THE SHIFTING OF SPECTRAL LINES.

I.

THE *Astrophysical Journal* for February contains some papers of the highest interest, touching small variations in the wave-lengths of spectral lines and the causes which produce them. These are stated to have been, in the first instance, established by Mr. Jewell by an examination of the Rowland series of photographs of the solar and metallic spectra taken by means of a concave grating of 21½ feet radius and 20,000 lines to the inch—an instrument of research which, so far as my own experience goes, is not to be obtained by workers in this country.

Mr. Jewell's investigations began in 1890. Another paper by Messrs. Humphreys and Mohler details the results of work begun last year on the effects of pressure on the arc spectra of the elements, work suggested by Mr. Jewell's prior researches.

Mr. Jewell has, as a basis for his new conclusions, practically studied under modern conditions classes of phenomena which I was the first to observe and describe, as near as may be a quarter of a century ago.

To show the relation of the new work to the old, it is best to begin with a short historical statement, which will have the advantage of giving to non-experts an idea of the meaning of some of the terms employed.

I first employed the method of throwing an image of a light source on to the slit of a spectroscope by means of a lens in 1869, and some of the results obtained by the new method were the following.

(1) The spectral lines obtained by using such a light source as the electric arc, were of different lengths; some only appeared in the spectrum of the core of the arc, others extended far away into the flame and outer envelopes. This effect was best studied by throwing the image of a horizontal arc on a vertical slit. The lengths of the lines photographed in the electric arc of many metallic elements were tabulated and published in *Phil. Trans.*, 1873 and 1874.

(2) The longest lines of each metal generally were wider than the others, the edges fading off; and they reversed themselves; by which, I mean, that an absorption line ran down the centres of the bright lines. These results were afterwards confirmed and extended by Cornu ("Chemistry of the Sun," p. 379).

(3) From experiments with mixtures of metallic vapours and gases, it came out that the longest lines of the smaller constituent remained visible after the shorter lines had disappeared, the spectrum of each substance present getting gradually simpler as its percentage was reduced,[1] the shorter lines being extinguished gradually. Shortly after these observations were made, I included among some general propositions:[2] "In encounters of dissimilar molecules the vibrations of each are damped."

(4) The various widths of the lines, especially of the winged longest ones, were found to depend upon pressure or density, and not temperature.[3]

(5) The "longest lines" of any one metal were found to vary in their behaviour in most extraordinary fashion in solar phenomena, being furthermore differentiated from the shorter ones; and on this and other evidence I founded my working hypothesis of the dissociation of the chemical elements at the solar temperature. In 1876 I set out the facts with regard to calcium.

(6) In 1883, Prof. W. Vogel, in a friendly criticism, pointed out the evidence then beginning to accumulate, that under certain circumstances the wave-lengths of lines are changed.[4] In 1887, I extended this evidence,[5] and I think it was I who coined the word "shift" to express these changes.[1]

I now pass on first to the results which Mr. Jewell claims to have established.

With the enormous dispersion produced by the instruments referred to, it is found that certain metallic lines, but not all, are displaced or "shifted" towards the violet when compared with the corresponding solar lines. "There was a distinct difference in the displacement, not only for the lines of different elements, but also for the lines of different character belonging to the same element."

The "different character" above referred to turns out to relate not so much to the intensity as to the length, and, associated with this, the reversibility of the lines; the longest lines are the most displaced, the shortest, least.

Further, in the spectrum of the arc itself, the position of a line with but little material present "was approximately the same as the position of the line when reversed." Now since the longest lines are most displaced to the violet, this means that the smaller the quantity of a substance present the greater is the displacement towards the violet; and therefore the greater the quantity present, the greater the displacement towards the red.

Further on, Mr. Jewell expressly states "it was found that with an increase in the amount of the material in the arc there was an increasing displacement of the line towards the red," and then he adds, "unless the line became reversed, when all further progress in that direction ceased."

Here is an observation regarding the red line of cadmium. "It was found that if the micrometer wires were set upon it with very little cadmium in the arc, then as the amount was increased the line almost bodily left the cross-hairs, always moving towards the red."

Mr. Jewell considers he has established that the vibration period of an atom depends to some extent upon its environments. "An increase of the density of the material, and presumably an increase of pressure, seemed to produce a damping effect upon the vibration period."

My result of 1872 with regard to pressure is endorsed, "the new results are found to be due to pressure and *not* temperature."

We seem then now to be in presence of two damping effects in the case even of metallic lines, one which extinguishes lines when we deal with dissimilar molecules, and one which changes their wave-length towards the red when we deal with similar molecules.

A carefully prepared table is given by Mr. Jewell, showing the origin, intensity and character of the solar lines considered, the intensity and character of the corresponding metallic lines, the wave-lengths of both, and the observed displacement.

There are many references to solar phenomena in Mr. Jewell's paper, but I do not propose to discuss them now. There is one point, however, I must refer to, in justice to my critics. He considers that the conclusions to be drawn from a study of the new shifts "effectually disposes of the necessity of any dissociation hypothesis to account for most solar phenomena." I have already pointed out that this was Prof. W. Vogel's conclusion with regard to possible shifts, so far back as 1883.

It is quite easy. "Two adjacent lines of iron, for instance, may show the effects of a violent motion of iron vapour in opposite directions, in the neighbourhood of spots, or one line (the smaller one corresponding to one of Lockyer's 'short lines') may show a broadening and increase of intensity in the spectrum of a sun-spot,

[1] *Phil. Trans.*, 1873, p. 482.
[2] "Studies in Spectrum Analysis," 1878, p. 140.
[3] *Phil. Trans.*, 1872, p. 253.
[4] NATURE, vol. xxvii., 1883, p. 233.
[5] "Chemistry of the Sun," p. 369.

[1] Since the parentage is uncertain, I may say that perhaps "shiftings" would have been a better word, as shift is otherwise employed, *e.g.* Love's last shift (translated by a French author, *la dernière chemise de l'amour*).

while the other line (the larger one corresponding to one of Lockyer's 'long lines') is unaffected. But this does not prove that iron vapour is dissociated in the sun. It merely shows that the apparently similar portions of the two lines in the solar spectrum are produced at different elevations in the solar atmosphere. The stronger iron line will be affected in a sun-spot as much as the other one, but it is the portion of the line produced at the same level as the other line, and may be masked completely, or very largely, by the emission line produced at a higher level, while the second absorption line in the solar spectrum may be entirely unaffected, being produced at a still higher altitude."

"This also explains why some of the lines (the short lines generally) of an element may be most prominent in sun-spot spectra, while others (generally the long lines) are those most frequently seen in prominences or in the chromosphere."

My thirty years' work at solar physics leaves me with such an oppressive feeling of ignorance that I willingly concede to Mr. Jewell a knowledge so much greater than my own as to give him a perfect right to dismiss all my work in two lines; but I am compelled to point out that he has not carefully read what I have published.

A comparison of the facts brought together in Figs. 112 and 114 of my "Chemistry of the Sun," for instance, drives his last paragraph into thin air: it is distinctly shown that we have to do with the short lines in the chromosphere and with the long lines in spots, the exact opposite of his statement. Mr. Jewell is not running counter to my views in supposing that different phenomena are produced at different elevations. I thought I had abundantly proved in my eclipse observation of 1882 ("Chemistry of the Sun," p. 363), that the iron lines, to take a concrete instance, are produced at different heights in the solar atmosphere; and that was one among many reasons which compelled me to abandon the thin reversing layer suggested by Dr. Frankland and myself in 1869 in opposition to Kirchhoff's view; but surely the more we consider the solar atmosphere as let out in flats, with certain families of iron lines free to dwell in each and to flit *à discretion*, the more a dissociation hypothesis is wanted. And beyond all this, we have to take into account that at the sun-spot maximum no iron lines at all are seen amongst the most widened lines, while at the minimum we have little else.

Another very interesting part of Mr. Jewell's paper refers to the phenomena of absorption. There is room for plenty of work here. As I pointed out in 1879, we get unequal widenings, "trumpetings," and a whole host of unexplained phenomena.[1] It is clear that the enormous dispersion at Mr. Jewell's command will largely help matters.

I now pass to Messrs. Humphreys and Mohler's paper.

Messrs. Humphreys and Mohler have used an electric arc enclosed in a cast-iron cylindrical vessel, which enabled them to vary the pressure up to fourteen atmospheres. One hundred photographs have been taken, and the shifts of some lines of twenty-three elements have been measured. The accompanying rough diagram, bringing together specimens of their observations, will indicate the kind of result they have obtained.

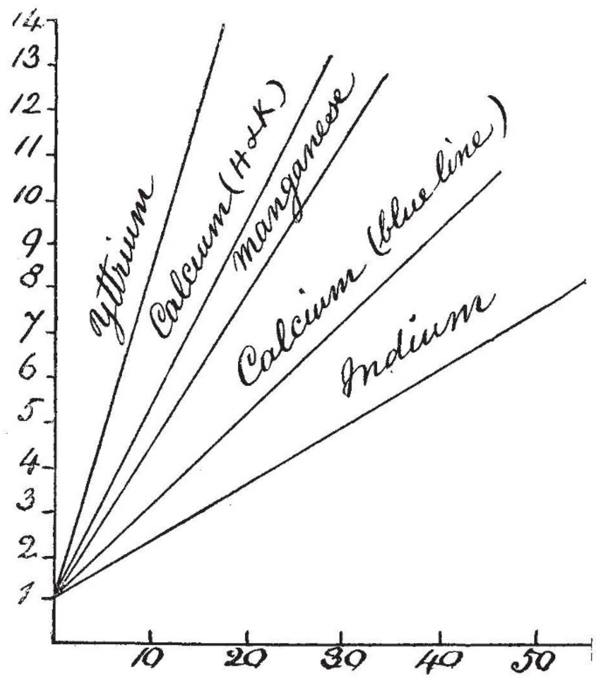
The pressures in atmospheres are shown to the left. The shift towards the red in thousandths of an Angström unit are shown below. The shifts have been reduced to what they would be at λ 4000, in the neighbourhood of which most of the work was done. I must refer to the paper itself for the method of measurement adopted.

The displacement or shift varied greatly for different elements. It was always towards the red, and directly proportional to the wave-length and the excess of pressure over one atmosphere.

Only one exception to this general statement is given; it refers to calcium. "The lines H and K, among others, shift only about half as much as *g* (the blue line at 4226), and the group at wave-length 5600. That *g* should differ in this respect from H and K is not very surprising, since it is known to differ greatly from them in many other respects."

On this exceptional behaviour of these lines of calcium, I quote the following, from a note by Prof. Hale, which appears in the same number of the journal.

"The difference in behaviour of H and K and the blue line of calcium discovered by Messrs. Jewell, Humphreys, and Mohler, seems to support Lockyer's views as to the dissociation of calcium in the arc and sun. The remarkable variations of the calcium spectrum with temperature have long been known principally through the investigations of Lockyer. The writer has shown that the H and K lines are produced at the temperature of burning magnesium and in the oxy-coal-gas flame. They could not be photographed in the spectrum of the Bunsen



burner, though an exposure of sixty-four hours was given. Since these experiments were made, I have been informed by Prof. Eder that his own efforts to photograph the lines in the Bunsen burner were no more successful, though an optical train of quartz and fluor-spar was employed. It would thus appear that the temperature of the dissociation of calcium is between that of the Bunsen burner and that of the oxy-coal-gas flame. The high molecular weight of calcium has hitherto conflicted with our belief in the presence of this metal in prominences. If, however, it be granted that dissociation can be brought about by temperatures even lower than that of the arc, the difficulty is very greatly lessened."

I may add that it will be very interesting to see if the strontium line at 4607 behaves like the calcium *g* in relation to the lines at 4077 and 4215 representing H and K.

I have said enough in the present paper to show the extreme importance of these new results. So much care has been taken, that there is little doubt that subsequent

[1] "Chemistry of the Sun," pp. 380-387.

work will confirm them; and when this is done, students of spectrum analysis will find a new region of the highest importance open to their inquiries.

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(*To be continued.*)

THE VARANGERFJORD REGION AND THE FORTHCOMING SOLAR ECLIPSE.

WE expect to have during this summer a good many visitors to the far north of Norway under the 70th parallel of north latitude, and close to the frontier of Russia. The total eclipse of the sun on August 9 (a few minutes before 5 a.m.) will attract many astronomers to these high latitudes. The sun will rise only 14° above the horizon during the eclipse, but the mountains here are not so high as to prevent the selection (though with some little difficulty even on the fjords) of places where their height will not prove an obstacle to the observers. In case one is in doubt, our official almanac gives the time when the sun will be visible on May 3; add nine minutes to that time, and it will be the time when the sun will rise over the mountains at the particular place.

It will be more difficult for astronomers to get a clear sky. The neighbourhood of Vardö, which otherwise would be very suitable, is plagued with fogs in the summer. Vadsö has more advantages, but still better are such inland places as Polmag, Utsjoki, Karasjok, Kautokeino, and Karasuando (in Sweden).

I shall give here some information for the guidance of those who intend to visit this remote corner of the earth.

The Varangerfjord ("ng" pronounced as in singer, not as in anger) runs inland west-north-west; the land lying north of it is called the Varanger Peninsula, and that to the south of it South Varanger. All the land is fjeld (mountainous land, highlands), but it rises nowhere to any great height. There are no good maps of this region, except of the eastern part of South Varanger, of which the Government recently published a map on the scale of 1 in 100,000; it is the best map. There is also the ethnographical map of Finmark, by Friis, scale 1 in 200,000 (Christiania, 1888). On this remarkable map every family is indicated by a separate mark; it indicates also the language they speak, and gives other details. It is, naturally, only in such a very sparsely populated region that such minute details can be represented on a map.

The Varanger Peninsula is a plateau which on its western border attains a height of 2200 feet, and on its southern about 1500 feet. The plateau is, however, not quite level, but presents such long, gentle undulations as are seen on the open ocean in calm weather. The permanent population, which keeps to the sea-coast, has here and there some outlying fields in the open parts of the valleys near the sea.

With the exception of these and the immediate neighbourhood of the settled places, the whole region consists of rolling mountain-tops practically unknown to the civilised world. It can, according to all that we know of it, be described as a wilderness of rocks, a stony desert covered here and there with reindeer moss (*Cladonia rangiferina*), and some swampy places where there thrives a scanty vegetation of green plants. Towards the inner part of the Varangerfjord there are some stretches of damp ground, overgrown with dwarf willows. About the centre of the peninsula are some large lakes full of fish, which only a few Norwegians have visited. However, access to them (apart from the question of distance) is not difficult from the south, for although there is no road, one can be driven there in a little cart. In winter, a few clever snow-shoe skaters have crossed this completely desolate, uninhabited land from north to south, a distance of forty English miles.

The western side of the Varanger Peninsula has a steep coast-line, but between Vardö and Vadsö the slope of the land seawards is very gentle; to those who sail along the coast the country seems quite level.

The appearance of the coast at Vardö is seen in the illustration on p. 418, desolate and dreary, truly an Arctic desert land; to the right is a bay of the sea, and the flat land in the foreground, consisting of gravel, exhibits some characteristic curved lines; they are raised sea-beaches. Probably one must go to the great lakes of America to find equally brilliant examples of former water-levels. The uplifting of the land has not been uniform. On the north side of Varanger Peninsula the old beaches are 70 feet above tide, but on the south, at Vadsö, they have been raised to between 260 feet and 295 feet. Probably the land is rising at the present time. In Vardö, old people point out quays which have risen several feet during their lifetime. The Austrian astronomer, Pater Hall, who came to Vardö in 1769 to observe the transit of Venus, was so much interested in this question, that he caused a little pillar to be erected, the height of which above the then existing tide-level was accurately determined. He inserted in the parish register of Vardö a description of the position of this pillar; but, alas! though the register is still in existence, the pillar has disappeared. The land on the south side of Varangerfjord, South Varanger, is not quite so bleak and bare as Varanger Peninsula; it has some pine forest in the valleys. It also can be considered a plateau; but it is furrowed by valleys and fjords, and is thereby broken up into a multitude of small, flattish, dome-topped mountain masses. The plateau character is shown by the fact that all the mountains rise to about the same height; in the eastern part, near the sea, to about 1300 feet.

These differences in the landscape and in the character of the country are connected with the fact that there are not the same kinds of rocks on the south side of the fjord as on the north side; probably there is a line of faulting along the fjord. On the south side there are Archæan gneiss and granitic rocks; on the north side younger rocks (conglomerates, sandstones, and slates), probably of Cambro-Silurian age; but fossils have not as yet been discovered in them. A remarkable conglomerate occurs in the inner part of the Varangerfjord; it may have been formed during a very remote Glacial period, probably Cambro-Silurian. It contains striated boulders, and rests partly on an underlying bed which shows glacial striations.

We shall now take a glance at the inhabitants of this province, Finmark, which touches the Russian frontier. The Norwegians gradually migrated into it during the last few centuries, but the Laps were already there. Many of the Laps wander as nomads with their reindeer, and dwell in tents, but the greater part of them live on the sea-shore, poor fishermen and farmers (like the crofters in the isles of Scotland), who grow a little hay for their cattle, and a few potatoes for themselves. There are no cereals in this northerly province.

Many of the inhabitants live in wretched earth-huts, which they share with their cattle. The Fins, who came from the grand-duchy of Finland, were the last to migrate into this district. The immigration commenced more than a century ago; it attained its maximum between twenty and ten years ago, and it is now decreasing. The language of the Laps differs about as much from that of the Fins as English differs from German; the Norsk language, as is well known, belongs to another group, the Germanic. All the three races are Lutherans. Finmark is very thinly peopled; the whole population in 1891 was 23,000 on an area of 47,000 square kilometres, or about two square kilometres to each individual. Finmark