impossible entirely to exclude diffuse light—probably due to the diffusion on the faces of and inside the prisms, so that we shall always have to take account of its presence, even though it be only to a very slight degree. In fact, we have not investigated any apparatus or prism, in which the disturbing influence of this phenomenon was not more or less felt. The question whether a certain diffusion still occurs with a really macro-homogeneous, optically "empty" refracting medium, is difficult to solve, and must for the present be considered a pending problem.[1])

The "vignettation" amounts on an average to 25 %, as may be observed by accommodating on the square objective diaphragm. When the apparatus was used as a monochromator the intensity of the light came up to what we expected; with sunlight it is still from 5 to 10 times higher (according to meteorologic circumstances) than with an arc-lamp crater projected on the entrance slit. Accordingly with monochromatic light of great purity even polarisation apparatus of very slight transmitivity may be used. When thus applying the instrument to illuminative purposes the entire path of the beam from the source of light on to the retina, and especially its divergence, ought to be carefully adapted to that part which lies within the apparatus, if all the possible benefit is really to be derived from it.

Physics. — *"The influence of temperature and magnetisation on selective absorption spectra"*, II. By Prof. H. E. J. G. DU BOIS and G. J. ELIAS. (Communication from the Bosscha Laboratory).

§ 12. Since our former communication (These Proc. Febr. p. 578) the cryomagnetic arrangement was further improved in some respects in order to obtain a stronger field, and to diminish the inconvenient formation of rime. The truncated end-planes of the conic polar pieces had a diameter of 6 mm., the split cores[2]) a diameter of 3,5 mm.; the width of the slit at the end was from 0.4 to 0.6 mm., the slit being wedge-shaped so as to fit the convergence and divergence of the beam of rays between two lenses; it was arranged in such a way that the whole surface of the grating was illuminated, so that the theoretical dissolving power, — amounting to about 100.000 — had its full effect. Subsequent in the direction of the rays was a doubled quarter-wave plate with horizontal demarca-

1) C. A. LOBRY DE BRUYN and L K. WOLFF, Rec. d. Trav. Chim. **23**, p. 155, 1904; L. MANDELSTAM, Physik. Zeitschr. 8, p. 608, 1907; M. PLANCK, ibid. 8, p. 906, 1907.
2) H. DU BOIS, Zeitschr. fur Instr. Kunde **19** p. 360, 1899.

tion adjusted at the laboratory according to CORNU and W. KÖNIG [1]). On account of the considerable astigmatic difference in the images of horizontal and vertical lines formed by a concave grating, the plate was placed near the focus of a third lens in order to enable us to cancel this astigmatism for different parts of the spectrum by comparatively small displacements. The line of demarcation could then be adjusted sufficiently sharply in the spectrum, which KÖNIG had not succeeded in doing. A nicol followed the mica plate, and then came the principal slit. With this arrangement a normal doublet is known to appear in the spectrum as a broken line e. g. thus ꜝ; and on rotation through 90° of the nicol round the direction of the rays or of the $^1/_4$ plate round its *vertical* diameter ꜝ at once appears.

§ 13. As a rule the samples were mounted in a copper frame-piece and clasped between the polar end-planes; it is desirable to have an airtight fitting so as to prevent cold currents of air with formation of rime. The level of the liquid air may now rise above the openings so that the sample is quite immersed. The air stagnating in the bores is effectually dried by the preliminary cooling with solid carbon dioxide. With thin samples we obtain in this way a field of 40 kilogauss, which is quite essential for the proper resolution of the quadruplets etc to be described later. With sunlight and a width of 0.05 mm. of the principal slit there was still plenty of light even in the violet; the FRAUNHOFER lines, however, proved so troublesome in many cases that the much weaker arc light had to be used. The spectrum was measured by means of a magnifying glass and a graduated glass scale, the divisions of which amounted to 0.225 mm., exactly corresponding to 0,1 $\mu\mu$ in the spectrum of the first order. The auto-collimator, which we also used has been described since our first communication (see the preceding paper).

All the following experiments were made with a longitudinal field, in other words with an axial direction of the rays; many new adjustments would be required after turning round the heavy electro-magnet, so that we hope to extend the observations to an equatorial direction of rays later on.

§ 14. Third series. Of the large number of coloured com-

[1]) A. CORNU, Compt. Rend. **125** p. 555, 1897. — W. KÖNIG, Wied. Ann. **62** p. 242, 1897. We found it safer not to place this arrangement at the end of the beam near the magnifying glass, on account of polarisation by the grating; cf. P. ZEEMAN, These Proc, Oct. 1907.

pounds of trivalent titanium and vanadium we investigated some without, however, having found anything noteworthy as yet. The selective properties in this series culminate for chromium; we shall therefore restrict ourselves to a closer investigation of some chromic compounds already discussed in our former paper.

Chromium alum.

From the well-known regular crystals plates of a thickness of about 2 and 3 m.m. were cut. At 18° a rather intense band 669,8—671,6 is seen in the red; at —193° it becomes considerably narrower, viz.: 668,6 —669,4, the centre shifting 1.7 $\mu\mu$ towards the violet; moreover another rather strong line 670,2 appears; between 619 and 716 no less than 21 fainter and sharper bands and lines are actually visible.

In a field of 34 kilogauss the two principal lines appeared broken; the horizontal distance of the corresponding edges of their upper and lower halves, henceforth briefly called the *break*, amounted to about 0,10 $\mu\mu$; the sense was *opposite* [1]). Band 668.6– 669.4 shows one fine narrow satellite on the red side, towards the violet two of them; the former disappeared in the field; the two latter ones became very vague, and seemed, as seen with sunlight, to join in the break of the principal band.

Ruby.

§ 15. With the square plate (7 × 7 × 3 m.m.) mentioned in our preceding paper a long edge contained the optical axis. From the same ruby cone a small quadratic prism (1,5 × 1,5 × 4 m.m.) was now ground, the axis being parallel to a short edge. With the slight thickness of 1,5 m.m. sufficient absorption is shown even with grating dispersion. We must now distinguish the cases that the optical axis is || or ⊥ with respect to the direction of the field.

I. O p t i c a l a x i s || d i r e c t i o n o f f i e l d :

A. Pair of bands in the blue at —193°. Besides the two bands in the red already described, a pair in the blue are rather striking among the other 8; we shall briefly call these B_1 and B_2. At —193° their situation is: $B_2 = 474,2—474,9$, and $B_1 = 476,1—476,5$ (at 18° they lie 474,9—475,7 and 476,5—477,1, more towards the red). The distance of the central lines measured in the grating spectrum, amounted to 1,63 $\mu\mu$. In a field of 36 kgs (= kilogauss) the break for B_1 amounted to 0,04 $\mu\mu$ and for B_2 to 0.055 $\mu\mu$, the sense being

[1]) I. e. with respect to that which has been found up to now for all vapours; such an opposite sense was also observed by J. BECQUEREL in most cases.

opposite; an asymmetry in the break of the bands towards both sides — with respect to their position with field off — appeared to exist, but could not be measured with sufficient certainty. At a temperature considerably exceeding that of liquid air, the blue bands are no longer to be determined in the grating spectrum.

§ 16. *B. Pair of bands in the red*; we call them R_1 and R_2.
1) At $-193°$ we have $R_2 = 691{,}7$ and $R_1 = 693{,}1$, the distance measured in the grating spectrum being 1,38 $\mu\mu$.

Line R_1: Width with field off 0,065 $\mu\mu$. With 23 kgs. a *triplet* begins to appear, which is not yet clearly visible with 18 kilogauss; lefthand line (red side) not sharply divided from middle line, forming together a strong line, 0,10 $\mu\mu$ wide; righthand line (violet side) divided from middle line at a distance of 0,09 $\mu\mu$. With 26,5 kgs. the triplet further resolves, the distance on either side becoming 0,11 $\mu\mu$.

With 36 kgs. the lefthand line is strong, the middle line perhaps stronger still, not sharply divided, distance 0,165 $\mu\mu$; the righthand line faint, at a distance of 0,14 $\mu\mu$ from the middle line.

Line R_2: Width with field off 0,055 $\mu\mu$. With 23 kgs. triplet: lefthand line not separated from middle line, forming together broad line 0,075 $\mu\mu$ wide; righthand line separated from middle line at a distance of 0,07 $\mu\mu$. With 26 kgs. the triplet further resolves; distance 0,08 and 0,09 $\mu\mu$ respectively.

With 36 kgs. the lefthand line is rather strong, not quite detached from the middle line, at a distance of 0,115 $\mu\mu$; the righthand line faint, more clearly separated from the middle line, at a distance of 0,15 $\mu\mu$.

In all these cases the lateral components were circularly polarised in the opposite sense; as the middle line vanished at neither of the two positions of the $\lambda/_4$ plate, it could not be circularly polarized; linear polarisation was not observed and quite excluded on account of axial field-symmetry. It is not yet the moment here to enter into an explanation of this highly remarkable phenomenon; it may perhaps simply be due to imperfect resolution of the inner lines of a quadruplet [1]). A magnetic displacement of the middle line with respect to its position with field off [2]) could not be ascertained; at all events it never amounted to more than 1 or 2 hundredths of $\mu\mu$.

There is no reason in this case to doubt of the proportionality of the resolution with the intensity of the field.

1) Cf. P. Zeeman, These Proc. Febr. 1908.

2) Cf. H. Kayser, Handb. d. Spectroscopie, 2 p. 655, Fig. 52. Something similar was also sometimes observed for the sextuplet of D_2.

2) At — 79° the bands were already considerably widened and faded so that the thicker ruby plate had to be investigated through which the light proceeded 7 mm. in the direction of the axis.

Heating from —193° to — 79° displaced R_1 by 0,62 $\mu\mu$, R_2 0,58 $\mu\mu$ towards the red so that their distance now became 1,42 $\mu\mu$. In a field of 18,5 kgs. R_1 exhibited a lefthand break of 0,12, $\mu\mu$, a righthand one of 0,065 $\mu\mu$, and R_2 deviated 0,04 on the left, 0,07 $\mu\mu$ on the right.

3) At + 18° and a field of 18,5 kgs. R_1 exhibited a break of 0,07 $\mu\mu$ towards both sides, R_2 one of 0,055 $\mu\mu$. Heating from — 193° to + 18° shifted R_1 0,76 $\mu\mu$, R_2 0,69 $\mu\mu$ towards the red, so that their distance now became 1,45 $\mu\mu$ [1]).

4) At + 200° the phenomenon was rather vague. By estimation the two lines showed a symmetrical break of 0,04 $\mu\mu$ with 18,5 kgs. Heating from 18° to 200° moved both R_1 and R_2 1,1 $\mu\mu$ towards the red, their distance therefore not being changed. As yet we have not heated the ruby any higher.

In general we may perhaps conclude from the rather intricate course of the phenomenon that the influence of magnetisation slightly decreases with increase of temperature. The distance between R_1 and R_2, on the other hand, seems to become a little larger.

§ 17. We now proceed to the second case:

II. Optical axis ⊥ direction of field, where we must distinguish the ordinary and the extraordinary spectrum. In this case only the nicol, no longer the double $\lambda/4$ plate was used, because circular polarisation does not come in here.

1. *Ordinary spectrum*; plane of polarisation horizontal:

A. Pair of bands in the blue at — 193°. The width with field off amounted to 0,17 for B_1, to 0,14 $\mu\mu$ for B_2, the distance of the central lines being 1,68 $\mu\mu$; the lines looked about equal: In a field of 36 kgs. the width increased to 0,26 $\mu\mu$ for the two lines; half the increase in width amounted therefore for B_1 to 0,045, for B_2 to 0,06 $\mu\mu$.

B. Pair of bands in the red at — 193°. We have (cf. § 7) $R_2 = 691,8$ and $R_1 = 693,2$. The width with field off amounted to 0,08 for R_1, to 0,07 $\mu\mu$ for R_2, their distance in the grating spectrum being 1,41 $\mu\mu$.

With a field of 20 kgs. R_1 became widened, and seemed shaded

1) We gave up the idea of reproducing a photograph, because the reproduction in our former paper is greatly inferior in distinctness to our own prints. Moreover, where measurement proves possible, reproduction appears almost superfluous.

in the middle, R_2 showed a doublet at a distance of 0,3 $\mu\mu$; so the aspect was about the same as that preliminarily sketched in § 7 [1]).

With a field of 23 kgs. R_1 showed a *quadruplet*, the four components of which had about the same intensity, and the distances of which seemed slightly to decrease towards the violet. The intervals were now as bright as the spectral background; only between the pair lying on the violet side the interval seemed slightly darker; the distance of the outer lines was 0,28 $\mu\mu$, and the mutual distances differ little from a third of this. R_2 also gave a quadruplet, the two inner lines of which are much fainter than the outer ones, and symmetrically distributed (without careful focussing of the magnifying glass one may therefore feel inclined to see a doublet); the distance of the outer lines was 0,285 $\mu\mu$ respectively.

With 30 kgs. the phenomenon was exactly equal, with distances 0,39 and 0,38 $\mu\mu$.

With 36 kgs. R_1 exhibited a quadruplet as above, further resolved. From red to violet

the distances of the middle lines amounted to 0,15 0,145 0,14, total 0,435 $\mu\mu$
the widths of the lines „ 0,07 0,025 0,035 0,065 $\mu\mu$

The distance between the extreme limits amounted to 0,50 $\mu\mu$; the middle between them appeared to be displaced 0,04 $\mu\mu$ towards the violet with respect to the position with field off.

For R_2 on the other hand we obtained values for

the distances of the middle lines 0,15 0,20 0,085, total 0,435 $\mu\mu$
the widths of the lines 0,055 very narrow 0,045 $\mu\mu$.

The distance of the extreme limits amounted to 0,47 $\mu\mu$; the displacement of the middle with respect to the position with field off was less than for R_1 and could not be ascertained by measurement.

Let δR_1 and δR_2 stand for the total distances between the outer quadruplet lines and $\mathfrak{H}$ for the intensity of the field, then we have

$\mathfrak{H}$ (*Kilogauss*)	δR_1 ($\mu\mu$)	$\frac{1000\,\delta R_1}{\mathfrak{H}}$	δR_2 ($\mu\mu$)	$\frac{1000\,\delta R_1}{\mathfrak{H}}$
23	0,28	12,2	0,285	12,4
30	0,39	13,0	0 38	12,6
36	0,435	12,1	0,435	12,1

[2]) As was observed in § 7 the numerical determinations there bear a strictly preliminary character; through a misprint the estimation of the intensity of the field was 30 kilogauss: this should be 20 kgs. The data now given possess already greater reliability; they were each derived from 2 to 5 readings.

The sufficiently good agreement of the ratios proves the proportionality of the resolution with the intensity of the field, at least as a first approximation; it is rather improbable that weaker fields should exhibit any deviations from this proportionality.

§ 18. Almost analogously behave the lines in the

2. *Extraordinary spectrum*; plane of polarisation vertical.

A. Pair of bands in the blue at —193°. The width with field off amounted to 0,10 for B_1, to 0,15 $\mu\mu$ for B_2, the distance of the middle lines was 1,70 $\mu\mu$; the lines appear somewhat displaced compared with the ordinary spectrum, viz. B_1 0,025 $\mu\mu$ towards red, and B_2 0,007 towards violet; moreover B_2 was vaguer and paler than B_1.

In a field of 36 kgs. the widths became 0,18 and 0,22 $\mu\mu$; so for B_1 and B_2 respectively half the increase in width amounted to 0,04.

B. Pair of bands in the red at —193°. The width with field off amounted to 0,07 for R_1, to 0,06 $\mu\mu$ for R_2, their distance being 1,41 $\mu\mu$.

They both seem to have shifted 0,02 $\mu\mu$ towards the violet, compared with their position in the ordinary spectrum; R_1 is fainter.

With 36 kgs. R_1 exhibits a quadruplet of 4 lines about equally strong, at apparently equal distances, too indistinct, however, to be measured; distance of the extreme limits 0,49 $\mu\mu$; the middle appeared to have moved 0,02 $\mu\mu$ towards the violet with respect to the position with field off.

For R_2 the inner lines of the 4 were probably slightly stronger than the outer ones; the determinations were rather uncertain; the distance of the limits about 0,4 $\mu\mu$.

§ 19. Fifth series. Of this we now investigated a few sulphates of the material used in 1899, which crystallise monoclinically as octohydrates; they do so in plates containing both optical axes. As a matter of course no circular polarisation occurs; in this respect uniaxial and even more so cubic crystals, e. g. chromium alum, are to be preferred.

Neodymium sulphate [Nd_2 $(So_4)_3$. 8 H_2O]. Rosy-red plate 0,8 mm. thick at — 193°. Two narrow bands in the yellow, and three in the green exhibited an increase in width of from 0,05 to 0,08 $\mu\mu$ in a field of 40 kgs; two of the last mentioned became brighter in the middle, and so began to look like doublets.

Samarium sulphate [Sm_2 $(So_4)_3$. 8 H_2O]. Light yellow semi-transparent plate of crystal, 2,8 mm thick at —193°. Two narrow bands in the yellow-green exhibited an increase in width in a field of 28 kgs. the amount of which ought to be determined with a sample of better transparency.