ON THE X-RAY ABSORPTION FREQUENCIES CHARACTERISTIC OF THE CHEMICAL ELEMENTS.[1]

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SYNOPSIS.

Object.—The critical absorption wave-lengths associated with the K series of x-rays have been measured[2] for all but two of the known chemical elements from manganese ($N = 25$) to cerium ($N = 58$). The object of the experiments described in this paper was to extend the measurements to chemical elements of higher atomic numbers, using the same x-ray spectrometer.

Source of Current.—In the earlier experiments the electric current through the x-ray tube came from a storage battery of 20,000 cells, giving an electromotive force of about 43,000 volts when fully charged. A difference of potential of 43,000 can produce x-rays only a few per cent. shorter than the critical absorption wave-length associated with the K series of cerium, and to make the measurements for chemical elements of larger atomic numbers, having shorter critical absorption wave-lengths, requires a higher voltage applied to the x-ray tube. The authors, therefore, employed a transformer, with a set of condensers and kenotrons attached to it for producing approximately a constant difference of potential. Except for this generating plant the apparatus did not differ from that used in the earlier researches.

Results.—The K-critical absorption wave-lengths were measured for eight of the chemical elements from neodymium ($N = 60$) to lead ($N = 82$) both inclusive. The square roots of the vibration frequencies corresponding to their wave-lengths, when platted against the atomic numbers, indicate a still greater departure from the straight line law than do the values previously obtained for elements of lower atomic numbers.

As has been shown (*l.c.*), the equation

$$v = 0.00678\,(N - \tfrac{3}{2})c \qquad (1)$$

represents to within 1/5 per cent. the velocity of the electrons in the x-ray tube required to produce the K emission series of a chemical element of atomic number lower than $N = 58$, if the velocity is calculated by the quantum relation, using the expression for the transverse mass. The values of v calculated by the same formulas for elements of atomic numbers higher than 58 fall slightly below those given by equation (1). The greatest variations from the equation amount to a little over 1 per cent.

SEVERAL papers have been published[2] describing measurements of the critical absorption wave-lengths associated with the K series of x-rays characteristic of all but two of the known chemical elements from manganese (atomic number $N = 25$) to cerium ($N = 58$) both inclusive.

[1] A paper presented at the Baltimore meeting of the American Physical Society, December 28, 1918.

[2] Blake and Duane, PHYS. REV., Dec., 1917, p. 697; and Duane and Hu, PHYS. REV., June, 1918, p. 488.

In these experiments the electric current flowing through the x-ray tube came from a storage battery of 20,000 cells, giving, when fully charged, a difference of potential of about 43,000 volts. This difference of potential can not produce x-rays much shorter than the K critical absorption wave-length of cerium, and, as the critical wave-length decreases quite rapidly with increasing atomic numbers, it was found impossible to make good measurements for elements of higher atomic numbers than 58.

The authors therefore set up a generating plant similar to that designed by Dr. A. W. Hull. This consisted of a high tension transformer attached to a system of condensers and kenotrons for maintaining the voltage approximately constant. The plant gave us voltages up to about 115,000 volts and we were able to measure the critical absorption wave-lengths associated with the K series of eight of the chemical elements from neodymium ($N = 60$) to lead ($N = 82$).

Except for the generating plant the apparatus did not differ from that used in the earlier researches (*l. c.*), and the same precautions were taken to eliminate errors due to the penetration of the x-rays into the reflecting crystal (calcite), and to the width of the spectrometer's slits.

Curves were drawn for each chemical element similar to those published on page 701 of the PHYSICAL REVIEW for December, 1917, and the angular distances between the mid-points in the sharp drops gave us the grazing angle of incidence, θ, from which to calculate the wave-lengths by the formula

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

The following table contains the data. The critical absorption wave-lengths appear in the third column, and the square roots of the corresponding vibration frequencies in the fourth.

The values of the critical absorption wave-lengths given by de Broglie[1] are several per cent. smaller than ours.

Chemical Element.	Atomic Numbers.	$\lambda \times 10^8$.	$\sqrt{\nu} \times 10^{-9}$.	Ratio $\beta = v/c$.	$\beta_0 \times 1{,}000$.
Neodymium	60	.2861	3.237	.3952	6.756
Terbium	65	.2398	3.536	.4282	6.743
Dysprosium	66	.2308	3.604	.4356	6.753
Tungsten	74	.1786	4.097	.4877	6.726
Osmium	76	.1683	4.221	.5003	6.716
Gold	79	.1541	4.411	.5194	6.702
Mercury	80	.1501	4.469	.5252	6.690
Lead	82	.1424	4.588	.5369	6.669

c = the velocity of light.

[1] Journal de Physique, May-June, 1916, p. 161.

On platting the square roots of the vibration frequencies against the atomic numbers it can be seen that they depart from the straight line law still further than do the values previously obtained for chemical elements of lower atomic numbers.

It has been shown (*l.c.*) that the velocity of the electrons in the x-ray tube required to produce the K emission series obeys the law represented by the equation

$$\beta = \frac{v}{c} = \beta_0(N - 3/2) = 0.006783(N - 3/2), \tag{1}$$

for chemical elements up to cerium ($N = 58$), provided that we calculate v from the quantum equation.

$$\tfrac{1}{2}mv^2 = h\nu. \tag{2}$$

In this equation (2) ν is the critical absorption frequency, and m, the transverse mass of the electron, is given by the equation

$$m = \frac{m_0}{\sqrt{(1 - \beta^2)}}. \tag{3}$$

The fifth column in the table contains the values of $\beta = v/c$ calculated by equations (2) and (3), putting $h = 6.555 \times 10^{-27}$, $m_0 = 8.989 \times 10^{-28}$ and $c = 2.9986 \times 10^{10}$.

In the sixth column appear the values of β_0 calculated from the expression $\beta/(N - 3/2)$. The differences between these values of β_0 and that found previously for chemical elements of lower atomic numbers, namely, 0.006783, increase progressively with increasing atomic number, N, the greatest difference being a little more than 1 per cent.

As suggested in a former paper the fact that the *transverse* mass of the electron enters into the equations may mean that v is really the velocity of the electrons in an orbit. If so, the above variation in the value of β_0 may be due to the magnetic effect of the electrons in a ring on each other, and not to a lack of constancy in their angular momenta.

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