THE STORY OF HELIUM.[1]

CHAPTER II.

MY next chapter breaks new ground. I take you right away from the celestial regions, we leave the sun for a time, and I land you at Washington. I take you to a room in the geological department there, and I introduce you to one of the officials at work—a certain Dr. Hillebrand.

He is engaged upon the chemical examination of specimens of the mineral uraninite from various localities. The time was the year 1888.

He deals with a little crystal such as I have in my hand, he puts it in a vessel containing some sulphuric acid and water. He finds that he gets bubbles, bubbles of gas produced out of the crystal by means of the sulphuric acid. Well, he collects this gas, gets a quantity of it, tries to find out what it is, and he comes to the conclusion that it is nitrogen, and he publishes a statement that this gas obtained from the mineral uraninite consists of nitrogen.

This result was new. He thus writes about it:—

"In consequence of a certain observation" [the one I have just referred to] "and its results, an entirely new direction was given to the work, and its scope wonderfully broadened. This was the discovery of a hitherto unsuspected element in uraninite, existing in a form of combination not before observed in the mineral world."

It is not needful for my story to follow Dr. Hillebrand through all the painstaking and patient labour he cut out for himself, to explain this anomalous behaviour. Needless to say he did not omit to employ the spectroscope to test the nature of the new gas.

He writes[2]:—

"In a Geissler tube under a pressure of 10 millimetres and less, the gas afforded the fluted spectrum of pure nitrogen as brilliantly and as completely as was done by a purchased nitrogen tube. In order that no possibility of error might exist, the tube was then reopened and repeatedly filled with hydrogen, and evacuated till only the hydrogen lines were visible. When now filled with the gas and again evacuated, the nitrogen spectrum appeared as brilliantly as before, with the three bright hydrogen lines added."

On this paragraph I may remark that it has long been known that gases like nitrogen give us quite distinct spectra at different temperatures—one fluted, another containing lines. Which of these we shall see in a tube will depend upon the pressure of the gas and the electric current used. The fluted spectrum of nitrogen is very bright and full of beautiful detail in the yellow part of the spectrum; the line spectrum, on the other hand, is almost bare in that region.

Note well *that it so happened* that the pressure and electric conditions employed by Dr. Hillebrand enabled him to see the fluted spectrum.

Dr. Hillebrand concludes his paper by pointing out that—

"The interest in the matter is not confined merely to a solution of the composition of this one mineral; it is broader than that, and the question arises, May not nitrogen be a constituent of other species in a form hitherto unsuspected and unrecognisable by our ordinary chemical manipulations? And, if so, other problems are suggested which it is not now in order to discuss."

[1] Continued from p. 322.
[2] "On the Occurrence of Nitrogen in Uraninite,' *Bulletin*, No. 78, U.S. Geol. Survey, 1889-90, p. 55.

CHAPTER III.

Now, I have another part of the story to bring before you.

Following the recognised practice of story-tellers, I have to change the scene; instead of dealing with the sun, I must take you still further afield and consider some points connected with distant suns, which we call stars, and the nebulæ which are so often associated with those distant suns. A star appears to us as a point, but a nebula appears to us as a surface, and the result is that the method of investigating these two classes of heavenly bodies, to get at the facts I have to bring before you, is somewhat different.

Let us deal, in the first instance, with the method of photographing the spectrum of a star which appears to us as a point. The best way of doing that is to use an instrument represented in this diagram, which consists of a telescope with an object-glass at one end in front of which a prism of large dimensions is fixed, through which the light has to pass before it enters the telescope at all.

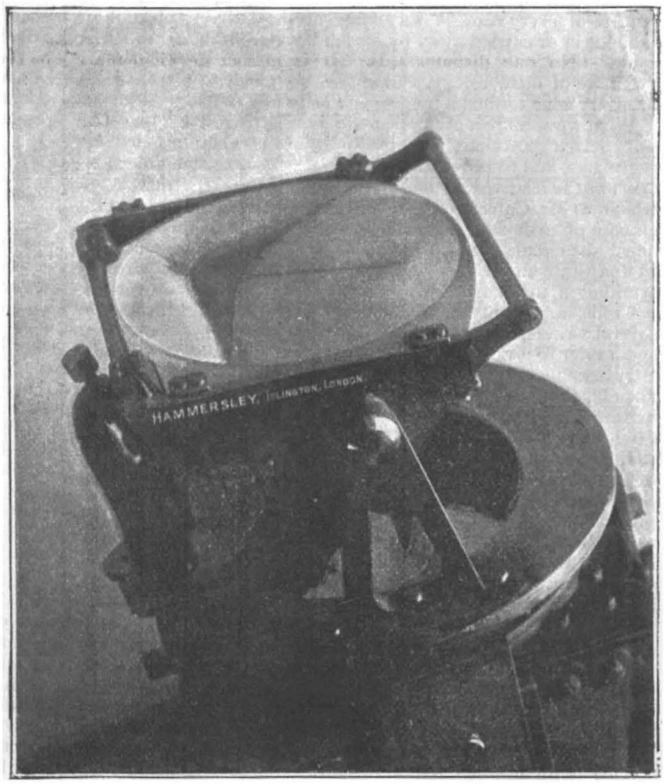

FIG. 8.—The objective prism.

Hence on the photographic plate, instead of the point formed by a star under ordinary conditions, owing to the tearing asunder by the prism of the different coloured rays of which the white light of the star is composed, we get a fine line, along which is represented the complete radiation, or complete system of hieroglyphics, from red to violet.

Another method is to employ a spectroscope of the ordinary construction in connection with a large reflector. The light from the star, which is grasped by the large mirror, is thrown by a diagonal mirror inside the tube on to the slit. In the case of the nebulæ, of course allowing first one part and then another to fall upon the slit of the spectroscope, we are enabled to determine what light-notes build up its light, and whether the light-notes from every part of the nebula are absolutely the same, or whether there are differences of chemical constitution in different parts. In this way it was found many years ago that both in the light of stars and of nebulæ we get very considerable varieties of spectra. Let me prove this point by referring to some recent observations.

FIG. 9.—Spectrum of Arcturus between G and K.

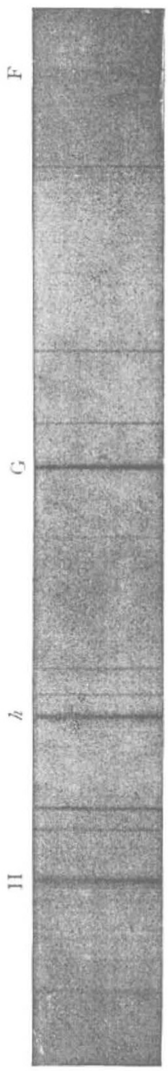

FIG. 10.—The spectrum of Bellatrix between H and F.

The original negative of the nebula of Orion, taken at my Observatory at Westgate-on-Sea in 1890, contains fifty-six lines, and of course by determining, as we have been able to do, the wave-lengths—the positions of these lines in the spectrum—we can determine the exact light-notes represented, and therefore the substances which produce them. Now I have to tell you that in this spectrum of the nebula of Orion we get lines of unknown origin exactly coinciding with those unknown lines which I have already referred to as having been seen in the sun's atmosphere. Mark it well, that some of the unknown lines in that atmosphere, those that we have not been able to see in our laboratories, are identical in position with some of the unknown lines in the nebula of Orion, the line D^3 being one case in point.

Then, I have next to say that in the spectra of many stars we have these same lines, which we have so far classified as unknown for the reason above stated, that in our laboratories we have not been able to get any lines which correspond with them.

I call attention to the spectra of some stars which have been carefully photographed and measured. You will see that the progress of this branch of science lately has been so considerable that any statement made with regard to the positions of lines, and therefore the chemical origins of them, may be made with a considerable amount of certainty as depending upon very accurate work.

It forms no part of my present purpose to indicate the various classes in which the stars have been classified by different observers according to their spectra, but some of the more salient differences must be pointed out. Thus we have stars with many lines in their spectra, others with comparatively few. I will take the many-lined stars first.

The diagram (Fig. 9) represents the spectrum of Arcturus, a star the spectrum of which closely resembles that of the sun. In α Cygni we have another star with many lines, but here we note, when we leave the hydrogen on one side and deal with the other stronger lines, that there is little relation between the solar spectrum and these lines.

I next come to the stars with few lines: these are well represented by many of the chief stars in the Constellation of Orion. Bellatrix is given as an example (Fig. 10).

Some astronomers hold the view that all the stars were hotter when they were first formed, than they ever have been afterwards. I have attempted to prove not only that this view is unphilosophic, but, further, that the spectroscopic facts indicate that we can arrange the stars along one line, provided the hottest stars are supposed to occupy the middle of it. In other words, that stars begin cool, get hotter, and then cool down finally.

In this way we are enabled to trace the chemical changes from one star to another, and that has been done with an expenditure of considerable labour.

CHAPTER IV.

Now I go to another chapter of my story. I ask you to accompany me in your mind's eye to another eclipse. The importance of eclipses in the abstract I think you will grant, from some of the results which I have already referred to. A method which was first employed by Respighi and myself during the eclipse of 1871, was employed on a large scale and with great effect during the eclipse of 1893. The light proceeding from the luminous ring round the dark moon was made to give us a series of rings, representing each bright line seen by the ordinary method, on a photographic plate. The observers this time were stationed in West Africa and in Brazil. The African station was up one of the rivers, not very far away from the town of Bathurst.

As a matter of fact, the very same instrument which was previously referred to as used for obtaining photographs of the stars was sent here, in order that photographs of the eclipse of the sun might be taken on exactly the same scale as the photographs of the stars had been. We next come to the Brazilian station. Here again the instruments were somewhat similar. I have another view of the

Brazilian station, and it affords me very great pleasure to bring this before you, because it enables me in this public way, as President of the Vesey Club, to tender thanks to Sir Benjamin Stone for the help he gave the Brazilian party.

We next pass to the results which were obtained by Messrs. Fowler and Shackleton, who were in charge of the instruments at the two stations. The diagrams will indicate the kind of celestial hieroglyph—to come back

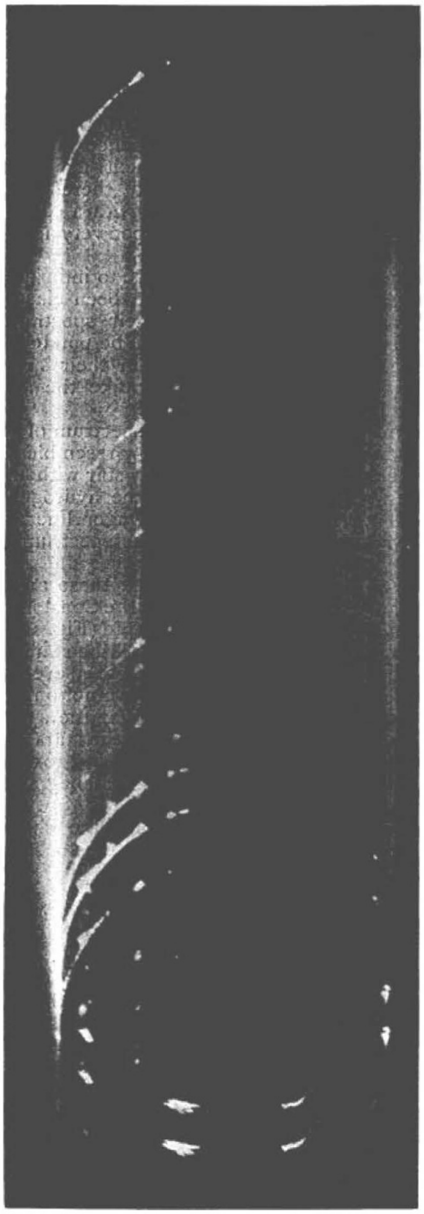

FIG. 11.—Untouched reproduction of photograph (African station) taken very shortly after the commencement of totality, the exposure being "instantaneous." At this phase of the eclipse a considerable arc of the chromosphere was visible, and its spectrum is therefore shown in addition to the spectrum of the higher reaches of some of the large prominences extending beyond the moon's limb. It will be seen that at H and K there are long arcs of chromosphere and prominences, the absent portions being of course obscured by the moon. One very small prominence is especially rich in lines.

to the old image—we have to deal with when this method is employed.

We get more or less complete rings when we are dealing with an extended arc of the chromosphere, or lines of dots when any small part of it is being subjected to a disturbance which increases the temperature and, possibly, the numbers of the different vapours present.

The efficiency of this method of work with the dispersion employed, turns out to be very marvellous, and in securing such valuable and permanent records as these, you will acknowledge that we have done very much better than if we had contented ourselves with the style of observations that I have referred to as having been made in 1871.

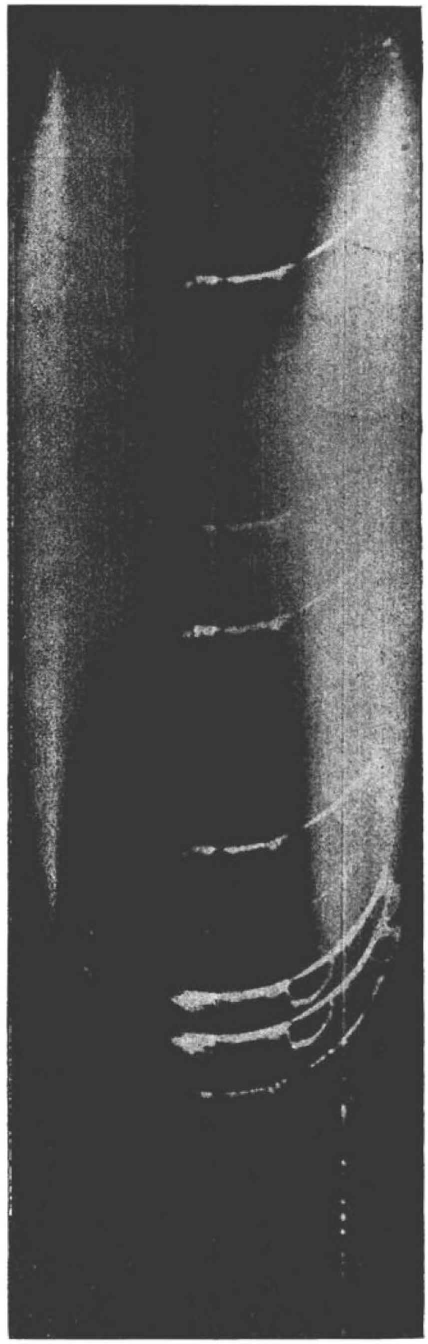

FIG. 12.—Photograph 21 (African station), taken shortly before the end of totality. A portion of the chromosphere on the other edge of the dark moon is now visible in addition to numerous prominences. It will be seen that one of the smallest prominences is rich in lines, and closely resembles that which appears in Fig. 11.

And now the plot of my story begins to thicken. On examining these eclipse records, we find that we have to do exactly with those unknown lines which had already been photographed in the stars and in the nebulæ.

As was to be expected we, of course, deal with the lines recorded in the first observations of the solar disturbances, and chronicled in that table of Prof. Young's, to which I have already called attention; but the important thing, the unexpected thing, is the marvellously close connection between eclipse- and star-spectrum photographs.

CHAPTER V.

Again I recall you from the heavens to the earth ; the time is the beginning of the present year.

You remember that last year was made memorable by the announcement of the discovery by Lord Rayleigh and Prof. Ramsay of a new gas called argon, and you know that the discovery was brought about chiefly in the first instance by the very accurate observations of Lord Rayleigh, who found that when he was determining the weight of air in a globe of a certain capacity, the weight depended upon the source from which he got the nitrogen.

From the nitrogen from atmospheric air he obtained one weight, and from that obtained by certain chemical processes he obtained another, and ultimately it was found that there was an unknown element which produced these results, these various changes in the weight; and as a consequence we had the discovery of argon.

It struck Mr. Miers, of the British Museum, that it might be desirable to draw attention to the nitrogen which we have seen Dr. Hillebrand in 1888 obtaining from his crystal of uraninite; his observations, of course, were more in the mind of Mr. Miers than in the minds of the pure chemists. He therefore communicated with Prof. Ramsay, who lost no time, because it was very interesting to study every possible source of nitrogen and see what its behaviour was in regard to the quantity of argon that it produced, and in the relation generally of the gas to the argon which was produced from it.

Prof. Ramsay treated uraninite in exactly the same way that Dr. Hillebrand had done in 1888. The gas obtained as Dr. Hillebrand had obtained it was eventually submitted to a spectroscopic test, following Dr. Hillebrand's example. But here a noteworthy thing comes in. *It so happened* that the pressure and electrical conditions employed by Prof. Ramsay were so different from those used by Dr. Hillebrand that, although nitrogen was undoubtedly present, the fluted spectrum which, as I have previously stated, floods the yellow part of the spectrum with luminous details, was absent. But still there was *something* there.

Judge of Prof. Ramsay's surprise when he found that he got a bright yellow line; that was the chief thing, and *not* the strong suggestion of the spectrum of nitrogen. Careful measurements indicated that the twenty-six-year-old helium had at last been run to earth, D^3 was at last visible in a laboratory. Prof. Ramsay was good enough to send specimens of the tubes containing this gas round to other people, and he sent one of them to me.

I received Prof. Ramsay's tube on March 28, but as it was not suitable for the experiments I wished to make, in his absence I obtained some gas for myself by a different method with which I need not trouble you. From March 30 onwards my assistants and myself had a very exciting time. One by one the unknown lines I had observed in the sun in 1868 were found to belong to the gas I was distilling from bröggerite, not only D^3 but 4923, 5017, 4471 (Lorenzoni's *f*) 6677 (the BC of Fig. 7), referred to previously, and many other solar lines, were all caught in a few weeks.

But this was by no means all. The solar observations had been made by eye, and referred therefore to the less refrangible part of the spectrum, but I had obtained and studied hundreds of stellar photographs, so I at once proceeded to photograph the gas and compare its more refrangible lines with stellar lines.

Here, if possible, the result was still more marvellous. In the few-lined stars, by May 6, I had caught nearly all the most important lines at the first casts of the spectroscopic net. Fig. 13, which includes some later results, will give an idea of the tremendous revelation which had been made as to the chemistry of some of the stages of star-life.

These results enabled us at once to understand how it was that the "unknown lines" had been seen both in the sun's chromosphere and some nebulæ and stars. The gas obtained from the minerals made its appearance in the various heavenly bodies in which the conditions of the highest temperatures were present, and the more the work goes on we find that this gas is really the origin of most, but certainly not of *all*, of the unknown lines which have been teasing astronomical workers for the last quarter of a century.

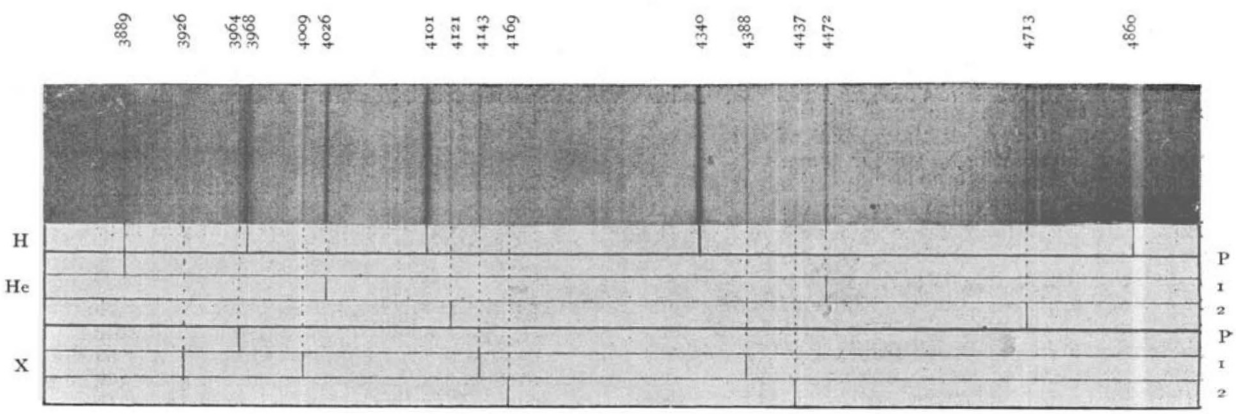

FIG. 13.—The spectrum of Bellatrix showing the lines of hydrogen and those which have been traced to the gas obtained from minerals.

A great deal of work has been done upon these gases from other points of view than those which affect my story, and perhaps I may be allowed just to refer for a minute or two to one of the results which have been obtained by myself.

It is perfectly obvious that the gas as obtained from uraninite is a mixture of several gases; that the gas which gives the yellow line has not yet been isolated, but is always mixed up with other gases which give other lines.

In May I communicated to the Royal Society some experiments which indicated in a most conclusive manner the fact that the lines D^3 and 667, to deal with two only for the sake of simplicity, were not produced by the same gas, and that 667 seemed to be a compound gas of which D^3 represents one of the constituents.

Some little time after, Profs. Runge and Paschen, from an entirely different standpoint, arrived at exactly the same conclusion. They recognised two gases, one represented by D^3, the other by 667, and further they showed that the lines might be arranged into six similar and beautifully rhythmic series, a principal and first and second series for each gas. These are indicated in the diagram of Bellatrix on p. 345, and in Fig. 14; He = helium is the gas which contains D^3, the other gas I so far call "gas X."[1]

This result is, however, more important from the chemical than from the astronomical point of view *at present*.

A word in conclusion referring to the occurrence of this gas in terrestrial minerals.

We are brought face to face with one question, which ought to influence many lines of work for many years to come. I have already suggested to you that we really now can talk with something like certainty and definiteness about hot stars and cooler stars, and that in the hottest stars we know of, the atmospheres of those stars consist almost entirely of hydrogen and helium.

But see what a little trace of helium we have in this small planet of ours, which undoubtedly was once a sun, which undoubtedly once had an atmosphere just as glorious in its hydrogen and its helium as any of the other stars are now glorious.

What has become of that helium? This question will have to be very carefully considered in the next few years.

We appear to be in presence of the *vera causa*, not of two or three, but of many of the lines which so far have been classed as "unknown" by students both of solar and stellar chemistry, and we are also apparently in the presence of a new order of gases of the highest importance to celestial chemistry, though perhaps they may be of small practical value to chemists, because their compounds and associated elements are for the most part hidden deep in the earth's interior. Why do I suggest a *new* order of gases? Look at the facts.

All the old terrestrial gases, with the exception of hydrogen, are spectroscopically invisible in the sun and stars—though they doubtless exist there—and these new gases, scarcely yet glimpsed, have already supplied us with many points of contact between our own planet and the hottest part of our central luminary that we can get at, and stars like Bellatrix.

The work certainly is full of hope for the future, not only in relation to the possibility of more closely correlating celestial and terrestrial phenomena, but since it indicates that terrestrial chemistry, founded on low density surface products in which non-solar gases largely enter, is capable of almost infinite expansion when the actions and reactions of the new order of gases, almost, it may be said, of paramount importance in certain stages of stellar evolution, shall have been completely studied.

I have some other results to refer to, but it is quite sufficient, I think, to leave my story as I have told it to you without going back on any of the characters, or without dealing in any greater detail with the *dénouement* of the plot.

But the story has a moral. The more we can study the different branches of science in their relation to each other, the better for the progress of all the sciences. Another point is, that in the study of nature we behave in a very foolish way if we think there is anything unimportant which comes under our eyes. *If it had so happened* that Dr. Hillebrand had seen the line spectrum of nitrogen in 1888, we should have saved all these seven years of waiting for this terrestrial source of helium; and I may add, further, that argon would have been discovered as well in the first hour's work. In science, results of the first importance depend upon the minute examination of so-called residual phenomena; it is too much the general tendency, of scientific work on a large scale, to think too much of those results which may have a practical importance.

Geologists, natural philosophers generally, have been familiar with the mineral world for a considerable number of years. What have they been doing all the time? They have confined their attention too exclusively to the contained metals, and have neglected the gases; whereas it now seems that if they had been less careful of the metals, and had studied the gases, it would have been very much better for our nineteenth century knowledge. And that is the moral of my simple story.

J. NORMAN LOCKYER.

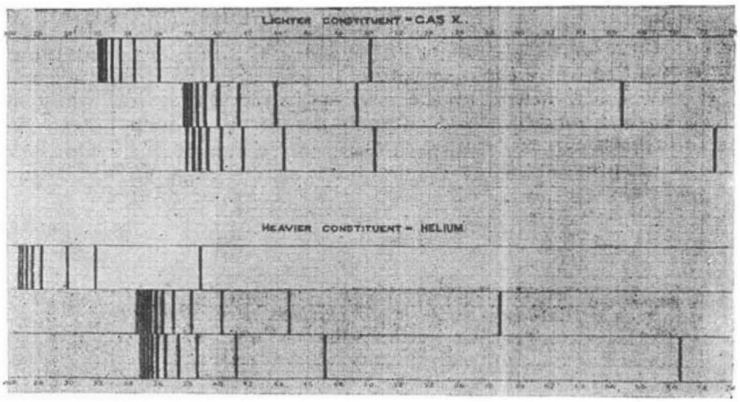

FIG. 14.—Runge and Paschen's results suggesting that cleveite gives off two gases, each with three series of lines.

[1] In the many comparisons I had to make, I soon found the inconvenience of not having a name for the gas which gave 667, 501, and other lines. When, therefore, Profs. Runge and Paschen, who had endorsed my results, and had extended them, called upon me, I thought it right to suggest to them that, sinking the priority of my own results, we should all three combine in suggesting a name. Prof. Runge (under date October 20) wrote me, "the inference that there are two gases is a spectroscopical one, being based on the investigation of the 'series.' Now, though we think this basis quite sound, we must own that the conclusion rests on induction. . . . For this reason we do not want to give a name to 'gas X.'" I have so far suggested no name, though Orionium and Asterium have been in my mind.

SCIENCE TEACHING IN SECONDARY SCHOOLS.

THE School Syllabus of Chemistry and Physics, which has just been put forward by a Committee of the Incorporated Association of Headmasters, is an attempt to indicate to those who are dissatisfied with the ordinary course of qualitative analysis, the lines on which the practical study of science may be made more profitable.

It is a great misfortune that in constructing a syllabus for use in schools, one has constantly to keep in mind its relation to the examination fiend. A short notice upon this syllabus, in this journal on Jan. 16 (p. 262), contained the observation that the teaching in schools is governed entirely by the examinations; and nothing could be more sadly true, nor a greater hindrance to a more rational system of teaching.

A syllabus may be perfect of its kind, but school authorities do not ask "How will it develop certain powers?" but "How will it examine?" and they base their estimation of it upon the answer to this question; while the relative value of the two in the eyes of parents