THE ABSORPTION COEFFICIENT OF HARD γ-RAYS

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Communicated May 15, 1930

1. The relation between the frequency of hard radiations and the absorption coefficient is not experimentally well established at the present time. In order to obtain definite information it is necessary to use a radiation with high homogeneity. γ-Rays from ThC″ are found to fulfill this requirement. Investigations of the absorption coefficient of these rays have been made by Russell and Soddy,[1] and Rutherford and Richardson,[2] almost 20 years ago before the modern technique of sensitive current measurement was developed. It has also been measured recently by Bastings.[3] But as all of these observers used fairly divergent beams with the electroscope placed near the absorber, an appreciable amount of the scattered rays entered the electroscope. This tends to lower the apparent value of the absorption coefficient. In fact, in Bastings' experiment this was purposely done in order to obtain the change of this apparent absorption coefficient. It is therefore thought desirable to make measurements on a narrow beam by the use of modern sensitive apparatus so that the value of the absorption coefficient, experimentally determined, fits the ordinary definition and thus make possible a comparison with the theoretical values of Klein and Nishina's formula[4] and Dirac's formula.[5] The work is carried out for various elements to test the variation with the atomic number.

2. Radio-Thorium is used as the radio-active source. It is separated from Ms-Th and is found to be quite pure from a measurement of the rate of decay. (The γ-ray intensity changes from 3.595 to 3.210 in 115 days after the equilibrium state is reached. This gives the half period = 705 days.) ThC″ is formed after several transformations and is the source of γ-rays used in this experiment. This latter element emits a narrow band of γ-rays of wave-length around 4.7 X. U., which is quite intense and far removed from the remaining γ-ray spectrum of the elements formed after Rd-Th.

In determining the absorption coefficient, particular care is taken to secure a parallel beam and to avoid the scattered rays from the container of the source and the absorber. An apparatus similar to that of Kohlrausch[7] is used. The radio-active source is put in the center of a lead cylinder which is 32 cm. long and 32 cm. in diameter. A conical beam of semi-angle 2.5° is led out for observation. Lead filters of different thickness are used to cut off the soft γ-rays.

As measuring apparatus, Professor Millikan's cosmic-ray electroscope is used at a distance of 2 meters from the source. In a later group of experiments an ionization chamber connected to a vacuum electrometer of the type developed by Professor Hoffmann is used at a distance of 1 meter from the source.

The absorption coefficient is determined by measuring the ionic current due to γ-rays with and without the absorber. Each reading is corrected for both the natural leak and scattering by subtracting the value of the ionic current observed when the lead cylinder is rotated through 6.5° so that the primary beam just misses the ionization chamber or the electroscope. In the experiment with the electrometer, two sets of readings are taken for each substance; each set consists of about 10 readings with, and 10 without, the absorber and 5 correction readings with, and 5 without, the absorber. The ratios of the initial reading to the final reading from two sets differ by less than 0.6%. The consistency of the correction readings is of about the same order. The probable error of the absorption coefficient computed from their mean is about 2%.

The results obtained by the use of the electroscope and the electrometer agree very well. This work will be reported in more detail at a later date.

3. The absorption coefficient of μ of lead, for γ-rays from ThC″ which have been filtered through different thicknesses of lead, is given in table A,

TABLE A

μ OF PB AFTER DIFFERENT PB-FILTERS (BY ELECTROSCOPE)

THICKNESS OF PB-FILTER, CM.	μ (CM.$^{-1}$)
0	0.88
1.36	0.565
2.72	0.515
4.08	0.496
5.44	0.487
6.80	0.477

TABLE B

μ OF VARIOUS SUBSTANCES AFTER A PB-FILTER OF 6.8 CM.

	H_2O	Al	Cu	Zn	Sn	Pb
ρ (density)	1.00	2.68	8.90	7.17	7.29	11.36
No. of external electrons in one atom	8+1+1	13	29	30	50	82
μ, calculated (for λ = 4.7 X. U., from Klein and Nishina's formula)	0.0419	0.0973	0.306	0.248	0.231	0.338
μ, observed by electroscope	0.0438	0.1029	0.338	0.275	0.280	0.477
μ, observed by electrometer	0.0435	0.1023	0.335	0.274	0.278	0.478
μ, observed, mean	0.0437	0.1026	0.337	0.275	0.279	0.478
μ/ρ	0.0437	0.0383	0.0378	0.0383	0.0383	0.0420
$\mu_e \times N (= \mu_e \times 6.06 \times 10^{23})$	0.0787	0.0794	0.0829	0.0834	0.0909	0.1062

where the first column gives the thickness of Pb-filters, and the second column gives the corresponding value of μ, which is obtained when a separate Pb-absorber is introduced in addition to the Pb-filter.

The absorption coefficient of various substances for γ-rays from ThC″ filtered through 6.8 cm. of lead is given in table B.

The lead absorber is of 0.682 cm. thick, and the thickness of other absorbers is approximately equivalent to this.

From the above table, it is seen that the value μ_e obtained by dividing the absorption coefficient μ by the number of external electrons per cc., increases with the atomic number, while according to the theoretical formulæ it should be constant. This might be explained by the following alternatives. (1) A part of the scattering may be due to electrons inside the nucleus as suggested by Professor Millikan in a report made to the National Academy in Nov., 1929, in which cosmic rays were shown to exhibit this same effect in still greater degree. (2) The scattering of a tightly bound electron of the atoms of high atomic numbers may be greater than that of a loosely bound electron. (3) There may still be some true absorption due to the photo-electric effect. At present, an investigation of the process of scattering is being carried on which might possibly throw some light on these questions.

I should like to express my gratitude to Professor R. A. Millikan and Professor I. S. Bowen for the suggestion of this experiment and their help in carrying it through, and also to Dr. H. N. McCoy who helped with the preparation of the Radio-Thorium.

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[1] Russell and Soddy, *Phil. Mag.*, **21**, 130 (1911).

[2] Rutherford and Richardson, *Ibid.*, **26**, 937 (1913).

[3] Bastings, *Ibid.*, **5**, 785 (1928).

[4] Klein and Nishina, *Zeit. Physik*, **52**, 853 (1928).

[5] Dirac, *Proc. Roy. Soc. London*, **A 109**, 205 (1925).

[6] Black, *Ibid.*, **A 109**, 166 (1925).

[7] Kohlrausch, *Wiener Ber.*, **126** (1917), *Handbuch der Experimentalphysik*, **15**.

ON THE CONDITIONS OF ELICITATION OF CERTAIN EATING REFLEXES

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Communicated April 21, 1930

The behavior of an intact organism differs from the reflex activity of a "preparation" chiefly in the number of its independent variables. An unconditioned reflex requires, for example, not only a stimulus of adequate intensity but a facilitating condition within the organism. Similarly a conditioned reflex depends upon a facilitating condition peculiar to its underlying unconditioned reflex. The series of reflex acts by means of