is derived and the values ϱ/ϱ_D have been calculated finally, which values determine the dispersion of the magnetic gases. These different numbers are combined in table 2, while fig. 3 shows graphically the values of ϱ/ϱ_D.

TABLE 2.

a	λ	ϱ	ϱ/ϱ_D	a	λ	ϱ	ϱ/ϱ_D
112	420	0 02748	2 003	211.5	575	0.01455	1.061
116	431	2653	1 835	216	579	1425	1.039
124	446	2482	1 810	219 5	583	1402	1.022
130 5	458	2358	1.719		[589]	[1372]	1 000
165	510	1865	1 360	231	599	1332	0 971
166	512	1854	1 351	235 5	604	1307	0.953
176 5	527	1744	1.271	237	604	1299	0 947
184.5	536	1668	1 216	249.5	616	1234	0 899
189 5	543	1624	1.184	250	621	1231	0 898
196 5	554	1566	1 142	273	643	1127	0 822
196	555	1570	1 145	283	659	1089	0.794

In this calculation the rotation in the glass plates has been neglected. A simple calculation shows us that this is permissible; for it should be remembered that this is done both for the measurements with methyl chloride and with water.

As the result of this research I find that the magnetic rotation constant for liquid methyl chloride under atmospheric pressure for sodium light is 0'.01372, and that the rotation dispersion is normal, deviating little from that with gases and with water.

The research will be continued with other gases.

Physics. — "*Diffraction of Röntgen-Rays.*" By Prof. H. HAGA and Dr. C. H. WIND, second communication.

In the March meeting 1899 we stated as the result of our experiments that Röntgen-rays show diffraction; with these experiments the rays passing through a narrow slit first fell on a second wedge-shaped slit, then on a photographic plate. The image proved not to be what was to be expected with rectilinear propagation but presented broadenings from which an estimation could be derived concerning the value of the wave-length which proved to be of the order of 0,1 $\mu\mu$.

In September of last year in one of the meetings of the "Deutsche Naturforscher Versammlung" at Hamburg Dr. WALTER[1]) protested against those experiments; he had arranged his experiments in entirely the same way as we had; moreover he had taken still greater precautions to get a steady mounting of the slits and the photographic plate and he had used stronger Röntgen-rays. WALTER obtained images quite similar to the second slit and attributed our broadenings to inaccuracies of the photografic plate brought about by long development.

These negative results gave rise to a renewed investigation on our side, now that we had greater means at our service than three years ago. We have succeeded in obtaining more clearly than before phenomena of diffraction, so that according to us one can no more doubt the character of Röntgen-rays to be that of disturbances in the ether.

The method of investigation has not changed in principle, but making use of the experience obtained by Dr. WALTER and ourselves we have been able to make improvements still in some respects.

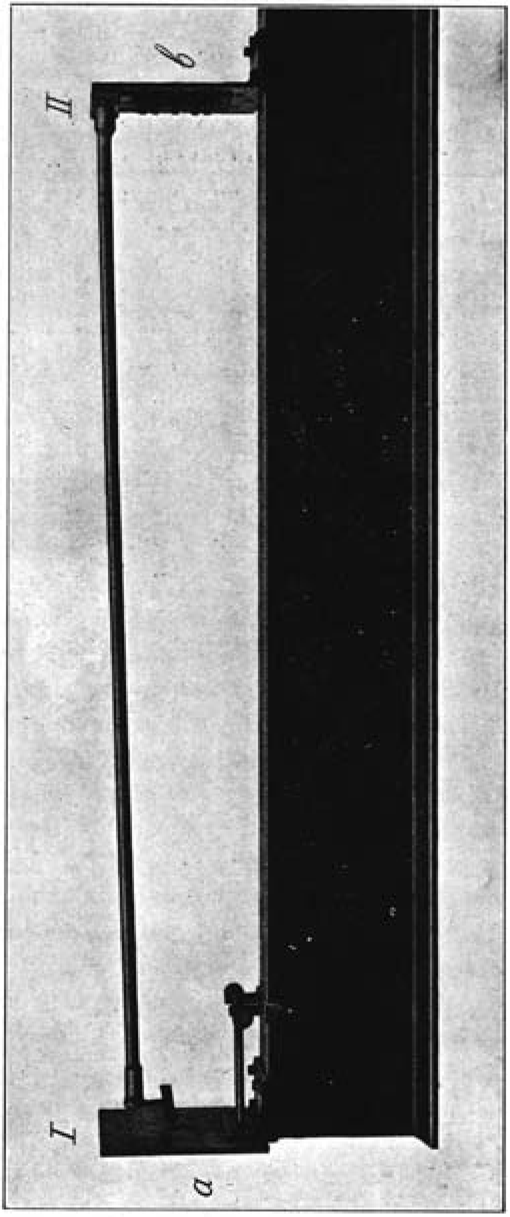
On the upper surface width 5.5 cm. of an iron beam of I-shaped profile, long 2 m. and high 12.5 cm. three pieces of angle-iron were screwed down, one at the end, the two others 75 cm. and 150 cm. distant from it, the edge perpendicular on the length of the beam and the side of 3.5 cm. erect; in the figure the two first pieces of angle-iron are visible; against the vertical sides brass plates — 12 cm. high, 10 cm. wide and 4 mm. thick — were screwed. In the middle of plate I was the first slit, in the middle of plate II the wedge-shaped diffraction slit while against the third plate in a black envelope the photographic plate was clamped[2]). During the experiments the second and the third of these brass plates were enclosed in an oblong leaden case, which had to prevent the secondary Röntgen-rays or rays diffused by the air, from affecting the photographic plate and causing a fog.

The iron beam was fastened by means of plaster of Paris on two free-stone plates borne by free-stone columns; the columns were placed on a firm pillar; on this same pillar, likewise on a free-stone plate borne by a stone column, was the Röntgen-tube in a large leaden

---

1) B. WALTER, *Physik. Zeitschrift* 3. p. 137, 1902.

2) SCHLEUSSNER's "Röntgenplatten" were used.


II
b
I
a

case (thickness of the side 2 mm.); only the back of this case was left open for the connecting wires of the induction coil, whilst in the front a small aperture was made opposite the first slit to let the Röntgen-rays pass. The first slit was formed by two platina plates, thick 2 mm. and high 2 cM; a leaden screen left but the middle of it free over a height of 4 mm.; the width of this slit was 15 μ. The diffraction slit was formed by two platina plates thick $^1/_2$ mm., high 4 cm., tapering at the upper end from a width of 25 μ to nearly zero at the other. Greatest care was given to the grinding of the platina plates. For these slits, just as in our former experiments, the sides were everywhere equally thick and not ground wedge-shaped at the edge of the slit as is the case with slits for light-experiments.

To produce the Röntgen-rays an induction coil of SIEMENS and HALSKE was used with a sparklength of 60 cm., a primary with 4 coils and a WEHNELT-interruptor. The current was furnished by a battery of accumulatörs of 110 Volt. The newest Röntgen-tubes of MULLER (Hamburg), were exclusively used; the anticathode being kept cool by water.

More care than formerly was taken to bring the passages of the two slits accurately into the same line. Peculiar difficulties are incident to this, which is a result of the extraordinarily great depth of the slits together with a width so slight that common light, on account of the arising phenomena of diffraction, cannot be used to fix accurately the direction of the passage. For this last reason we had to have recourse to Röntgen-rays to do so. And here again the slight width of the slits caused the pencils of rays passing through them to be so very faint, that in the case of the *first* slit, wide 15 μ, they could be observed on a fluorescent screen at the place where it was necessary, namely near the second slit only with an eye accustomed to complete darkness. The pencil of rays, allowed to pass through the most interesting part of the *second* slit viz. that part, where the width was about 5 μ, could be observed not even by this way, but only by the impression it made on a sensitive plate after a lengthy exposure (4 hours). In order to deduce from this impression a mark for the direction of the passage of the second slit, a small strip of brass was fastened near and slightly above the first slit; (see figure); in this strip, held by an arm fixed to plate II, some vertical rows of small holes had been drilled side by side, differing in number and size. A Rontgen-tube was placed behind plate II in *b* and a photographic plate between the brass strip and plate I; a small leaden screen left of the second slit but the part to be observed free. On the photographic impression one or two of the rows of the holes became visible and from this could be deduced without difficulty, which part of the strip was situated in the direction of the passage of the second slit. It was now easy to place plate II with its piece of angle-iron in such a way — the holes in the iron were somewhat larger than the diameter of the screws — that, seen from the centre of the second slit, the part of the strip, just now determined, appeared exactly above the first slit. Plate I being able to revolve round an axis through the first slit, the latter could be directed in such a way that the rays from a Röntgen-tube placed near *a* fell on the second slit; by means of a fluorescent screen we could make sure that this had been obtained. During the course of the diffraction experiments itself the exact position of the tube was several times controlled and if necessary corrected.

The width of the second and first slits were arrived at from photographs when the photographic plate was placed immediately behind plate II and the Röntgen-tube at *a* or the photographic plate at *a* against plate I and the Röntgen-tube at *b*; the photograph of the second slit was taken both before (namely April 10th, plate N^{o}. 1) as after (namely Aug. 23rd, plate N^{o}. 2) the experiments.

As has been mentioned before the self-regulating tubes with water-cooling were exclusively used; how well these tubes work and how excellent they are for the usual medical purposes, for the uncommon demands of this investigation only a few of them could be of service. For we wanted tubes which were "soft" and remained so for hours at a stretch, whilst the effect was so great that the cooling-water kept on boiling; most of the tubes became harder after a ten hours'use; when the discharges took place to the sides of the leaden case another tube had to be taken.

Three very good photographs were obtained, to be distinguished as *A*, *B* and *C*.

A, obtained on May 7th and 8th after an exposure of 9 hours and a half, principally by a very excellent tube furnishing very strong rays and of great softness; developed during three quarters of an hour in 200 ccm. of glycine [1]) 1 to 5.

B, obtained on July 8th, 9th, 10th, 12th; time of exposure 31 hours; two tubes were used, one of which was soft for four hours and after that became hard and the second continually hard; developed in one quarter of an hour with glycine 1 to 5.

---

1) Vogel's Taschenbuch, 1901, pg. 128.

C, Aug. 14th, 15th, 16th, 17th, 18th; time of exposure 40 hours; two tubes used, one of which worked 10 hours and was pretty hard, the other a very good tube which remained soft for the remainder of the time; developed in 10 minutes with glycine 1 to 6.

There is scarcely any fog on the plates.

In order to enquire how wide that part of the diffraction slit was, through which the rays have passed that have worked upon the photographic plate at a definite point, small round holes were drilled just as in our preceding investigation in one of the sides of the second slit and close to it at the extreme ends and in the centre. On account of this on the plates N°. 1 and N°. 2 serving for the measurement of the second slit, circular images had appeared and elongated ones on the plates *A*, *B* and *C*. (From these pinhole-photographs of the active part of the anticathode, limited by the width of the first slit, is proved that this active part was only 2 mm. high). The distances between the centres of these images were divided by the dividing-machine into the same number of equal parts, so that the corresponding division-marks point to corresponding places of slit and image.

For the measurement of N°. 1 and N°. 2 object-glass *D* and measuring-eye-piece 2 were used where one division of the micrometer corresponds to 3,6 μ.

For the measurement of the image of the slit on *A*, *B* and *C* the microplanar Ia, 2 was used as object-glass and as eye-piece the compensation eye-piece 6; one division of the eye-piece-micrometer corresponds to 55 μ, the magnifying power was 27 with a distance of the image of 25 cm.

In the following table are mentioned for the successive division-marks indicated by their number in the first column:

in column 2: the mean of the values derived from N°. 1 and N°. 2 of the width of the second slit in micra;

in column 3: the double width of the second slit augmented by the width of the first slit (15 μ), thus the theoretic width of the image, without diffraction; the distance between the photographic plate and the first slit being double the distance between the first and second slit;

in column 4, 5 and 6: the width of the images respectively on *A*, *B* and *C* as measured in divisions of the eye-piece-micrometer (1 div. $=$ 55 μ);

in column 7: the mean width of the images in micra (rounded off).

Number of the division-mark.	Width of the second slit.	Theor. width of image without diffraction	Measured width.			
			A.	B.	C.	Mean.
1	27 μ.	69 μ	1 0	1.0	1.0	55 μ
2	22,5	60	0.85	0.85	0.9	50
3	19,5	54	0.75	0.75	0.8	40
4	18	51	0.6	0.7	0.7	40
5	17	49	0.55	0.7	0.7	35
6	16	47	0.45	0.65	0.65	30
7	14	43	0.4	0.6	0.65	30
8	12	39	0.35	0.5	0.6	25
9	9,5	34	0 3	0.4	0.6	25
10	8	31	0 3	0.35	0.5	20
11	6	27	0.4	0.4	0.55	
11½			0.6	0.45	0.6	
12	4	23	1	0.45	0.7	
12½			±1½	0.8	±1½	
13	3.5	22		±1½		

When considering these figures we must keep in view that the image on account of the width of the first slit is not sharply outlined but is hazy; this causes the measurement to remain uncertain and so somewhat deviating figures are found by different observers or by the same observer at various times; all measurements, however taken, proved, as can be noticed from the figures mentioned in the table, that for the *wide* part of the slit the figures of the third column are larger than the corresponding ones of the last column. The figures of this third column indicate the theoretic width of the image for the case that the plates have been affected to the *outer* edge of the rays to which they were exposed and that no diffraction, vibration, displacement or photographic irradiation has played a part; the latter three causes might bring about a broadening, yet this would necessarily have been greatest on the places of greatest influence thus at the *wide* part of the slit. Now that no broadening whatever is found *there*, the brush-shaped broadenings, whose width is 2 or 3 times greater than the theoretic, found on all the three plates at the narrow part of the slit, can certainly not be attributed to those three causes.

These broadenings, however, are exactly of a character as is to be expected in the case of diffraction; and therefore as long as another explanation is wanting, we can but consider our three plates as so many proofs of *diffraction of the Röntgen-rays.*

Of the most important parts of N°. 1, *A*, *B* and *C* we have made enlarged copies on glass by means of the microplanar, on which, if not so clearly as under the microscope, the broadening of the image of the slit is yet verydistinct; the difficulty of reproducing these enlargements well has made us refrain from publishing them; we are quite willing to send these copies to those who are interested in them.

As to the question to estimate the wave-lengths of these rays, various ways are open; but in no case can one attain at anything but a very rough estimation, as on one hand the real nature of the kind of radiation dealt with is unknown, so that it is uncertain with which kind of diffraction-image our images must be compared, and on the other hand it is very difficult to find out what is accurately the physical meaning of the limits of the image, on which is pointed when measuring.

If however we are forced to limit ourselves to a very rough estimation it is rather indifferent, as far as the result goes, which of the ways already indicated [1]) we take; the simplest method deserves recommendation, namely the one we followed in our first communication about this subject, based upon our estimating the tabular width v of the slit equal to 1.3 at the place where the broadening begins to make its appearance in the image. With a radiation of simple periodical disturbances this tabular width is connected with the wavelength and the linear width, and with the known distances a and b by means of the relation:

$$v_s = s\sqrt{\frac{2\,(a+b)}{a\,b\,\lambda}} \text{ or } \lambda = \frac{s^2}{v_s^2}\,\frac{2\,(a+b)}{a\,b}.$$

As in the experiments a and b both amounted to 75 cm. we obtain after substitution of the value of v_s

$$\lambda = 0{,}032\, s^2.$$

From the above table ensues for s: the width of the slit where the broadening begins to appear, respectively about 7, 4 and 6 μ for the plates *A*, *B* and *C*. From this would ensue for the

1) H. Haga and C. H. Wind. These reports 7 page 500, 1899. C. H. Wind Wied. Ann. 68, page 896 and 69. page 327, 1899; Physik. Zeitschrift 2. p. 189. 265 and 292, 1901. A. Sommerfeld, Physik. Zeitschrift 1, pg. 105, 1900 and 2, pg. 58, 1900; Zeitschrift. f. Math. und Physik. 46, pg. 11, 1901.

wave-lengths if Röntgen-rays are simple periodical disturbances:

for plate A, B, C,
$\lambda = 0{,}16 \quad 0{,}05 \quad 0{,}12 \ \mu\mu$.

Now that this supposition does certainly not hold, we shall have to consider these values as estimations of wave-lengths, which in the three different experiments have been more or less prominent in the curve of energy [1]) of the Röntgen-rays.

Mention ought to be made here, that, although not too much importance must be attached to the three values of λ as far as the absolute figures go, the difference they show is probably real and connected with the difference in hardness of the tubes. As was mentioned above the tubes used for plate B were distinguished by a considerable hardness from the others, which were relatively very soft.

Worth noticing is also the fact, that the values of λ found here are of the same order as those deduced from our former experiments.

Finally we wish to state emphatically that we continue to regard as the chief result of our investigations the proof they furnish that the Röntgen-rays ought to be considered as a phenomenon of radiation in the ether.

Physical Laboratory University Groningen.

Physics. — H. A. Lorentz. "*The fundamental equations for electromagnetic phenomena in ponderable bodies, deduced from the theory of electrons.*"

§ 1. In framing a theory that seeks to explain all electromagnetic phenomena, in so far as they do not take place in free aether, by means of small charged particles, electrons, we have to start from two kinds of equations, one relating to the changes of state in the aether, the other determining the forces exerted by this medium on the electrons. To these formulae we have to add properly chosen assumptions concerning the electrons existing in dielectrics, conductors and magnetizable substances, and the forces with which the ponderable particles act on the electrons in these several cases.

In former applications of the theory I have restricted myself to

1) C. H. Wind. ll. cc.