[Second Series.

## PROCEEDINGS

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### THE LAW OF ABSORPTION OF X-RAYS AT HIGH FREQUENCIES.<sup>1</sup>

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I T has been shown, from Barkla's absorption data and Moseley's table of wave-lengths, that the coefficient of absorption of all metals varies approximately as the cube of the wave-length, except in the immediate vicinity of one of the characteristic wave-lengths of the metal. The experimental data extends over a range of wave-lengths from 4 to 0.5 Å.U. approximately, but the law has frequently been extrapolated to very short wave-lengths and used as a measure of wave-length. It is important to know how far such extrapolation is justified.

The measurements given below were made on narrow portions of a beam of "white" radiation from a tungsten target, dispersed by a rock-salt crystal and isolated by a very narrow slit in the lead face of the ionization chamber. The absorbing sheets were 15 cm. from this slit, so that the amount of fluorescent and scattered radiation entering the chamber was negligible.

The energy taken from the beam by the absorbing sheets consisted, therefore, of two parts:

1. That which was transformed into energy of a different form or different wave-length, such as heat, fluorescent radiation, corpuscular radiation.

2. That which was re-emitted as radiation of the same wave-length, viz., the scattered radiation. The observed absorption coefficient  $\mu/\rho$  may therefore be written

$$\frac{\mu}{\rho} = \frac{\tau}{\rho} + \frac{\sigma}{\rho},$$

where  $\tau$  is what may be called the transformation coefficient and  $\sigma$  the coefficient of scattering.

On the simple electromagnetic theory we should expect  $\sigma$  to be independent of wave-length and proportional to the number of scattering electrons per unit volume, *i. e.*, to the density approx., so that  $\sigma/\rho$  should be a universal constant. This hypothesis is substantiated, within the limit of experimental error, by

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Barkla's measurements. If we assume that the other part of the absorption, the "transformation coefficient," varies as the cube of the wave-length, eq. I becomes  $\mu/\rho = a\lambda^3 + b$ , where a is constant for a given absorber between its absorption bands, and b is the same for all substances and all wave-lengths.

Taking *a* from Barkla's data on long wave-length radiations, and b = 0.12, the observed absorption coefficients for aluminum and copper should be given by

$$\left(\frac{\mu}{\rho}\right)_{A1} = 14.9\lambda^3 + 0.12,$$
$$\left(\frac{\mu}{\rho}\right)_{Cu} = 150.\lambda^3 + 0.12,$$

where  $\lambda$  is in Angströms.

These equations are plotted in the figure (full lines), and agree with the experimental values within experimental error (the errors were rather large for the shortest and longest wave-lengths measured, on account of small deflec-



Mass Absorption Coefficient  $(\mu/\rho)$  for Al, Cu, and Pb, between  $\lambda = 0.12$  and  $\lambda = 0.39$  Aengstroms.

Full lines = theoretical curves for complete absorption coefficient.

Broken " = theoretical curves for "corrected absorption" or "transformation" coefficient.

= Rutherford's value for  $\gamma$  rays.

Fig. 1.

tions). Rutherford's value for the absorption in aluminum of the shortest  $\gamma$ -rays from radium *B*, viz.,  $(\mu/\rho)_{A1} = 0.19$  for  $\lambda = .164$  Å.U., is also shown in the figure. It falls satisfactorily on the curve.

For lead, the region investigated includes one of the characteristic absorption bands of lead. Photographs of the spectrum through a lead sheet showed that this band, which is due to the excitation of the K fluorescent radiation of lead,

begins at  $\lambda = 0.149$  Å.U. For wave-lengths longer than this, the absorption obeys the equation  $(\mu/\rho)_{\rm Pb} = 430\lambda^3 + 0.12$  (full curve). The value of a = 430 is subject to some error on account of the difficulty of measuring the thickness of the lead sheet. For wave-lengths shorter than 0.149 the data is not sufficient to determine the law, but it is evident that extrapolation of the above equation is not justified.

If, instead of dealing with the coefficient of total absorption, as above, we calculate the "corrected absorption coefficient" or "transformation coefficient," by subtracting  $\sigma/\rho = 0.12$  from the observed values of  $\mu/\rho$ , we have for all substances and all wave-lengths thus far investigated the very simple law

$$\frac{\tau}{\rho} = a\lambda^3,$$

where a is a constant for each substance over the entire range between its absorption bands. This law is shown graphically for aluminum and copper (broken lines) in the figure.

Wave-length. Ångstroms.	Mass Absorption Coefficient.					
	A1.		Cu.		Pb.	
	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.
0.392	0.860	1.02				
0.343	0.726	0.721				
0.294	0.493	0.499	3.84	3.94	11.1	11.04
0.245	0.342	0.339	2.24	2.33	6.7	6.44
0.221	0.283	0.281	1.70	1.74	4.63	4.76
0.208	0.255	0.254	1.39	1.47	3.70	3.99
0.196	0.243	0.232	1.27	1.25	3.40	3.36
0.184	0.218	0.213	1.07	1.06	2.71	2.80
0.172	0.199	0.196	0.91	0.88	2.32	2.31
0.160	0.178	0.181	0.79	0.74	1.82	1.88
0.147	0.154	0.167	0.71	0.60	1.50	
			1		2.80	
0.122					3.00	