Dr. P. ZEEMAN. *On the influence of magnetism on the nature of the light emitted by a substance.* (*Part I.*)

1. Several years ago, in the course of my measurements concerning the KERR-phenomenon, it occurred to me whether the light of a flame if submitted to the action of magnetism would perhaps undergo any change. The train of reasoning by which I attempted to illustrate to myself the possibility of this is of minor importance at present, at any rate I was induced thereby to try the experiment. With an extemporized apparatus the spectrum of a flame, coloured with sodium, placed between the poles of a RUHMKORFF electromagnet, was looked at. The result was negative. Probably I should not have tried this experiment again soon had not my attention been drawn some two years ago to the following quotation from MAXWELL's sketch of FARADAY's life.

Here (MAXWELL. Collected Works II. p. 760) we read: „Before we describe this result we may mention that in 1862 he made the relation between magnetism and light the subject of his very last experimental work. He endeavoured, but in vain, to detect any change in the lines of the spectrum of a flame when the flame was acted on by a powerful magnet." If a FARADAY thought of the possibility of the above mentioned relation, perhaps it might yet be worth while to try the experiment again with the excellent auxiliaries of the spectroscopy of the present time, as I am not aware that it has been done by others. I will take the liberty stating briefly the results I have obtained up till now.

2. The electromagnet used was one made by RUHMKORFF and of middle type. The magnetizing current furnished by accumulators was in most of the cases 27 ampères and could be raised to 35 ampères. The light of the source of light used was analysed by a ROWLAND grating, with a radius of 10 ft. and with 14438 lines per inch. The first spectrum was used and observed with a micrometer eye-piece with a vertical cross wire. An accurately adjustable slit is placed near the source of light under the influence of magnetism.

3. Between the paraboloidical poles of an electromagnet, the middle part of the flame from a BUNSEN burner was placed. A piece of asbestos impregnated with common salt, was put in the flame in such a manner that the two D-lines were seen as narrow and sharply defined lines on the dark ground. The distance between the poles was about 7 m.m. If the current was put on, the two D-lines were distinctly widened. If the current was put off, they returned in their original condition. The appearing and disappearing of the widening was simultaneous with the putting on and off of the current. The experiment could be repeated an indifferent number of times.

4. The flame of the BUNSEN burner was interchanged with a flame of lightgas fed with oxygen. In the same manner as in 3 asbestos impregnated with common salt was introduced in the flame. It ascended

vertically between the poles. If the current was put on again the D-lines were widened, becoming perhaps 3 or 4 times their former width.

5. With the red line of lithium, used as carbonate, wholly analogous phenomena were observed.

6. Possibly one will regard the observed phenomenon (3, 4, 5) as nothing particular.

One may reason in this manner: widening of the lines of the spectrum of an incandescent vapour is caused by increasing the density of the radiating substance and by increasing the temperature [1]. Now under the influence of the magnet, the outline of the flame is undoubtedly changed (as is easily seen) hence the temperature and possibly also the density of the vapour is changed. Hence one may be inclined to account in this manner for the phenomenon.

7. Not so easily is another experiment explained. A tube of porcelain, glazed inside and outside, is placed horizontally between the poles with its axis perpendicular to the line joining the poles. The inner diameter of the tube is 18 mm., the outer one 22 mm. The length of the tube is 15 cm. Caps are screwed on at each end of the tube [2]; these caps are closed by a plate of parallel glass at one end, and are surrounded by little waterjackets. In this manner, by means of a current of water the copper caps and the glass plates may be kept sufficiently cool, if the tube of porcelain is rendered incandescent.

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[1]) Cf. however also PRINGSHEIM (Wied. Ann. 45 p. 457. 1892).

[2]) PRINGSHEIM uses in his investigation concerning the radiation of gases analogous tubes l. c. p. 430.

In the neighbourhood of the glass plates, side-tubes provided with taps are fastened to the copper caps. With a large BUNSEN burner the tube could be made incandescent over a distance of 8 cm. The light of an electric lamp, placed sideways at about two metres from the electromagnet in order to avoid disturbing action on the arc, was made to pass the tube by means of a metallic mirror. The spectrum of the arc was made by means of the grating. With the eyeglass the D-lines are focussed. This may be done very accurately, as in the centre of the bright D-lines the narrow reversed lines are seen. Now a piece of sodium was introduced into the tube. The BUNSEN flame is ignited and the temperature begins to raise. A coloured vapour soon begins to fill the tube, being at first of a violet, then of a blue and green colour and at last quite invisible to the naked eye. The absorption soon diminishes as the temperature is increased. The absorption is especially great in the neighbourhood of the D-lines. At last the two dark D-lines are visible. At that moment the poles of the electromagnet are pushed close to the tube, their distance now being about 24 m.m. The absorption lines now are rather sharp the greatest part of their length. At the top they are thicker, where the spectrum of the lower denser vapours was observed. Immediately after the closing of the current the lines *widen* and are seemingly *blacker*, if the current is put off they immediately recover their initial scharpness. The experiment could be repeated several times, till all the sodium had disappeared. The disappearing of the sodium is chiefly to be attributed to the chemical action of it on the glazing of the tube. For further experiments therefore unglazed tubes were also used.

8. One will perhaps try to account for the last experiment (7) in this direction. It is true that the tube used at the top and at the bottom was not of the same temperature, further it appears from the shape of the D lines (7) that the density of the vapour of sodium is obviously different at different height. Hence certainly convection currents caused by differences of temperature between the top and bottom were present. Under certain suppositions one may calculate that by the putting on of the electromagnet, differences of pressure are originated in the tube of the same order of magnitude as those caused by the difference of temperature.

Hence the magnetization will push e. g. the denser layer at the bottom in the direction of the axis of the tube. The lines become widened. For their width at a certain height is chiefly determinated by the number of incandescent particles at that height in the direction of the axis of the tube. Although this explanation yet gives rise to some difficulties, certainly something may be said for it.

9. The explanation of the widening of the lines initiated in (8) is no more applicable to the following variation of the experiment, in which a un-glazed tube is used. The inner diameter of the tube, about 1 m.m. thick, was 10 m.m. The poles of the electromagnet could be moved till the distance was 14 m.m. The tube now was heated by means of the blow pipe instead of with the BUNSEN burner and became in the middle part red hot. The blow pipe and the smaller diameter of the tube make it easier to bring the upper and lower parts to the same temperature. This was now higher than

before (7) and the sodium lines remained visible continuously [1]). One now can wait till the density of the sodium vapour is the same at various heights.

By rotating the tube continuously round its axis, I have still further advanced this. The absorption lines now are equally broad from the top to the bottom. If the electromagnet was put on, the absorption lines immediately widened along their whole length. Now the explanation in the manner of (8) fails.

10. I should like to have studied the influence of magnetism on the spectrum of a solid. Oxide of erbium has, as was found by BUNSEN and BAHR the remarkable property of giving by incandescence a spectrum with bright lines. With the dispersion used however the edges of these lines were too indistinct to serve my purpose.

11. The different experiments from 3 to 9, make it more and more probable, that the absorption- and hence also the emission-lines of an incandescent vapour, are widened by the action of magnetism. Hence, if this is really the case, then by the action of magnetism in addition to the free vibrations of the atoms, which are the cause of the line spectrum, other vibrations of changed period appear.

I hope to decide by future investigation whether it is really inevitable to admit this specific action of magnetism.

1) PRINGSHEIM l. c. p. 456.

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12. From the representation I had formed to myself of the nature of the forces, acting in the magnetic field on the atoms, it seemed me to follow that with a band-spectrum and with external magnetic forces the phenomenon I had found with a line-spectrum would not occur.

It is however very probable that the difference between a band- and a line-spectrum is not of a quantitative but of a qualitative kind [1]). In the case of a band-spectrum the molecules are complicated, in the case of a line-spectrum the widely dissociated molecules contain but a few atoms. Further investigation has shown that the representation I had formed of the cause of the widening in the case of a line-spectrum, in the main was really true.

13. A glass tube closed at both ends by glass plates with parallel faces, was placed between the poles of the RUHMKORFF electromagnet in the same manner as the tube of porcelain in § 7. A small flame under the tube vapourized the iodine, the violet vapour filling the tube.

1) KAYSER in WINKELMANN's Handbuch II. 1. p. 421.