Dr. P. ZEEMAN. *On the determination of the optical constants of magnetite.*

With a view to further magneto-optic measurements I wanted the optical constants, principal angle of incidence and principal azimuth of magnetite. As these seem never to have been measured until now, I communicate them below. The heads sufficiently explain the table.

Nr.	J.	H.	colour	wave-length	originating from
1.	68°35′	9°0′	D-light	0.589μ	Fort-Henry. N.-York.
2.	68°25′	8°38′	D- »	»	Pfitsch Tirol.
3.	68°33′	7°55′	H-line α	0.656μ	
	68°27′	8°48′	D-light	0.589μ	» »
	68°27′	10°10′	H-line γ	0.434μ	

Dr. L. H. SIERTSEMA. *On the dispersion of the magnetic rotation in oxygen.*

The apparatus described in the former communication [1]) with which measurements now have been made with oxygen and with air, has in some important respects been improved and completed.

In the first place it appeared that better precautions were necessary to keep the temperature of the experimental tube constant and so to prevent currents in the gas. Between the tube and the coil concentric brass tubes, connected with the water-conduct have been inserted, so that the water is obliged to flow from one end of the tube to the other and back. From thermometer-readings at the beginning and at the end of this circulation also the temperature of the gas was deduced. Between the experimental tube and the interior water-tube we find still a layer of india-ruber for equalizing the temperature. By this arrangement the just mentioned convection-currents are almost completely avoided in summer, even if by a long continuation of the observations the coils have become sensibly

[1]) Zittingsverslag Kon. Ak. Amsterdam Afd. Natuurk. Juni 1893. Comm. Lab. of Physics. Leiden N°. 7.

heated. In wintertime however this proved to be still insufficient owing to the greater difference between the temperature of the room and the water, and the aim was not reached before the bronze endpieces and the ends of the experimental tube had been coated with cotton-wool.

Secondly a better arrangement was devised for turning the small endpiece containing the first nicol. A strong bronze ring provided with a downward handle accurately fits round the nuts of the flange. Two steel-wires are fastened to the handle, one of which is always kept stretched by a heavy weight and the other one goes over a small pulley to the other end of the apparatus where it is fastened to a screw which can be turned by the observer. By this arrangement the observer is enabled to give small rotations to the nicol, while sitting before the telescope.

The screw is attached to the beams on which the coils and the experimental tube are mounted. In the same manner the telescope and scale of the scale and mirror reading-arrangement, with which the rotation of the small endpiece is measured by means of an intermediate mirror, were at first attached to this beam. Now it soon became apparent by the inequality of rotations to right and left that this method of mounting had some drawbacks. By the rotation of the experimental tube and also by the heavy weight with which the steel-wire was loaded at the other end, this beam was no longer absolutely fixed, which could be proved by fixing a small mirror to various parts of the apparatus. For this reason the scale and mirror-reading no longer

answered to its purpose and moreover the measured rotations were inaccurate because the large endpiece with the nicol was also somewhat turned in the same direction. An efficacious improvement in the mounting of the coils could not be effected without much trouble and loss of time, so that it seemed simpler to follow another way. First all parts of the scale and mirror arrangement were mounted, independent of the apparatus, on a fixed pillar which has no contact with the floor of the room, and secondly the rotations of the large endpiece were taken into account by measuring them with a level, attached to this endpiece and previously carefully calibrated. After these improvements the difference between the rotations to left and right existed no longer. For the sake of security however the rotations were limited to values of 3° to 4° by varying the intensity of the current.

The measurement of the intensity of the current was attended with some difficulties. For an accurate measurement of a current of about 60 amp. the ordinary commercial ampèremeters are not suited. Moreover the instrument has, because of the vicinity of the coils, to fulfill the condition that it is not affected by the exterior magnetic field and with a view to the variability of the dynamo-current, it must admit of a quick reading. For this purpose a d'Arsonval galvanometer with objective mirror-reading, through which a branch of the main current is sent, proved the most satisfactory. The branch is made by conveying the main current through a copper tube placed in streaming water, the temperature of which is noted every now and then. The calibration of this instrument is effected by measuring a current of 60 amp. from accumulators, simultaneously with this instrument and with a large tangent-galvanometer in another room, consisting of two circles of 1 M. diameter at a distance of nearly 2 M. from each other.

Between these a magnet with mirror is suspended above a revolving divided circle with which a telescope is connected which is always adjusted perpendicularly to the mirror. The deflection for the said current amounts to about 40°. We may suppose that the reductional coefficient of this instrument is constant, which is sufficiently confirmed by a few comparisons with a copper-voltameter.

From these simultaneous measurements it appears that the deflections of the galvanometer may be put proportional to the intensity of the current and besides, that its reductional coefficient is in a simple way related to the temperatures of the shunt and of the galvanometer. It is about 0,023, the deflections being from 150 to 300 scale-divisions.

The temperature of the galvanometer is read on a thermometer placed at its interior. By wrapping up in cotton-wool quick variations of temperature were prevented.

Overheating of the coils was prevented by closing the current in the coils only during the pointings. The difficulties attending the repeated opening and closing of a dynamo-current were obviated by transferring the current each time with a key on an iron-wire resistance-

coil of a resistance nearly equal to that of the coils. Another double key serves for changing the direction of the current in the coils.

The pressure of the gas is read to 0,1 atm. on a large manometer of 25 cM. diameter, the corrections of which have been determined by the Physikalisch-Technische Reichsanstalt at Berlin.

In the measurements I have exclusively employed the method cursorily mentioned in the preceeding communication in which the light of the arc-lamp passes first through a collimator and then through the experimental tube, is then analyzed by a glass prism and is observed with a telescope. The slit of the collimator has been shortened by a couple of little screens to a length of 2 mM. Thus the too obliquely incident light which by reflections in the tube disturbs the pointings, is avoided.

When turning the nicol, one sees, when the current is closed a black band moving through the spectrum, which admits of very good pointings. Only at the ends of the spectrum, especially at the violet end, they are less accurate owing to the small intensity of the light, but it is improved by a diaphragma with broad vertical slit in the eye-glass of the telescope, by which only part of the spectrum is seen. It will be seen that in this method we miss the previously mentioned black line which crosses the field of crossed nicols horizontally and moves vertically over the image of the slit and the accuracy attainable in the pointings is consequently less. For compensating this, however, we have some advantages. First the wave-length can be better determined. If formerly this was done by placing a small spectroscope behind the experimental tube *after* the measurements, now we can find them by pointing the telescope, after having read its position on a divided circle, at a few neighbouring fixed points in the spectrum, for which in the case of oxygen the already formerly mentioned absorption-bands of LIVEING and DEWAR can serve and also some bright lines in the spectrum of the electric light. By comparing these lines and bands with FRAUNHOFER's lines, their wave-lengths have been controlled and the dispersion-curve of the prism has been determined. With the observations on air only the mentioned bright lines can be used as fixed points. The telescope has always been adjusted on the fixed points before and after the adjustment of the black band so that possible small displacements of the spectrum can have no influence. In the adjustments the telescope was always first pointed at a definite point of the spectrum and then, after having closed the current, the band was adjusted by turning the nicol. In this manner it is possible to make a number of successive observations, retaining the same wave-length.

Besides the better and quicker determination of the wave-length, the method followed offers still the advantage that the convection-currents in the gas, occasioned by differences of temperature, which it is very difficult to prevent completely, make the image of the slit very turbulent and the pointing of the horizontal black line very inaccurate, while the band in the spectrum is only influenced by much stronger currents. This influence becomes first apparent in a deviation of the direction of the issuing light, which with stronger

convection-currents can become so considerable that it is no longer possible to pass a ray of light through the tube. If we look in such a case through the tube it seems to be curved. In the method followed, it is possible to continue, with the necessary precautions, the observations for a very long time.

The crossed position of the nicols without current cannot be pointed at so correctly, as here the whole of the spectrum is darkened. This pointing can better be effected by putting a mirror between the experimental tube and the prism and by observing the direct white image of the slit in this mirror. If the nicols in the experimental tube are so placed that the black line in their field is vertical, which is the most favourable position for the band in the spectrum, and if the slit of the collimator is not too narrow, this line can be very well pointed at. Regular observations of this null-position however were made only in the beginning in order to judge of the correctness of the pointings and of the equality of the rotations to the right and to the left. Afterwards the rotations have always been deduced from two pointings with nearly equal currents in opposite directions. The possible loss of accuracy in this method of working is amply compensated by the larger number of observations which can be done in the same time.

The gas which was drawn off after the observations was then also analyzed with HEMPEL's pipetts. It soon became clear that the purity of the gas in the well-known iron cylinders was quite insufficient.

If in the former communications a purity of 94%

was mentioned, the cylinders with which I worked afterwards showed a less favourable percentage, sometimes no more than 60%. The admixture is probably nitrogen. In order to be able to make observations on pure oxygen I was obliged to prepare it myself.

This preparation has been effected by electrolyzing diluted sulphuric acid in ten apparatus with lead electrodes and with a current of 12 to 13 ampères. The gas delivered by the generating apparatus passes through a wash-bottle containing potassium iodide for arresting ozone, which otherwise vigorously attacks the india-rubber connections and is then collected in a reservoir from which, after having been led trough a few wash- and drying-bottles, it is forced into an iron cylinder to upwards of 100 atmospheres by the mercury-compressor described by Prof. Dr. KAMERLINGH ONNES [1]). The first gas yielded contained much air and was not collected, but after the production had been continued for some time, this improved, the purity of the gas in the filled cylinder being found, on examination, to be 98,7 perc. Besides with this gas, observations were made with air and with gas from a cylinder of 87.8 percent.

From the observations numbers have been deduced, proportional to the rotation. These have further been reduced to equal intensities of the current and also to a pressure of 100 atmospheres and to a constant temperature, supposing that they are proportional to the current and the density of the gas. The succession of

---

[1]) Zittingsversl. Kon. Akad. Amsterdam 1894/95 p. 197. Comm. of the Lab. of Physics. Leiden N°. 14.

the observations has for the rest been so chosen, that each time from readings in immediate succession two rotations are deduced for the same wave-length, which consequently must be equal and the observations were cancelled if their difference was too great. On the whole 184 adjustments were made with oxygen, 68 with air. With the numbers found in this way, to which by means of the observations on air a small correction has been applied for the remaining 1,3% of nitrogen, a curve has been drawn which consequently represents the magnetic rotatory dispersion for oxygen.

These numbers are

wave-lenght in 10^{-3} mM.	ω_o (oxygen)	ω_a (air)	ω_n (nitrogen)
0,423	2897	3544	3715
0,436	2741	3310	3460
0,4455	2674	3173	3305
0,453	2575	3064	3193
0,460	2524	2967	3084
0,477	2384	2754	2852
0,505	2182	2470	2546
0,527	2067	2272	2326
0,5385	2018	2180	2223
0,549	1927	2103	2150
0,578	1831	1900	1918
0,604	1716	1740	1746
0,630	1617	1602	1598
0,664	1545	1464	1442
0,684	1516	1390	1357

The corresponding numbers for air have been added and the numbers deduced from these for nitrogen by extrapolation, for both of which gases also curves have been drawn. (See Fig. 5).

On nitrogen however I hope to be able to give more direct observations afterwards.

In these reductions we have assumed that the rotation ω of a mixture of p vol. of oxygen and q vol. of nitrogen can be represented by

$$\omega = \frac{p}{p+q}\,\omega_0 + \frac{q}{p+q}\,\omega_n.$$

The validity of this rule and the accuracy of the observations can be shown by comparing the rotations found for the 87,8 percent gas with the calculated values. As we found only numbers proportional to the rotations these can only be equal, save a constant factor.

wave-length in 10^{-3} mM.	rotation calculated	rotation observed	ratio
0,423	3002	3027	1,008
0,436	2834	2906	1,025
0,4455	2756	2777	1,008
0,453	2655	2700	1,017
0,460	2597	2632	1,013
0,477	2445	2497	1,021
0,505	2229	2290	1,027
0,527	2101	2140	1,019
0,5385	2045	2070	1,012
0,549	1956	2015	1,030
0,578	1842	1863	1,011
0,604	1720	1740	1,012
0,630	1615	1628	1,008
0,664	1532	1531	0,999
0,684	1496	mean	1,015

The accordance may be considered sufficient.

The absolute rotations will be given afterwards.

If we consider the results found for oxygen more closely, we see that the preliminary result mentioned in the former communication, viz. that the rotation in oxygen for violet is about twice that for red, is here confirmed.

Let us now see how far the observed rotations in oxygen can be represented by one of the numerous formulae, given for the magnetic rotatory dispersion. These formulae invariable express the rotation by means of the wave-length, the refractive index and one or two constants. Excepting NEUMANN's formula, which needs not be considered, and taking into account the ordinary slight dispersion in gases, the formulae with one constant give all a rotation very little deviating from $\frac{c}{\lambda^2}$. From what follows it will become clear that such a formula cannot be used here. The formulae with two constants of BECQUEREL [1]), LOMMEL [2]), VOIGT [3]), VAN SCHAIK [4]), all lead, if we take n constant to expressions of the form

$$\omega = \frac{c_1}{\lambda^2} + \frac{c_2}{\lambda^4}$$

---

1) BECQUEREL. Ann. de Ch. et de Ph. (5) 12. p. 1 (1877).
2) LOMMEL. Münch. Sitz-Ber. 1881. p. 454; Wied. Ann. 14.
3) VOIGT. Wied. Ann. 23. p. 493 (1884).
4) VAN SCHAIK. Dissertatie. Utrecht 1882; Arch. Néerl. 21. p. 1 (1886).

MASCART's formula [1]) on the contrary gives

$$\omega = \frac{c_1}{\lambda} + \frac{c_2}{\lambda^3}.$$

From calculations by the method of least squares in which to each number a weight has been given proportional to the number of adjustments (these weights have been indicated in the curve), it will appear that by a formula of the first-mentioned form the observations cannot but very unsatisfactorily be represented. Only by adding a third term we find with

$$\omega = \frac{937{,}22}{\lambda^2}\left(1 - \frac{0{,}1572}{\lambda^2} + \frac{0{,}01388}{\lambda^4}\right)$$

a sufficient accordance with a mean error of 17,4 or about 1% which agrees with the accuracy to be expected in the final result from the various readings and adjustments.

The second formula on the other hand gives already a sufficient accordance in the given form. We find:

$$\omega = \frac{868{,}028}{\lambda}\left(1 + \frac{0{,}07202}{\lambda^2}\right)$$

with a mean error of 17,5. The preliminary results for nitrogen can also be represented by formula of the same form:

$$\omega = \frac{560{,}41}{\lambda}\left(1 + \frac{0{,}32424}{\lambda^2}\right)$$

with a mean error of 19,1.

---

[1]) MASCART et JOUBERT. Leçons sur l'électricité et le magnétisme I, p. 656. See also: JOUBIN, Ann. de Ch. et de Ph. (6) 16. p. 78. (1889).

From an investigation of JOUBIN it appears that MASCART's formula holds in all other known cases. In connection with this we would conclude from the above observations that the formula

$$\omega = \frac{C}{\lambda}\left(n - \gamma\,\lambda\,\frac{\partial n}{\partial \lambda}\right)$$

represents the magnetic rotatory dispersion best of all known formulae.

In this comparison we should however bear in mind that but little is with certainty known about the refractive indices of oxygen under a pressure of 100 atmospheres.

Therefore I intend to make a separate determination of the ordinary dispersion at high pressure, when the investigation will be extended to ultra-violet and ultrared light.

15

Fig. 3.

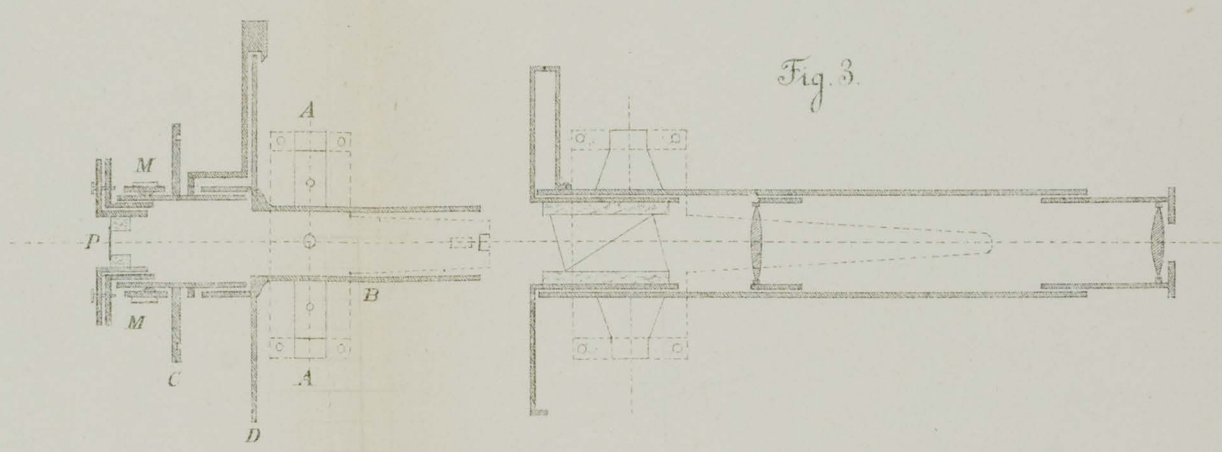

Fig. 2.

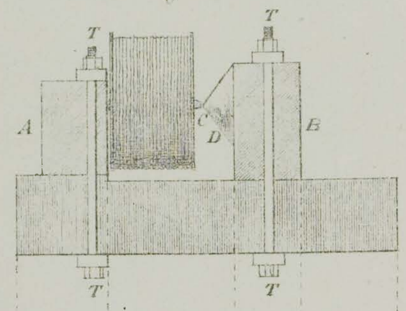

Fig. 4.

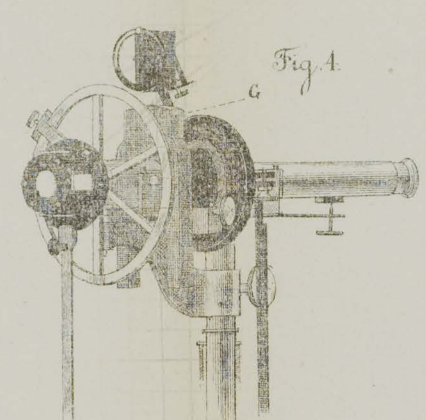

Fig. 1.

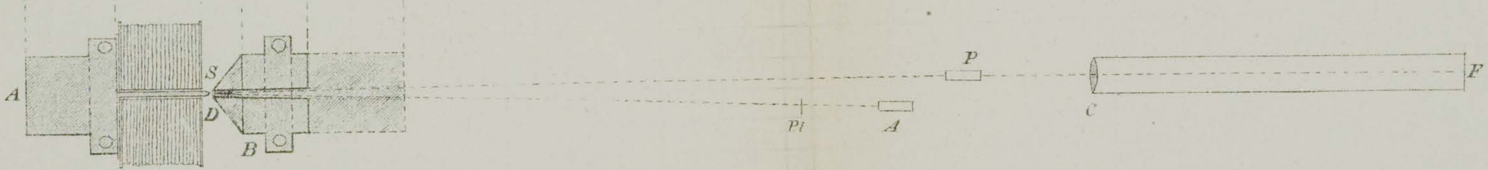

Fig. 5.

Siertsema Magnetic rotatory dispersion

Eduard Ydo. Printer. Leiden.