SOLAR PHYSICS—THE CHEMISTRY OF THE SUN[1]

The Test supplied by Change of Refrangibility

WE have then got so far. Limiting our studies to iron we find that the prominence spectrum is made up of one set of lines seen in the terrestrial spectrum, and the spot spectrum made up of another set. And more than this, if we add the lines seen in the prominence and spot spectra together we do not then by any means make up the complete spectrum.

It is fair to ask the following question:—Have we any other means of establishing this extraordinary fact of the separation of the iron lines in spots and storms? We have. Reference has already been made to the change of refrangibility of the lines brought about by the change of velocity of movement of the various solar vapours. But if, as already hinted, the lines of iron behave to each other in precisely the same way as the lines of two perfectly distinct substances behave to each other; then if we observe changes of refrangibility in the iron lines, both in spots and flames, we should get the same differentiation as we have already got in the lines thickened or intensified in the spectra of spots and flames.

We will now see the results which have been obtained along this line of research, and it should be pointed out that it is not a method by which it is easy in a short time to accumulate a large number of observations, because metallic prominences are very rare except at the sun-spot maximum, and in the case of spots we not only want a spot, but we want that spot to be in a very considerable state of commotion, in order that the change of refrangibility may be obvious enough to enable us to record the phenomena.

So far as this inquiry has gone at present we have only observed the lines contorted in spots.

In the diagram (Fig. 37) the zig-zag lines indicate the iron lines which changed their refrangibility in a number of spots observed at the end of last year. The point is that, although we have a great many of the iron lines bent, twisted, contorted—with their refrangibility changed, yet some of the iron lines mixed with them give us no indication of movement. All these observations have been made upon lines seen at the same moment in the same field of view. Observations of this nature exist twelve years old, but no importance can be attached to them, for the reason that the phenomenon was not understood, as I hope it is understood now, and precautions were not taken in the observations then made to show that no motion of the slit across the spot took place in the interval between the two observations. For, of course, it is not fair to compare a line which one sees in one part of the spectrum with a line seen in another, unless one is absolutely certain that the slit has not moved on the sun's image; because one-thousandth part of an inch on the sun's image means a good many miles on the sun. Referring to Fig. 37 we have, at wave-length 5366–70, three lines, two in motion, and one at rest, all belonging to a well-known group of iron lines. At a later date we have the line at 5382 at rest, while that at 5378 is in motion. Thus it will be seen that these points and others prove there is just as much individuality in the way in which the lines of iron change their refrangibility as there is in the way in which one particular line, and then another, is thickened in a sun-spot or brightened in a prominence; and if we go further we find this very interesting and additional fact, that the lines which are not contorted are in a great many cases precisely those lines which are seen in the flames, but not in the spots.

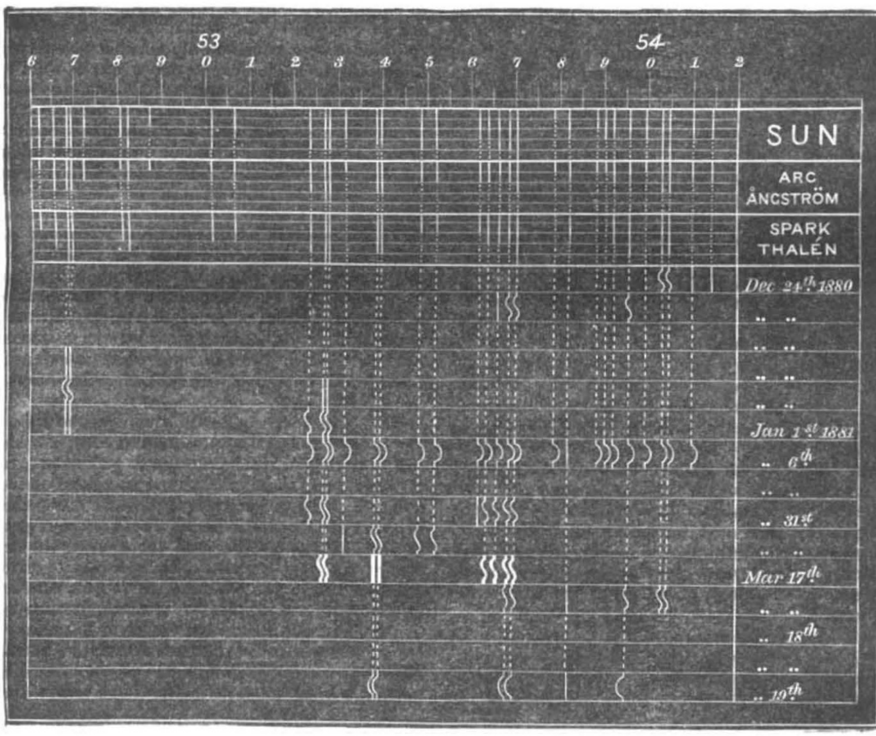

FIG. 37.—Different rates of motion registered by different iron lines.

It is seen therefore that the evidence afforded by change of refrangibility is of like nature to that afforded by the thickening of lines in spots and brightening of lines in flames.

The explanation which lies on the surface is that the vapours in the flames produce one set of lines in one place or at a certain temperature, and the vapours in the spots produce another.

Sometimes these vapours are mixed up by up-or-down rushes, and sometimes therefore the lines are common.

Bearing of these Observations on the Origin of the Fraunhofer Lines

At the end of the last lecture it was pointed out that the observations we are now discussing seem to indicate that in time we may be able to say that the absorption to which any particular Fraunhofer line is due takes place in a certain region of the solar atmosphere, whereas formerly we could only say that it was produced by absorption *somewhere*.

[1] Lectures in the Course on Solar Physics at South Kensington (see p. 150). Revised from shorthand notes. Continued from p. 324.

The time has now come, I think, to go into this question in more detail.

Let us consider the maps. Of the 96 iron lines in that first region which we considered only 4 are seen in the flames; 92 of those therefore must not be looked for in the flame region, for the reason that twelve years of patient work have not divulged their existence. Again of these same 96 lines only about 32 are seen in the spots at all extensively affected. It is useless therefore to look for the remaining 60 lines or thereabouts in the same spot region, for the reason that they have been looked for for a long time without being seen equally widened.

Of course it must be remembered that these changes are due to *change of intensity*, and that other lines may be there of an intensity so low that they have escaped the keen eyes of those anxious to chronicle them. Still it will be acknowledged, I think, that the method of treatment I have adopted is the best open to us, and is a fair one on the whole.

The facts being so, it looks really as if the origin of the mass of the absorption to which the Fraunhofer spectrum of iron is due is to be sought in a region of the solar atmosphere much nearer to the place assigned to it by Kirchhoff originally than to that lower region where we considered we were driven to place it when the new method was first established. When the new method had been working for some considerable time observers recorded hydrogen with magnesium underlying it, and with sodium underlying that. And since they were metals of low atomic weight and vapour density we were justified in considering them as occupying the highest levels—the very extreme limit of the solar atmosphere.

It was therefore fair to argue that if the substances of the lowest atomic weights were really close to the photosphere, those of highest atomic weights were really in the photosphere itself, and therefore, being in the photosphere, the absorption by means of which we were able to determine their existence really took place in or near the photosphere.

This later work, I think, seems to show that that view requires reconsideration; and it may well be that subsequent work will show that those Fraunhofer lines, which we do not trace in flames and which we do not trace in the spots, are probably absorbed in a cooler, higher region of the atmosphere, much more nearly occupying the place assigned to the general atmosphere by Kirchhoff than that which has been given to it by later observers. If we accept this the work becomes a little plainer, and the reason that we get such an excessively simple spectrum in the lower reaches of the sun is because the more complex vapours exist at a considerable elevation above them, and as the interior of the sun must be hotter than any of its envelopes, no cold substances—nothing approaching the solid state which we have learnt for many years gives us the most complete spectrum of the substance—nothing approaching a solid can enter those charmed regions.

Therefore we are also again driven to the view that these cooler vapours—vapours much nearer the solid state, much more condensed, much more complex than those which can exist alone in the hottest layer—probably originate the great mass of absorption; that is, many lines not traced either in spots or flames are produced in the higher regions.

If this be so, the Fraunhofer spectrum is really not the spectrum of any particular part of the sun; but because it contains lines thickened in the spots, lines brightened in the flames, and other lines about which we know nothing, it must really be the summation of the absorption of the different strata which compose the solar atmosphere; so that chemically the solar atmosphere, with regard to the iron spectrum, gets more and more complex every mile we go upwards. Of course, too, if this is good for iron it is good for every other substance which we believe to exist in, or to have some connection with, the solar atmosphere.

Further Test supplied by this View

If this be so we really can go on with our tests; we can bring the laboratory into the field, and we must learn in our laboratory experiments to make abstraction of those lines which are due to the more complex masses reduced by the transcendental temperature which we employ, if there is any truth in the view that I am bringing before you. In a laboratory experiment, for instance, when we want to observe the vapour of iron we have to employ two poles of solid iron. We have no means, such as are afforded us by the sun, of shielding the precise part we want to observe by a considerable number of envelopes of gradually-increasing temperature, so that even if we can get the highest temperature in the laboratory this result of the highest temperature will be cloaked, masked, and hidden by all those results, by all those simplifications which have been brought about to produce that precise effect of the highest temperature. So that the only thing we can do is to watch the intensities of the lines when we considerably change our temperature. I am speaking now of iron. I will show by and by that for some other substances there is a method which enables us to get over this excessive difficulty, for no doubt a very great difficulty it is; but in the case of iron, that really is the only thing that remains to us. Fig. 38 will give an idea of the way in which we may be misled if we do not examine our light source with the greatest care. It is engraved from a photograph of the spectrum taken between two poles of a Siemens machine, moistened with a salt of calcium, an image of the vertical poles having been thrown on the vertical slit.

It is seen how wonderfully we get the simplifications brought about by the electric current, depicting themselves in two perfectly distinct ways. The lower part gives the spectrum of the positive pole, and the upper part of the spectrum of the negative pole. In the first place it will be seen that there is no axis of symmetry for these lines; some of them elongate considerably in one direction; others of them elongate considerably in the other; some of them are exceedingly short, and only appear close to that region of the negative pole where the lines broaden; others again are brighter in the region much nearer the middle of the field. Others of the lines start from a region far removed from the arc; others again seem to start almost in the arc itself. Now this not only reminds one of what one sees in a solar storm, but it shows us most distinctly that even in the electric arc, when we have had time to study it sufficiently, these very simplifications which we have been so long in search of may be recognised eventually and permanently recorded.

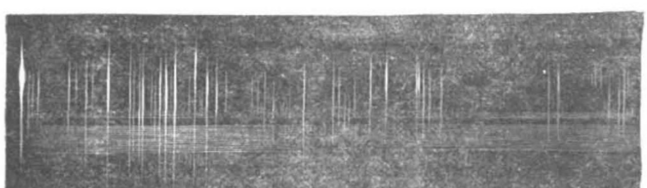

FIG. 38.—Photograph of the spectrum of the poles, showing that the lines start and end in different levels.

Tests supplied by the Variations between Solar and Terrestrial Spectra

Attention has been called to Kirchhoff's statement that the existence of the terrestrial elements in the sun is established by the fact of the coincidence of wave-length and *intensity* between the lines visible in our laboratories and the lines recorded as existing in the solar spectrum.

We have now arrived at a point when we can discuss this with advantage.

I propose to show first that the statement is not true; and, secondly, how the tests supplied by the variations from terrestrial spectra can be explained on, and bring most valuable confirmation to, my view. We are now able to say that at least two causes are at work, and they will require to be discussed separately.

But first as to the facts. We have already seen what enormous differences there are in the spectrum of calcium under different conditions. In the diagram of the calcium spectrum (Fig. 28) we saw that H and K, the most important lines in the sun, are really thin lines at the temperature of the electric arc, but that they kept intensifying and were rendered visible almost alone, when, instead of using the electric arc we used an induced current of considerable tension. But when we pass from the case of calcium, which occupied the attention of solar observers several years ago, to other elements, and when we go still more into the minute anatomy of the thing, we find that the further we go the less final is the statement that the matching in intensity of the lines is perfect.

Nor is this all. *Not only is the matching less perfect in intensity, but whole reaches of lines in various spectra are left out which cannot be accounted for on the long and short principle.* It has been before pointed out that of the 26 lines of aluminium, 2 only being left in the solar spectrum is easily explained, because the 24 dropped were short lines. But when we come to other elements, we find of adjacent lines—lines of equal length, and which, so far as we can gather, ought to be equally represented in the sun—one is absent, and one is present, probably with more intensity than it would seem to deserve from its behaviour among other lines of the spectrum. A table will best exhibit the sort of variation that crops up and insists on being recorded when the solar spectrum is photographed in anything like the detail which it absolutely demands. The method of recording will be at once understood.

Metal.	Wave-length.	Intensity in sun. 1=darkest.	Intensity in photograph. 1=brightest.	Intensity. Thalèn. 1=brightest.	
Mn	4083·0	4	2	5	
	4083·5	3	2	3	
Fe	4197·5	1	2	–	
	4198·1	3	2	–	Stronger line.
Co	4118·0	2	1	–	
	4120·5	4	1	–	Stronger line.
Ni	4458·6	2	2	–	
	4647·8	3	2	5	
Cr	4344·4	4	3	2	
	4351·8	3	3	2	
Mo	4706·5	3	1	4	
	4757·5	0	1	4	
W	4842·0	5	1	1	
	4887·5	3	2	2	
Ti	3980·8	2	1	–	
	3989·25	1	1	–	
Zn	4679·5	3	1	1	
	4721·4	4	1	1	
Pt	4442·0	4	2	4	
	4551·8	3	2	2	
Pd	3893·0	1	1	–	
	3958·0	3	1	–	Stronger line.
Zr	3957·22	2	1	–	
	3990·45	3	1	–	Stronger line.
Di	3989·65	0	1	–	
	3993·98	3	1	–	
Rb	4201·0	0	1	2	Stronger line.
	4215·5	3	1	0	

Now if Kirchhoff's view be anything like a representation of the whole truth there ought not to be any difference between these intensities; the line least intense in the photograph ought to be least intense in Thalèn's tables, and if it existed in the sun at all, it ought to be least intense amongst the Fraunhoferic lines, but as a matter of fact, there is an absolute inversion. The cobalt line 4120·5 is four times as intense in the sun as in the photograph; in the titanium line 3989·25 the intensities are equal; while in tungsten 4842·0 they are inverted, being represented as of minimum intensity in the sun, and maximum by Thalèn and in the photograph. In the sun one of the lines of iron is given as of first, and the other as of third intensity, while in the photograph they are both of second order. Again, in didymium we get a first order line recorded in the photograph which is absent from the sun altogether, whereas another line of the first order near it is there as a line of small intensity; so also in rubidium, and so we might go on. Indeed it is evident that the moment we go into minute details in this work we find that the general statement requires a very considerable amount of modification. And in addition to that too, there comes the question, how on this theory of the identity of the nature of the substances in the earth and the sun, are we to account for the bright lines seen in the sun itself—for the bright lines seen in the photosphere, to say nothing of those seen in the chromosphere — which have no corresponding Fraunhofer lines at all—lines so numerous that in a prominence of moderate complexity we may say that half the lines are absolutely unknown to us? Now when the other lines observable under these conditions—lines which we can get accurately, are lines known to us (we are dealing with the product of the very highest temperatures which we can command) we are justified, I think, in imagining that these lines which we do not get at, are lines which we could get at if we could proceed a little further. They elude our grasp; we know nothing about them; we put a query against them all because we cannot get at that stage of temperature at which they are produced.

There is one very beautiful case of this kind that comes out from Tacchini's observations (Fig. 39). From the beginning of February, 1872, Tacchini had observed the two iron lines 4922·5, 5016·5, when suddenly the whole rhythm of his observation was broken, and at the end of December, 1872, these iron lines ceased to be visible in the flames altogether.

On no one occasion after this for some time was either of these iron lines observable, but from January to September, 1873, he saw two lines of wave-lengths, 4943 and 5031, about which absolutely nothing whatever is known; so that it really is, I think, a perfectly justifiable suggestion that these lines are the spectrum of a substance which exists in the flames which is produced at a much higher temperature than that needed to give us those other forms of "iron" which produce the lines in the spots.

That is a suggestion which is obvious from a reference to the maps, and if it is correct we must acknowledge that when the sun was in that intense state of quiescence that there were no downward currents—nothing to bring the cooler vapours from the higher regions of the sun down to obstruct the general tenour of the solar way in the flame region, that at last, in consequence of this wonderful tranquillity, even the iron lines—the only two lines which indicate the presence of iron in the flames—faded away because iron, as we know it, faded away. There is no other explanation that I know of. In addition to those two lines we have two other lines about which we know nothing, except that they are probably due to a temperature which we cannot approach.

Special Test with regard to Iron

Part of the work which has been undertaken in connection with this special branch of the investigation, has been a careful inquiry into the changes brought about in the spectrum of iron by exposing it to as widely different temperatures as possible. The research is a very laborious one, and it may be some day we shall get a very much better record than that which my assistants and myself have produced; what we have been able to do we have done over the region of the spectrum which we have already worked over in the spots and flames.

In different horizons we have recorded the results observed when we use either the arc or the coil, or the oxyhydrogen flame or the Bessemer flame or some other light-source, and we vary in each case, as far as can be, the temperature employed. For instance, when we use the quantity coil we use a big jar, a little jar, and no jar at all; and the same with the intensity coil. Now if this map is carefully studied,[1] it will be seen that the intensity of the lines is very considerably changed when we pass from one set of observations taken under one set of conditions, to another set taken under other conditions. It is not a mere question of dropping out the lines when we pass from the temperature of the arc to the temperature of the coil, but it really is a considerable intensification of certain of the lines under certain conditions. There are three conditions under which we get the two lines 5339 and 5340, and they are not seen afterwards. The line 5433 is seen rather faint in the sun and very strong in the Bessemer flame. 5197·5 is very faint in the sun, but its intensity is doubled and even trebled with certain conditions of the quantity coil. I have introduced these facts to point a remark about Kirchhoff's statement; when Kirchhoff made that statement he was amply justified by the science of the time. He was familiar naturally with the spectrum of iron, which he had studied in his own laboratory, and other good observations of the spectrum of iron had been recorded in his time. But, with observations like these before one, which

[1] The map is too large and too detailed to be reproduced here.

one must take into account; it is too *coarse* a statement—I do not use the word in any offensive sense—to say that the iron lines in the sun correspond with the iron lines seen on the earth. Which iron lines—which of these horizons—are to be taken? It will be seen in a moment, if there are differences between these horizons, that if we take any one, we throw all the others out of court, and we have no right to do that; so that statement about the coincidence in the intensity could not be made with the facts now at our disposal. Any one wishing to make that statement would have to go over that work, and he would, following it honestly, I believe, find that the statement was true in no instance whatever. Fig. 40, which is an engraving from a photograph, will show the kind of difference one gets, even when one deals with the electric arc, which undoubtedly gives an iron spectrum which is the nearest approximation to the Fraunhoferic spectrum. The lines at wave-lengths 4325·0, 4300·7, 4271·0 are three of the strongest iron lines in the arc spectrum, and those at 4071·0, 4063·0, 4045·0 are also strong iron lines, though less strong than the others. Now it will be seen that in the solar spectrum the last three are much more important, much thicker, and much darker than the first, so that here is an absolute inversion in the thickness of the lines. I

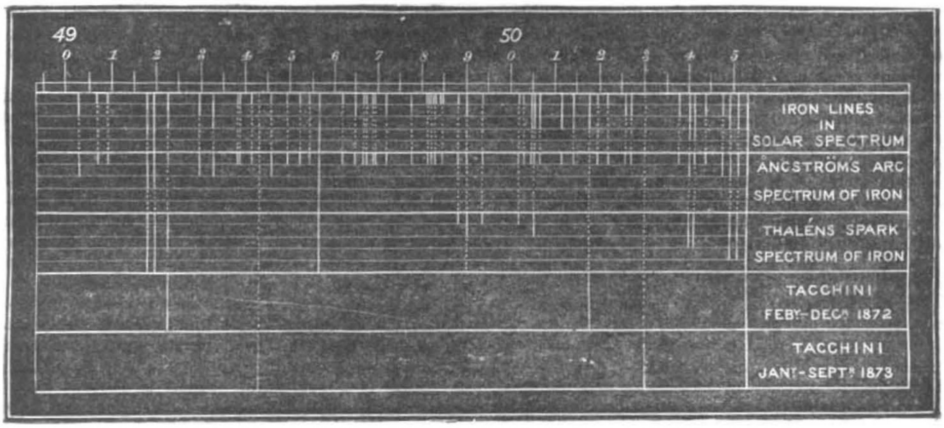

FIG. 39.

appeal to the photograph because there is no partiality about it; it has no view, no anxiety therefore to intensify one particular part of it at the expense of the other. This photograph is referred to only as the exemplar of many similar reversals which we see whenever such observations are made.

Let us now take some iron lines which have been studied in spots and storms, and consider the differences in their intensity among the Fraunhofer lines. We may also note the changes brought about in our laboratories.

The diagram (Fig. 41) gives the main results in a convenient manner. It does not profess to go over the whole ground, but I think it will enable me to point out the way in which the phenomena observed on the sun are re-echoed and endorsed by the work which has been done in the laboratory,

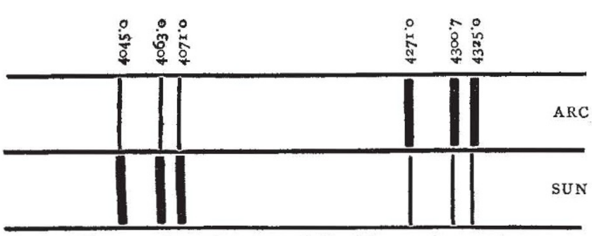

FIG. 40.—Anomalous reversals (iron) from a photograph.

and how severe the tests applied have been, and how well the view has borne the strain.

The diagram refers to three lines visible in the first map—three lines that in an instrument of ordinary dispersion might easily be mistaken for a single line in the sun. We have, as before, the intensities among the Fraunhofer lines recorded in the upper part of the diagram; we then go to our photographs of the arc, and find that the line at 4923·2 is entirely absent. We then pass on to the quantity coil, which gives us the three lines; but there is a difference between the intensities of the lines as seen in the quantity coil with a jar, and the lines seen in the sun, 4918 being thinner than in the sun. If we take the jar out of circuit 4923·2 almost disappears, and we get very nearly the same result as we get from the arc. We then try the intensity coil, which is supposed to give us an equivalent or higher temperature than the quantity coil does. What do we find there? That 4923·2 is enormously expanded and developed, apparently at the expense of 4918, which becomes thin. Taking the jar out, we come back to a result which is very much like the solar spectrum, with the difference, however, that 4918 is somewhat less intense than in the sun. Then come the facts which have already been brought forward throughout with special reference to these particular lines, that the two lines which are seen alone in the arc are seen alone in the spots, or at all events in 73 spots out of 100; and the other line which is so enormously

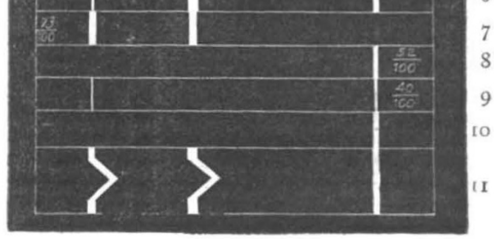

FIG. 41.—Diagram showing the behaviour of three iron lines under different conditions, solar and terrestrial. 1, solar spectrum; 2, arc; 3, quantity coil with jar; 4, quantity coil without jar; 5, intensity coil with jar; 6, intensity coil without jar; 7, spots observed at Kensington; 8, Prominences observed by Tacchini; 9, prominences observed by Young; 10, reversed in penumbra of spot observed on August 5, 1872, by Young; 11, motion indicated by change of refrangibility.

expanded when we use the highest temperature is seen alone in 52 out of 100 prominences by Tacchini. Again, further connecting this diagram with the last one, we have found in several cases when a change of refrangibility has been observed in the iron lines in the spots visible on the sun that the two lines 4918 and

4919 8 have been affected, while 4923·2 has remained at rest. That will give an idea of the way in which we really do find the laboratory work and the observatory work, each coming to the rescue of the other, each helping us to understand something which, without the other record, would be excessively difficult.

Tests supplied by the Absence of Lines from the Solar Spectrum

It is my conviction that many lines of the different chemical substances are absent from the solar spectrum when that absence cannot be attributed to anything depending upon reduction in the quantity of the substance present. In connection with this point there is an experiment to which attention may now be directed, because it is an attempt to imitate solar conditions somewhat; so that the inquiry is rendered possible as to whether these lines may not owe their absence from the Fraunhofer lines to their being the product of a very low temperature, a temperature which we cannot expect to find in the sun in any regions where the pressure would be sufficient to enable any absorption phenomena to take place. The point of the experiment is this: There are bodies which we can render incandescent at low temperatures. For iron, as we have already seen, we have to use a coil, but such substances as magnesium, sodium, lithium and the like can be volatilised at the temperature of the Bunsen flame, and at that temperature we get a certain spectrum from them. Now a great many different spectra have been recorded by different observers for these bodies, and the question was, could we get any independent method of determining which lines were really due to high and which to low temperatures. Now it is generally conceded that the temperature of the Bunsen flame is lower than the temperature of an induction spark; and we have an arrangement by which we can pass a spark between horizontal platinum poles through a flame in which the substance to be experimented on is volatilised. In this way we can see what change in the spectrum is introduced by the passage from the temperature of the flame to the temperature of the spark. We can fill the flame with the vapour, say of sodium, and observe its spectrum; then when the flame is nicely charged in the region between the two poles, we can pass a spark through it, and by throwing the image of the spark upon the slit of the spectroscope we can first of all get a spectrum of the flame, and then the spectrum also of that particular part of the flame through which the spark is passing. Now we really have got a good deal of light from that method of observation. In the case of magnesium, for instance, the change is very striking (see Fig. 42).

The flame gives us a spectrum in which are seen two lines corresponding with the two least refrangible members (b_1 and b_2) of a very prominent group of lines in the green part of the solar spectrum, and associated with these is a less refrangible line unrepresented in the sun, the whole forming a wide triplet. On passing the spark this last line is very greatly enfeebled, if not abolished altogether, for the very obvious reason that the molecule which gives rise to it is dissociated more rapidly at the temperature of the spark than it is at the temperature of the flame, and as that line dies out another solar line (b_4) appears, the three forming a triplet similar to, but narrower than, that

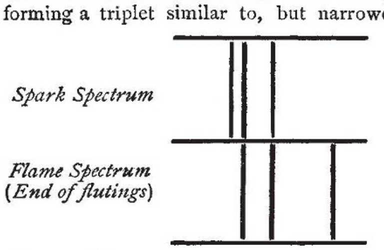

FIG. 42.—Flame and spark spectra of magnesium.

produced in the flame alone. Kirchhoff showed that potassium was not present in the sun, the line upon which he worked being the red line which is seen when potassium is thrown into a flame. The fact that we get that red line in the flame shows that it is a line produced by a low temperature; the molecule which produces the vibration therefore may probably be one which is produced at a low temperature. But when we pass a spark through a vapour giving us that red line we do not increase, but rather reduce, the intensity of the line, and we bring a great many lines into prominence which were not seen before, and those lines, I believe we are justified in saying, do exist among the Fraunhofer lines. In the same way we can colour the flame red with lithium, but the red line of lithium is not in the sun; but by passing a spark through lithium vapour we can intensify the line in the yellow and the line in the blue; and the line in the blue is undoubtedly among the Fraunhofer lines. Therefore it appears that we really can account for a great many of these variations in the solar spectrum by simply assuming that those lines which are absent represent molecular groupings so complex that there is no part of the sun where their absorption could be visibly produced, cold enough to allow them to exist.

Test supplied by the Lines strengthened in Spots and Flames and those seen in the Spectra of Two or more Substances

It has already been pointed out that these lines, which have been called basic lines, have been tested in two ways. In the first place, a list of lines had been prepared from Ångström's tables and Thalèn's tables, and then they had been discussed in connection with the bright lines seen by Young in his observations on Mount Sherman. The result was striking, inasmuch as of the 345 lines which were included by Young, only a small number of which were seen in spots and storms, 15 of the lines which were recorded as common to two substances by Thalèn, had been seen almost without exception, the only exception being in the case of some of the spots. The attack was then varied by taking 100 observations of sun-spots at Kensington, determining, without any reference to the basic nature of the lines at all, the 12 most widened lines in each spot which it was possible to observe; and then taking, side by side with these observations of the spots, 100 observations of flames from the rich store which has been recorded by Prof. Tacchini of Palermo. Then again, without reference to the basic character of the lines, to plot the lines down in each flame day by day.

As a reminder we may again refer to the diagram already given (Fig. 36). It will be remembered that the result was a very remarkable one. We found the lines of iron (we limited ourselves to iron) seen in the spots were few in number; that the lines of iron seen in the flames were still fewer in number, and moreover that the lines seen in the flames were not the lines seen in the spots. That was a result which might have been considered as very extraordinary if we had brought to it no other considerations than those with which we were conversant ten years ago when the work began.

What we have to do now, then, is to find what has been the result of this inquiry with regard to the basic nature of these lines. Have we, as a matter of fact, or have we not, in these most widened lines in spots, and the most brightened lines in flames, picked out those lines which are common to two substances. The facts are these:—We have, in the first horizon of the lower part of the accompanying map, the lines recorded by Ångström in his first memoir as common to two substances; the names of the two substances being given below. In the fourth horizon we have the observations of Thalen made a few years after the observations of Ångström. And in passing from Ångström to Thalèn we pass from the temperature of the arc to the temperature of the induction coil. Now it will be seen that Thalèn also gives us lines in some cases agreeing with Ångström's, in other cases extending the information given by him, and in order to make this work as complete as possible we have gone over this region with the arc as Ångström did, and with the induction coil as Thalèn did, only we have had the advantage probably of using a more powerful coil. In fact we have used two coils—one so arranged as to give us the maximum effect of tension, and the other the maximum effect of quantity. In the first place it will be seen there is a general agreement between the observations—an agreement marred only in appearance here and there by the fact that in some cases the lines are so near the position of air lines that it has been impossible to make the observation absolutely complete. In other cases the appearance of imperfection arises from the fact that lines which are not seen at the temperature of the arc begin to make their appearance at the temperature of the coil; so that in a case like *that* at wave-length 5017, for instance, where Ångström gives no line as common to two substances, yet Thalèn does. We find that both are right; that at the temperature of the electric arc that line does not appear in one substance or the other, while at the temperature both of the quantity and the intensity induction coil the line is certainly there. In Fig. 36 A represents Ångström's work, T Thalèn's, and L Q and L I my own work with the quantity and intensity coil.

What then is the total result? It is this—that every important line in the spots, every important line in the storms, has been picked up by this method, and in fact *the map of basic lines along this region is practically a map of the lines widened in spots and present in storms, and nothing else.* Now it may be said that result is interesting, and perhaps important, but that it deals only with a very limited part of the inquiry. That is perfectly true.

The spectrum of iron, and the spectra of other substances have however been attacked in other regions. It is unnecessary to go into many details, but the general result is the same; in other regions we have as in the old region an almost perfect coincidence between the lines most widened in spots, and the lines regarded as basic by previous observers.

So much then for the result in the case of iron, to which, although we have not absolutely limited our attention, we have to a very large extent confined it. This result may be expressed in rather a different way, and it will then be easy to see the extraordinary parallelism which goes on between two perfectly distinct sets of facts, first, the statement of the spectroscope that such and such a line is seen in the spectra of two or more substances, and then the statement of the telescope with the attached spectroscope that such and such a line is seen widened in spots or brightened in flames. Here we have the numbers for the two regions which I have already discussed the region from F to *b*, and from *b* towards D.

Iron

	F-*b*	*b*-548
Total number of lines	96	67
Number in spots and flames	38	41
Basic lines	15	17
,, seen in ,, ,, ...	14	15
,, not seen ,, ,, ...	1	2

The total number of iron lines in the first case is 96. Of those 96 lines only 38, or less than half, are found in the spots and flames. When we go into the lower regions of the solar atmosphere, we leave in fact more than half of the iron lines on one side. Of these 96 lines 15 are found by other observers as well as myself to be common to two or more substances. Now comes the question, what is the behaviour of these common lines with reference to spots and storms? The table shows that among the lines seen in spots and storms fourteen of these basic lines are seen. It must be remembered that our records only give us day by day the results of the 12 most widened lines, and not of all the lines widened. In the next region the number of iron lines is somewhat less—67; 41 of these, or more than half, are picked out by spots and storms; Seventeen are basic; of the 17 basic ones 15 are seen in the spots and storms, and only two are lines that are not seen.

Now, we will turn to another substance, nickel, and there we see very much the same kind of thing at work. In nickel for the region F to *b* we have 20 lines recorded by Thalén.

Nickel.

	F-*b*
Total number of lines	20
Number in spots and flames	3
Basic	5
,, Seen	3
,, Not seen	2

Of these 20, 17 are dropped, abolished, when we come to observe the bright lines and the widened lines of nickel in the spots and storms—the 20 comes down to 3. Among the 20 lines 5 are found to be common to two substances. Of those 3 are seen in the flames, that is to say, every line of nickel seen in a spot or flame is common to two substances, and only 2 are visible in the 20 lines not affected by spots and storms. This is all the work of this nature which we need now consider, but it is not all the work that has been done. Neither my assistants nor myself, I am sure, have spared our attempts, nor ourselves, for the matter of that, in trying to get at the bottom of this matter, and the facts which have been here brought forward are typical of a much larger number of facts which have been observed. In the case of every part of the spectrum, in the case of every substance, the verdict is the same. We have the fact, that two things are going on exactly parallel to each other—first that some lines are common to two substances; next that the lines common to two substances are seen almost exclusively alone, both in the sun's spots and in the sun's flames. So that in addition to the fact that the hottest regions of the sun seem to simplify the spectra of the substances enormously, we have this result that the simpler the spectrum becomes, the more complex becomes the origin of the lines; by which I mean that in the ordinary solar spectrum there are a great many lines due to iron, and to nothing else; but the moment we come to the simpler spectrum yielded to us in the spots or the flames, then we have no more right to say that those lines belong to iron than that they belong to titanium, cerium, nickel, and other substances with which those lines are generally observed to be basic.

This, then, is a help towards the demonstration of the view which was first announced in the year 1874, that the line-spectra of bodies (we are dealing almost exclusively with line-spectra) are not produced by the vibration of similar molecules, but they probably represent to us the vibrations of a great number of simplifications brought about by the temperature employed to produce the incandescence of the vapours.

Can we go further than this? Here we must confess both our imperfect instrumental and mental means. We cannot talk of *absolute* coincidence because the next application of greater instrumental appliances may show a want of coincidence. On the other hand there may be reasons about which we know at present absolutely nothing which should make absolute coincidence impossible under the circumstances stated. The lines of the finer constituents of matter may be liable to the same process of shifting as that at work in compound bodies when the associated molecules are changed; but however this may be the fact remains, whatever the explanation may be, that the lines of the elementary bodies mass themselves in those parts of the spectrum occupied by the prominent lines in solar spots and storms.

J. NORMAN LOCKYER

(*To be continued.*)

STATE MEDICINE[1]

FIRST: a few words on what may be called the general theory of our subject-matter. The term "State Medicine" corresponds to the supposition that, in certain cases, the Body-Politic will concern itself with the health-interests of the people —will act, or command, or deliberate, or inquire, with a view to the cure or the prevention of disease. Before any such supposition can be effectively realised, the science of medicine—that is to say, the exact knowledge of means by which disease may be prevented or cured—must have reached a certain stage of development; and unless the science be supposed common to all persons in the State, the existence of State medicine supposes a special class of persons whom the unskilled general public can identify as presumably possessing the required knowledge. Thus, given the class of experts to supply the required exact knowledge, the Body-Politic undertakes that, within the limits of its own constitutional analogies, it will make the knowledge useful to the community.

I have intimated that in State Medicine (just as in private medicine) the medical function may be exercised either in curing or in preventing disease; but practically these two departments of State Medicine are not of equal magnitude, nor are dealt with in quite the same spirit.

As regards curative medicine, modern Governments have in general found it needless to interfere in much detail in favour of persons who require medical treatment.

Larger and far more various than the action taken by the State with reference to the cure of disease is that which it takes in regard of prevention; and it is particularly of preventive medicine that I propose to speak. In its legal aspect it is represented by a considerable mass of statutes (nearly all of them enacted within the last thirty-five years), and by an army of administrative authorities and officers appointed to give effect to those enactments. I need not describe in detail the laws and administrative machinery to which I refer, but I may remind you of the largeness and variety of the scope, even by quoting only the terms in which I was able, twelve years ago, to speak of the public health law of England: "It would, I think, be difficult to over-estimate, in one most important point of view, the progress which, during the last few years, has been made in sanitary legislation. The principles now affirmed in our statute-book are such as, if carried into full effect, would soon reduce to quite an insignificant amount our present very large proportions

[1] An Address delivered at the opening of the Section of Public Medicine, in the International Medical Association, by John Simon, C.B., F.R.S., D.C.L., LL.D.