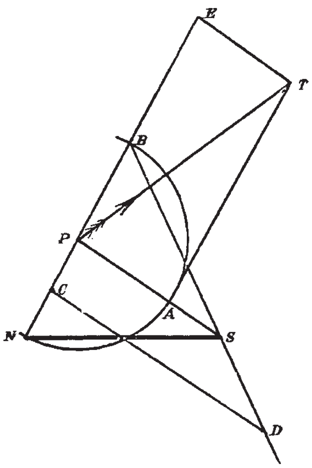
Construction for the Direction of a Magnetic Line of Force.

IN Prof. Gray's review of Riecke's *Lehrbuch*, a construction for the direction of the line of force at any point, due to a short magnet, is given.

If the magnet be long, then the following construction holds:

Let N and S be the two ends of the magnet and P the point, nearer, say, to N than to S. Take A in PS and B in NP produced, so that PA = PB = PN. Take C in BN, so that BC measured towards N equals PS. Draw CD parallel to PS, D being in the line BS. Measure PE away from N, so that PE = CD. The diagonal PT of the parallelogram AE is the direction required.



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THE determination of the direction of the resultant force, at any point, due to a long, thin magnet, is of some importance as a laboratory exercise, and it is necessary to be able to compare the direction which a small needle takes up in its field with the theoretical direction. For such an exercise the bar should be a long, thin magnet as nearly uniformly magnetised as possible. For this case Mr. Vincent's construction gives the theoretical direction very neatly.

The direction may also be found by dividing the line NS externally, at a point R, say, in the triplicate ratio of NP to SP. The line joining R to P is the direction sought. This construction can be made with only a parallel ruler.

My friend Mr. G. B. Mathews has pointed out to me that this construction may be very conveniently used to draw the whole family of curves. For describe a circle through P dividing NS internally and externally in the ratio of NP to SP. The lines joining any point on this circle with N and S are in this ratio. Hence the direction of the force at each point of the circle is the line joining it with R. Thus, by a succession of circles and corresponding positions of R, the whole series of curves can be laid down.

The following method is perhaps not so good, but is also very easy to remember. A diagram is not necessary. Describe a circle touching the line NP at N, and cutting the line SP produced beyond P in the points H, K, of which H is the nearer to P. From P towards N lay off a distance PL equal to PH, and through L draw a circle touching SP at S and cutting PN, produced, if necessary, in M. The diagonal passing through P of the parallelogram described on PK, PM as adjacent sides is in the direction of the line of force at P.

When either of the angles SNP, NSP is very obtuse, the last construction should be carried out by drawing the circles so as to give equal segments PH, PL both lying on the side of P towards NS. Then a distance PK′ = PK can be laid off along SP produced, and the parallelogram described on PK′, PM as adjacent sides. There are probably a great many ways of solving this problem: I have hit upon three other distinct methods, which I will not take up space with describing here. I may mention also that I have given a simple method of laying down successive points on a line of force in my "Magnetism and Electricity," vol. i. p. 14, figs. 12 and 13.

The construction for the direction of the force due to a short magnet, described in my review of Prof. Riecke's book, was given by Hansteen ("Magnetismus der Erde," s. 208), and again by Gauss ("Vorschriften," &c., Werke Bd. 5, s. 435). It is to be found in Prof. Chrystal's article on "Magnetism" in the "Encyclopaedia Britannica," and in my treatise on "Absolute Measurements," vol. ii.

A. GRAY.

THE CHEMISTRY OF THE STARS.[1]

WHEN, on returning from India, I found that you had during my absence done me the honour of unanimously electing me your President, I began to cast about for a subject on which to address you. Curiously enough, shortly afterwards an official inquiry compelled me to make myself acquainted with the early doings of the Royal Commission of the Exhibition of 1851, on which I have lately been elected to serve, and in my reading I found a full account of the establishment of your Institute; of the laying of the foundation-stone by the late Prince Consort in 1855, and of his memorable speech on that occasion. Here, I thought, was my subject; and when I heard that the admirable work done by this and other local institutions had determined the inhabitants of this important city and neighbourhood to crown the edifice by the foundation of a University, I thought the matter settled.

This idea, however, was nipped in the bud by a letter which informed me that the hope had been expressed that I should refer to some branch of astronomical work. I yielded at once, and because I felt that I might thus be able to show cause why the making of knowledge should occupy a large place in your new University, and thus distinguish it from other Universities more or less decadent.

The importance of practical work, the educational value of the seeking after truth by experiment and observation on the part of even young students, are now generally recognised. That battle has been fought and won. But there is a tendency in the official direction of seats of learning to consider what is known to be useful, because it is used, in the first place. The fact that the unknown, that is the unstudied, is the mine from which all scientific knowledge with its million applications has been won is too often forgotten.

Bacon, who was the first to point out the importance of experiment in the physical sciences, and who predicted the applications to which I have referred, warns us that "lucifera experimenta non fructifera quaerenda"; and surely we should highly prize those results which enlarge the domain of human thought and help us to understand the mechanism of the wonderful universe in which our lot is cast, as well as those which add to the comfort and the convenience of our lives.

It would be also easy to show by many instances how researches, considered ideally useless at the time they were made, have been the origin of the most tremendous applications. One instance suffices. Faraday's trifling with wires and magnets has already landed us in one of the greatest revolutions which civilisation has witnessed; and where the triumphs of electrical science will stop, no man can say.

This is a case in which the useless has been rapidly sublimed into utility so far as our material wants are concerned.

I propose to bring to your notice another "useless" observation suggesting a line of inquiry which I believe sooner or later is destined profoundly to influence human thought along many lines.

Fraunhofer at the beginning of this century examined sunlight and starlight through a prism. He found that the light received from the sun differed from that of the stars. So useless did his work appear that we had to wait for half a century till any considerable advance was made. It was found at last that the strange "lines" seen and named by Fraunhofer were precious indications of the chemical substances present in worlds immeasurably remote. We had, after half a century's neglect, the foundation of solar and stellar chemistry, an advance in knowledge equalling any other in its importance.

[1] An inaugural address delivered at the Birmingham and Midland Institute on October 26, by Sir Norman Lockyer, K.C.B., F.R.S., President.

In dealing with my subject, I shall first refer to the work which has been done in more recent years with regard to this chemical conditioning of the atmospheres of stars, and afterwards very briefly show how this work carries us into still other new and wider fields of thought.

The first important matter which lies on the surface of such a general inquiry as this is that if we deal with the chemical elements as judged by the lines in their spectra, we know for certain of the existence of oxygen, of nitrogen, of argon, representing one class of gases, in no celestial body whatever; whereas, representing other gases, we have a tremendous demonstration of the existence of all the known lines of hydrogen and helium.

We see then that the celestial sorting out of gases is quite different from the terrestrial one.

Taking the substances classed by the chemist as non-metals, we find carbon and silicium—I prefer, on account of its stellar behaviour, to call it silicium, though it is old-fashioned—present in celestial phenomena; we have evidence of this in the fact that we have a considerable development of carbon in some stars and an indication of silicium in others. But these are the only non-metals observed. Now with regard to the metallic substances which we find, we deal chiefly with calcium, strontium, iron and magnesium; others are not absolutely absent, but their percentage quantity is so small that they are negligible in a general statement.

Now do these chemical elements exist indiscriminately in all the celestial bodies, so that practically, from a chemical point of view, the bodies appear to us of similar chemical constitution? No, it is not so.

From the spectra of those stars which resemble the sun, in that they consist of an interior nucleus surrounded by an atmosphere which absorbs the light of the nucleus, and which therefore we study by means of this absorption; it is to be gathered that the atmospheres of some stars are chiefly gaseous, *i.e.* consisting of elements we recognise as gases here, of others chiefly metallic, of others again mainly composed of carbon or compounds of carbon.

Here then we have spectroscopically revealed the fact that there is considerable variation in the chemical constituents which build up the stellar atmospheres.

This, though a general, is still an isolated statement. Can we connect it with another? One of the laws formulated by Kirchhoff in the infancy of spectroscopic inquiry has to do with the kind of radiation given out by bodies at different temperatures. A poker placed in a fire first becomes *red*, and as it gets hotter, *white*, hot. Examined in a spectroscope we find that the red condition comes from the *absence* of blue light; that the white condition comes from the gradual addition of blue as the temperature increases.

The law affirms that the hotter a mass of matter is the further its spectrum extends into the ultra-violet.

Hence the hotter a star is, the further does its complete or *continuous* spectrum lengthen out towards the ultra-violet, and the less is it absorbed by cooler vapours in its atmosphere.

Now to deal with three of the main groups of stars, we find the following very general result:—

Gaseous stars	Longest spectrum.
Metallic stars	Medium spectrum.
Carbon stars	Shortest spectrum.

We have now associated two different series of phenomena, and we are enabled to make the following statement:—

Gaseous stars	Highest temperature.
Metallic stars	Medium temperature.
Carbon stars	Lowest temperature.

Hence the differences in apparent chemical constitutions are associated with differences of temperature.

Can we associate with the two to which I have already called attention still a third class of facts?

Laboratory work enables us to do this. When I began my inquiries the idea was, one gas or vapour one spectrum. We now know that this is not true; the systems of bright lines given out by radiating substances change with the temperature.

We can get the spectrum of a well-known compound substance—say carbonic oxide; it is one special to the compound; we increase the temperature so as to break up the compound, and we then get the spectra of its constituents, carbon and oxygen.

But the important thing in the present connection is that the spectra of the chemical elements behave exactly in the same way as the spectra of known compounds do when we employ temperatures far higher than those which break up the compounds; and indeed in some cases the changes are more marked. For brevity I will take for purposes of illustration three substances, and deal with one increase of temperature only, a considerable one and obtainable by rendering a substance incandescent, first by a direct current of electricity, as happens in the so-called "arc lamps" employed in electric lighting, and next by the employment of a powerful induction coil and battery of leyden jars. In laboratory parlance we pass thus from the arc to the jar-spark. In the case of magnesium, iron and calcium, the changes observed on passing from the temperature of the arc to that of the spark have been minutely observed. In each, new lines are added or old ones are intensified at the higher temperature. Such lines have been termed *enhanced lines*.

These enhanced lines are not seen alone: outside the region of high temperature in which they are produced, the cooling vapours give us the cool lines. Still we can conceive the enhanced lines to be seen alone at the highest temperature in a space sufficiently shielded from the action of all lower temperatures, but such a shielding is beyond our laboratory expedients.

In watching the appearance of these special enhanced lines in stellar spectra we have a third series of phenomena available, and we find that the results are absolutely in harmony with what has gone before. Thus

Gaseous stars ...	Highest temperature...	Strong helium and faint enhanced lines.
Metallic stars ...	Medium temperature	Feeble helium and strong enhanced lines. No helium and strong arc lines.
Carbon stars ...	Lowest temperature...	Faint arc lines.

It is clear now, not only that the spectral changes in stars are associated with, or produced by, changes of temperature, but that the study of the enhanced spark and the arc lines lands us in the possibility of a rigorous stellar thermometry, such lines being more easy to observe than the relative lengths of spectrum.

Accepting this, we can take a long stride forward and, by carefully studying the chemical revelations of the spectrum, classify the stars along a line of temperature. But which line? Were all the stars, in popular phraseology, created hot? If so, we should simply deal with the running down of temperature, and because all the hottest stars are chemically alike, all cooler stars would be alike. But there are two very distinct groups of coolest stars; and since there are two different kinds of coolest stars, and only one kind of hottest star, it can not be merely a question either of a running up or a running down of temperature.

Many years of very detailed inquiry have convinced me that all stars save the hottest must be sorted out into two series—those getting hotter and those, like our sun, getting cooler, and that the hottest stage in the history of a star is reached near the middle of its life.

The method of inquiry adopted has been to compare large-scale photographs of the spectra of the different stars, taken by my assistants at South Kensington; the complete harmony of the results obtained along various lines of other work carries conviction with it.

We find ourselves here in the presence of minute details exhibiting the workings of a chemical law, associated distinctly with temperature; and more than this, we are also in the presence of high temperature furnaces, entirely shielded by their vastness from the presence of those distracting phenomena which we are never free from in the most perfect conditions of experiment we can get here.

What, then, is the chemical law? It is this. In the very hottest stars we deal with the gases hydrogen, helium, and doubtless others still unknown, almost exclusively. At the next lowest temperatures we find these gases being replaced by metals in the state in which they are observed in our laboratories when the most powerful jar-spark is employed. At a lower temperature still the gases almost disappear entirely, and the metals exist in the state produced by the electric arc. Certain typical stars showing these chemical changes may be arranged as follows:

Stars getting hotter.	Hottest stars.	Stars cooling.
	Bellatrix	
ζ Tauri		β Persei
Rigel		γ Lyra
α Cygni		Castor
γ Cygni		Procyon
α Orionis		Arcturus and Sun

This, then, is the result of our first inquiry into the existence of the various chemical elements in the atmospheres of stars generally. We get a great diversity, and we know that this diversity accompanies changes of temperature. We have also found that the sun, which we independently know to be a cooling star, and Arcturus, are identical chemically.

We have now dealt with the presence of the various chemical elements, generally, in the atmospheres of stars. The next point we have to consider is whether the absorption which the spectrum indicates for us takes place from top to bottom of the atmosphere, or only in certain levels.

In many of these stars the atmosphere may be millions of miles high. In each the chemical substances in the hottest and coldest portions *may* be vastly different; the region, therefore, in which this absorption takes place, which spectroscopically enables us to discriminate star from star, must be accurately known before we can obtain the greatest amount of information from our inquiries.

Our next duty then clearly is to study the sun—a star so near us that we can examine the *different parts* of its atmosphere, which we cannot do in the case of the more distant stars. By doing this we may secure facts which will enable us to ascertain in what parts of the atmosphere the absorption takes place which produces the various phenomena on which the chemical classification has been based.

It is obvious that the general spectrum of the sun, like that of stars generally, is built up of all the absorptions *which can make themselves felt* in every layer of its atmosphere from bottom to top, that is from the photosphere to the outermost part of the corona. Let me remind you that this spectrum is *changeless* from year to year.

Now sun-spots are disturbances produced in the photosphere; and the chromosphere, with its disturbances, called prominences, lies directly above it. Here, then, we are dealing with the lowest part of the sun's atmosphere. We find first of all that in opposition to the changeless general spectrum, great changes occur with the sun-spot period, both in the spots and chromosphere.

The spot spectrum is indicated, as was found in 1866, by the widening of certain lines; the chromospheric spectrum, as was found in 1868, by the appearance at the sun's limb of certain bright lines. In both cases the lines affected seen at any one time are relatively few in number.

In the spot spectrum, at a sun-spot minimum, we find iron lines chiefly affected; at a maximum they are chiefly of unknown or unfamiliar origin. At the present moment the affected lines are those recorded in the spectra of vanadium and scandium, with others never seen in a laboratory. That we are here far away from terrestrial chemical conditions is evidenced by the fact that there is not a gramme of scandium available for laboratory use in the world at the present time.

Then we have the spectrum of the prominences and the chromosphere. That spectrum we are enabled to observe every day when the sun shines, as conveniently as we can observe that of sun-spots. The chromosphere is full of marvels. At first, when our knowledge of spectra was very much more restricted than now, almost all the lines observed were unknown. In 1868 I saw a line in the yellow, which I found behaved very much like hydrogen, though I could prove that it was not due to hydrogen; for laboratory use the substance which gave rise to it I called helium. Next year I saw a line in the green at 1474 of Kirchhoff's scale. That was an unknown line, but in some subsequent researches I traced it to iron. From that day to this we have observed a large number of lines. They have gradually been dragged out from the region of the unknown, and many are now recognised as enhanced lines, to which I have already called attention as appearing in the spectra of metals at a very high temperature.

But useful as the method of observing the chromosphere without an eclipse, which enables us

"... to feel from world to world,"

as Tennyson has put it, has proved, we want an eclipse to see it face to face.

A tremendous flood of light has been thrown upon it by the use of large instruments constructed on a plan devised by Respighi and myself in 1871. These give us an image of the chromosphere painted in each one of its radiations, so that the exact locus of each chemical layer is revealed. One of the instruments employed during the Indian eclipse of this year is that used in photographing the spectra of stars, so that it is now easy to place photographs of the spectra of the chromosphere obtained during a total eclipse and of the various stars side by side.

I have already pointed out that the chemical classification indicated that the stars next above the sun in temperature are represented by γ Cygni and Procyon, one on the ascending, the other on the descending branch of the temperature curve.

Studying the spectra photographed during the eclipse of this year we see that practically the lower part of the sun's atmosphere, if present by itself, would give us the lines which specialise the spectra of γ Cygni or Procyon.

I recognise in this result a veritable Rosetta stone which will enable us to read the celestial hieroglyphics presented to us in stellar spectra, and help us to study the spectra and to get at results much more distinctly and certainly than ever before.

One of the most important conclusions we draw from the Indian eclipse is that, *for some reason or other*, the lowest hottest part of the sun's atmosphere does not write its record among the lines which build up the general spectrum so effectively as does a higher one.

There was another point especially important on which we hoped for information, and that was this. Up to the employment of the prismatic camera insufficient attention had been directed to the fact that in observations made by an ordinary spectroscope, no true measure of the height to which the vapours or gases extended above the sun could be obtained; early observations, in fact, showed the existence of glare between the observer and the dark moon; hence it must exist between us and the sun's surroundings.

The prismatic camera gets rid of the effects of this glare, and its results indicate that the effective absorbing layer—that, namely, which gives rise to the Fraunhofer lines—is much more restricted in thickness than was to be gathered from the early observations.

We are justified in extending these general conclusions to all the stars that shine in the heavens.

So much then, in brief, for solar teachings in relation to the record of the absorption of the lower parts of stellar atmospheres.

Let us next turn to the higher portions of the solar surroundings to see if we can get any effective help from them.

In this matter we are dependent absolutely upon eclipses, and I shall fulfil my task very badly if I do not show you that the phenomena then observable when the so-called corona is visible, full of awe and grandeur to all, are also full of precious teaching to the student of science. This also varies like the spots and prominences with the sun-spot period.

It happened that I was the only person that saw both the eclipse of 1871 at the maximum of the sun-spot period and that of 1878 at minimum; the corona of 1871 was as distinct from the corona of 1878 as anything could be. In 1871 we got nothing but bright lines indicating the presence of gases; namely hydrogen and another, since provisionally called coronium. In 1878 we got no bright lines at all, so I stated that probably the changes in the chemistry and appearance of the corona would be found to be dependent upon the sun-spot period, and recent work has borne out that suggestion.

I have now specially to refer to the corona as observed and photographed this year in India by means of the prismatic camera, remarking that an important point in the use of the prismatic camera is that it enables us to separate the spectrum of the corona from that of the prominences.

One of the chief results obtained is the determination of the position of several lines of probably more than one new gas, which, so far, have not been recognised as existing on the earth.

Like the lowest hottest layer, *for some reason or other*, this upper layer does not write its record among the lines which build up the general spectrum.

General results regarding the locus of absorption in stellar atmospheres.

We learn from the sun, then, that the absorption which defines the spectrum of a star is the absorption of a middle region, one shielded both from the highest temperature of the lowest reaches of the atmosphere where most tremendous changes are continually going on, and the external region where the temperature must be low, and where the metallic vapours must condense.

If this is true for the sun it must be equally true for Arcturus, which exactly resembles it. I go further than this, and say that in the presence of such definite results as those I have brought before you, it is not philosophical to assume that the absorption may take place at the bottom of the atmosphere of one star, or at the top of the atmosphere of another. The *onus probandi* rests upon those who hold such views.

So far I have only dealt in detail with the hotter stars, but I have pointed out that we have two distinct kinds of coolest ones, the evidence of their much lower temperature being the shortness of their spectra. In one of these groups we deal with absorption alone, as in those already considered; we find an important break in the phenomena observed; helium, hydrogen and metals have practically disappeared, and we deal with carbon absorption alone.

But the other group of coolest stars presents us with quite new phenomena. We no longer deal with absorption alone, but accompanying it we have radiation, so that the spectra contain both dark lines and bright ones. Now since such spectra are visible in the case of new stars, the ephemera of the skies, which may be said to exist only for an instant relatively, and when the disturbance which gives rise to their sudden appearance has ceased, we find their places occupied by nebulae, we cannot be dealing here with stars like the sun, which has already taken some millions of years to slowly cool, and requires more millions to complete the process into invisibility.

The bright lines seen in the large number of permanent stars which resemble these fleeting ones—*new stars*, as they are called—are those discerned in the once mysterious nebulae which, so far from being stars, were supposed not many years ago to represent a special order of created things.

Now the nebulae differ from stars generally in the fact that in their spectra we have practically to deal with radiation alone, we study them by their bright lines, the conditions which produce the absorption by which we study the chemistry of the hottest stars are absent.

A new view of stars.

Here then we are driven to the perfectly new idea that some of the cooler bodies in the heavens the temperature of which is increasing and which appear to us as stars, are really disturbed nebulae.

What then is the chemistry of the nebulae? It is mainly gaseous; the lines of helium and hydrogen and the flutings of carbon, already studied by their absorption in the groups of stars to which I have already referred, are present as bright ones.

The presence of the lines of the metals iron, calcium, and probably magnesium, shows us that we are not dealing with gases merely.

Of the enhanced metallic lines there are none, only the low temperature lines are present, so far as we yet know. The temperature then is low, and lowest of all in those nebulae where carbon flutings are seen almost alone.

A new view of nebulae.

Passing over the old views, among them one that the nebulae were holes in something dark which enabled us to see something bright beyond, and another that they were composed of a fiery fluid, I may say that not long ago they were supposed to be masses of gases only, existing at a very high temperature.

Now, since gases may glow at a low temperature as well as at a high one, the temperature evidence must depend upon the presence of cool metallic lines and the absence of the enhanced ones.

The nebulae, then, are relatively cool collections of some of the permanent gases and of some cool metallic vapours, and both gases and metals are precisely those I have referred to as writing their records most visibly in stellar atmospheres.

Now can we get more information concerning this association of certain gases and metals? In laboratory work it is abundantly recognised that all meteorites (and many minerals) when slightly heated give out permanent gases, and under certain conditions the spectrum of the nebulae may in this way be closely approximated to. I have not time to labour this point, but I may say that a discussion of all the available observations to my mind demonstrates the truth of the suggestion, made many years ago by Prof. Tait before any spectroscopic facts were available, that the nebulae are masses of meteorites rendered hot by collisions.

Surely human knowledge is all the richer for this indication of the connection between the nebulae, hitherto the most mysterious bodies in the skies, and the "stones that fall from heaven."

Celestial evolution.

But this is, after all, only a stepping-stone, important though it be. It leads us to a vast generalisation. If the nebulae are thus composed, they are bound to condense to centres however vast their initial proportions, however irregular the first distribution of the cosmic clouds which compose them; each pair of meteorites in collision puts us in mental possession of what the final stage must be. We begin with a feeble absorption of metallic vapours round each meteorite in collision; the space between the meteorites is filled with the permanent gases driven out further afield and having no power to condense. Hence dark metallic and bright gas lines. As time goes on, the former must predominate, for the whole swarm of meteorites will then form a gaseous sphere with a strongly heated centre, the light of which will be absorbed by the exterior vapour.

The temperature-order of the group of stars with bright lines as well as dark ones in their spectra, has been traced, and typical stars indicating the chemical changes have been as carefully studied as those in which absorption phenomena are visible alone, so that now there are no breaks in the line connecting the nebulae with the stars on the verge of extinction.

Here we are brought to another tremendous outcome, that of the evolution of all cosmical bodies from meteorites, the various stages recorded by the spectra being brought about by the various conditions which follow from the conditions.

These are shortly that at first collisions produce luminosity among the colliding particles of the swarm, and the permanent gases are given off and fill the interspaces. As condensation goes on, the temperature at the centre of condensation always increasing, all the meteorites in time are driven into a state of gas. The meteoritic bombardment practically now ceases for lack of material, and the future history of the mass of gas is that of a cooling body, the violent motions in the atmosphere while condensation was going on now being replaced by a relative calm.

The absorption phenomena in stellar spectra are not identical at the same mean temperature on the ascending and descending sides of the curve, on account of the tremendous difference in the physical conditions.

In a condensing swarm, the centre of which is undergoing meteoritic bombardment from all sides, there cannot be the equivalent of the solar chromosphere; the whole mass is made up of heterogeneous vapour at different temperatures, and moving with different velocities in different regions.

In a condensed swarm, of which we can take the sun as a type, all action produced from without has practically ceased; we get relatively a quiet atmosphere and an orderly assortment of the vapours from top to bottom, disturbed only by the fall of condensed metallic vapours. But still, on the view that the differences in the spectra of the heavenly bodies chiefly represent differences in degree of condensation and temperature, there can be, *au fond*, no great chemical difference between bodies of increasing and bodies of decreasing temperature. Hence, we find at equal mean temperatures on opposite sides of the temperature curve, this chemical similarity of the absorbing vapours proved by many points of resemblance in the spectra, especially the identical behaviour of the enhanced metallic and cleveite lines.

Celestial dissociation.

The time you were good enough to put at my disposal is now exhausted, but I cannot conclude without stating that I have not yet exhausted all the conceptions of a high order to which Fraunhofer's apparently useless observation has led us.

The work which to my mind has demonstrated the evolution of the cosmos as we know it from swarms of meteorites, has also suggested a chemical evolution equally majestic in its simplicity.

A quarter of a century ago I pointed out that all the facts then available suggested the hypothesis that in the atmospheres of the sun and stars various degrees of "celestial dissociation" were at work, a "dissociation" which prevented the coming together of the finest particles of matter which at the temperature of the earth and at all artificial temperatures yet attained here compose the metals, the metalloids and compounds.

On this hypothesis the so-called atoms of the chemist represent not the origins of things, but only early stages of the evolutionary process.

At the present time we have tens of thousands of facts which were not available twenty-five years ago. All these go to the support of the hypothesis, and among them I must indicate the results obtained at the last eclipse, dealing with the atmosphere of the sun in relation to that of the various stars of higher temperature to which I called your attention. In this way we can easily explain the enhanced lines of iron existing practically alone in Alpha Cygni. I have yet to learn any other explanation.

I have nothing to take back either from what I then said or what I have said since on this subject, and although the view is not yet accepted, I am glad to know that many other lines of work which are now being prosecuted tend to favour it.

I have no hesitation in expressing my conviction that in a not distant future the inorganic evolution to which we have been finally led by following up Fraunhofer's useless experiment, will take its natural place side by side with that organic evolution the demonstration of which has been one of the glories of the nineteenth century.

And finally now comes the moral of my address. If I have helped to show that observations having no immediate practical bearing may yet help on the thought of mankind, and that this is a thing worth the doing, let me express a hope that such work shall find no small place in the future University of Birmingham.

DIFFUSION IN RELATION TO WORK.

IN this month's *Philosophical Magazine* Mr. A. Griffiths has an interesting paper on diffusion convection, in which he suggests an indirect method of measuring rates of diffusion of liquids, and concludes with the following deduction from the fact that diffusion sometimes produces convection currents and sometimes does not:—"Does not this indicate that the heat produced on mixing a solution with water depends on how the mixing takes place? Is the matter connected with a sort of surface-tension existing in the spaces between a strong and a weak solution?"

Mr. Griffiths does not seem to have observed that his investigation applies quite well to gases as to liquids, and that his indirect method of measuring rates of diffusion is applicable to gases. In the case of gases there can be sensible surface-tension, and, as the theory of diffusion in gases is quite simple, there is no serious difficulty in seeing how there is a difference between different ways of mixing them.

It is generally known that two different gases may be mixed by irreversible, or by, at least, partially reversible,