NOTE ON THE DEPENDENCE OF THE INTENSITY OF THE COMPTON EFFECT UPON THE ATOMIC NUMBER

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Abstract

Intensity of the displaced scattered radiation as a function of atomic number. —*Theory.* The integrated intensity of the scattered radiation S is shown to be proportional to $b/z^3\lambda^3$ where z is the atomic number or number of orbital electrons and b is the fraction of these that take part in the scattering. *Relative intensity for paraffin, aluminum, sulphur and calcium* for MoKα radiation was found to be 8, 1.25, 0.7 and 0.35. All radiators were of the same dimensions and were carefully placed in the same position by means of guides. The results give the product Sz^3 as constant except for paraffin for which, if we take $z=6$ the product is too small. So far as they go, the results indicate that b is constant and suggest that all the orbital electrons take part equally in the scattering effect.

On attempting to measure the displaced scattered frequency, a most noticeable effect is the decrease in intensity of the scattered radiation as the atomic number of the radiator increases. I have found the effect quite strong from paraffin, still stronger from lithium, while on the other hand the scattered radiation from copper was so weak as to be difficult of measurement by the spectrometer method. This decrease of energy is undoubtedly due to absorption of the incident and scattered radiation.

The experiments were made with radiators of exactly the same dimensions and placed in exactly the same position relatively to the x-ray tube and the slits of the spectrometer. This being the case, it is not necessary to integrate the incident and scattered radiations over the various angles of incidence and emergence, since such integration will give a constant of the same value for all the elements. One can proceed quite simply to find the intensity of the scattered radiation in terms of the absorption and the wave-length. If I_0 is the intensity of the incident radiation of wave-length λ, the intensity at any depth x will be

$$I = I_0 e^{-\mu_1 x} \qquad (1)$$

Let f_1 be the fraction of this radiation scattered in the observed direction from an element dx at a depth x. Then

$$dS = f_1 I e^{-\mu_2 (ax)} dx = f_1 I_0 e^{-(\mu_1 + a\mu_2 x)x} dx$$

where μ_2 is the coefficient of absorption of the displaced scattered radiation and a is the ratio of the paths of the incident and scattered rays in the specimen. The integrated intensity S of the displaced scattered radiation is then

$$S = nf_1I_0/(\mu_1 + a\mu_2) \tag{2}$$

where n = the number of electrons per unit volume, taking part in the scattering. The mass absorption is equal to $k\lambda^3$ and the two wave-lengths are so nearly equal that one may write

$$S = \frac{nc}{\rho} \frac{f_1 I_0}{k\lambda^3} \tag{3}$$

where ρ is the density, and c and k are constants.

If the scattering per electron may be considered constant, and if b represents the fraction of the number of orbital electrons z in each atom that take part in this scattering effect, the above becomes

$$S = K_1 b/Az^2\lambda^3 \tag{4}$$

where K_1 is a constant for each element. This shows at once that the scattered energy increases rapidly with the frequency of the exciting radiation. This, I believe, is found to be true by experiment.

Since the atomic weight A is proportional to the atomic number z, the scattered radiation may be represented by (from 4)

$$S = Kb/z^3 \tag{5}$$

for a constant wave-length λ.

Experiments

The experiments on the scattered energy were made with four substances, paraffin (largely carbon), aluminium, sulphur and calcium.

The scattered radiation was observed with an ionization spectrometer. The distance between forward and rear slits was 30 cm. The slit width was 2 mm. The wave-length of the scattered radiation was displaced in accordance with the explanation of the effect proposed by Compton.

The four specimens were of exactly the same dimensions in every particular. Special guides were provided so that each specimen could be placed in exactly the same position. The source of radiation was a water cooled molybdenum tube driven at a constant voltage of about 40 kv. The total energy was about one kilowatt.

The relative energies observed are given in the table, where S_o is the observed intensity of the displaced line

	Z	S_o	Z^2S_o	Z^3S_o
Paraffin	6(?)	8	288	1730
Aluminium	13	1.25	215	2750
Sulphur	16	.7	180	2870
Calcium	20	.35	140	2800

The product Z^3S_o is more nearly constant than Z^2S_o. Paraffin, however, does not agree with the other three elements. This departure in the case of paraffin may be in error.

So far as they go the results indicate that the scattering varies inversely as the cube of the atomic number. This is in agreement with Eq. (5) if b is constant. The results suggest that all the orbital electrons take part in the scattering effect. This is to be expected, as the frequency and energy of the exciting radiation ($\lambda = .7077$) was very much greater than the highest natural frequencies of these atoms. The binding forces are too feeble to affect the exchange of momentum appreciably.

The expression containing the wave-length λ shows that the effect would be very small with smaller frequencies, such as copper $K\alpha(\lambda 1.537)$, and would be difficult of observation. On the other hand, the characteristic radiation from tungsten is well suited for the investigation of this effect, particularly with the elements of higher atomic number.

I wish to acknowledge the assistance of Dr. H. M. Terrill in making the spectrometer observations.

Phoenix Physical Laboratories,
Columbia University,
March 12, 1925.