XXI. Measurements concerning radiation-phenomena in the magnetic field.—(I.)

Dr. P. Zeeman

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placed on the mercury near together, and such that their centres are on a normal to the waves, which are rectilinear before passing under the drops; but the portions of the waves which pass under the water are delayed, and on emergence a distinct bending is produced.

There is a white mark on each of the photographs of the drops. These are photographs of the virtual image of the spark in the convex water surfaces. This shows that the ripples pass only on the mercury, and do not disturb the water surface.

The Cavendish Laboratory,
Cambridge.

Erratum.

In the first paper on this subject (Phil. Mag. June, 1897) an error occurs in the description of fig. 5 (page 416).

For "half" read $\frac{1}{2\sqrt[3]{2}}$. This fraction equals $\frac{1}{2\cdot520}$ to four significant figures. The fraction obtained from measurements of the negative is $\frac{1}{2\cdot503}$.

XXI. Measurements concerning Radiation-Phenomena in the Magnetic Field.—(I.) By Dr. P. ZEEMAN*.

1. **I**N § 12 of my paper on "Doublets and Triplets"† I mentioned already that I was occupied in photographing the spectrum of a source of light placed in a magnetic field. However, it was not until October last that good photographs of the characteristic phenomena were obtained; some specimens were shown at the October meeting of the Amsterdam Academy‡. In order to study further quantitatively the radiation-phenomena in the magnetic field I have made the following measurements. For purposes of measurement there are several advantages in photographing the outer components of the magnetic triplets, quenching the light of the middle line by means of a nicol. By this latter device§ we also are enabled to measure accurately the magnetic effect in lines not entirely separated into triplets.

* Communicated by Dr. Oliver J. Lodge, F.R.S.

† Phil. Mag. xlv. pp. 55, 255 (1897).

‡ Cf. 'Nature,' vol. lvii. p. 192. That it is not very easy to photograph the characteristic phenomena is shown by a paper in 'Nature' (vol. lvi. p. 420). The authors obtained only negative results. Mr. Preston, working apparently with the same grating, has quite recently succeeded in actually photographing all the appearances I have described. ('Nature,' vol. lvii. p. 173.)

§ And also by the method of Cornu (*C.R.* Oct. 18, 1897) and König (*Wied. Ann.* Bd. lxii. p. 240, 1897).

I have measured negatives, obtained by means of a Rowland grating, using electrodes of various metals and a very strong field. The measurements, however, only refer to a relatively small part of the spectrum. I regret that it is not greater. Much time was lost because the grating was not mounted in the manner of Rowland, the various parts of the apparatus not being ready in time. Grating and camera-box were placed upon separate stands; it was now necessary to find the position of slit, grating, and camera-box for each part of the spectrum by a laborious process of error and trial. The dimensions of the camera-box permitted only the use of plates 13 or 18 centim. long. The results of this paper are hence to be regarded only as preliminary. I intend to go over the measurements once more and to make negatives of the whole spectrum, using a larger grating and the new apparatus, just now finished.

2. Measurements of the distance between the outer components of the triplet will also put to test the possible hypothesis, that it is only one kind of ions, having charges proportional to their effective masses, that are free to vibrate in the atom or molecule. On such an hypothesis, in a definite field the intervals between the outside components of the triplets should be (measured in change of wave-length) proportional to the square of the wave-length or (measured in difference of frequency) the same for all lines of the spectra of all substances*. The measurements communicated prove that for different substances the magnetic change is at least *of the same order* of magnitude, and certainly not directly dependent upon the atomic weight. The variation of the phenomenon with wave-length, however, seems more complicated than follows from the hypothesis mentioned, and in fact in Lorentz's theory there is no *à priori* reason to be given for its probability†.

3. The Rowland grating used was one of radius 6 feet and 14,438 lines to the inch. The second spectrum was used in most cases. With a medium-sized induction-coil and one large leyden-jar twenty minutes exposure was sufficient in the most sensitive part of the spectrum. Pure metals were used as electrodes. In each position of the apparatus always two (and often several) negatives were taken, one with and one without the magnetic field. The plates used were Cadett and Neal and Marion instantaneous; they were developed with hydroquinone. In some photochemical difficulties Dr. Ernst Cohen was kind enough to give me his assistance.

* Becquerel, *C. R. Nov. 8, 1897*; Larmor, *Phil. Mag.* vol. xliv. p. 503, § 4 (1897).

† Lorentz, *Wied. Ann. Bd. lxxiii. p. 278 (1897)*; Larmor, *l. c.* p. 506.

The lines on the plates were identified by comparison with the solar spectrum. The negatives were measured on an ordinary dividing-engine, with a microscope reading directly to $\frac{1}{100}$ of a millimetre, or by estimating the tenths of divisions on the head to $\frac{1}{1000}$ of a millimetre. The accuracy of the measurement of the interval between the components of course largely varies with the metal used as electrode. In a spectrum with sharp lines, for instance that of zinc or cadmium, this interval can be measured with an accuracy exceeding that of the magnetic measurements in our case. In the case of other substances, for instance copper or tin, the lines are so hazy, or of so small intensity, that it is only possible to make an estimation.

As an example of the accuracy obtained when magnetic triplets resulting from bright sharp lines are measured by means of the microscope of the dividing-engine, I will give some measurements concerning the line 4722 of the spectrum of zinc. The numbers in the following table are the readings ($\frac{1}{100}$ of a millimetre) on the head of a micrometer-screw when the first and the second component respectively was under the wire.

Determination of Distance between the Outer Components of the Triplet. (Zinc, $\lambda=4722$.)

Component I.	Component II.
28·8	49·8
28·8	48·7
28·9	49·9
28·2	49·5
28·8	48·7
28·2	48·9
<hr/>	
Mean 28·6	49·3
Difference = $20\cdot7 \times \frac{1}{100}$ millim.	

The negative was taken in the second spectrum. On the negative 1 millim. corresponded to about 4·41 Ångström-units.

The following results were obtained concerning lines in the blue, violet, and ultra-violet part of the spectrum.

4. *Zinc*.—The following tables contain under λ the wavelengths of the spectral lines. The meaning of the different columns will be clear from the headings. The intensity H of the magnetic field was measured by means of a bismuth spiral. There is a slight uncertainty in the value of H , the temperature-coefficient of the bismuth wire not being accurately known.

λ .	Distance between components in $\frac{1}{100}$ millim.	Scale of negative.	Order of spectrum.	H.
4811	18.6	1 millim.	2	$32 \cdot 10^3$
4722	20.7	$= 4.41$ A.U.		
4680	25.1			
3345	Imperceptible	1 millim.	3	$32 \cdot 10^3$
3303		$= 2.94$ A.U.		
3282	0			

It appears, as is also indicated in the table, that some lines are *not* changed under the influence of the field, or at least so little that the magnetic change, if it exists, is extremely small*. It deserves to be noted that between the first three lines in the table *clearly* showing the magnetic change, and the last three not showing it, there exists also another interesting difference. Indeed, the first are the group of three lines resulting from Kayser and Runge's *second* subordinate series for the value 3 of the coefficient n in their formula†. The second group of three lines follows from the *first* subordinate series, n being 4. Further inquiry must decide whether *all* lines of the first series are *not* influenced, only those of the second being changed.

5. *Cadmium.*—

λ .	Distance between components in $\frac{1}{100}$ millim.	Scale of negative.	Order of spectrum.	H.
4800	22.0	1 millim.	2	$32 \cdot 10^3$
4678	24.2	$= 4.41$ A.U.		

These are lines of Kayser and Runge's *second* subordinate series‡, n being 3 (*cf.* zinc). The line 5086, also of this series, unhappily could not be measured, being situated too near the border of the negative.

6. *Copper.*—The lines of the copper spectrum are, at least between 4800 and 4300, so hazy that they could not be measured. A rough estimation of some lines gave about 30 hundredths of a millimetre for the distance between the components.

7. *Tin.*—

λ .	Distance between components in $\frac{1}{100}$ millim.	Scale of negative.	Order of spectrum.	H.
4585	± 35	1 millim.	2	$32 \cdot 10^3$
4525	Imperceptible	$= 4.46$ A.U.		
4447	$\pm ?$			
4184	$\pm ?$			

* *Cf.* Lorentz, *l. c.* p. 284.

† Kayser u. Runge, *Wied. Ann.* Bd. xliii. p. 394 (1891).

‡ Kayser u. Runge, *l. c.* p. 399.

The lines of the tin spectrum are very feeble. With the magnetic field off, the lines indicated in the table all clearly appeared on the negative after an exposure of 15 minutes. Exposing, however, with the field on, only the first two lines were on the plate, notwithstanding that the time of exposure was prolonged to 23 minutes, the other circumstances being the same as before. Apparently the first and the last two lines undergo a magnetic change; the last lines (being the feeblest) did not impress their components on the plate. The components of 4585 were so feeble that they disappeared if looked at through the microscope. For this reason I have made a scratch at each of the components by means of a needle, and have measured the distance of these scratches.

Amsterdam, December 31, 1897.

XXII. *Notices respecting New Books.*

The 'Opus Majus' of Roger Bacon, edited, with Introduction and Analytical Table, by JOHN HENRY BRIDGES (vol. i. pp. 188 + 404, vol. ii. pp. 568). Oxford: Clarendon Press.

“**R**OGER BACON, l'un des plus puissants génies du Moyen âge, occupe le premier rang parmi les promoteurs de la renaissance générale des lettres et des sciences. Il contribua particulièrement aux progrès des Mathématiques en montrant, dans plusieurs de ses ouvrages (*Op. Maj.*: quatrième, cinquième et sixième parties), le rang qu'elles tiennent dans l'ensemble des connaissances humaines, et les secours qu'elles peuvent procurer dans toutes les recherches scientifiques, dont elles sont le fondement. Son Optique contient, comme tout le monde le sait, de savants aperçus et des découvertes réelles en théorie, et l'invention de plusieurs instruments devenus de la plus haute utilité. Ses connaissances en Astronomie lui firent reconnaître les erreurs du calendrier, dont il conçut la réformation. Le calendrier qu'il calcula, et qui est resté manuscrit, se distingue par sa correction et par l'usage des chiffres arabes, qui sont les mêmes que ceux de Sacro Bosco.” So writes Charles in his *Aperçu* (p. 517), and the same verdict is pronounced by Hallam and other writers whom we have consulted.

“The 13th century, an age peculiarly rich in great men, produced few, if any, who can take higher rank than Roger Bacon. He is in every way worthy to be placed beside such thinkers as Albertus Magnus, Bonaventura, and Thomas Aquinas” (*Encyc. Britannica*). The same writer quotes Dühring to the effect that Bacon was not appreciated by his age because he was so completely in advance of it; he is a 16th or 17th century philosopher, whose lot has been by some accident cast in the 13th century; he is no schoolman, but a modern thinker, whose conceptions of science are more just and clear than are even those of his more celebrated