14.8	La(57)	9.1
Ru(44)	3.79	Sn(50)	16.4	Ce(58)	10.6

This width anomaly can be explained very simply on the basis of the theory of line widths according to Weisskopf and Wigner (1930). According to this theory the width of an x-ray line is equal to the sum of the widths of the initial and final states; the width of a state is inversely proportional to the mean life of atoms in the state. If T is the mean life of atoms in state A and W is the width of the level in energy units, then

$$W = h/2\pi T = \sum_B \gamma_B^A$$

where γ_B^A is the probability of the transition A to B and the sum extends over all possible transitions.

The line $M\zeta$ arises from a transition from the M_V state to the N_{II} or N_{III} state, so its great width for elements such as silver must be due to a great width for one or more of these states. Work by Parratt (1938) on the silver L series reveals that the M_V level is narrow, but that the N_{II} and N_{III} levels are very broad.

The great widths of the N_{II} and N_{III} levels must be associated with very large values of the probabilities for certain transitions from these states. In the case of the N_{II} level the Auger (radiationless) transitions N_{II} to N_{III} $O_{II,III}$ are forbidden by energy conservation for elements of atomic number above 55. The probabilities of these transitions will be very small when the energy of the ejected electron is great, so these transitions will be very probable only for a few elements of atomic number under 56 and will rapidly become less probable for elements of atomic number below approximately 50. The N_{III} level should, by chance, be very wide in the same region because the Auger transitions N_{III} to $N_{IV,V}$ $N_{IV,V}$ are possible for all elements of atomic number below 56 and forbidden for elements of higher atomic number. The probabilities of these transitions will also have a maximum for elements just below Z = 56 and should drop off rapidly for elements of atomic number under 50 or thereabouts.

Thus the great width of M_ζ for elements of atomic number near 52 and the decrease in widths on both sides of the maximum is readily explained in terms of the high probabilities of the Auger transitions $N_{II} \rightarrow N_{III}\ O_{II,III}$ and $N_{III} \rightarrow N_{IV,V}\ N_{IV,V}$.

It is possible that the width increase between elements 56 and 58 is due to the increasing probability of the Auger transitions $N_{II} \rightarrow N_{IV,V}\ N_{IV,V}$ which is possible for elements of atomic number under 60, but the data do not cover a sufficiently large atomic-number range to be conclusive.

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