On the Production of a Bright-Line Spectrum by Anomalous Dispersion and its Application the "Flash-Spectrum."

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divisions divide the slide-wire into equal parts of any required length ; and the parallel-ruler can be moved, as a whole, along the wire. The angle at which the straight-edge is set depends upon the diameter of the wire under test, the length being constant ; the apparatus may therefore be calibrated in diameters as well as in conductivities.

LII. *On the Production of a Bright-Line Spectrum by Anomalous Dispersion and its Application to the "Flash-Spectrum."*
By Prof. R. W. WOOD*.

IN a communication published in the Proceedings of the Royal Academy of Sciences, Amsterdam, W. H. Julius makes the very brilliant suggestion that the "flash-spectrum," seen immediately at totality, may be due to photosphere-light abnormally refracted in the atmosphere of metallic vapours surrounding the sun : in other words, the light of the flash-spectrum does not come from the reversing layer at all, but from the photosphere. The author shows that the light which will be thus abnormally refracted will be of wave-lengths almost identical with the wave-lengths which the metallic vapours are themselves capable of radiating. This beautiful theory not only explains the apparent shallowness of the reversing layer, a thing that has always puzzled astrophysicists, but it accounts for the extraordinary brilliancy of the lines.

I have succeeded in producing such a flash-spectrum by an arrangement in which I have endeavoured to imitate as closely as possible the conditions supposed to exist at the surface of the sun : in brief, I have obtained a spectrum of bright lines, with light from a source showing a continuous spectrum, by means of anomalous dispersion in an incandescent metallic vapour.

The theory of Julius supposes the sun to be surrounded by an atmosphere of metallic vapours, the refractive index of which decreases with increasing distance from the surface.

* Read April 26, 1901.

In this atmosphere the rays of light coming from the photosphere will move in curved paths similar to rays in our own atmosphere.

The refractive index is, however, very small except for wave-lengths very near those which are absorbed by the vapour; consequently the light most strongly refracted, if it could be sorted out and examined with the spectroscope, would resemble very closely the light emitted by the vapours. Julius shows how this sorting out of the more refrangible rays may account for the bright-line spectrum usually attributed to the reversing layer, these rays moving in curved paths in the solar atmosphere, thus reaching us after the photosphere has been hidden by the moon.

For the reproduction of this phenomenon in the laboratory it is necessary to form an atmosphere of metallic vapour in which the refractive index changes rapidly from layer to layer. This I succeeded in accomplishing by allowing the flame of a Bunsen-burner, fed with metallic sodium, to play against the under side of a white plaster plate. On looking along the surface of the plate, it was seen that a dark space existed between the flame and the cold surface, resembling somewhat the dark space surrounding the cathode of a Crookes's tube. It seemed highly probable that, inasmuch as the temperature of the flame was lowered to such a degree by contact with the plate, the density of the sodium vapour would increase very rapidly from the surface of the plate downwards. The change may of course be abrupt instead of progressive, though I am inclined to favour the latter supposition. In either case the action will be practically the same, the case being similar to the transition from a curved ray to a broken-line ray, as the change of the index of the medium becomes less gradual. Having covered the under surface of the plaster plate with a non-homogeneous layer of sodium vapour, a spot at the edge of the flame was illuminated with sunlight concentrated by a large mirror. This spot radiated white light in every direction and corresponded to the incandescent photosphere of the sun. A telescope, provided with an objective direct-vision prism, was directed towards the white spot and moved into such a position that, owing to the reduction in the width of the source of light by

foreshortening, the Fraunhofer lines appeared in the spectrum (fig. 1). This represents the stage of an eclipse when only the thin crescent of the sun is visible. The sodium-flame appeared superposed on the spectrum of course. On moving the spectroscope until it was well inside of the plane of the illuminated surface and feeding the flame with fresh sodium, the solar spectrum vanished, and there suddenly blazed out two narrow bright yellow lines almost exactly in

Fig. 2.—Flash Spectrum of Sodium produced by Anomalous Dispersion.

the place of the sodium lines. Fig. 2 shows the inverted sodium-flame, the faint continuous spectrum and the "flash." Cutting off the sunlight with a screen caused the instant disappearance of the bright lines.

Repeating the experiment, I found that the bright lines

came into view on the sides of the sodium lines towards the blue ; that is to say, it is light for which the medium has an abnormally low refractive index that is bent around the edge of the plate and enters the instrument. This is precisely what we should expect, for sodium vapour has a refractive index of less than 1 for waves slightly shorter than D_1 and D_2 , as was shown by Julius in his paper*. The rays then will be concave upward in a medium in which the refractive index varies, as I have supposed it to vary in the present case. If the sodium vapour is very dense, we see only a single bright line bordering D_2 , owing to the complete absorption of the light between the lines.

I next instituted a search for the light of a wave-length slightly greater than that of the sodium lines. For these waves the vapour has a refractive index greater than 1, consequently the rays will be concave downward in the layer of vapour. (The paths are indicated on an exaggerated scale in fig. 1.) If we move our prismatic telescope down in a search for these rays, the solar spectrum will appear and drown out everything, but if we set up a screen (shown in fig. 3) in

Fig. 3.

such a position as just to cut off the light from the illuminated spot, and feed the flame with sodium, we shall presently see bright lines appear on the side of the sodium lines towards the red. In this case, when the vapour is dense we get only a single line bordering D_1 .

The arrangement described is inconvenient in many ways to work with, and I accordingly modified it in the following way :—

The light of an arc-lamp (fig. 3) is focussed on a horizontal slit, and a flat metal plate supported so that the plane in which

* I have since found that the refractive index is less than 1 for the entire yellow, green, and blue portion of the spectrum, and greater than 1 for the entire red, orange, yellow end. In other words, I have obtained a complete anomalous spectrum with sodium vapour.

its under surface lies coincides with the plane of the slit. The plate should be an inch or so thick, with a fairly level surface. At a distance of about two metres a telescope provided with a prism (direct-vision if possible), arranged so as to give a vertical spectrum, is placed at such a height that the prism barely catches the rays coming from the slit and grazing the surface of the plate. On looking into the telescope we see a bright continuous spectrum, and the telescope is to be raised until this becomes quite faint. The Bunsen-burner beneath the plate is now lighted, and a bit of sodium in a small iron capsule introduced into the centre of the flame. The results obtained are practically identical with those which have been described. I am now arranging apparatus by which I hope to obtain similar flash-spectra by the dispersion of vapours exhibiting more complicated absorption spectra than sodium. If these experiments are successful, much can be learned by comparing the flash-spectra with the emission-spectra. If it be found that certain lines are absent in the flash which are present in the emission-spectra, interesting comparisons can be made with photographs of the actual flash-spectrum of the sun. I am also engaged in making accurate determinations of the dispersion of metallic vapours by means of a metal prism of 45 degrees, furnished with mica windows. The prism is filled with hydrogen, and the metal—say sodium—vaporized in this atmosphere by the application of heat. The results obtained in this way are far superior to those yielded by prismatic flames. The angle of the prism is accurately known, and it is filled with non-luminous sodium vapour of uniform density and under known conditions of temperature and pressure. With this I have obtained much greater curvature of the spectrum in the vicinity of the absorption-lines than that figured by Julius (the total lateral bending in one case being 400 times the distance between the D lines), and the spectrum is perfectly steady instead of fluttering, as is the case when the deviation is effected by means of a sodium-flame of prismatic form. The work along these lines will be reported in a subsequent paper.

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DISCUSSION.

Prof. HERSCHELL expressed his interest in the experiments, and their application to the case of the flash-spectrum seen at totality.

LIII. *The Thermal Properties of Isopentane compared with those of Normal Pentane.* By J. ROSE-INNES, M.A., B.Sc., and SYDNEY YOUNG, D.Sc., F.R.S.*

[Plate V.]

In a paper read before the Physical Society in December 1898, attention was drawn to the great interest attaching to the comparison of the isothermals of two isomeric substances (Proc. Phys. Soc. xvi. p. 335; Phil. Mag. xlvii. p. 366). An experimental investigation of the relations between the temperatures, pressures, and volumes of isopentane had been carried out by one of us some time previously: and in the paper above referred to the results of a similar investigation into the thermal properties of normal pentane were given. A preliminary comparison was instituted between the thermal data belonging to the two substances respectively, and the conclusions provisionally arrived at were stated (*U. cc.* pp. 335-6; pp. 366-7). We have since undertaken a more exhaustive examination of the experimental results, and the conclusions now reached form the subject of our present paper.

If we could treat normal pentane and isopentane as perfect gases, we should be able to write $pv = RT$, where all the letters have their usual signification. In practice it is found that pv changes as p diminishes along any isothermal, in such a way that the limiting value of pv for $p=0$ is equal to RT ; but any actual value of pv lies below RT within the limits of temperature of the experiments. The quantity $RT - pv$, which should be zero if Boyle's law were correct, may be considered as measuring the error of Boyle's law, and we may term it "the departure from Boyle's law" for the particular volume and temperature in question. It then appears that the

* Read May 10, 1901.