

LXVII.—*An Improved Apparatus for Measuring Magnetic Rotations and Obtaining a Sodium Light.*

By WILLIAM HENRY PERKIN, sen.

THE magnetic field which is necessary for experiments on magnetic rotations has so far always been produced either by means of an electro-magnet with pierced pole pieces or a long coil or helix, and both methods have their advantages and disadvantages. The electro-magnet has the valuable property of producing a very powerful field, which makes it not only possible to obtain accurate results by the use of comparatively short measuring tubes requiring only small quantities of substance, but also to measure substances which are not perfectly

colourless or absolutely free from turbidity, and therefore impossible to measure in long tubes, but it has the drawback arising from the necessity of maintaining the massive pole pieces at the same temperature as the substance under examination, owing to the fact that the ends of the measuring tube containing the substance are nearly in contact with the pole pieces, and, as these possess high conducting power, any variation between the two prevents uniformity of temperature from being obtained. Although means have been devised by which these difficulties have been overcome, still they are cumbersome and consume much time (*Trans.*, 1896, 69, 1032, 1035).

In the case of the coil, this difficulty does not exist, but on the other hand the helical coils employed are usually very long, and consequently the measuring tubes also must be long, and this necessitates not only the use of much substance, but also requires that the substance shall be perfectly clear. The coil used by Rodger and Watson (*Phil. Trans.*, 1895, 186, 623) was 50 cm. long and the measuring tube 62 cm., or about six times as long as the tubes I frequently use in my electro-magnet apparatus. In order to overcome these difficulties, it was desirable to devise, if possible, an arrangement which would combine the advantages of both the magnet and coil without their disadvantages, that is to say, to construct an apparatus without pole pieces which would produce a magnetic field sufficiently powerful to allow of accurate measurements being made in comparatively short measuring tubes.

It appeared to me that these conditions could be secured by the use of a very powerful short coil encased in iron or steel. After discussing the matter with Prof. Ayrton and giving him the particulars of my requirements, he very kindly had the necessary details worked out for its construction. The apparatus was made by Messrs. C. Crompton & Co. Its construction will be understood from Figs. 1, 2, 3, 4, and 5.

Fig. 2 represents the magnet with part of its steel casing removed so as to show the coil, and Fig. 1 is the cross section.

The coils  $A$   $A'$  are wound on a strong gun-metal tube,  $B$ , 7.6 cm. in diameter and 15.6 cm. long, the interior of which constitutes, of course, the magnetic field. On the ends of this tube are screwed wrought iron flanges ( $C$   $C$ , Fig. 1) 0.5 cm. thick, covered on the inside with insulating material about 1.5 mm. thick. These flanges are bolted together in several places by means of iron stay rods (seen at  $D$  and  $D$   $D$   $D$ , Figs. 1 and 2) 1.0 cm. thick. The copper wire used for the coil is square,  $3.05 \times 2.7$  mm., and is doubly covered. There are 2000 turns of this wire wound in two separate sections  $A$   $A'$  of equal resistance. This arrangement was employed because at present about twenty-seven or twenty-eight Grove cells have to be used, there

not being any convenient electrical supply at hand, and it was therefore necessary that the two sections should be coupled parallel, but if a current of 100 volts was available they would be connected so as to form a single coil. The casing of the coil *E* is made of steel of high permeability, 1·0 cm. in thickness, and is in two halves: these are held together with bolts *F F*, the joint being machine planed; an opening is left in the centre, of the same diameter as that of the gun-metal tube. Each coil is provided with two binding screws fixed on an ebonite block and seen at *G*. This electro-magnet weighs about 155 kilograms; it is supported between the polariser and analyser of the polarimeter on a strong pitch-pine stand or stool, with the legs so arranged that the narrow table carrying the optical parts can go

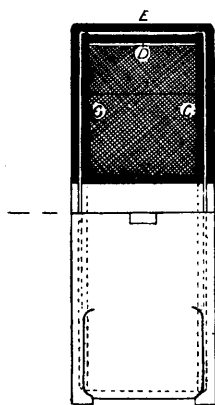


FIG. 1.

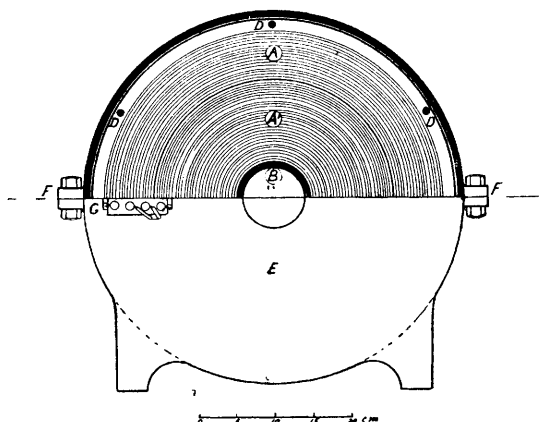
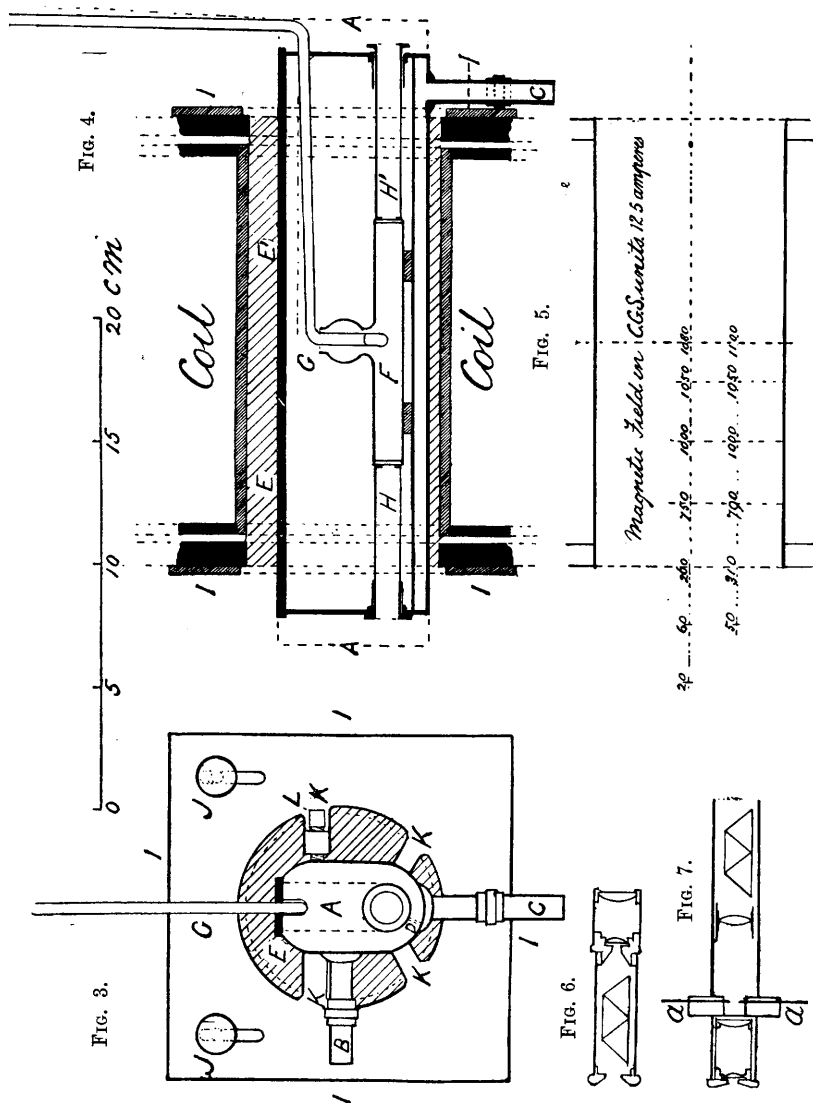


FIG. 2.

underneath it. This polarimeter and its optical parts have been described in detail in a previous communication (Trans., 1896, 69, 1027, 1031).

The new coil gives with the same battery a more powerful field than the ordinary electro-magnet previously used. Fig. 5 gives the measurements obtained in different parts of this field when using twenty-seven Grove cells, the ammeter in circuit indicating 12·5 amperes. From this diagram it will be seen that the magnetic field is not uniform, being strongest in the centre and especially near the walls of the gun-metal tube. As was anticipated, the amount of radiation outside the coil is very small. The want of uniformity is of no importance, as the measurements are always made relatively to water and in exactly the same position in the field. In order to support the measuring tubes in the magnetic field and maintain them

at any desired temperature, the arrangements shown in end view, Fig. 3, and in section, Fig. 4, are employed.  $A$  and  $AA$  consists of a



copper trough 23 cm. long, and therefore rather longer than the gun-metal tube. It is made with double walls so that water of different temperatures may circulate between them, and thus the temperature

may be regulated as desired. All the joints are silver soldered, so that the vapour of products of much higher temperatures than even that of boiling water may also be used if desired. The inlet and outlet (*B* and *C*, Fig. 3) of this jacket are both at one end of this trough, so that it can easily be drawn out of the gun-metal tube. In order to ensure that the water or hot vapour circulates thoroughly from end to end of the jacket and that the trough is equally heated in all parts, a diaphragm (*D*, Fig. 3) is inserted along the bottom of the jacket, but not quite throughout its entire length. The trough has a thick copper lid fitted to it by a rebate, which is made in two halves of unequal length, the shorter one, *E*, being fixed by means of a screw, the longer, *E'*, being loose so that it can be easily removed, and thus allow of the introduction of the measuring-tube and thermometer, *F* and *G*. This thick copper cover conducts the heat from the sides of the trough across the top, and thus converts the cavity into an air-bath. The glass measuring-tube, *F*, for holding the substance is supported in this trough or air-bath by two pieces of hollowed out cork. The inlet of the measuring-tube is enlarged into a bulb to make room for expansion of its contents with rise of temperature; it also receives the bulb of the thermometer, *G*. The thermometer is bent twice at right angles, as shown, and is graduated to tenths of a degree. Before making the readings, the thermometer bulb is allowed to sink right down into the measuring tube, *F*, so as to show accurately the temperature of its contents, but when the readings are being made it is raised out of the optical field into the position indicated by the dotted lines. To ensure the glass measuring-tubes being always in exactly the same part of the magnetic field, they are held in their places between sliding brass tubes, *H* and *H'*; one of these, *H*, when pushed into its place can be firmly fixed, whilst the other, *H'*, which is made slightly longer than necessary, on being pressed in as far as it will go will force the glass tube into its exact position, therefore no matter how often removed and replaced this vessel will always occupy the same part of the magnetic field. With this apparatus, measuring-tubes of different lengths are used according as to whether there is much or little substance at command; the different lengths used are 100, 150, and 175 mm., and for each of these a pair of brass tubes to place them always in the same part of the magnetic field have been provided. In order to prevent light passing along the walls of the glass tubes, the inner ends of the brass tubes, *H* *H'*, are provided with stops with apertures about 6 mm., or rather less than the internal diameter of the glass tubes, so that the light can only pass through the centre of the tube and the substance it may contain.

When easily volatile substances are to be examined, the measuring-tube is closed with a cork and the thermometer placed outside and

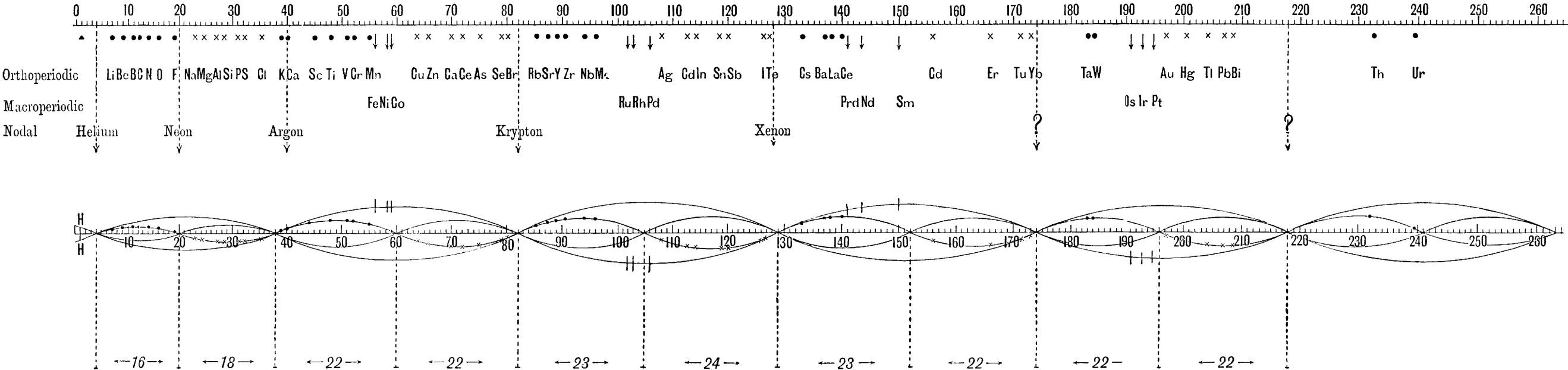
*Journ. Chem. Soc., June 1902.*

*Diagram illustrating the Periodic Relations of the Elements.*

NOTE TO BINDER.

This diagram is issued to take the place of the one on p. 613 (in the Journal for June), which is to be cancelled and removed.

When the Journal is bound the present diagram should be pasted at the back of the asterisks, and affixed to page 612, so as to face p. 613.



Walker & Cockerell sc.

against it; this arrangement answers well if sufficient time is given for the temperature to become practically constant.

To support the copper trough in the gun-metal tube, two thick square brass plates are provided (*IIII*, Fig. 3, and *IIII*, Fig. 4); these are fastened on the steel casing of the magnet by screws, as seen at *JJ*, Fig. 3, passing through slots to allow of adjustment. Eight cm. of the centre of these plates are cut away with the exception of four narrow pieces (*KKKK*, Fig. 3) which serve as arms to support the trough; on one of these arms is a set screw, *L*, so that the trough may be fixed quite rigidly if necessary. When using this trough it is pushed in as far as it will go, the outlet water-pipe (*C*, Fig. 4) acting as a stop, so that it and its contents always occupy exactly the same position in the magnetic field, thus rendering all measurements comparable.

When the apparatus is put together it will be seen that there is a free air space between the trough and the gun-metal tube, shown by the lightly shaded parts of Figs. 3 and 4, so that when the trough is heated the coil is but slightly affected, and conduction of heat is further prevented by the use of a tube of asbestos cardboard which lines the gun-metal tube.

With respect to the measurements made with this coil, it may be mentioned that if *absolute values* are required they can very easily be obtained by using the constants for water obtained by Rodgers and Watson (*Phil. Trans.*, 1895, 186, 650), because all the measurements are relative to water, which is taken as unity. This remark equally applies to all the determinations I have made from the commencement of my study of the subject of magnetic rotations.

The polariser is kept at a distance of 18 cm. from the coil so as to allow room for the withdrawal of the trough. The distance of the analyser from the coil is 9 cm. At these distances it is probable that the small amount of radiating magnetism has no practical disturbing influence on the optical parts: this is, in fact, borne out by observations, but in any case any negative magnetic rotation which may be caused in this way (see *Trans.*, 1884, 45, 435) will be allowed for during the measurements of the glass ends of the measuring-tubes (see *Trans.*, 1896, 69, 1038). These glass ends are cut out from one piece of glass, about 1.23 mm. thick, the surfaces of which are worked parallel so that they are all of exactly the same thickness. Their rotatory value in the different positions they occupy in the magnetic field when fixed on the measuring-tubes was carefully determined. For example, when using twenty-six quart Grove cells, the following numbers were obtained.

|  |        |
|--|--------|
| Two glass ends on empty tube 100 mm. long..... | 14'24" |
| " " " " " " 150 " " .....                      | 9'36"  |
| " " " " " " 175 " " .....                      | 5'24"  |

These numbers vary, of course, with the electrical power used.

The optical parts employed in connection with this new coil are the same as previously described (Trans., 1896, 59, 1027, 1029), and the sugar half shadow cell the same as *A'*, Fig. 3., p. 1030 of the same volume.

The steel-clad electro-magnet, which has now been in use for several years in place of the ordinary electro-magnet previously employed, has been found to be very much more convenient and a great improvement in many respects, and it was satisfactory to find that magnetic rotations made by the old and new apparatus gave identical results.

With this apparatus the following rotations are obtained for water in tubes of the three lengths usually employed, 26 Grove cells being used and the ammeter indicating 12 amperes.

| Length of tube. | Rotation. |
|-----------------|-----------|
| 100 mm. ....    | 5°59'     |
| 150 mm. ....    | 8°14'     |
| 175 mm. ....    | 9°3'      |

These readings are double readings, the sum of those obtained when the electric current is passed through the electro-magnet in two opposite directions.

#### *Measurement of the Plane of Polarisation.*

It is well known that the accurate measurement of the plane of polarised light by means of the shadow polarimeter and sodium light becomes more and more difficult as the angle of rotation increases on account of the light not being perfectly monochromatic, the two sides of the half-shadow disc forming the field of view being then seen to be differently coloured when at the correct measuring point, whereas they should be of the same tint. To overcome this difficulty, the light is usually filtered through potassium dichromate or some other similarly coloured medium, this being sometimes followed by a green screen, but any such arrangement only improves the light to a small extent and must always result in a considerable loss of intensity.

When measuring the optical activity of substances with large permanent rotations, the difficulty is often overcome by reducing the size of the rotation by dilution with an inactive solvent, or using very short measuring tubes. The measurement of magnetic rotations does not allow of such devices, because the readings are much smaller, and it is therefore necessary to employ the substances either in a pure state or in very concentrated solutions, and for the same reason very short tubes are inadmissible; in fact, these difficulties make it impossible to measure with any degree of accuracy the magnetic rotations of substances with large permanent rotations, because, although the



two properties are independent of each other, the magnetic rotation is additive to the permanent. For example, a tube 100 mm. long filled with *l*-limonene rotates the plane about  $91^\circ$ , and this forms the zero point in the subsequent determination of the magnetic rotation; ordinary sodium light then gives such considerable differences in the colour of the two sides of the shadow disc that accurate readings are impossible.

In attempting to get a pure light very many experiments were made with screens of different kinds, but without success, and in order to reduce the rotations quartz discs of varying thickness and opposite rotations to the substance under examination were tried, but with no really useful result. After many failures, the conclusion was eventually arrived at that satisfactory results would not be obtained until the light was purified by means of a prism, some such arrangement as that used by Sir William Abney (*Phys. Proc., Soc.*, 1885, 7, 182) being employed, although it was feared that this might lead to some difficulty in obtaining sufficient intensity of light even with the sodium flame.

Whilst experimenting with coloured screens it was often found convenient to use them at the eye-piece of the instrument instead of near the source of light, and this observation led to experiments being made with a direct vision spectroscope in this position. After trying various unsuccessful arrangements, the effect of a direct prism without either slit or lens was investigated, with the result that a well-defined image of the half-shadow disc was obtained, and when at zero, prismatic colours were feebly seen on either side of it. On examining substances with rather large rotations with this arrangement, the image was found to maintain its practically uniform colour over a wide angle; the loss of light was very small, but the prismatic colours on either side of the disc became much brighter as the rotation increased. On introducing lithium and thallium compounds into the source of light, three discs appeared, being respectively red, yellow, and green, so that it was evident that the 6 mm. stop next to the shadow disc acted in the same way as a wide slit. Coloured solutions illuminated with white light of course cannot be used as screens with this arrangement, because, not being monochromatic, a blurred patch only is seen in the place of a sharp image.

As previously mentioned, the colours of the spectrum on either side of the disc become brighter as the rotation increases, and at about  $150^\circ$  they are so bright that the field looks like that of the ordinary spectrum with a yellow moon almost melting into it, and, moreover, the two sides of the disc do not show perfect uniformity of colour, but shade off to the colour of the spectrum, although the centre is nearly uniform, indicating that the 6 mm. stop forms too wide an opening for

such large angles. With the ordinary half-shadow polarimeter and a sodium light it is well known that the full shadows of the disc change with large rotations from dark grey or nearly black to bluish-violet, and so forth, and the colour becomes paler with increase of rotation; at the same time, it is not possible to get uniformity of colour in the centre of the disc. When using the direct prism, the dark grey shadows also gradually change, becoming coloured when the rotations are very large, and when about  $150^\circ$  and above, the full shadows on the red side of the spectrum become red and almost merge into the spectrum, and the full shadows on the green side become green, but when the measuring position is obtained the centre of the disc is homogeneous, although the sides shade off somewhat to the red and green. In these circumstances it was found advantageous to have an adjustable slit placed just behind the half-shadow disc. Both jaws of this slit have to be adjustable, because it is necessary to keep the centre line of the half-shadow disc in the centre of the slit, which should be just sufficiently open to observe the shadows on either side; this can be done even if the slit is only one or two millimetres wide. In the case of very large rotations, a grey band comes into the field and lies across the centre line when the correct measuring position is obtained; this, however, does not interfere with the readings, but is rather helpful. With this slit arrangement, rotations of  $360^\circ$  or more can be read with moderate accuracy, although of course, more care is required and the average of a larger number of readings taken than when smaller rotations are measured.

This addition to the polarimeter commends itself on account of its simplicity, all that is necessary being to have a small direct vision prism screwed on to the eye-piece (see Fig. 6), and, if exceptionally large rotations have to be measured, to have besides this a slit with both sides adjustable placed next to the half-shadow disc. By these arrangements, I have been able to measure the magnetic rotations of the different sugars, camphor and its derivatives, and also the terpenes, which would otherwise have been impossible.

The direct vision prism can be used in other positions besides that in front of the eye-piece; for example, it can be placed behind the telescope, as in Fig. 7, and if this is done it is easy to cut off the extraneous part of the spectrum by having shutters behind the eye-piece (as shown at *a a*), but I usually prefer to place it in front (as in Fig. 6), because of the better definition of the image, and one soon gets used to the other colours of the spectrum on each side of the image, although at first they are annoying. With a suitably adjusted outlet, the prism might be used next to the analyser, but experiments in this direction showed a great loss of intensity of light.

In the optical arrangements employed, the half-shadow disc is

connected with the *analyser* and not the polariser, as is usually the case.

This arrangement makes it now possible to investigate magnetic rotations from the point of view of dispersion; this was impossible without the use of a prism, because the salts of lithium, thallium, and other usual sources of monochromatic light are not sufficiently pure,

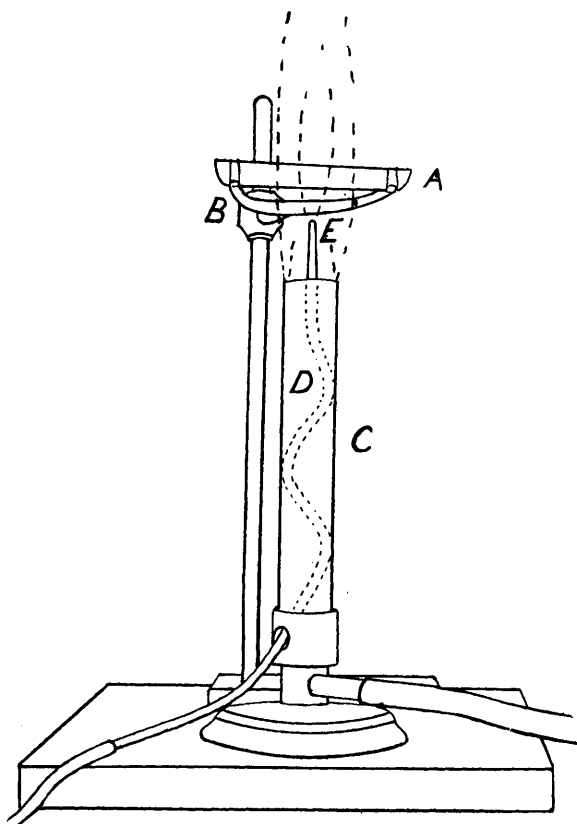


FIG. 8.

this being especially the case with lithium salts, which all contain sodium, even the best preparations.

#### *Sodium Light.*

In my previous arrangement for obtaining a monochromatic light the vapour of heated sodium was carried forward by a current of hydrogen and then burnt (Trans., 1884, 45, 424), but I have now

reverted to the use of sodium chloride and heat this to a much higher temperature than is generally employed. The apparatus is shown in Fig. 8. Fused sodium chloride is placed in a platinum boat, *A*, which is supported by and securely wired to the half of a small retort ring, *B*; the boat is heated by a large Bunsen burner, *C*, and through one of the air-holes of this and then up the inside of the burner a fine copper tube, *D*, is passed, bent in a zigzag manner so that it may be kept rigidly in its place. The top end of this tube is fitted with a platinum jet, *E*; this is conveniently and cheaply made by rolling a piece of platinum foil round a slightly conical piece of wire; it is then gently pressed on to the end of the copper tube and does not require any fastening. The diameter of the jet should be about one millimetre. The copper tube is supplied with oxygen, and the oxygen gas flame produced in the centre of the Bunsen flame is so placed that half of it impinges on the bottom of the platinum boat containing the sodium chloride, the other half passing up in front of the boat and receiving the vapour of the salt as it volatilises. In this way, a very intense yellow flame is obtained. The sodium chloride in the boat on either side of the high temperature flame is kept partially fused by the heat of the Bunsen burner and gradually flows to the centre and replaces that which is volatilised, so that the flame may be kept burning for a considerable time without attention. The air supply of the Bunsen burner should only be moderate, so as to produce a somewhat soft flame, otherwise the light is not so good. This light, of course, like all other sodium flames, is not purely monochromatic, but when the previously described arrangement with the prism is used this is of no consequence.

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