Citation:

Wind, C.H., A hypothesis relating to the origin of Röntgen-rays, in:
KNAW, Proceedings, 9 II, 1906-1907, Amsterdam, 1907, pp. 714-718

Physics. — *"A hypothesis relating to the origin of* RÖNTGEN*-rays."* By Prof. C. H. WIND.

W. WIEN [1]) has measured the energy of RÖNTGEN-rays, converted into heat in a bolometer or in a thermo-element, and has compared it with that of the cathode-rays, likewise converted — with exception of the small fraction transformed in energy of R.-rays — into heat in the anti-cathode. He finds for the proportion of the total quantities of energy of the two kinds of rays

$$\frac{E_r}{E_k} = 2{,}18 \;.\; 10^{-3}\ ^{2}).$$

Supposing that the R.-rays are the radiation of energy, emitted by cathode-ray electrons being brought to rest, and that this stoppage may be considered as a continually decreasing motion, he proceeds with the aid of the theory of M. ABRAHAM to deduce the duration of the stoppage and from it the thickness of the R-waves. For the latter he finds

$$\lambda = 1{,}15 \;.\; 10^{-10} \text{ cm}.$$

Results of the same order of magnitude have afterwards been attained by EDNA CARTER [3]) in an investigation, also made at the laboratory directed by WIEN.

These results do not very well agree with the values, derived by HAGA and myself for the wave-length of R.-rays from diffraction-experiments:

$$\lambda = 270 \text{ to } 12 \;.\; 10^{-10} \text{ cm } ^{4})$$

and

$$\lambda = 160 \;,\; 120 \;,\; 50 \;.\; 10^{-10} \text{ cm. } ^{5})$$

If the R.-rays have to be considered as disturbances in ether of the single pulse character assumed by WIEN in accordance with the current conception, the same numbers must be divided by $\frac{3.7}{1\frac{1}{2}}$ or $2\frac{1}{2}$ [6]) in order to represent the corresponding values of the thickness of the pulse-waves, which consequently become

$$\beta_1 = 110 \quad \text{to} \quad 5 \;.\; 10^{-10} \text{ cm},$$
$$\beta_2 = 64,\; 48,\; 20 \;.\; 10^{-10} \text{ cm}.$$

1) W. WIEN. WÜLLNERS Festschrift, Leipzig, 1905; Ann. d. Ph. 18, p. 991, 1905.

2) L. c. p. 996. The number is doubled here, on account of the remark made regarding it on page 1000.

3) E. CARTER. Ann. d. Ph. 21, p. 955, 1906.

4) H. HAGA and C. H. WIND. These Proc. I. p. 426.

5) Id. Ibid. V. p. 254.

6) C. H. WIND. Physik. Zschr. 2, p. 96. Fussnote 2), 1901.

WIEN's experiments would have led to results more in keeping with the diffraction experiments, if the values found for the energy of the R.-rays had been 20 to 100 times smaller. The difference is too great to ascribe it to errors of observation. We must rather think of fundamental errors in the method of observation or of a viciousness in our conceptions concerning the mechanism of the phenomena.

As for the method of observation WIEN himself pointed out[1]) the possibility that the quantity of heat, generated in the bolometer or in the thermo-element, should not be to its full amount converted energy of R.-rays, but partly also — perhaps even for the greater part — converted atom-energy, liberated by a, say, catalytic action of the R.-rays.

J. D. v. d. WAALS Jr.[2]) suggests the additional idea that the electrons are not generally stopped at once by a simple uniform decrease of velocity, but will mostly, by their interacting with the particles of the anti-cathode, before being brought to rest move for some time amidst the latter in rapidly changing directions with great velocities, sending out a new R.-pulse at every change of motion. Starting from this idea we could, indeed, expect from each electron a much greater contribution to the energy of radiation than in the theory accepted by WIEN and find the results of WIEN's energy-measurements in better agreement with those of the diffraction-experiments.

Nevertheless it seems to me that by the side of this another idea deserves our attention, which might be more in keeping with the properties of cathode-rays as far as known. It would be this, *that not simply the cathode-ray electrons, but in combination with these the atoms of the anti-cathode are the principal centres of emission of R.-rays.*

It should be imagined, that the electrons, arriving at the anticathode with their immense velocities, are not, generally, thrown into an other direction by the atoms, but will for the greater part pass straight through them, and even, in doing so, will mostly not suffer any persisting decrease of velocity. This idea is by no means a new one. It has been worked out by LENARD[3]), who sees in it the best explanation for the laws of absorption of the cathode-rays. In very few cases only it will happen that an electron, when piercing an atom, gets imprisoned

1) W. WIEN. Drudes Ann. d. Ph. 18, p. 1005, 1905; cf. also E. CARTER. Ann. d. Ph. 21, p. 957, 1906.

2) J. D. v. d. WAALS JR. Ann. d. Ph. 22. p. 603. 1907.

3) P. LENARD. Drudes Ann d. Ph. 12, p. 734, 1903.

or changes its direction considerably [1]) in a centre of exceedingly strong electromagnetic action; in the great majority of cases it will, by the abundance of vacant space in the interior of the atom [2]), fly across it without experiencing a considerable decrease of velocity.

In this way the greater part of the electrons will pierce thousands or tens of thousands of atoms before being stopped, and we find easily explained the great penetrating power of the cathode-rays, which may still in appreciable quantity pass through a layer of aluminium 10 μ [3]) thick or a layer of atmospheric air, some cm thick [4]).

If we consider the values given by the diffraction-experiments for the order of magnitude of the thickness of R.-waves as correct, it follows from WIEN's experiments — apart from a possible catalytic action of the R.-rays — that the radiation of the cathode-ray corpuscles, by the simple fact of their stoppage, could account only for something like $\frac{1}{20}$ or $\frac{1}{100}$ of the whole energy of the R.-rays. Consequently for by far the greater part this energy must, if LENARD's views may be accepted, have a different origin. What this can be, is obvious. The atoms namely will by no means remain undisturbed during the sudden passage of an electron. Themselves probably consisting of negative and positive corpuscles, they will see their electromagnetic fields during the passage altogether altered and at the same time will no doubt send out a pulse or wave of disturbance [5]) into the surrounding ether. About the character or shape of these pulses, which moreover may vary from one case to an other, we can, without making any more definite assumptions as to the structure of the atom, say little; but there is one important point, in which all these pulses will be to a certain degree similar, viz. their *duration*.

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1) Together with the expulsion of electrons originally belonging to the atom, which will often occur at the same time, these changes of direction could very well account for the diffusion of the cathode-rays according to LENARD.

2) LENARD calculates (Drudes Ann. d. Ph. 12, p. 739, 1903) that only 10^{-9} of the volume of an atom is occupied by the "dynamids", of which he considers it to consist.

3) LENARD. Wied. Ann. 51, p. 233, 1894.

4) Id., Ibid., p. 252.

5) LENARD expresses himself ("Ueber Kathodenstrahlen", Nobel-vorlesung, p. 37, Leipzig 1906) as follows: "Das durchquerende Strahlenquant" — the electron — "wird vermöge der abstossenden Kräfte, welche es auf die anderen, dem Atom eigenen, negativen Quanten ausübt, eine gewaltige Störung innerhalb des Atoms hervorbringen können", and then continues thus: "und als Folge dieser Störung kann ein dem Atom gehöriges Quant aus ihm hinausgeschleudert werden (sekundäre Kathodenstrahlung)"; but he does not speak of a radiation emitted by the atom.

The latter will be, if a represents the diameter of an atom and v the velocity of the electron, which is piercing it, something like (rather smaller than) $\frac{a}{v}$, causing the wave emitted to be of a thickness of something like (rather smaller than) $c\,\frac{a}{v}$, c being the velocity of light in ether. By putting $a = 10^{-8}$ and $v = 10^{10}$, we get by this way for $c\,\frac{a}{v}$ 3.10^{-8}, a number which only slightly exceeds the order of magnitude of the values of β (p. 714), derived from diffraction experiments. It might therefore be possible, *that the waves of disturbance in question should be identical with the Röntgen rays.*

As by this theory a single electron would disturb some thousands or tens of thousands of atoms, every atom, being traversed by an electron, need only send out something like $\frac{1}{100}$ of the quantity of energy emitted by an electron itself in its total stoppage, in order to account for the relatively large amount of energy found by WIEN in the R-rays. That such proportions should exist, seems to me not impossible at all.

The views presented here as to the origin of the R.-rays bestow a new and great importance on the "wave-length" of these rays, as they intimately connect this measurable quantity with the dimensions of the atoms. Whether there really exists such a close connection, could perhaps be experimentally put to the test by diffraction experiments with anticathodes made from different materials. More generally it might be expected that experiments of this kind would throw some new light upon the structure of atoms, and also of molecules or molecule aggregates. In such experiments it would certainly have a peculiar interest to use crystals as anticathodes, as perhaps the regular structure of these bodies could manifest itself both in rather sharply defined wave-lengths of the R.-rays emitted by them as in a polarisation of these rays.

The question, whether R.-rays should or should not be expected to show total or partial polarisation, may be treated on the basis of the above hypothesis, as soon as this be supplemented by definite suppositions about the structure of the atom.

The relation that, according to our views, should have to exist between the wave-length of R.-rays and the velocity of the cathode-rays, is of course liable to rather direct experimental verification.

49*

Two further questions connected with those views and perhaps liable also to be answered by way of experiment, are these:

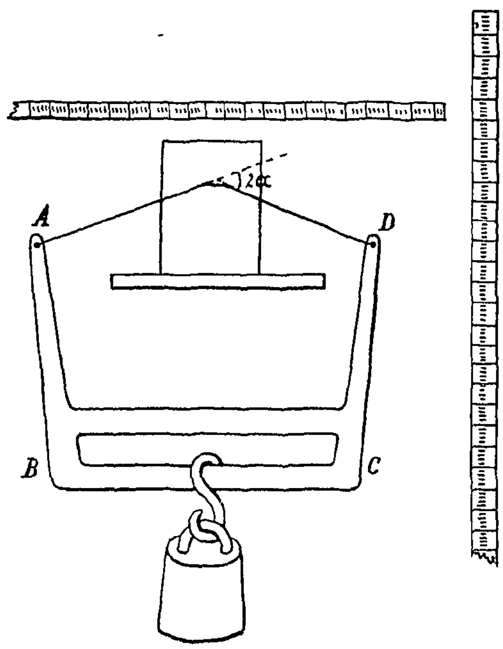
1. whether the air molecules on the outside of the aluminium window of LENARD emit R.-rays in appreciable quantity;

2. whether the γ-rays of a radio-active substance, except by the substance itself, are to a considerable extent emitted also by the atoms of air in its neighbourhood on their being pierced by the electrons constituting the β-rays.

Physics. — *"On the motion of a metal wire through a piece of ice."* By Dr. J. H. MEERBURG. (Communicated by Prof. H. A. LORENTZ).

(Communicated in the meeting of January 26, 1907).

During the last and the preceding winter I made some measurements with a purpose of testing the formulae, expressing the velocity of descent of a metal wire through a block of ice, which Mr. L. S. ORNSTEIN had derived from the theory of regelation [1].



In my experiments the metal wire was fastened at both ends to

[1] L. S. ORNSTEIN. These Proc. VIII, p. 653.