Has the middle line of a triplet the same wavelength as the unmodified line?

9. The change of wavelength here contemplated undoubtedly must be extremely small, for no one of the physicists occupied with the radiation phenomena in a magnetic field has, to my knowledge, come across phenomena which decide the question put above this paragraph.

Some observations made with an echelon spectroscope have given me evidence, that different spectral lines and among these the mercury lines undergo in very strong fields displacements of the order of 6 or 10 thousandth parts of an Angström unit, in most cases towards the violet. The matter seems of sufficient interest to be treated in a separate paper, which I hope to give rather soon.

Physics. — *"Change of wavelength of the middle line of triplets."* (First Part). By Prof. P. Zeeman.

1. In dealing with radiation in a magnetic field it has been tacitly assumed by all experimentalists I know of, that the middle line of triplets or of other symmetrical separation figures occupies the same position in the spectrum as the unmodified line. During a rather detailed investigation of the asymmetrical separation shown by some lines (see the paper immediately preceding) experiments on the light emitted in the direction of the magnetic force showed that symmetry was not always present where it was expected.

The interest attaching to the encountered anomaly suggested the question whether the original line is displaced during magnetisation. The following paper gives sufficient evidence to assert that such is the case. The asymmetrical position of the very weak line observed between the components of the doublet of line 5791 (see § 8 of the paper immediately preceding) is not explained however by this displacement. The contrary is the case. The theoretical interest of the subject is probably intimately connected with the existence of couplings between vibrations parallel and perpendicular to the field [1]).

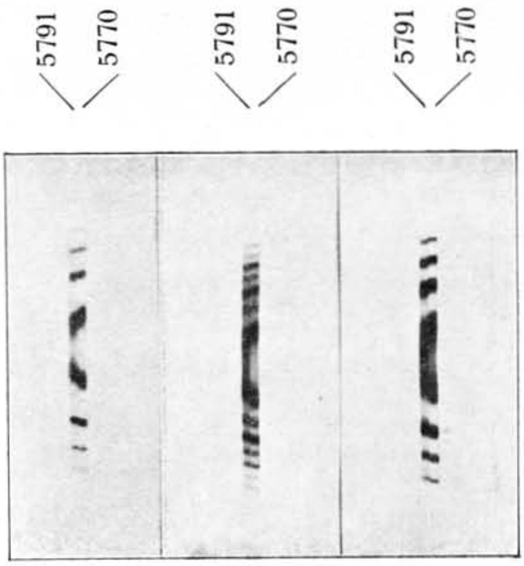
2. For the further discussion I will recapitulate here very briefly the formulae [2]) giving for Michelson's echelon grating the angular

[1]) Cf. however Voigt. Annalen d. Phys Bd. **24**, p. 195, 1907.

[2]) Michelson. Journal de Physique, (3), Vol. 8, p. 305, 1899.

Fürst B. Galitzin. Zur Theorie des Stufenspectroscops. Bull. de l'Acad. Imp. des Sciences St. Pétersbourg 1905 (5) T. 23. N⁰. 1 et 2.

P. ZEEMAN. New observations concerning asymmetrical triplets.



field off. 1st coïncidence 2d coïncidence.

dispersion and the distance of adjacent orders of the same line.

Let λ denote the wavelength of the light considered, μ being the index of refraction, θ the angle of diffraction, t the thickness of the glassplates, s the width of the steps of the echelon.

Then in the case of normal transmission:

$$\frac{d\theta}{d\lambda} = \frac{t}{s.\lambda}\left((\mu-1) - \lambda.\frac{d\mu}{d\lambda}\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

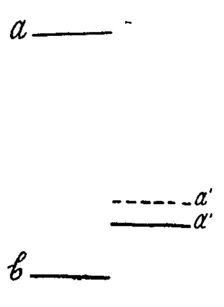
Δ being the distance of adjacent orders, we have further

$$\Delta = \frac{\lambda^2}{t\left((\mu-1) - \lambda.\frac{d\mu}{d\lambda}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

3. The most simple hypothesis that could be made was, that of the two lines under consideration only 5791, which exhibits asymmetrical separation and not line 5770, would show a displacement of the middle line.

In order to test this hypothesis I used the echelon spectroscope in such a manner that different lines could come *simultaneously* under comparison. The ordinary manner of using the echelon only permits the examination of one line at the same time or at least only of lines which differ by a small fraction of an ÅNGSTRÖM unit.

We may however place the steps of the echelon in a horizontal position, the slit of the echelon collimator being also horizontal, thus rotating these parts through 90° from the position commonly used. The slit of the auxiliary spectroscope may remain vertical. This arrangement, which is principally that of NEWTON's crossed prisms or that of GEHRCKE's "Interferenzpunkte", has the advantage of showing simultaneously the behaviour of different lines. To every spectral line correspond small horizontal lines, the length of which is determined by the width of the slit of the auxiliary spectroscope. It depends



upon the position of the echelon whether two or one of the orders of a line will be visible. Fig. 1 represents that part of the field of view, which relates to the yellow mercury lines. The lines a and b represent the successive orders of line 5770, a' the only visible order of line 5791, supposing that the small vacuum tube, charged with mercury vapour, is out of the field.

During the establishment of the magnetic field the well known components are seen moving upwards and downwards. Moreover any change in wavelength of line 5791, that of the other line remaining constant, must manifest itself in a relative displacement, determined by equations (1) and (2).

Taking two negatives with the smallest possible interval of time any change of position of line a' can be made out by measurement. A small displacement of line a' to a position a'', was noticed.

4. The annexed table gives in detail the results of measurements on negatives, taken according to the method of § 3 on different days and under somewhat different circumstances.

The echelon used, was described on a former occasion [1]; it has 30 plates 7,8 m.m. thick, the depth of the steps being 1 m.m.

The distance of line a to line b is measured in m.m. and indicated as distance $a—b$ and so on. H denotes the strength of field in Gauss.

Plate Nr.	Field on			H in Gauss	Field off		
	Distance				Distance		
	$a—b$	$a—a'$	$b-a'$		$a—b$	$a—a'$	$b—a'$
135	1.215	0 896	0.319	7830	1.219	0.898	0.321
139	1.200	0.891	0 309	10920	1.208	0.898	0.310
140	1.214	0.882	0.332	8580	1.221	0.905	0.316
141	1 147	0.861	0.286	7700	1.150	0.867	0.283
142	1.140	0 849	0.291	7180	1.147	0.862	0.285
144	1.140	0.855	0.285	15120	1.145	0.872	0.273
146	1 136	0.819	0.307	20340	1 143	0.861	0.282
150	1.093	0.746	0.347	23470	1.116	0.818	0.298

It appears from this table that the position of line a' relatively to a and b is changed by magnetization and that the displacement increases with the field intensity.

It is not less clear however that the observed displacement is due not only to a change of wavelength of line 5791, but to a superposition of change of frequency of the two lines considered. Indeed the distance $a—b$, i. e. the distance of the adjacent orders of line 5771, is always smaller in the first section of the table than in the second one. Hence we must conclude to a change of wavelength of

[1] ZEEMAN. These Proceedings 30 November 1901.

line 5771. The amount can easily be given in A. U. The change of $a-b$ amounts to 0,023 m.m. in the strongest field of 23470 Gauss. *Half* this amount determines the change of wavelength. It becomes 0,007 A. U., the distance of two orders of the echelon = 1.116 m.m. corresponding to 0,689 A. U.

5. The simplicity of the results obtained by means of the method of § 4 is considerably diminished by the fact, that line 5770 undergoes a change of wavelength as well as line 5791. The sensibility of the method for discovering *relative* changes of wavelength is very clearly seen by a comparison of the two columns under $a-a'$.

In order however to be sure of a simple interpretation of results and also on account of gain in the intensity of the light I returned, the reality of a change of wave-length being now rather evident, to the arrangement as it is most commonly used. The slit of the auxiliary spectroscope is then parallel to that of the echelon.

The results obtained for the yellow mercury lines are given in the table.

Plate Nr	λ	Distance of orders, field off in m.m.	Distance of orders, field on in m.m.	H	δ_r in A. U.
160*a*	5770	1.081	1.067	20100	0.004
160*b*	5791	1.061	1.044	20100	0.006
160*c*	5791	1.058	1.050	8900	0.003
161*a*	5770	1 110	1.089	23800	0.007
161*b*	5770	1 110	1.106	9000	0.001
164	5770	0.855	0.834	24400	0.009
165*a*	5791	0 856	0.847	13750	0.004
165*b*	5770	0.859	0.843	16450	0.007

The observations recorded in the last three columns have been taken with other orders of the echelon. δ_r gives in A. U. the change of wavelength by magnetization. The largest change observed is one of 0.009 A. U. recorded on plate 164 for a field of 24400 Gauss.

The evidence from these experiments tends to confirm those obtained in § 4.

The separate numbers show some discrepancies which needs a discussion, which will be given later on. Before proceeding further, I think it appropriate however to call attention to the fact that the change of wavelength of the middle line of a triplet seems not to be confined to the light emitted by a Geissler tube.

During the writing of this paper my attention was arrested by a passage in a Thesis of W. HARTMANN [1]:

"Es mag schon an dieser Stelle erwähnt werden, dass der Abstand der Ordnungen beim Einschalten des Magnetfeldes sich mehrfach änderte, und zwar im allgemeinen mit wachsender Feldstärke kleiner wurde.

Dieser Änderung würde rein ausserlich betrachtet eine Verkurzung der Wellenlänge entsprechen, doch konnte eine wirkliche Gesetzmässigkeit nicht constatirt werden."

The observations of HARTMANN were made by means of an echelon spectroscope, the source of light being the self-induction spark in vacuum after MICHELSON's arrangement. HARTMANN's negatives concerning copper, iron, gold and chrominum were made with fields ranging from 8000 to 12000 Gauss. Perhaps the author would have expressed his opinion with less reserve, if he had operated with stronger fields, in which case the phenomenon is more definite. In the light however of our own observations there seems to be sufficient evidence to conclude, that also the middle lines of the triplets of other metals undergo the kind of change existing in the case of mercury.

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

§ 1. As soon as the unequalled paramagnetic properties of the compounds of so-called rare earth-metals had been demonstrated [2]), attention was drawn to the fact that most likely also the magneto-optic phenomena would show important peculiarities; this was done in the following words: "La polarisation rotatoire magnétique "a le signe positif ou négatif pour les composés des différents "métaux de cette série, comme d'ailleurs pour ceux de la série "du fer. Je n'ai pas pu constater jusqu'ici un effet particulier de "l'aimantation sur le spectre d'absorption très caractéristique d'une

1) WALTHER HARTMANN. Das ZEEMAN-Phaenomen im sichtbaren Spectrum von Kupfer, Eisen, Gold und Chrom. Dissertation, Halle a. d. S. 1907. p. 10.

2) H. DU BOIS & O. LIEBKNECHT, Ann. d. Physik (4) 1 p. 196, 1900; St. MEIJER, Ann. d. Physik (4) 1 p. 664, 1900.