

ON THE CRITICAL ABSORPTION AND CHARACTERISTIC EMISSION X-RAY FREQUENCIES.

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SYNOPSIS.

In the analysis of X-ray line spectra it is of considerable importance to know whether or not the critical absorption, the critical ionization and the highest characteristic emission frequencies associated with any one single X-ray series are exactly equal to each other. Such knowledge must have a marked influence on speculation and theories as to the mechanism of X-radiation and the structure of atoms.

The object of the research reported in this paper has been to measure these three frequencies, as precisely as possible, using the same instruments throughout the work. The measurements have been made with the X-ray spectrometer employed several years ago to determine the value of h . The X-rays came from the steadiest sources at present available, namely, Coolidge tubes excited by currents from a high tension storage battery.

As results of our research we conclude that the critical ionization frequency equals the critical absorption frequency to within considerably less than 1/10 per cent.; and that the critical absorption frequency exceeds the frequency of the γ line in the emission series by 1/4 per cent. or 1/3 per cent., these being determined by measuring from the centers of the drops and peaks in the curves corresponding to them respectively.

IN the analysis of characteristic X-ray spectra we recognize four different kinds of frequency of vibration associated with each series of lines. In the K series of a chemical element, for example, we have: (a) several emission frequencies; (b) one critical absorption frequency; (c) one critical ionization frequency and (d) one frequency such that when it is multiplied by Planck's action constant, h , the product equals the minimum energy the electron in the X-ray tube must have in order that it may be able to produce the K emission series.

It is known that the highest frequency in the emission spectrum (the γ line) and the other three frequencies (b), (c) and (d) lie close together, *i.e.*, within a few per cent. of each other.

The object of the research reported in this paper has been to determine whether, within the limits of experimental error, the γ line frequency the critical absorption frequency and the critical ionization frequency, are exactly equal to each other or not.

¹ A paper presented at the New York meeting of the American Physical Society, April 27, 1918.

Throughout these experiments we used the same X-ray spectrometer (namely that described in the *PHYSICAL REVIEW* for December, 1917, page 624), and, in order to eliminate some of the possible sources of error, we did not change the general set up of the instrument.

We calculated the wave-lengths of the X-rays reflected from the surface of the calcite crystal by means of the equation

$$\lambda = 6.056 \times \sin \theta \times 10^{-8} \text{ cm.}$$

where θ is the grazing angle of incidence.

The X-rays came from tubes of the Coolidge type. One of the tubes had a tungsten target and the other had a rhodium target.

The X-rays passed through two narrow slits before they reached the calcite crystal. As the third slit, that in front of the ionization chamber, was large enough to admit the entire reflected beam, this method eliminates large corrections for the penetration of the X-rays into the crystal (*l.c.*).

The electrical current (2 milliamperes) through the X-ray tube came from a high potential storage battery. In most of the experiments we held the difference of potential between the electrodes of the tube constant at 37,750 volts, and, if any small unavoidable variation from this value occurred, we corrected for it.

In order to avoid actually determining the zero point on the scale of the instrument we either measured the lines on each side of it, or else found their positions in both the first and the second order spectra. The various sets of measurements agree with each other to within the limits of experimental error.

In order to determine whether or not the critical absorption frequency differs from the critical ionization frequency, we filled the ionization chamber with methyl-iodide and used a thin layer of potassium iodide as the absorber.

The curves in Fig. 1 represent the ionization currents as functions of the readings of the verniers attached to the crystal table. The curves *A* and *A'* refer to experiments in which no absorber was used. The sharp breaks in the curves occur at angles corresponding to the critical ionization wave-length of iodine. X-rays of shorter wave-length than this critical wave-length produce more ionization than X-rays of longer wave-length do. Measuring from the center of the drop on one side of the zero to the center of the drop on the other side we get for the double grazing angle 2θ (after subtracting an excentricity correction of $22''$) $2\theta = 7' 4' 25''$. Whence the critical ionization wave-length λ_i is $\lambda_i = .3736 \times 10^{-8} \text{ cm.}$

Curve *B* represents an experiment in which the X-rays passed through

a thin layer of potassium iodide before reaching the spectrometer. The iodine in the salt absorbs X-rays of shorter wave-lengths than the critical absorption wave-lengths to a greater extent than it does longer waves. The magnitude of the change in the absorption depends, of course, upon the thickness of the absorbing layer, and in this experiment the layer was thick enough to more than counteract the increase in ionization for X-rays shorter than the critical ionization wave length. The ordinates in curve *C* are the ratios of those in curve *B* to those in curve *A* respectively. Curve *C* represents, therefore, the true critical absorption effect un-

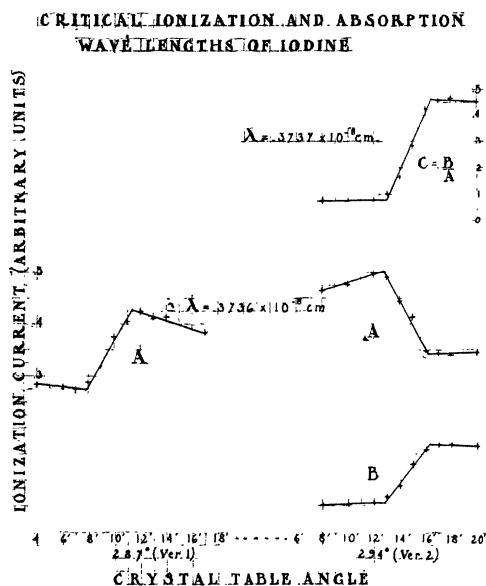


Fig. 1.

influenced by the change in ionization at the critical ionization wave-length; and the angle measured to the center of the drop corresponds to the critical absorption wave-length λ_a . It appears from the graphs that the centers of the drops in curve *A* and curve *C* fall sensibly at the same abscissa; that is, the angles corresponding to the critical absorption and critical ionization wave-length do not differ from each other by more than a few seconds of arc. A difference of 10'' of arc could be detected, which means that *the critical absorption and critical ionization wave-lengths are equal to each other to within less than 1/10 per cent.*

In order to determine whether or not the K critical absorption wave-length (λ_a) of a chemical element is the same as that of the γ emission line in the K series we have investigated the emission spectrum of an X-ray tube having a rhodium target.

The curves in Fig. 2 represent the ionization currents as functions of the readings of one of the verniers attached to the crystal table.

For the two α lines readings were taken $15''$ of arc apart on both sides of the zero. The peaks corresponding to these two lines are separated from each other, but the separation appears to be better on the right hand side than on the left. Some slight inequality in the structure of the crystal planes may account for this.

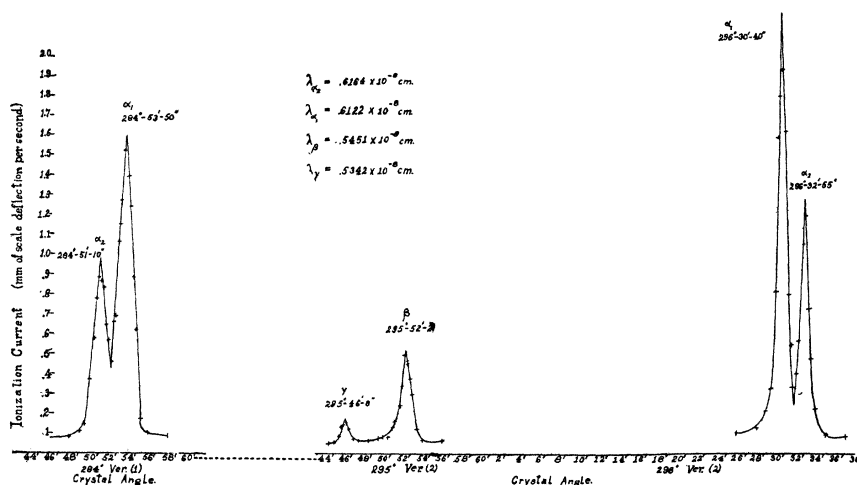


Fig. 2.

As the difference between the wave-lengths of the two α lines amounts to only two thirds of one per cent. this gives an idea of the precision with which the wave-lengths can be estimated. It appears to be possible to determine between which two settings of the instrument a peak lies, and also which of the two settings it lies nearer to. This means that the precision of the measurement is the precision with which the angles can be read by means of the verniers. The verniers' scales are supposed to give readings to $5''$ of arc. By estimating from several readings on the two sides of each peak it seems reasonable to suppose that the wave-lengths can be determined with a precision considerably less than one tenth per cent., the grazing angles for these lines being larger than 6° .

The curves in Fig. 2 show also the peaks corresponding to the β and γ lines. The readings for these were taken on one side of the zero only, but the wave-lengths have been calculated from the zero determined by the α line measurements.

The curves in Fig. 3 represent the two α line peaks in both the first and the second order spectra. Passing from the first to the second order

spectrum the distance between the two peaks about doubles itself, while the breadth of each peak remains about the same.

The wave-lengths of the α lines calculated from the first and second order spectra, without direct reference to the zero, equal the corresponding wave-lengths calculated from the first order spectra alone.

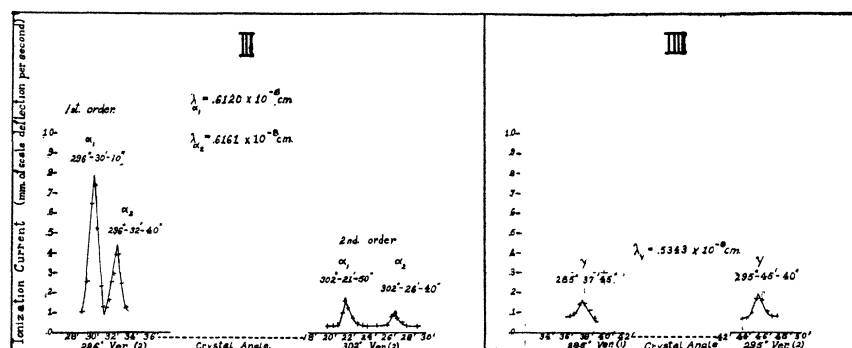


Fig. 3.

Fig. 4.

The peaks in the curves of Fig. 4 correspond to the γ line in the first order spectrum on each side of the zero.

The curves in Figs. 2, 3 and 4 furnish three independent methods of estimating the position of the zero on the scale.

A correction for eccentricity amounting to about $45''$ of arc must be subtracted from the double grazing angle.

The following table contains the wave-lengths of all four lines.

K Series of Rhodium (45). $\lambda \times 10^8 \text{ cm}$.

α_2	α_1	β	γ
.6164	.6122	.5451	.5342
.6163	.6121	.5453	.5343
.6164	.6120	.5454	.5342

In 1917¹ Prof. F. C. Blake and one of us obtained the value $\lambda = .5324 \times 10^{-8} \text{ cm}$. for the critical K absorption frequency of rhodium. As this differs from the values of λ_γ contained in the above table by slightly more than the probable error of the measurement, and as the spectrometer had been partly dismantled and the parts reassembled, the authors of this paper decided to re-measure the critical absorption wave-length.

For this purpose we used the tungsten target X-ray tube and an absorbing layer of rhodium salt placed between the tube and the spectrometer.

¹ PHYS. REV., December, 1917, p. 702.

Measuring from the centers of the sharp breaks in the curves on the two sides of the zero line, we get for the critical K absorption wave-length of rhodium $\lambda = .5330 \times 10^{-8}$. This value agrees with that obtained in 1917 to within approximately one tenth per cent., but differs from the wave-length of the γ emission line by almost one fourth per cent.

In order to obtain additional evidence as to whether or not this difference really exists, we have made some experiments using the rhodium target tube both with and without the rhodium salt absorber.

The curves in Fig. 5 represent the results obtained. The widths of

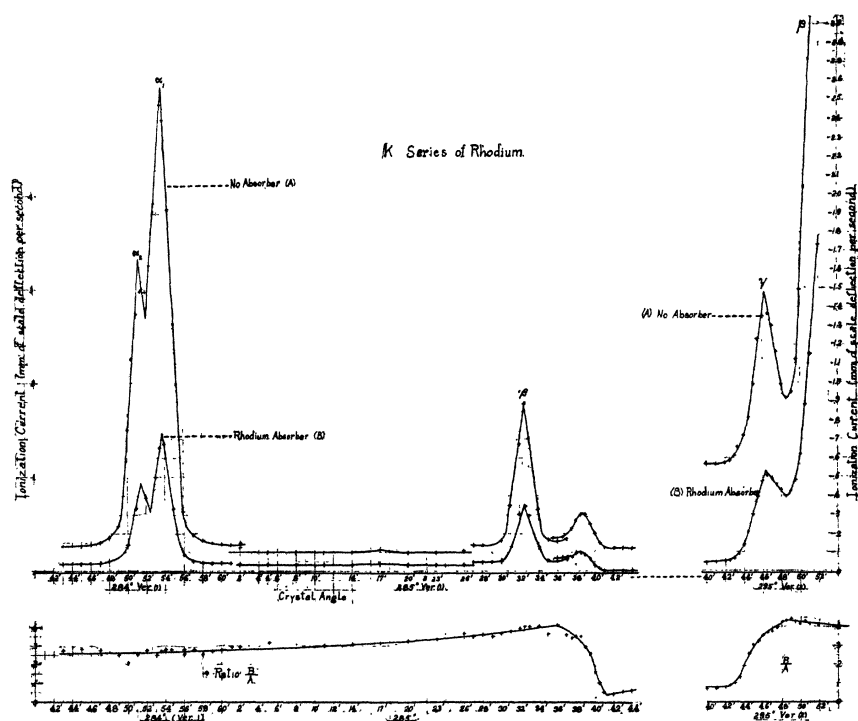


Fig. 5.

the slits were somewhat larger than in the previous experiments. They were larger, also, for the measurements on the right hand side of the zero, than on the left. The readings for corresponding parts of the curves with and without the absorbing screen were made on the same day, but the readings for different sections of the curves were made on different days. This is shown by the discontinuities in and overlappings of the curves.

Curve A has been platted from the data obtained without the absorb-

ing screen, and curve *B*, with the absorbing screen. The third curve below represents the ratio of the *B* to the *A* ionization currents.

The curves indicate that *the rhodium has no appreciable selective absorption for the X-rays in its own α_1 , α_2 and β emission lines.* The marked increase in absorption occurs, however, close to the peak representing the γ line. Further the wave-length corresponding to the center of the γ line peak is about one third per cent. longer than that corresponding to the center of the absorption drop.

It appears, therefore, from both experiments that, if the wave-length of the emission line corresponds to the center of the peak, and, if the critical absorption wave-length corresponds to the center of the absorption drop, *the critical absorption wave-length is about one fourth per cent. shorter than that of the γ emission line.*