



XXXVIII. Radiation in a magnetic field

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XXXVIII. *Radiation in a Magnetic Field.**By* A. A. MICHELSON*.

FURTHER analysis of the radiations emitted in a magnetic field shows that the phenomenon is much more complex than was supposed. An examination of the separate components of the "triplet" brings out the fact that in general these are multiple lines.

The laws may be summarized as follows:—

A.

1. All spectral lines are tripled when the radiations emanate in a magnetic field.
2. The separation is proportional to the strength of field and is approximately the same for all colours and for all substances.
3. Viewed in a plane perpendicular to the magnetic field, the outer lines are polarized parallel to the field, and the central line is polarized at right angles with the field.
4. Viewed in a direction parallel with the magnetic field, the central line vanishes, while the outer ones are circularly polarized; the shorter waves in the direction of the magnetizing current, the longer waves in the opposite sense.

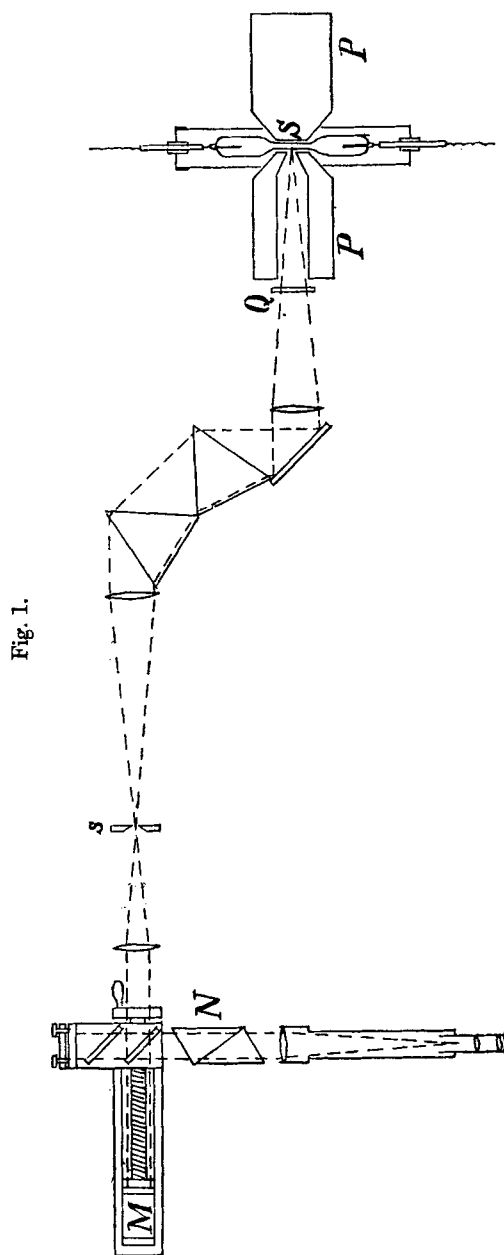
To these laws (which were verified by the examination of a dozen or more lines) the following must now be added:—

B.

1. The "middle line" is a symmetrical triple, the distance between the components being one-fourth that of the "outer lines," and hence also proportional to the strength of field.
2. The relative intensity of the components varies for different substances and for different lines of the same substance; and accordingly the group may appear as a single line or a double or a triple.
3. The "outer lines" are unsymmetrical, but are symmetrically placed with respect to the "middle line." The distance between the components is usually one-fourth that between the "outer lines," but is in some cases one-sixth.
4. The intensity of the components varies for different spectral lines, and these variations do not always correspond to those of the "central line." The outer groups may accordingly appear as single or double or triple or multiple lines.

Fig. 1 represents a plan of the arrangement of apparatus

* Communicated by the Author.



employed in the investigation. S is the source of light, either a small hand-blowpipe with a bead of the substance to be examined in the flame, or a vacuum-tube, which is usually placed in a metal box (for heating) of such form as to permit a close approach of the pole-pieces P of an electromagnet. One of these is bored out to permit examination of the axial ray. The light from S undergoes a preliminary analysis by the spectroscopic train (two bisulphide prisms), the radiation to be investigated being isolated by the slit *s*. It then enters the interferometer, one of the mirrors of which, M, is moveable on ways so accurately ground that no readjustment is necessary in any part of its path; that is, the mirror remains so nearly parallel with itself that the interference-fringes (concentric circles) are always as clear as possible. The emergent beam then passes through the analyser N to the observing telescope.

The clearness or "visibility" of the interference-fringes is estimated at positions of the mirror M corresponding to increments of the difference of path of 1, 2, or 5 mm. according to the nature of the curve. This, it must be admitted, leaves much to be desired in the way of precision, and in some cases there may be corrections of as much as 20 per cent., to reduce the observations to the value they should have, namely,

$$V = \frac{I_1 - I_2}{I_1 + I_2},$$

where I_1 is the maximum intensity and I_2 the minimum for adjacent fringes. Doubtless much more accurate readings could be obtained by the use of a double quartz lens* for comparison; but the process is so much more tedious and troublesome that the form of the curve is liable to alter on account of changes in the source during the observations. The case is somewhat analogous to making eye-estimates of stellar magnitudes, which are but little inferior to photometric determinations and much less troublesome. In any case it is always easy to distinguish ascending and descending slopes, and maxima and minima can be located with very great accuracy, and this is usually quite sufficient to permit a fairly accurate deduction of the distribution of light in the spectrum. It has been shown† that with the definition of visibility just given, if $y = \phi(x)$ is the intensity-curve of the spectrum,

$$PV = \sqrt{C^2 + S^2},$$

in which

$$P = \int \phi(x) dx, \quad C = \int \phi(x) \cos kx dx,$$

* Phil. Mag., Sept. 1892.

† Ibid.

and

$$S = \int \phi(x) \sin kx \, dx,$$

the integration extending over the whole spectrum.

But by Fourier's formula

$$\phi(x) = \int_0^\infty C \cos kx \, dk + \int_0^\infty S \sin kx \, dk;$$

so that if C and S are both known, $\phi(x)$ can be determined. In general this is not the case unless another relation between C and S is given. Such a relation is furnished by the "phase curve," which gives the displacement of the fringes from the position they would have occupied had the source been homogeneous. If δ is this displacement and $\theta = 2\pi\delta/\lambda$, then

$$C = V \cos \theta \quad \text{and} \quad S = V \sin \theta.$$

In general the θ curve is troublesome to obtain, on account of the difficulty in securing a sufficiently homogeneous comparison source; but in the present instance this is furnished by the non-magnetized radiations*.

Usually, however, the assumption was made that the spectrum was symmetrical, and in only a few cases was the solution verified by the complete analysis. In this simpler form we have $\theta = 0$, $S = 0$, and $C = V$, whence

$$\phi(x) = \int_0^\infty V \cos kx \, dk.$$

This integral may frequently be calculated when V can be expressed in simple analytical form as a function of k . In general this is not the case, and it was for the solution of such problems that the harmonic analyser† was devised. The curve $V = f(k)$ is "fed" to the machine, which then draws the curve $y = \phi(x)$, the whole operation taking but a few minutes.

It was found on completing the analysis of some fifty or more visibility-curves, that the resulting spectra could be classified under three types; there were some interesting variations which would merit a separate investigation, but most of the cases could be identified at a glance.

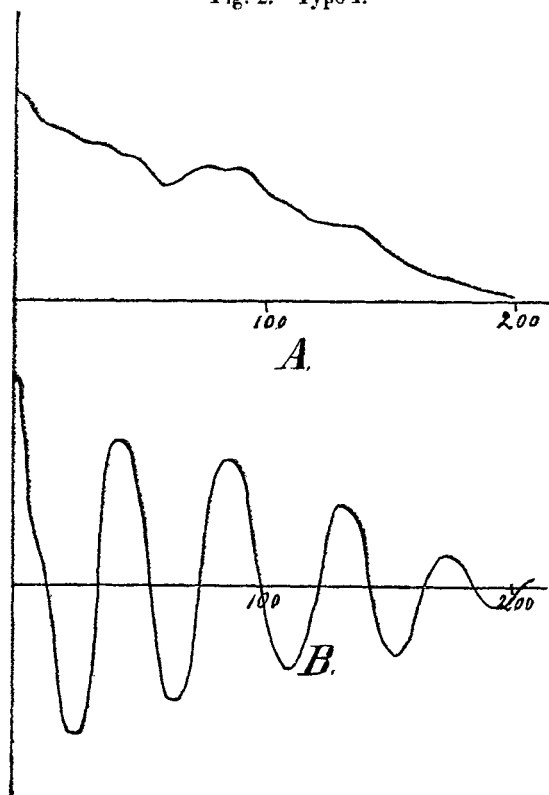
The three types of visibility-curve are given in figs. 2, 3,

* These are not always sufficiently simple as in the case of the green thallium line.

† Phil. Mag., Jan. 1898.

and 4. Those marked A referring to observations made with the line of sight at right angles with the magnetic field and with the plane of polarization perpendicular to the lines of force ; while B correspond to observations with the line of sight still normal to the field, but plane of polarization parallel with the lines of force.

Fig. 2.—Type I.



It was found that there was no appreciable difference between these last and the observations taken when the line of sight was parallel with the field ; but in this case it was possible to analyse either one of the outer groups separately by the use of the quarter-wave plate, Q, fig. 1. This was done in a few cases, but no new result was obtained.

The abscissæ of the visibility-curves are differences of path in millimetres, reduced to a field-strength of 10,000 as determined by a bismuth spiral.

Fig. 3.—Type II.

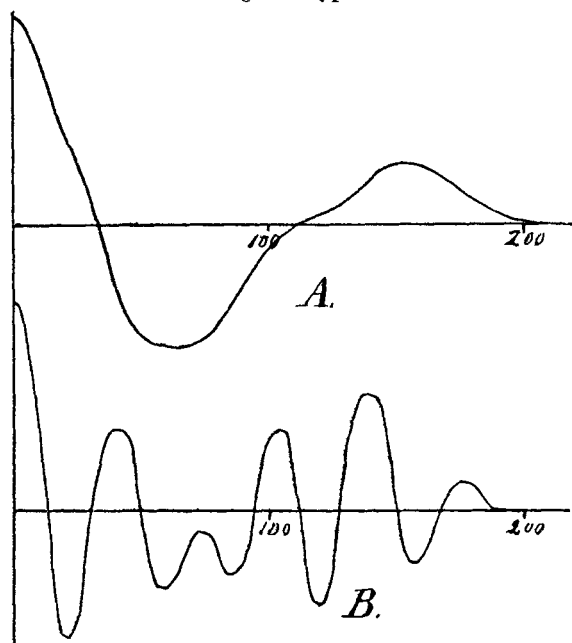


Fig. 4.—Type III.

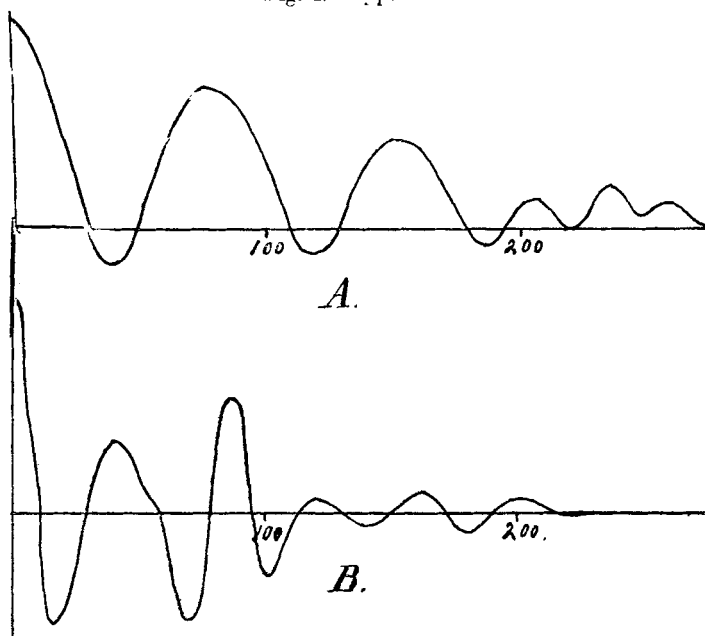


Fig. 5.

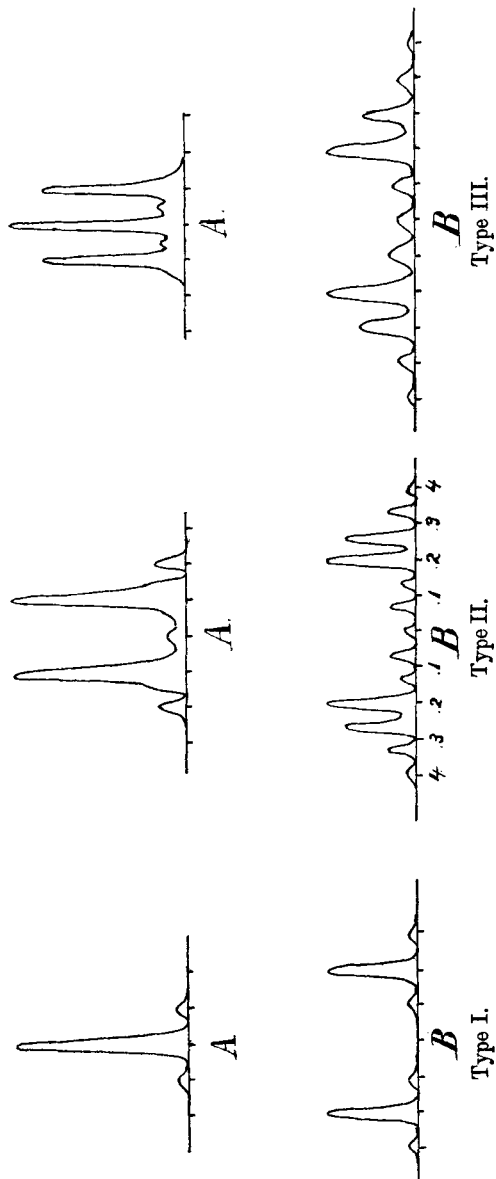


Fig. 5 gives the intensity-curves of the corresponding spectra, the abscissæ being expressed in tenth-metres†.

Following is a list of the radiations examined and their classification :—

Mercury	Yellow lines.	Type I.
	Green line.	Type III.
	Violet line.	Type II.
Cadmium.....	Red line.	Type I.
	Green line.	Type III.
	Blue line.	Type II.
Zinc	Red line.	Type I.
	Green line.	Type III.
	Blue line.	Type II.
Sodium.....	Yellow lines.	Type II.
Thallium	Green line.	Type II. (doubtful).
Lithium	Red line.	(Too broad to determine.)
Hydrogen.....	Red and blue lines.	(Too broad to determine.)
Helium.....	Yellow and green lines.	(Too broad to determine.)

The following table shows that the law A 2 is only approximately true.

In fact, owing to the complexity of the spectra, there is considerable latitude in the choice of the distance between the outer groups. If this correspond to the brightest components, the law can hardly be said to hold at all; but if the distance be taken between the centres of gravity of the light areas, a fair agreement is found. The table gives separation in tenth-metres for a field 10,000. The lines marked with an asterisk are less accurate than the others, on account of broadening.

*Hydrogen	Red.	0.48
*Lithium	Red.	0.60
Cadmium	Red.	0.42
Zinc	Red.	0.42
Mercury	Yellow.	0.36
*Sodium	Yellow.	0.50
*Helium	Green.	0.37
Mercury	Green.	0.40
Cadmium	Green.	0.41
Zinc	Green.	0.40
*Thallium	Green.	0.36
Cadmium	Blue.	0.40
Zinc	Blue.	0.33
Mercury	Violet.	0.33

Taking into account the uncertainty alluded to, the results show on the whole a fair agreement, from which it may be concluded that the separation is independent of the radiating substance and of the colour.

It is possible that some of the resemblances in the preceding

† For this the abscissæ of the curve drawn by the analyser are multiplied by the square of the wave-length.

tables are due to the fact that the substances in question are chemically related; and perhaps it is scarcely justifiable to generalize from such a limited number; and it may well be that a wide range of elements would show other peculiarities.

I desire to express my hearty appreciation of the efficient service rendered in this work by Mr. C. R. Mann, and especially to recognize the patience and skill shown in the tedious and delicate process of preparation of the vacuum-tubes, to which in great measure the success of the investigation is due.

XXXIX. *On Discontinuities connected with the Propagation of Wave-motion along a Periodically Loaded String.* By CHARLES GODFREY, B.A., Scholar of Trinity College, Isaac Newton Student in the University of Cambridge*.

1. **T**HE system described below shows rather remarkable discontinuous properties. The work was suggested by a passage in Sir George Stokes' Read lecture, and formed part of an essay written in December 1896.

A heavy string of density ρ under tension T extends from $-\infty$ to $+\infty$. From $-\infty$ to 0 it is free from loads; from 0 to $+\infty$ it is loaded at equal intervals l with equal particles of mass M . To avoid ambiguity we will suppose that the motion of each mass is retarded by a small viscous force; this will finally be neglected. We will investigate the steady vibration of the system when simple transverse waves are travelling along the string from $-\infty$. These impinge on the system of masses; a reflected wave is generated which travels back along the string; furthermore, the masses are agitated in a certain manner.

2. We will denote by ξ the lateral displacement of a point on the string between $x = -\infty$ and $x = 0$. The velocity of propagation along the string is $\sqrt{\frac{T}{\rho}} = v$. For a motion whose frequency is given by e^{int} we have

$$\xi = Ae^{in(t - \frac{x}{v})} + Be^{in(t + \frac{x}{v})}. \quad \dots \quad (i.)$$

Let the displacement of the mass B_r at time t be denoted by y_r . For a point in the r th string $B_{r-1}B_r$ let the displacement be ξ_r ; and let the distance of such a point from B_{r-1} be x_r .

* Communicated by R. T. Glazebrook, F.R.S.