THE SIZE AND SHAPE OF THE ELECTRON.

By Arthur H. Compton.

Synopsis.

In this paper it is pointed out that Sir J. J. Thomson's explanation of the fluorescent absorption of X-rays on the basis of incident radiation consisting of short double pulses, taken in connection with Moseley's law relating atomic number and the wave-length of characteristic X-radiation, leads to Owen's experimental law for the fluorescent absorption of moderately soft X-rays, namely that $\tau/\nu = KN^4\lambda^3$, τ/ν being the atomic fluorescent absorption coefficient, N the atomic number, λ the wave-length of the incident radiation, and K a constant. Thus, though Thomson's explanation cannot be considered complete, it affords a provisional theoretical basis for Owen's law which has heretofore been lacking.

It is then shown that the law of absorption which holds for moderate frequencies must be modified in order to apply at very high frequencies in view of the fact, shown in a previous paper, that the wave-length becomes comparable with the radius of the electron. For absorbing elements in which excess scattering of the primary beam is inappreciable, the following law of absorption is derived: $\mu/\nu = K\varphi N^4\lambda^3 + \sigma/\nu$ where μ/ν is the atomic total absorption coefficient, σ/ν is the atomic scattering coefficient, and φ and σ are functions of the ratio of the wave-length to the radius of the electron which are evaluated in the paper.

It is found that this formula agrees satisfactorily with the experimental values for the absorption of high frequency radiation in aluminium, the only substance for which the requisite data are available to make an adequate test, if the electron is taken to be a ring of radius $(1.85 \pm .05) \times 10^{-10}$ cm. This result is in good agreement with the value 2×10^{-10} cm. previously estimated by the writer on the basis of measurements of the scattering of high frequency radiation.

II. The Absorption of High Frequency Radiation.

In the first paper of this series[1] it was pointed out that the experimental observations on the scattering of high frequency radiation by matter could be explained only on the hypothesis that the radius of the electron is comparable with the wave-length of hard γ-rays. The phenomena of scattering were found to be quantitatively accounted for, within the probable errors of observation, if the electron was considered to be a flexible ring of electricity with a radius of 2×10^{-10}.cm. The present discussion will deal chiefly with the modifications to be expected in the law of absorption of high frequency radiation if the electron is considered to have appreciable dimensions. Before studying these modifications, however, it will be instructive to consider the law of absorption for wave-lengths which are long compared with the radius of the electron.

---

[1] A. H. Compton, Phys. Rev., 14, 20 (1919).

The absorption of high frequency radiation is due to two independent processes. The more important of these is usually the energy absorbed in exciting corpuscular and fluorescent radiation. There is always, however, a certain amount of energy removed from the primary beam because of scattering by the electrons in the absorbing screen. Thus the total absorption coefficient may be written as

$$\mu = \tau + \sigma,$$

where τ represents the fluorescent absorption, and σ is the absorption due to scattering. In order to compare directly the absorption by different elements, it is customary to consider the "atomic absorption coefficient," μ/ν, where ν is the number of atoms per unit volume of the absorbing screen and μ is the linear absorption coefficient. We may then write

$$\frac{\mu}{\nu} = \frac{\tau}{\nu} + \frac{\sigma}{\nu}.$$

Owen has shown[1] that the atomic fluorescent absorption coefficient follows the experimental law,

$$\frac{\tau}{\nu} = KN^4\lambda^3, \tag{1}$$

where N is the atomic number of the absorber, λ is the wave-length of the incident rays, and K is a constant over certain ranges but changes abruptly when λ passes the critical wave-length required to excite a characteristic radiation in the absorber. The quantity σ/ν has been shown by Barkla and Dunlop[2] to be calculable for the lighter elements and for moderately hard X-rays according to Thomson's formula,

$$\frac{\sigma_0}{\nu} = \frac{8\pi}{3}\frac{e^4N}{m^2C^4}, \tag{2}$$

where e is the charge and m the mass of an electron and C the velocity of light. The total atomic absorption coefficient, for the elements of low atomic weight and for X-rays of moderately short wave-length, obeys therefore the experimental law,

$$\frac{\mu}{\nu} = KN^4\lambda^3 + \sigma_0/\nu. \tag{3}$$

The absorption which is expressed by relation (1) is generally supposed to be due chiefly to a transformation of the incident energy into fluorescent radiation of longer wave-length. As in the similar case of ordinary light, no satisfactory explanation of this fluorescent absorption has been

---

[1] E. A. Owen, Proc. Roy. Soc., 94, 522, 1918.

[2] C. G. Barkla and J. G. Dunlop, Phil. Mag., 31, 222, 1916.

proposed. Sir J. J. Thomson has suggested a partial explanation, however, on the basis of an incident X-ray pulse of special wave-form, which leads to the experimental law for the variation of the fluorescent absorption with the wave-length of the incident rays and with the atomic number of the absorber. He shows[1] that if the pulse consists of an electric intensity X through a distance d followed by an intensity $-X$ for a distance d, after which the field due to the pulse vanishes, and if the distance $2d$ is short compared with the wave-length of the radiation excited by the absorbing electron, the atomic fluorescent absorption coefficient is

$$\frac{\tau}{\nu} = 4\pi^3 \frac{e^2}{mC^2} d^3 \sum_k \frac{n_k}{\lambda_k^2}. \tag{4}$$

In this expression $2d$ may be taken as the wave-length of the incident radiation, and n_k is the number of electrons per atom of the type k, the wave-length of whose free radiation is λ_k.

Moseley has shown that the square root of the frequency of either the K or the L characteristic X-radiation is nearly proportional to the atomic number of the radiator. The same relation holds for Siegbahn's M radiation. We may therefore write $1/\lambda_k^2 = c_k N^4$, where N is the atomic number of the absorbing element, and the constant c_k has different values for the different types of characteristic radiation, but it is the same for all elements. The factor $\Sigma n_k/\lambda_k^2$ may therefore be written as $N^4 \Sigma c_k n_k$. Since the number of the electrons of any type k is probably the same for all the elements which have electrons of this type, and since those terms in the summation which are due to the most rigidly bound electrons are the most important, the factor $\Sigma c_k n_k$ may be considered to be practically constant for all elements except possibly the very light ones, which may not possess electrons of the same high frequency types as do the heavier elements. Writing also for the thickness $2d$ of the incident X-ray pulse its equivalent λ, Thomson's expression for the fluorescent absorption coefficient becomes:

$$\frac{\tau}{\nu} = K_1 N^4 \lambda^3, \tag{5}$$

where

$$K_1 = \frac{2}{\pi^3} \frac{e^2}{mC^2} \Sigma c_k n_k.$$

As thus stated, Thomson's result is identical in form with the experimental law expressed by equation (1).

The incompleteness of this solution of the problem is evident, however,

---

[1] Sir J. J. Thomson, Conduction of Electricity through Gases, 2d ed., p. 325.

from the following considerations. In the first place, the solution by hypothesis does not apply if the natural period of any of the electrons in the absorbing material is comparable with or shorter than the period of the incident radiation. That is, the result is derived strictly for only the case where the wave-length of the incident radiation is considerably shorter than the wave-length of the K radiation characteristic of the absorbing material. In the second place, the value of the coefficient K_1 is too great by a factor of about 10.[1] In the third place, the basic hypothesis of incident X-rays consisting of very short pulses is inconsistent[2] with the fact that crystal analysis shows no X-radiation of frequency higher than that given by the relation $h\nu = eV$.

The exact similarity of form of the two expressions, and the fact that even the coefficient K_1 is not far from the proper order of magnitude, are nevertheless coincidences too remarkable not to have some physical significance. Thus, for example, we could hardly expect such an agreement if this absorption were not really due principally to fluorescent transformations. In any case this explanation affords a provisional theoretical basis for Owen's Law which has heretofore been lacking.

Expression (2) represents the scattering coefficient if the electrons in the atom are far enough apart to scatter independently, and if the wave-length is great enough for the electrons to act sensibly as point charges. The first of these conditions has been shown by the experiments of Barkla and Dunlop to be satisfied for X-rays of ordinary hardness in the case of absorbing elements of lower atomic weight than copper. For the heavier elements they find the scattering to be greater than thus calculated. This is probably due chiefly to a grouping of the electrons so close together in the heavy atoms that the waves scattered by the different electrons are nearly in the same phase. The increased scattering may also be partly due to the fact that there are in the heavier atoms certain electrons whose natural frequency is near that of ordinary X-rays. The second condition, that the electron must be small compared with the wave-length of the incident beam of X-rays, has been shown in the first paper of this series to hold for moderately hard radiation but not to hold if the wave-length of the incident rays is shorter than about 0.3 A.U.

In order to obtain an expression for the total absorption which will be valid at shorter wave-lengths, two modifications must be made in formula (3). In the first place, as just suggested, the value of the atomic scattering cannot be considered constant, but must decrease when the

---

[1] If, however, as suggested by Thomson's recent theory of atomic structure (Phil. Mag. 37, 419, 1919), not all the atoms possess electrons of a given type K, it is possible that K_1 may be equal to K.

[2] Cf. D. L. Webster, PHYS. REV., 7, 609, 1916.

wave-length becomes comparable with the diameter of the electron. If the electron is assumed to have the form of a flexible ring of electricity, it has been shown in the first paper of this series that the scattering will be expressed by the formula

$$(6)\quad \frac{\sigma}{\nu} = \frac{\sigma_0}{\nu}\left\{ 1 - 29.61\left(\frac{a}{\lambda}\right)^2 + 524.2\left(\frac{a}{\lambda}\right)^4 - 5{,}398\left(\frac{a}{\lambda}\right)^6 + \cdots \right\},$$

where σ_0/ν is the atomic scattering coefficient as expressed by equation (2), a is the radius of the electronic ring, and λ is the wave-length of the incident radiation. The values of the coefficients of the powers of a/λ have been given in detail in the previous paper.[1]

The second modification concerns the coefficient of λ^3 in the term representing the fluorescent absorption. In the derivation of Thomson's expression (4) for the fluorescent absorption, he shows that the energy absorbed from the incident ray by an electron is proportional to the square of the acceleration to which the electron is subject. It would seem that this relation must hold in whatever manner the fluorescent absorption is calculated. The acceleration of a comparatively large electron will be less than that of a small electron of the same mass, however, when both are traversed by X-rays of the same intensity, since in the former case the phase of the incident ray will not be the same at all parts of the electron. The fluorescent absorption due to a large electron will therefore be less than the value $KN^4\lambda^3$ by the factor,

$$\varphi = \left\{ \frac{\text{acceleration of large electron}}{\text{acceleration of small electron}} \right\}^2.$$

If the large electron is assumed to have the form of a ring, its acceleration when traversed by an X-ray may be calculated in the following manner. Let us consider the motion of the electron represented by the heavy ring in Fig. 1, when traversed by an electromagnetic wave propa-

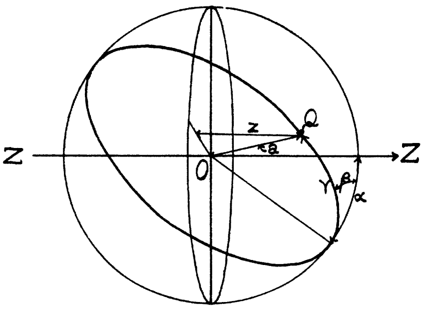


Fig. 1.

---

[1] A. H. Compton, *loc. cit.*, p. 42.

gated in the direction $-ZOZ$. The electric intensity at a given instant at the point $Q(a, \alpha, \beta, \gamma)$ on the ring is

$$X = A \cos 2\pi \left(\frac{\delta - Z}{\lambda} \right),$$

where A is the amplitude of the incident electric intensity, $2\pi\delta/\lambda$ is the phase angle at the point O and z is the Z coördinate of the point Q. But

$$z = a\,(\cos\alpha \cos\gamma + \sin\alpha \cos\beta \sin\gamma),$$

where a is the radius of the electron. The acceleration of the electron at this instant is therefore

$$\frac{Aa\eta}{m} \int_0^{2\pi} \cos \frac{2\pi}{\lambda} \{\delta - a\,(\cos\alpha \cos\gamma + \sin\alpha \cos\beta \sin\gamma)\} d\gamma,$$

where η is the charge per unit length along the circumference of the electron, and m is the electron's mass.

This integral is obviously a maximum when δ is zero. The amplitude of the acceleration is therefore,

$$f = \frac{Aa\eta}{m} \int_0^{2\pi} \cos \left\{ \frac{2\pi a}{\lambda} (\cos\alpha \cos\gamma + \sin\alpha \cos\beta \sin\gamma) \right\} d\gamma.$$

This quantity may be written

$$f = C_1 \int_0^{2\pi} \cos\,(k \cos\gamma + l \sin\gamma) d\gamma,$$

where

$$C_1 = Aa\eta/m,$$

$$k = 2\pi \frac{a}{\lambda} \cos\alpha,$$

$$l = 2\pi \frac{a}{\lambda} \sin\alpha \cos\beta,$$

or

$$f = C_1 \int_0^{2\pi} \cos\,\{M \sin\,(\gamma + \Delta)\} d\gamma,$$

where $M = \sqrt{k^2 + l^2}$ and Δ is the appropriate phase angle. Since the integration extends from 0 to 2π, the value of Δ is immaterial, and may therefore be put equal to zero. The integral then becomes:

$$f = C_1 \int_0^{2\pi} \cos\,(M \sin\gamma) d\gamma$$

$$= 2\pi C_1 J_0(M),$$

where

$$J_0 M = 1 - \frac{M^2}{2^2} + \frac{M^4}{2^2 4^2} - \frac{M^6}{2^2 4^2 6^2} + \cdots,$$

i.e., Bessel's J function of the zero order. Substituting

$$M = \frac{2\pi a}{\lambda}\sqrt{1 - \sin^2\alpha\cos^2\beta}$$

and

$$2\pi C_1 = \frac{A}{m}\cdot 2\pi a\eta = Ae/m,$$

where e is the total charge on the electron, we obtain

$$f = \frac{Ae}{m}J_0\left(\frac{2\pi a}{\lambda}\sqrt{1 - \sin^2\alpha\cos^2\beta}\right).$$

The ratio of the acceleration of the ring electron to that of a sensibly point charge electron is therefore

$$J_0\left(\frac{2\pi a}{\lambda}\sqrt{1 - \sin^2\alpha\cos^2\beta}\right).$$

The required value of φ is obviously the mean square of this quantity averaged over all angles α and β at which the ring electron may be oriented, *i. e.*,

$$\varphi = \frac{1}{\pi^2}\int_0^{\pi}\int_0^{\pi} J_0^2\left(\frac{2\pi a}{\lambda}\sqrt{1 - \sin^2\alpha\cos^2\beta}\right)d\alpha d\beta.$$

This is the same integral as that which enters into the calculation of the scattering by a ring electron, the solution being

$$\varphi = 1 - \alpha\left(\frac{2\pi a}{\lambda}\right)^2 + \beta\left(\frac{2\pi a}{\lambda}\right)^4 - \gamma\left(\frac{2\pi a}{\lambda}\right)^6 + \cdots,$$

where the constants α, β, $\gamma\cdots$ have the values given on page (42) of the first paper of this series. For purposes of calculation this function may be more conveniently expressed as

$$\varphi = 1 - n\frac{a^2}{\lambda^2} + o\frac{a^4}{\lambda^4} - p\frac{a^6}{\lambda^6} + \cdots$$

where

$n = (2\pi)^2\alpha = 14.8044,$
$o = (2\pi)^4\beta = 93.6041,$
$p = \cdots = 306.6932,$
$q = 608.7241,$
$r = 807.8924,$
$s = 766.5255,$
$t = 545.4744,$
$u = 301.8218,$
$v = 133.5450,$
$w = 48.3256,$
$x = 14.5661,$
$y = 3.7134,$
$z = .8111,$
$a = .1535,$
$b = .0254,$
$c = .0037,$
$d = .0005,$
$e = .0001.$

The values of φ, and of the ratio σ/σ_0 of the scattering by a ring electron to that of an electron of negligible size, are shown for different values of λ/a by curves *I* and *II* respectively of Fig. 2.[1]

---

[1] In a preliminary paper on the absorption of high frequency radiation (Phys. Rev., 13, 296, 1919), the quantity $\sqrt{\sigma}$ was used in place of the quantity φ. This was justified by the fact that for values of λ/a greater than 8, with which that paper was concerned, φ is almost exactly equal to $\sqrt{\sigma/\sigma_0}$.

The total absorption of high frequency radiation by the lighter elements may therefore be expressed by the formula,

$$\frac{\mu}{\nu} = K\varphi N^4\lambda^3 + \frac{\sigma}{\nu}, \tag{8}$$

where σ/ν and φ have the values assigned by equations (6) and (7), and depend upon the radius of the electron. If this radius is taken as .02 A.U., as estimated from determinations of the scattering, K is the only arbitrary constant involved in this expression; though it must be admitted that the exponents of N and λ have no conclusive theoretical support.

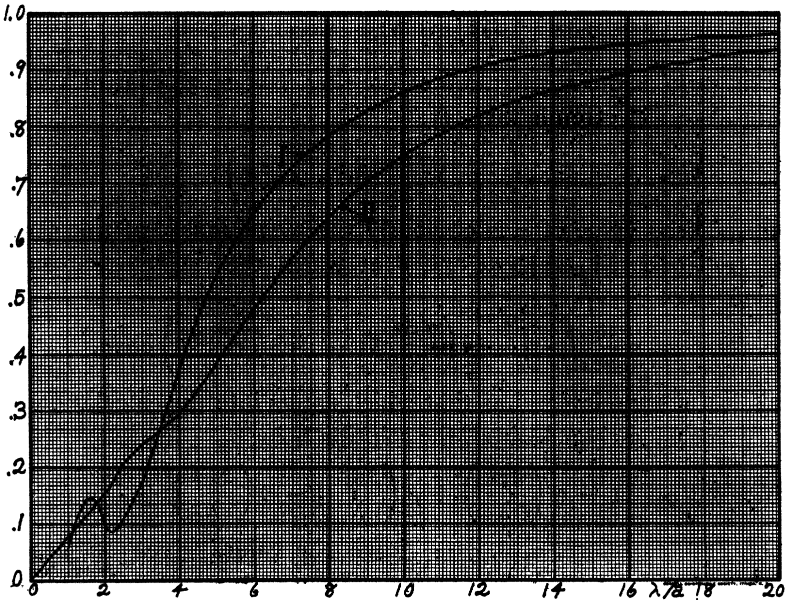


Fig. 2.

The only reliable experimental data which are of value in testing expression (8) are those which refer to the mass absorption coefficients in aluminium.[1] In Fig. 3 are plotted the cube roots of the mass absorp-

---

[1] It is unfortunate that the measurements by Barkla and White (Phil. Mag., 34, 270, 1917) were not made with strictly homogeneous rays of known wave-length. They determine the effective wave-length of their rays by the absorption in copper, using the values given for this material given by Hull and Rice. Since, however, the variation of the absorption coefficient with wave-length of the light materials, aluminium, paper, paraffin, used by Barkla and White is much smaller than the variation in the case of copper, the effective wave-length of a heterogeneous beam will not be the same in the different materials. Moreover, the effect of inflection in the experimental absorption curves renders the true absorption for any definite wave-length uncertain. It would be of great interest to have the measure-

tion coefficients for this metal against the wave-length. The data include all the published measurements for strictly homogeneous rays of known wave-length which I have been able to find. The dotted line represents the simple cube law as expressed by equation (1), which neglects the absorption due to scattering. The broken line represents Owen's formula (3), which takes into account the scattering but is based on the hypothesis of a relatively small electron. The solid line represents equation (8), calculating the absorption on the basis of a ring electron of radius .02 A.U. as estimated from determinations of the scattering.[1] These curves are obtained from the values of μ/ν as calculated from expressions 1, 3 and 8 respectively, by multiplying by the factor ν/ρ, taking ν for alumin-

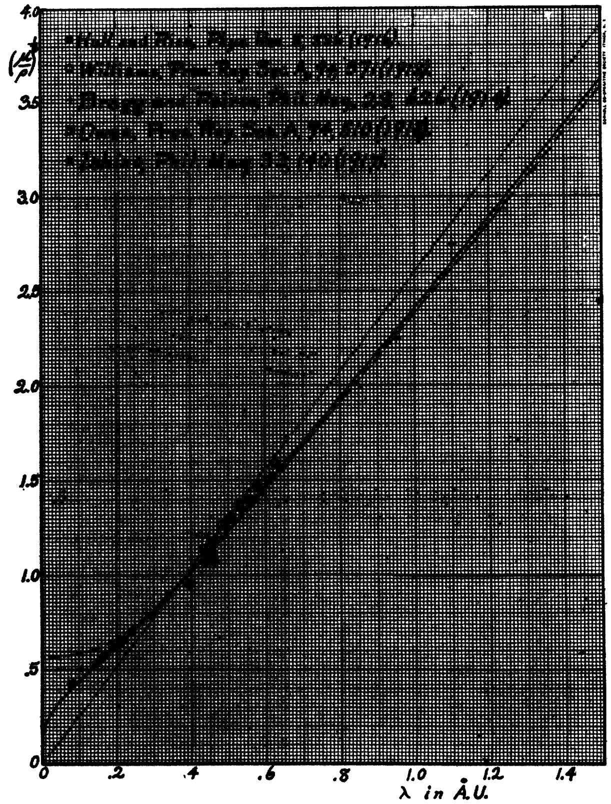


Fig. 3.

---

ments on these absorbers of low atomic weight repeated with strictly homogeneous radiation, since the predominance of the scattering over the fluorescent absorption by the light elements makes the measurements made on them of maximum value in determining the radius of the electron.

[1] Ibid.

ium to be 6.06×10^{22} and ρ to be 2.71. For the longer wave-lengths the three formulas differ but little, and the experimental variations are of little significance. It is at the shorter wave-lengths that the effects of the different hypotheses become evident. Here it is apparent how failure to take into account the scattering in equation (1) and the effect of the electron's size in equation (3) makes the dotted and the broken lines depart seriously from the experimental values, whereas the solid line shows a very fair agreement.

The mass absorption coefficients of aluminium for wave-lengths less than .35 A.U. are plotted in Fig. 4 in larger scale, in order to show the effect on the form of the theoretical curve of changing the value assumed for the radius of the electron. Here, as in Fig. 3, the dotted and the broken curves represent formulas (1) and (3) respectively, and both are obviously inaccurate for these very hard rays. It is of particular interest to note that the fact that the total absorption falls below the value of σ_0/ρ, required for the scattering coefficient alone on the basis of a small electron shows the hypothesis of a sensibly point charge electron to be untenable. Of the three solid lines, curve *I* is calculated on the basis of an electron of 2.0×10^{10} cm. radius, curve *II* for a radius of 1.85×10^{10} cm., and curve *III* for a radius of 1.7×10^{10} cm. Unless there is some

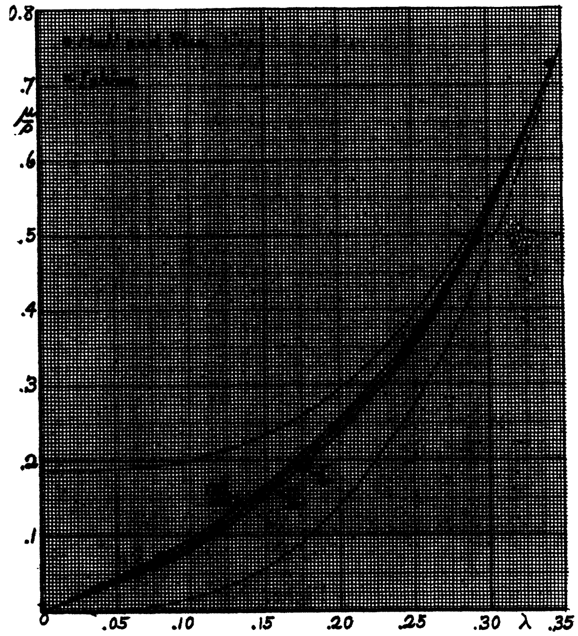


Fig. 4.

consistent error in the experimental figures, we can, on the basis of the agreement of these curves, take the radius of the electron to be $(1.85 \pm .05) \times 10^{10}$ cm.[1]

---

[1] Attention has been called repeatedly (cf. Nature, 100, 510, 1918; H. S. Allen, Proc. Phys. Soc., 30, 143, 1918; 31, 53, 1919) to the fact that my original estimate of the radius of the electron (Jour. Wash. Ac. Sci., 8, 1, 1918) as 2.3×10^{-10} cm. was based on the value 9×10^{-10} cm. for the wave-length of the hard rays from radium C as determined by Rutherford and Andrade (Phil. Mag., 28, 263, 1914) instead of a value one third to one tenth as large more recently estimated by Rutherford (Phil. Mag., 34, 153, 1917) in light of measurements on the absorption of hard X-rays. In these latter measurements the X-radiation was obtained from a Coolidge tube operated by an induction coil, and the rays were filtered through considerable thicknesses of iron and lead. The wave-length of the end radiation was estimated according to the relation $\lambda = hC/eV$, where h is Planck's constant, C is the velocity of light, e the electronic charge, and V is the voltage across the X-ray tube. The value of V used in Rutherford's calculations was the *maximum* voltage across the tube, which obviously is considerably greater than the effective voltage. Furthermore, the filtering method of obtaining the radiation which has the shortest wave-length is uncertain in its results, as is apparent from the false indications obtained by this method by Rutherford, Barnes and Richardson (Phil. Mag., 30, 339, 1915). Both of these sources of error lead to a calculated value of the effective wave-length which is smaller than the true value.

That these errors are actually present in Rutherford's work is suggested by the following considerations. (1) For $\lambda = .086$ A.U. (maximum voltage = 144,000) he was unable to measure the intensity of the beam accurately after it had passed through 5 mm. of lead, whereas Rutherford and Andrade (Phil. Mag., 28, 266, 1914) find that homogeneous radiation shorter than 1.16 A.U. penetrates 6 mm. of lead without great loss.

(2) The absorption coefficient measured by Rutherford "is intermediate between μ and $\mu + \sigma$ (where μ is the true [fluorescent] absorption coefficient and σ the scattering coefficient), and probably closer to the former. The value of μ as given by Hull and Miss Rice corresponds to $\mu + \sigma$ in the above notation." That is, using the notation of the present paper, the data of Hull and Rice refer to the total absorption μ, while the figures given by Rutherford refer more nearly to the fluorescent absorption τ. Nevertheless, Rutherford points out that his measurements on both aluminium and lead agree with those of Hull and Rice for the wave-lengths which overlap. These wave-lengths are, however, in the neighborhood of .135 A.U., where, whether the electron is taken to be very small or of the size here estimated, by far the greater part of the total absorption in the case of aluminium is due to scattering. Rutherford's values for the absorption coefficient should therefore have been much smaller for aluminium than the values of Hull and Rice.

(3) That the minimum wave-length produced by the tube is not separated out by the filtering process is apparent from the following data on the absorption coefficient in lead for various thicknesses of the lead screen, as taken from Rutherford's paper (p. 154):

Max Voltage.	Range of Thickness in Lead, mm.	Absorption Coefficient.	Max Voltage.	Range of Thickness in Lead, mm.	Absorption Coefficient.
170,000	3.1–3.7	18	196,000	4.3–5.5	13
	3.7–4.3	17		5.5–6.4	12
	4.3–5.5	16		7.8–9.2	10
				8.8–10.0	8.5

If the absorption coefficients for 196,000 volts, for example, are plotted against the reciprocal of the mean thickness of the absorption screen, the curve shown in Fig. 5 is obtained. There is apparently no tendency for the absorption coefficient to approach a constant finite value for large thicknesses of the absorption screen. In fact these figures would rather lead to the con-

If a similar calculation is made in the cases of copper and lead, the absorption coefficients of which for very short wave-lengths have been determined by Hull and Rice, the agreement for long wave-lengths is satisfactory, but for shorter wave-lengths the calculated values are somewhat too low. The difference is greater in the case of lead than in the case of copper. This discrepancy is doubtless due at least in part to the fact, pointed out by Barkla and Dunlop,[1] that a considerable excess scattering occurs in these metals when traversed by X-rays, while

---

clusion that the absorption coefficient of the rays, after passing through a very thick lead screen, approaches zero. It is certain, at least, that the true absorption coefficient corresponding to the shortest wave-length produced at 196,000 volts is much less than the value 8.5 used by Rutherford.

It appears from these considerations that the wave-lengths assigned by Rutherford to correspond with the different observed absorption coefficients are considerably too short.

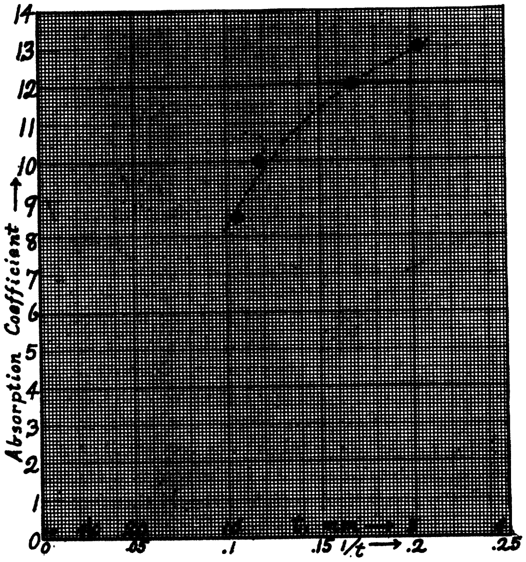


Fig. 5.

For this reason I have not considered his estimate of the wave-length of hard γ-rays, based on these absorption measurements, as reliable as the direct determinations of Rutherford and Andrade.

Note added September 3, 1919: After reading over these comments, Professor Rutherford still believes in the accuracy of his later measurements rather than in the earlier determinations by himself and Andrade. He writes me, "When I recall the faintness of the radium *C* lines and the difficulty of fixing them. . . . I am inclined to think that a mistake could easily arise. . . . I am inclined to give a good deal more weight to the Coolidge Tube experiments than you do." As Rutherford suggests, the question is one which must finally be answered by more refined measurements of the absorption of very hard homogenous rays of known wave-length.

[1] Barkla and Dunlop, *loc. cit.*

it does not occur to an appreciable extent in the case of aluminium for these wave-lengths. It is therefore impossible to test on the basis of measurements on lead and copper the validity of the assumptions underlying formula (8), which applies strictly to only those absorbing materials in which excess scattering does not occur.

Conclusions.—The excellent agreement of the absorption as calculated by equation (8) with the experimental values, in the only case (aluminium) in which the requisite data are available to make an adequate test, constitutes a strong support of the fundamental assumption of an electron of a size comparable with the wave-length of short X-rays. This agreement is the more significant since it is impossible to account for the low values of the absorption observed for very short X-rays if the electron is assumed to be sensibly a point charge of electricity.

These results must also be considered as a partial confirmation of the formula (8) proposed from theoretical considerations for the absorption coefficients of elements which do not show appreciable excess scattering.

Assuming the validity of this formula and the accuracy of the measurements of Hull and Rice on the absorption of hard X-rays in aluminium, and considering the electron to have the form of a flexible ring of electricity, the radius of the electron is calculated to be $(1.85 \pm .05) \times 10^{10}$ cm.

Research Laboratory,
Westinghouse Lamp Company,
May 24, 1919.

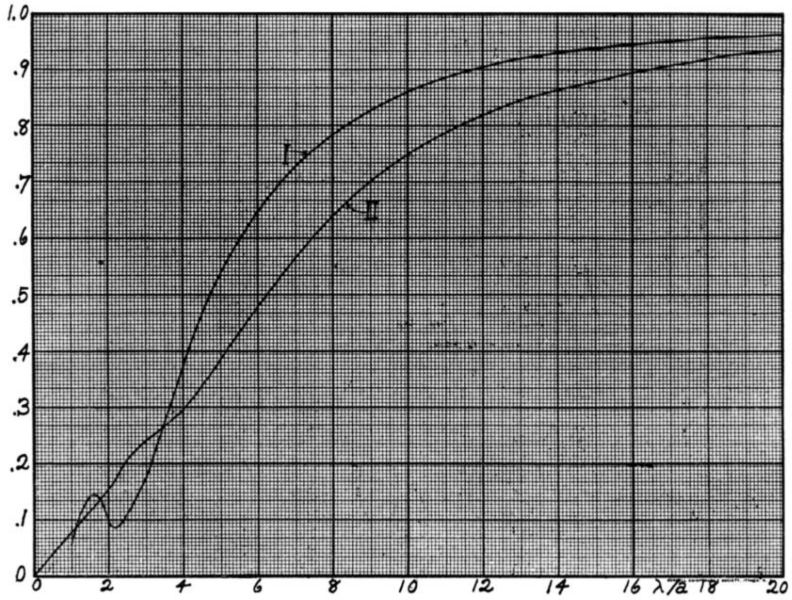
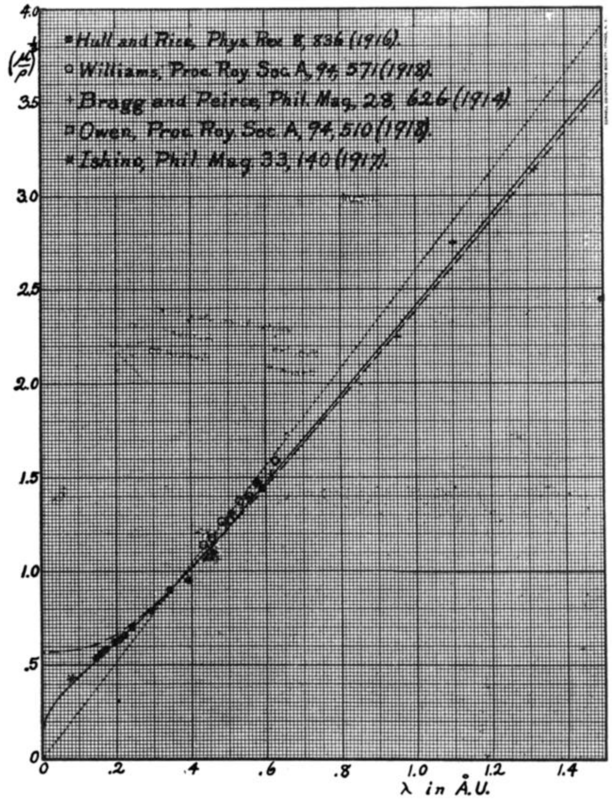
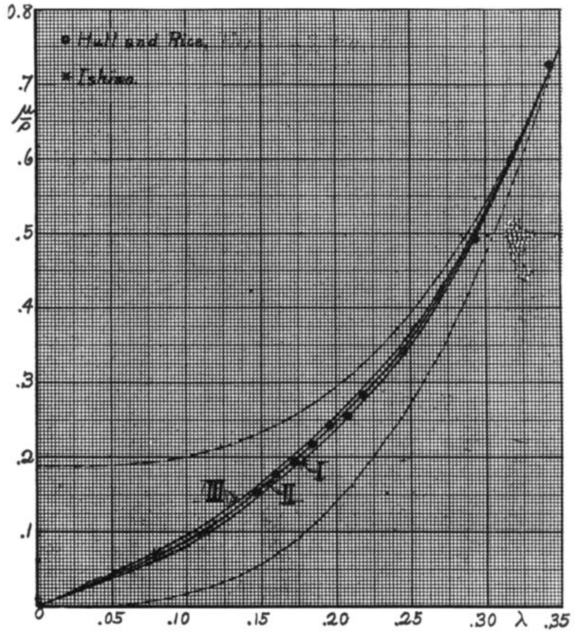


Fig. 2.



■ Hull and Rice, Phys. Rev. 8, 836 (1916).
○ Williams, Proc. Roy. Soc. A, 94, 571 (1918).
+ Bragg and Peirce, Phil. Mag. 28, 626 (1914).
□ Owen, Proc. Roy. Soc. A, 94, 510 (1918).
* Ishino, Phil. Mag. 33, 140 (1917).
$\left(\frac{\mu}{\rho}\right)$
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
0
.2
.4
.6
.8
1.0
1.2
1.4
λ in Å.U.

Fig. 3.



0.8
● Hull and Rice.
✱ Ishino.
.7
μ/ρ
.6
.5
.4
.3
.2
.1
I
II
III
0
.05
.10
.15
.20
.25
.30
λ
.35

Fig. 4.

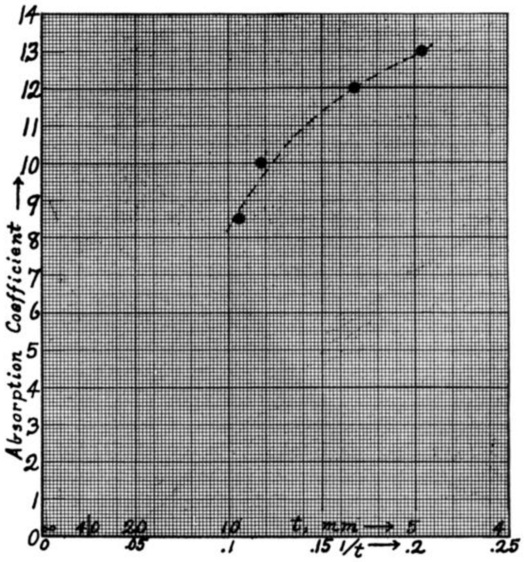

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Absorption Coefficient →
∞
40
20
10
t, mm →
5
4
0
.05
.1
.15
1/t →
.2
.25

Fig. 5.