ON THE SPECTROSCOPE AND ITS APPLICATIONS

IV.

IN what has now been stated we first saw Newton founding spectral analysis, by using a hole in a shutter and a prism; then we discussed Wollaston's substitution of the slit; after that Mr. Simms' introduction of the collimating lens was referred to; and then the growth of the modern spectroscope.

It is time, now, that we came to the applications of the instrument. And in dealing with these applications I shall divide my subject into two perfectly distinct portions. I shall first deal with those which depend upon the different modes in which light is given out or radiated by

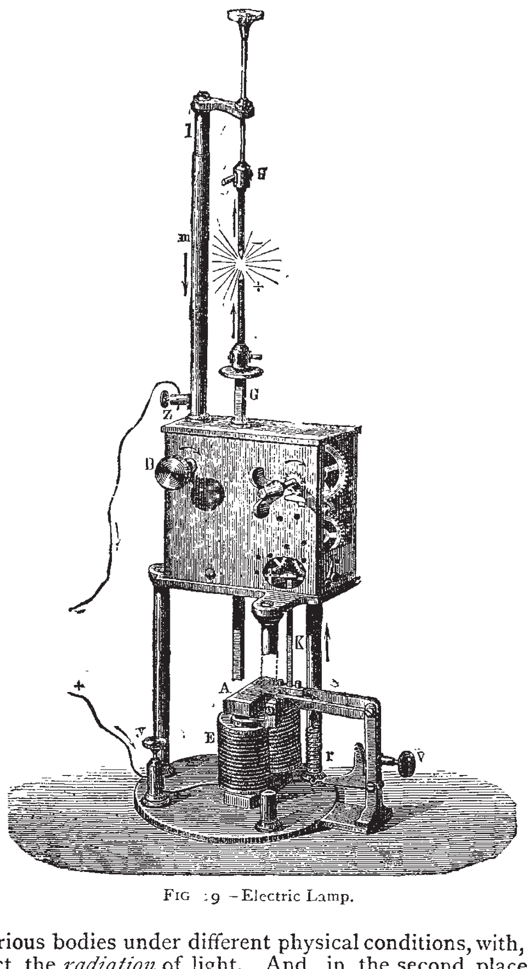

FIG. 19.—Electric Lamp.

various bodies under different physical conditions, with, in fact, the *radiation* of light. And, in the second place, I shall deal with the spectroscope's story of the way in which white light giving a continuous spectrum is stopped or absorbed by different transparent bodies—with in fact the *absorption* of light.

The first application of this question of radiation is one of the most general importance. It enables us to differentiate between solid, liquid, and gaseous substances, and between gaseous or vaporous substances in different stages of pressure. If, for instance, we take a platinum wire and heat it to redness, and examine by means of the spectroscope, the light emitted we shall find that only red rays are visible, then if the wire be gradually heated more strongly, the yellow, green, and blue, rays will become visible, until finally when the wire has attained a brilliant white heat, the whole of the colours of the spectrum will be present. If I were to burn a piece of paper, or a match or an ordinary coal gas flame, you all know we should get a white light, but you may possibly not all know that if we raise any solid or liquid to a state of incandescence or glowing heat we should get exactly that same sort of light, which will always give us a continuous spectrum. Before a large audience the best method of showing this fact is to use an apparatus called the electric lamp, and to pass the current of electricity through two carbon points, which are intensely heated by their resistance to the passage of the current. The spectrum obtained from these points, by means of the dispersion of two bisulphide of carbon prisms, is quite continuous from end to end. Now carbon is a solid, and therefore if we take carbon as an example of a solid or liquid substance in a state of vivid incandescence, and we obtain from these carbon points a continuous spectrum, you must accept that as an indica-

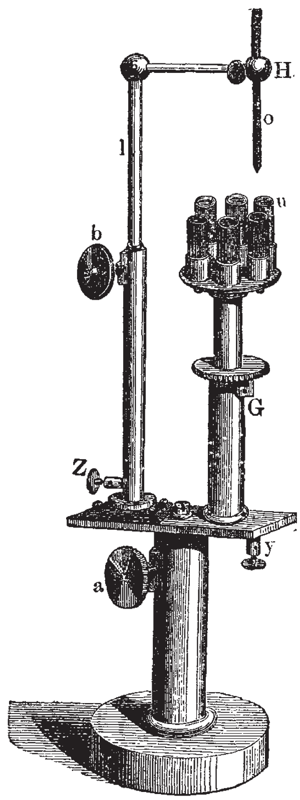

FIG. 20.—Arrangement of the electric lamp used for rapid comparisons.

tion of the truth of what I say, for I have not time to experiment on every solid and every liquid substance. The spectrum is received on the screen, and you see it is continuous, that is to say, there are no breaks, such as those we saw in the figure representing a portion of the solar spectrum on page 167 where the black lines represent the breaks in the solar spectrum which are called the Fraünhofer lines.

Let us then consider this fact established, namely, that solid or liquid bodies, when heated to a vivid incandescence, give a continuous sprectrum without bright lines. Under these circumstances the light to the eye, without the spectroscope, will be white, like that of a white hot poker; if the degree of incandescence is not so high, the light may only be red, like that of a red-hot poker. But so far as the spectrum goes—and it will expand towards the violet, as the incandescence increases, as before stated—it will be continuous.

Now, suppose, instead of giving you the spectrum of these solid white-light-giving carbon points or that from an ordinary gas flame, I show you the spectrum of a light source which is coloured. If, for instance, we burn some coloured fire, such as the red fire of our pyrotechnic displays. You must not consider that this is sensational, for Sir John Herschel, very many years ago, was on the eve

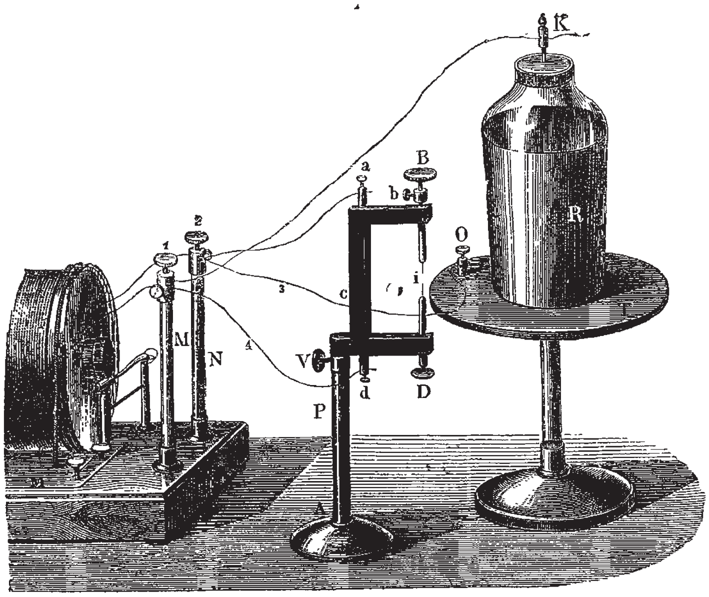

FIG. 21.—Arrangement for determining the spectra of metals by means of the electric spark.

of discovering the great point of spectrum analysis which I have to bring before you, by merely examining these coloured fires. If we examined such a light by means of the spectroscope you might expect that we should obtain the red

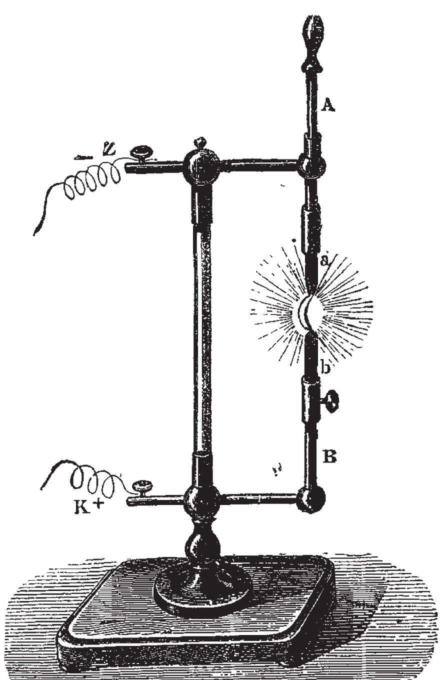

FIG. 22—The Electric Arc

end of the continuous spectrum; that on burning green fire we should see the green portion of the spectrum and so on. But this is not so; we find that the background of the spectrum is dark or nearly so, and that we have certain localisations of light or bright lines in different parts of the spectrum. Now, the differences in colour are accompanied by differences in the spectra. We have something very different from the continuous spectrum we had before, and this is, in fact, one of the first practical outcomes of spectrum analysis. It enables you in a moment to determine the difference between a solid or liquid body, which gives you a continuous spectrum, and a vapour or gas, which gives you a spectrum containing bright lines. The reason that different vapours and gases are of different

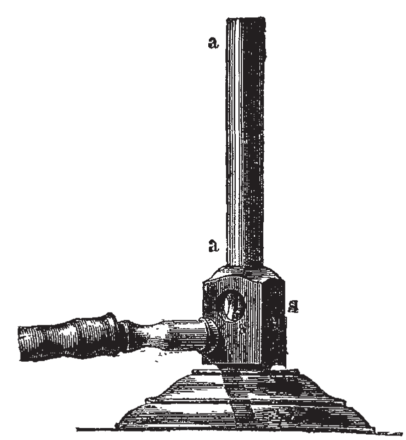

FIG. 23—Bunsen's burner for flame spectra.

colours is now clear; if we examine the light by means of a spectroscope, we find that the light rays which they emit are located in different parts of the spectrum.

In these instances then, the spectra consist of lines which are located in different parts of the spectrum. Let us burn some sodium in air, and then examine the spectrum of its vapour, or better still, let us place some sodium, or a salt of this metal, such as table salt, in a gas flame which is consuming a mixture of air and gas, in a burner known under the name of a Bunsen's burner, the bluish flame of which is due to the complete com bustion due to the greater supply of air from the holes at the bottom. The flame immediately becomes of an intense yellow colour due to the vapour of sodium. In this we have further evidence of the connection between the colour of the light which we get from a vapour and the spectrum of that vapour. It is usual to place the salt to be examined in a platinum spoon, and insert it in the flame, but the utmost constancy is insured by adopting an arrangement of Mitscherlich's shown in the accompanying drawing, (Fig. 24) in which a platinum wick is kept continually moistened by a solution of the salt, generally the chloride, the spectrum of which is required to be examined. You will imagine, *à priori*, from what I have already said, that as in the case of sodium vapour, the colour of the light is orange, the line of the vapour will appear in the yellow or orange part of the spectrum, and you will not be mistaken. For you will see on examining this flame with a spectroscope, that we obtain a spectrum consisting of a brilliant yellow line upon an almost black background; if, however, the flame is observed by means of a very narrow slit, this line will appear double, that is it really consists of two extremely fine lines which are very close to each other, and if the slit be wide the images overlap one another.

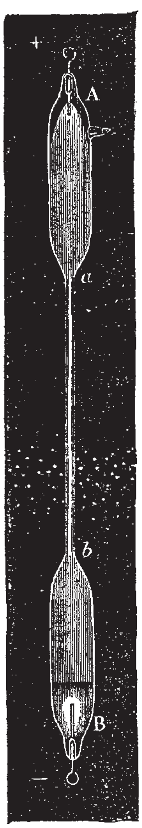

FIG. 24.—Geissler's tube, showing electric discharge.

If we then pass on to another substance, and take some lithium instead of sodium, we obtain a brilliant carmine tinted flame, which on examination by the spectroscope, is found to give a spectrum consisting of one splendid red, and a fainter orange line. Potassium gives a violet coloured flame, and yields in the spectroscope a red line and a violet line. If, again, we take a salt of strontium, which was one of the ingredients in red fire, it colours the flame crimson, and by the eye the flame can scarcely be distinguished from the colour of the lithium flame, but in the spectroscope there is no possibility of doubt, the spectrum of strontium, consists of a group of several lines in the red and orange, and a fine line in the blue end of the spectrum.

If a higher temperature than that of the Bunsen flame is required the blow-pipe flame may be resorted to; in this, the quantity of air and coal-gas is varied at pleasure, and a very high temperature may be obtained.

We might proceed thus to examine all the elementary substances one by one, but to observe the spectra of the metals, it will be found necessary to use a higher temperature still, and for this purpose the electric arc or spark is employed. If a temperature only slightly greater than that of the blow-pipe flame is used, the spark from an induction coil worked by five Grove cells may be taken as shown in Fig. 21, the Leyden jar not being employed; a few metallic lines will then be seen, and a background consisting generally of bands of light here and there.

If a higher temperature still is used, the jar may be thrown into the circuit, upon which the spark will become more intense, according to the power of the coil and size of the jar; or the electric arc may be employed. The spectra thus obtained are much more complex; the spectrum of iron, for instance, when examined at this high temperature, is found to consist of no less than 460 lines, many of which are situated in the green part of the spectrum.

With regard to solid and vaporous bodies, the electric lamp affords a very handy method when properly employed, of examining and exhibiting the spectra of these bodies to large audiences.

But there are a great many gases which the spectroscopist also has to study, and to study with the greatest

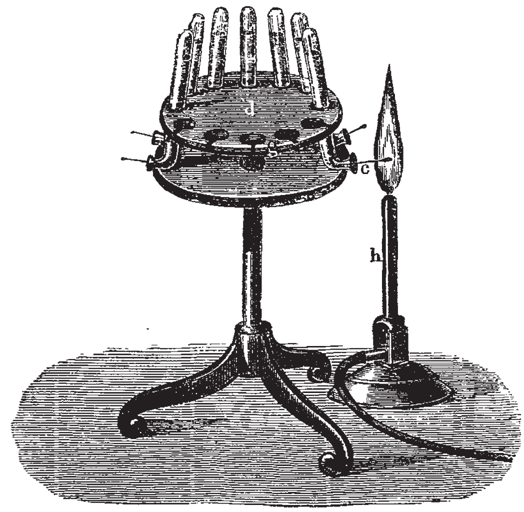

FIG. 25—Mitscherlich's arrangement for flame spectra.

care; and here, I am sorry to say, the electric lamp utterly fails us. The light which we get from a gas by the electric discharge is so feeble that it is quite impossible to throw its spectrum on the screen, so as to be observed by large audiences, for we cannot render strontium incandescent in the way in which we render incan-

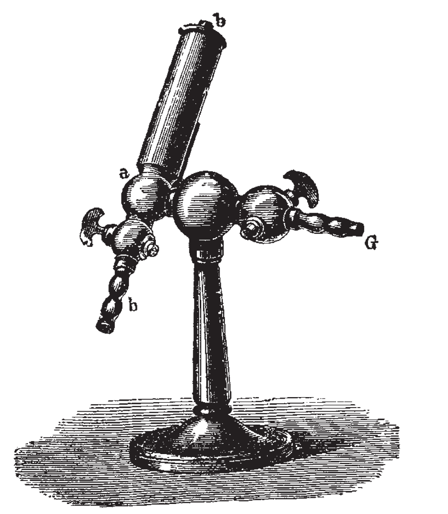

FIG 26.—Herapath's Blow-pipe.

descent sodium and the other substances I have brought before you. But we have other means of examining the spectra. I have here some tubes containing hydrogen and other gases at different pressures, and when we wish to study the spectrum of a gas, we do it in this way: we enclose it in a tube, and send a current through it by means of an induction-coil. If we pass a stream of electric sparks through a tube containing hydrogen at the pressure of one atmosphere, we shall see that the colour of the incandescent gas is a bright carmine red, the spectrum of which can easily be observed by placing the spark tube in front of the slit of one of the spectroscopes before described. This arrangement is one that is in daily use in many of our laboratories, and it must be borne in mind as being the *modus operandi* by which a great deal of the work has been done to which I shall have to allude shortly. If again we take a tube which contains hydrogen that has been extremely rarefied, and pass a series of electric sparks through it, instead of having the brilliant red colour, we shall have a pale greenish spark, quite different from the former. This great difference is due to the difference in the pressures of the hydrogen of the two cases.

The two spectra are equally distinct, the red light shows three splendid lines, one in the red, another in the bluish green, and the third in the violet, together with a considerable amount of continuous spectrum, whilst almost the only spectrum which can be obtained in the second case, is a single green line in the same position as the former green line spoken of. There is also this difference which will be observed, that the green line obtained from the tube at the atmospheric pressure is very broad and indistinct at the edges; and that the line as seen from the almost vacuous tube is very thin, comparatively speaking, and perfectly sharp and well defined. If we were to take another tube, with a pressure somewhere between the two already mentioned, it would be seen that this green line was not so wide and woolly as in the tube at one atmosphere, and yet not so sharp and well defined as in the almost vacuous tube. Thus it will be seen that this widening out of the line is due to the difference of pressure.

J. NORMAN LOCKYER

(*To be continued.*)

NOTES

OUR readers will be sorry, though not surprised, to hear that the venerable Professor Sedgwick died at Trinity College, Cambridge, on the morning of the 27th instant, aged 87 years. He was fifth wrangler in Trinity in 1808, and was elected to a fellowship in 1810. His contributions to science were very numerous, and are mainly to be found in the Transactions of various learned societies.

THE Vice-Chancellor of Cambridge University has given notice that the election of a Woodwardian Professor of Geology, in the place of Dr. Sedgwick, will be held in the Senate House on Thursday, February 20, at 1 P.M. The Vice-Chancellor and Proctors will receive the votes from 1 to 2.30, when the election will be declared. The stipend attached to the professorship is 500*l*. per annum.

WE are very glad indeed to hear that renewed and better organised efforts are likely to be made to induce Government to undertake the expense of an Arctic expedition. We have good reason to believe that Sir Henry Rawlinson will address a letter to the President of the Royal Society urging the importance of that body taking a lead in the advocacy of such an expedition. This is as it should be, and we have no doubt if the matter is gone about in a thoroughly well considered manner, a second rebuff will not be experienced. Meanwhile we are glad to learn from an obliging correspondent that Mr. Leigh Smith will proceed on his third voyage of Arctic discovery in the spring. He has a fine strong steamer, the *Diana*, admirably adapted for the purpose; and will undoubtedly achieve all that can be done in the way of discovery in the Spitzbergen seas, during the season of 1873. For Mr. Smith is a good observer and explorer, and is now becoming a veteran Arctic voyager. In 1871 he made the most remarkable voyage in that direction since 1707, discovering a large extent of coast line both on the north and south sides of North East Land. He also attained the highest latitude that has been reached in a ship, except by Scoresby and the Swedes. In 1872 he went out again, and though the unfavourable state of the ice prevented him from doing much, he succeeded in taking a very important series of observations of sea-temperatures at various depths. In 1873 he will again, with better means and in a steamer instead of a sailing vessel, make an attempt to explore the unknown lands east of Spitzbergen, and to attain the highest latitude that skill and perseverance will enable him to reach.

THE Senior Wrangler at Cambridge this year is Mr. Thomas Olver Harding, eldest son of the Rev. Thomas Harding, Wesleyan minister of Whitehaven. Mr. Harding, in January, 1866, gained the first exhibition at the matriculation examination of the London University, and the Gilchrist Scholarship at University Hall. In 1867 he gained the Andrews Scholarship in mathematics at University College. In 1868 he proceeded to the degree of B.A., in the University of London; and in 1869 and 1871 he passed the first and second examinations for the degree of B.Sc., gaining the exhibition in mathematics at each. Last year he was elected fellow of University College. In 1869 he entered Trinity as senior minor scholar in mathematics, and was elected foundation scholar in 1871. Mr. Harding has just completed his twenty-third year. His private tutor was Mr. Routh; his college tutor the Rev. E. W. Blore. The Second Wrangler, Mr. Edward John Nanson, was educated at the Grammar Schools of Penrith and Ripon. In 1869 he obtained a Minor Scholarship at Trinity College. In July 1869, he commenced reading with Mr. Routh, of St. Peter's College. In 1870 he obtained a Foundation Scholarship. He was Prizeman, and placed in the first class at each of the annual College Examinations. His college tutor was Mr. Blore.

AN alteration has been made in Prof. Tyndall's arrangements. We are now enabled to state that he will leave America on the 5th of next month in the *Cuba*.

WE are glad to see from the account of the annual meeting of the Anthropological Institute officially forwarded to us, that Prof. Busk has been elected President, and along with him the following strong Council:—Vice-Presidents—John Beddoe, M.D.; J. Barnard Davis, M.D., F.R.S.; John Evans, F.R.S.; Col. A. Lane Fox, F.S.A.; Prof. Huxley, F.R.S.; Sir John Lubbock, Bt., F.R.S. Director—E. W. Brabrook, F.S.A. Treasurer—J. W. Flower, F.G.S. Council—H. G. Bohn, F.R.G.S.; Capt. R. F. Burton; A. Campbell, M.D.; Hyde Clark; W. Boyd Dawkins, F.R.S.; Prof. P. M. Duncan, F.R.S.; Robert Dunn, F.R.C.S.; David Forbes, F.R.S.; A. W. Franks; Francis Galton, F.R.S.; C. R. Markham, C.B.; Capt. Sher. Osborn, C.B., R.N.; Capt. Bedford Pim, R.N.; F. G. H. Price, F.G.S.; J. E. Price; F. W. Rudler, F.G.S.; C. R. Des Ruffières, F.R.S.L.; W. Spottiswoode, V.P.R.S.; E. Burnet Tylor, F.R.S.; A. R. Wallace, F.L.S.

A WORK of considerable importance, a geological map of Australia and Tasmania, has been recently commenced by Mr. R. Brough Smyth, secretary to the Mining department of the Australian Government, which, when finished, will be of value not only to the colony, but to the whole scientific world. As the Minister of Mines has cordially approved of the work, it is intended to communicate with the Governments of the various colonies, forwarding a draft of the map after it has been partially completed from the sources at hand, and a scale showing the colours of the various rock formations, with a request that they will as far as possible fill in the blanks from the records of the departments in the respective colonies. By this means it is anticipated that much reliable information will be obtained, as