It is unlikely that better conditions exist anywhere than in the region above referred to. Some of the waters are land-locked, some open to the ocean; the great variety in the range of the tide, tending to magnify the undulations where the range is great, and leaving scarcely anything else but these undulations and the effect of storm disturbance, where the tide is flat; the completeness of the meteorological data and the well-charted storm tracks, furnish ample material for comparison. The investigation has not yet been taken up by this Survey, which has to be carried on with so little means and assistance as to confine it at present to the direct practical issues in the preparation of tide-tables, &c. But where such good material exists, it is very unfortunate that descriptions of the phenomena from a few illustrations should be given as an average account of their characteristics, or that conclusions should be founded upon too narrow and incomplete a basis.

W. BELL DAWSON,
Engineer-in-Charge of Tidal Survey.

Ottawa, February 10.

MR. DAWSON characterises my letter as "misleading," and yet, in the course of his own letter, quite neglects to point to an incorrect statement in mine. This is certainly unfortunate.

To show how little Mr. Dawson's remarks touch the substance of my letter, permit me to briefly re-state my position. (1) The oscillations are regular where the basin is fairly regular. This is not questioned by Mr. Dawson, and, as regards the Bay of Fundy, it is amply confirmed by my own observations and the records of Mr. Dawson's department. (2) The oscillations are of irregular period in markedly irregular basins, such as the Gulf of St. Lawrence. This is also not questioned by Mr. Dawson. It is founded on records of four days each from seven different points on the Gulf of St. Lawrence (see the Tidal Report referred to by Mr. Dawson and quoted in my previous letter). Mr. Dawson's only criticism is that he has many other records from the same places; but he does not tell us whether they contradict the published ones. It would certainly be surprising if they did. (3) The period is determined by the dimensions of the basin, and can be calculated from those dimensions, as I have tried to show. (4) The cause of the initial disturbance is probably atmospheric. This point is discussed by Mr. Napier Denison in a short but valuable paper that reached me after my first letter was published. Mr. Denison confines his remarks to the cause of the initial disturbance.

That the period of these oscillations should be determined by the atmosphere seems to me quite incredible. It is surely sufficient refutation that, within a radius of twenty miles from St. John, we have three points at which the regular periods are 35 seconds, 12½ minutes, and 43 minutes respectively, and at one of these points the 35-second and 43-minute oscillations coexist.

Perhaps I have misunderstood Mr. Dawson. If his purpose was to call attention to the valuable materials being gathered by the Canadian Tidal Survey, which Mr. Dawson directs, then I must express my hearty approval, and add the hope that the excellent work may continue and receive efficient support. May I add that my interest is not that of a casual visitor to St. John (as implied by Mr. Dawson), but of a Canadian, most of whose life was passed in St. John? A. WILMER DUFF.

Purdue University, Lafayette, Ind., U.S.A.

The Natural Prey of the Lion.

JEAN BAPTISTE TAVERNIER, in his "Travels in India" (translated by V. Ball, 1889, vol. ii. p. 397), mentions a case similar to what Mr. Crawshay describes under this heading in your last number (p. 558). "At a distance of two or three leagues from the fort [at the Cape], the Dutch found a dead lion which had four porcupine's quills in its body which had penetrated the flesh three-fourths of their length. It was accordingly concluded that the porcupine had killed the lion. The skin is still kept with the spines sticking in the foot." Thereon it is noted by the English translator that "numerous cases are recorded of tigers having died in India from this cause, and also of occasionally having been found when shot to have porcupine's quills sticking in them." The old Chinese motto, "*the hedgehog defeats the tiger*, and the serpent stops the leopard" (in Liu Ngan, "Hwui-nan-tsze," second century B.C.), is probably founded on observations allied to these. KUMAGUSU MINAKATA.

7 Effie Road, Walham Green, S.W., April 15.

THE PRESENT STANDPOINT IN SPECTRUM ANALYSIS.

IN a former article I referred to some of the difficulties encountered by the earlier researchers in spectrum analysis. In the present one I propose to pass over the history of nearly twenty years' work with all its attendant doubts and difficulties, and deal with what that work has brought us, a perfect harmony between laboratory, solar and stellar phenomena.

It has been proved beyond all question that not only are both fluted (or channelled-space) spectra and line spectra visible in the case of most of the elements, but that many of the metallic elements with which I shall have to deal in the sequel have at least two sets of lines accompanying, if not resulting from, the action of widely differing temperatures.

It is important to mention that the different chemical elements behave very differently in regard to the action of heat and electricity upon them as we pass from the solid to the liquid and vaporous forms; that is, the two different forms of energy are apt to behave very differently, the permanent gases as opposed to the elements which generally exist in the solid form is the first differentiation, the elements of low atomic weights and low melting point as opposed to the rest, is the second.

In the cases in which heat-energy can go so far, we first get an increase in the free path of the molecules, and ultimately the latter are made to vibrate.

In the case of electricity, on the other hand, increase of free path is scarcely involved, and hence we may have effects similar to those produced by high temperature, with scarcely perceptible effects of heat in the ordinary sense.

Conversing on this subject with my friend Clifford, many years ago, we came to the conclusion that the energy imparted to a molecule might cause (1) an extension of free path; (2) a rotation, and (3) a vibration. To get concrete images of these effects we spoke of *path-heat*, *spin-heat*, and *wobble-heat*. The facts seemed to show that heat energy had no effect in producing line-spectra until the two first results had been obtained, and, further, that in all gases and many metals it had no effect in producing vibrations; while, on the other hand, electrical energy generally acted as if it began at the third stage, and is effective in the case of every chemical substance without exception.

However this may be, we now know that many elements present changes at several widely differing stages of heat. The line spectra of elements like sodium, lithium, and others may be obtained by the heat of the flame of a spirit lamp, or an ordinary Bunsen's burner, the substance being introduced into the flame by a clean platinum wire twisted into a loop at the end.

This temperature has no effect upon iron and similar metals. To get any special spectral indication from them a higher temperature than that of the Bunsen is required, the blowpipe flame may be resorted to; in this a stream of air is blown through the centre of a flame of coal gas burning at the end of a cylindrical tube.

We get in this way what is called a "flame-spectrum," in which flutings and some lines are seen. In order to obtain the complete line-spectra of some of the less volatile metals, like iron and copper, we are driven to use electrical energy and employ the voltaic current, and (for choice) metallic poles which are so strongly heated by the passage of the current that the vapour of the metal thus experimented on is produced and rendered incandescent.

We may say generally that no amount of heat-energy will render visible the spectra of gases. These are obtained by enclosing the gases in glass tubes and illuminating them by means of an electric current. We may go further and say that the ordinary voltaic current used in laboratories is equally inoperative. We must have the induced current, and with different tensions different spectra are produced.

We have then arrived so far. Heat-energy, which does give us line-spectra in some cases when metals are concerned, fails us in the case of the permanent gases and many metals. A voltaic current gives us spectra when metals are in question, but, like heat-energy, it will not set the particles of the permanent gases vibrating.

But when both metals and the permanent gases are subjected to the action of a strong induced current—that is, a current of high tension when an induction coil with leyden jars and an air break are employed, we get this vibration ; gases now become luminous, a distinct change in the spectra of the metals is observed, a change as well marked, or perhaps better marked, than any of the previous lower temperature changes to which I have already drawn attention.

When the tension is still further increased, the differences in the spectra are most marked in the case of gases, for the reason that, being enclosed in tubes, they cannot escape from the action of the current ; all the molecules are equally affected. *The spectrum is sometimes* NOT *a mixed one.* In the case of the metals the spark is made to pass between two small pointed poles, and the region of most intense action is a very limited one ; we get from the particles outside this region the spectrum obtained with a lower degree of electrical energy. *The spectrum* IS *a mixed one.* Even when we take the precaution of throwing an image of the spark on the slit of the spectroscope, the outer cooler layers pierced by the line of sight add their lines to the spectrum of the centre.

Not only so, but the individuality of the various chemical elements comes out in a remarkable manner.

To take one or two instances. I will begin with the gases with a weak and strong induced current. Hydrogen gives us what is termed a structure spectrum, a spectrum full of lines ; this changes to a series. Oxygen gives us series which change into a complicated line-spectrum in which no series has been traced. Nitrogen gives us a fluted spectrum which changes into a complicated line-spectrum.

I next pass to the metals, and again, for brevity's sake, I will deal with three substances only. 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 : as in the case of the spark, so in the arc outside the region of high temperature in which they are produced, the cooling vapours give us the lines visible at a lower temperature.

Bearing in mind what happens in the case of the gases, 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 ; still, as I shall show, in the atmospheres of the stars we have probably the closest approximation open to our observation of that equally heated space condition to which I have referred.

The enhanced lines are very few in number as compared with those seen at the temperature of the arc. In the case of iron thousands are reduced to tens.

The above statements are only general : if we include the non-metals, more stages of temperature are required, and it then becomes evident that different kinds of spectra are produced at the same temperature in the case of different elements ; in other words, at many different heat-levels changes occur, always in one direction but differing widely for different substances at the lower temperatures. At the highest temperatures—at the limit—there is much greater constancy in the phenomena observed if we disregard the question of series. If considered from the series point of view, there is no constancy at all.

It is obvious that with all these temperature effects observed in a large number of elements, very many comparisons are rendered possible. All these suggest that if dissociation is really in question, in some cases, at least more than two simplifications in the line stage are necessary to explain the facts. It is possible that the effects at first ascribed to quantity may be due to the presence of a series of molecules of different complexities, and that this is the true reason why "the more there is to dissociate, the more time is required to run through the series, and the better the first stages are seen."[1]

After this general statement of the changes in spectra observed to accompany change in the quantity and kind of energy used in the experiments, I propose to refer briefly to the most recent work on this subject, touching the changes observed on passing from the arc to the spark in the case of many of the metallic elements. By the kindness of Mr. Hugh Spottiswoode, the photographs of the enhanced lines have been obtained by the use of the large induction coil, giving a 40-inch spark, formerly belonging to Dr. Spottiswoode, P.R.S. I am anxious to express here my deep obligation to Mr. Hugh Spottiswoode for the loan of such a magnificent addition to my instrumental stock-in-trade.

The spark obtained by means of the Spottiswoode coil is so luminous that higher dispersions than those formerly employed can be effectively used, and in consequence of this, the detection of the enhanced lines becomes more easy ; their number therefore has been considerably increased.

At the higher temperature enhanced lines have been found to make their appearance in the spectra of nearly all the metals already examined. Lithium is one exception.

Neglecting then all changes at the lowest temperatures, but including the flame spectrum, four distinct temperature stages are indicated by the varying spectra of the metals ; for simplicity I limit myself to iron as an example. These are :—

(1) The flame spectrum, consisting of a few lines and flutings only, including several well-marked lines, some of them arranged in triplets.

(2) The arc spectrum consisting, according to Rowland, of 2000 lines or more.

(3) The spark spectrum, differing from the arc spectrum in the enhancement of some of the short lines and the reduced relative brightness of others.

(4) A spectrum consisting of a relatively very small number of lines which are intensified in the spark. This, as stated above, we can conceive to be visible alone at the highest temperature in a space efficiently shielded from the action of all lower ones, since the enhanced lines behave like those of a metal when a compound of a metal is broken up by the action of heat.

Each line of each element at whatever temperature it is produced, can at once be compared in relation to position in the spectrum with the lines visible in celestial bodies with a view of determining whether the element exists in it.

At the time at which the earlier inquiries of this kind were made it was only possible for the most part to deal with eye observations of the heavenly bodies. The results were, therefore, limited to the visible spectrum.

During the last few years photographs of the spectra of the brighter stars and of the sun's chromosphere during eclipses have been obtained ; it became of importance, therefore, to extend the observations of terrestrial spectra into the photographic regions for the purpose of

[1] *Proc. Roy. Soc.*, 1879, No. 200.

making the comparisons which were necessary for continuing the inquiry.

The recent work has been done with this object in view.

The way in which the enhanced lines have been used is as follows. Those belonging to some of the chief metallic elements have been brought together, and thus form what I have termed a "test-spectrum." This has been treated as if it were the spectrum of an unknown element, and it has been compared with the various spectra presented by the sun and stars.

How marvellous, how even magnificent, the results of this inquiry have been, I shall show later in detail; but I may here say by way of anticipation that the test-spectrum turns out to be practically the spectrum of the chromosphere; that is, the spectrum of the hottest part of the sun that we can get at, and that a star has been found in which it exists almost alone, nearly all the lines of which had previously been regarded as "unknown."

This last result is of the highest order of importance because it should carry conviction home to many who were not satisfied with the change of spectrum as seen in a laboratory, where, of course, the enhanced lines when seen in the spectrum of the centre of the spark have alongside them the lines in the spectrum of the outer envelope, which of course is cooling, and in which the finer molecules should reunite. For twenty years I have longed for an incandescent bottle in which to store what the centre of the spark produces. The stars have now provided it, as I shall show.

Although I have promised to pass over the history of the work generally, I must still point out that the enhanced lines in the test-spectrum actually include all those first studied years ago when everything was dim, and we were seeing through a glass darkly; not as we are now, face to face. To show the rigid connection of the new with the old, it is desirable to refer briefly to some of the work undertaken in relation to some of the first anomalies noted.

One advantage of this method of treatment is that it shows that the immense mass of evidence now available supports all the conclusions drawn from the meagre evidence available a quarter of a century ago.

Some of the anomalies were as follows: they are given as specimens of many.

(1) Inversion of intensity of lines seen under dfferent circumstances.

I showed in 1879 that there was no connection whatever between the spectra of calcium, barium, iron, and manganese and the chromosphere spectrum beyond certain coincidences of wave-length. The long lines seen in laboratory experiments are suppressed, and the feeble lines exalted in the spectrum of the chromosphere. In the Fraunhofer spectrum, the relative intensities of the lines are quite different from those of coincident lines in the chromosphere.

(2) The simplification of the spectrum of a substance at the temperature of the chromosphere. To take an example, in the visible region of the spectrum, iron is represented by nearly a thousand Fraunhofer lines; in the chromosphere it has only two representatives.

(3) In sun-spots we deal with one set of iron lines, in the chromosphere with another.

(4) At the maximum sun-spot period the lines widened in spot spectra are nearly all unknown; at the minimum they are chiefly due to iron and other familiar substances.

(5) The up-rush or down-rush of the so-called iron vapour in the sun is not registered equally by all the iron lines, as it should be on the non-dissociation hypothesis. Thus, as I first observed in 1880, while motion is sometimes shown by the change of refrangibility of some lines attributed to iron, other adjacent iron lines indicate a state of absolute rest.

Laboratory work without stint has been brought to bear, with a view of attempting to explain the anomalies to which attention has been directed.

I only refer here to the work done on iron, magnesium and calcium, to show that in those metals the anomalies were to a large extent due to the lines now termed enhanced—that is, the lines seen to considerably change their intensities when the highest temperatures are employed.

Iron.

In the course of my early observations of the spectrum of the chromosphere, I discovered on June 6, 1869, a bright line at 1474 on Kirchhoff's scale, which I stated to be coincident with a line of iron. On June 26 I discovered another at 2003·4 of the same scale.

The later researches on the spectrum of iron have shown that the iron line which I observed in 1869 to be coincident with the bright chromospheric line at 1474 on Kirchhoff's scale, having a wave-length of 5316·79, is an enhanced line, agreeing absolutely with Young's latest determination of the wave-length of the 1474 chromospheric line.

Similarly the line at 2003·4 of Kirchhoff's scale, with a wave-length of 4924, is also an enhanced line of iron.

The first experiments were made to explain my own and the Italian observations of the chromosphere which proved the presence of only these two lines of iron in the part of the spectrum ordinarily observed; the ordinary spectrum of iron in which 460 lines had been mapped at that time was entirely invisible.

The anomalies were investigated in the experimental work with sparks produced by quantity and intensity coils with and without jars in the circuit. The outcome of these experiments was to show that the chromospheric representatives of iron were precisely the lines which were brightened on passing from the arc to the spark, while the lines widened in spots corresponded to a lower temperature.

The next anomaly observed was that in a sun-spot the iron line at 4924 often indicated no movement of the iron vapour, while the other iron lines showed that it was moving with considerable velocity.

It seemed perfectly clear then that in the sun "we were not dealing with iron itself, but with primitive forms of matter contained in iron, which are capable of withstanding the high temperature of the sun, after the iron observed as such, has been broken up, as suggested by Brodie."[1]

On this view, the high temperature iron lines of the chromosphere represent the vibrations of one set of molecules, while the lines which are widened in spots correspond to other molecular vibrations. Similarly, the idea of different molecular groupings provides a satisfactory explanation of the varying rates of movement of iron vapour indicated by adjacent lines, the lines being produced by absorption of different molecules at different levels and at different temperatures.

Magnesium.

In 1879 I passed a spark through a flame charged with vapours of different substances. In the case of magnesium the effect of the higher temperature of the spark was very marked; some of the flame lines being abolished, while two new ones made their appearance, one of them at 4481. The important fact was that the lines special to the flame did not appear among the Fraunhofer lines, while those of the spark did appear.

This line at 4481 now takes its place among the enhanced lines like those of iron previously mentioned; special cases now form part of the more general one.

Here again the experiments pointed to varying degrees of dissociation at different temperatures as the cause of the non-appearance of some of the magnesium lines in the Fraunhofer spectrum.

[1] *Proc. Roy. Soc.*, vol. xxxii. p. 204.

From these experiments, the results of which were subsequently mapped in relation to the various heat-levels indicated by solar phenomena, I drew the following conclusions in 1879:—

"I think it is not too much to hope that a careful study of such maps, showing the results already obtained, or to be obtained, at varying temperatures, controlled by observations of the conditions under which changes are brought about, will, if we accept the idea that various *dissociations* of the molecules present in the solid are brought about by different stages of heat, and then reverse the process, enable us to determine the mode of evolution by which the molecules vibrating in the atmospheres of the hottest stars *associate* into those of which the solid metal is composed. I put this suggestion forward with the greater confidence, because I see that help can be got from various converging lines of work."

Calcium.

In 1876 I produced evidence that the working hypothesis that the molecular grouping of calcium which gives a spectrum having its principal line at 4226·9 is nearly broken up in the sun, and quite broken up in the spark, explained the facts which are that the low temperature line loses its importance and practically disappears from the spectrum of the sun, in which H and K are by far the strongest lines.[1]

I summed up the facts regarding calcium as follows:[2] "We have the blue line differentiated from H and K by its thinness in the solar spectrum while they are thick, and by its thickness in the arc while they are thin. We have it again differentiated from them by its absence in solar storms in which they are almost universally seen, and, finally, by its absence during eclipses, while the H and K lines have been the brightest seen or photographed."

I afterwards attempted to carry the matter further by photographing the spectra of sun-spots. In all cases H and K lines were seen reversed over the spots, just as Young saw them at Sherman, while the blue calcium line was not reversed.[3] The oldest of these photographs which has been preserved bears the date April 1, 1881.

The experimental results in the case of calcium, therefore, followed suit with those obtained from iron and magnesium, and indicated that the cause of the inversion of intensities in the lines of a substance under different circumstances is due to the varying degrees of dissociation brought about by different temperatures.

Both in the case of iron, magnesium and calcium the high temperature lines involved are not seen at all at lower temperatures, and even in the case of calcium, when photographic exposure of 100 hours' duration have been employed. It should be sufficiently obvious to everybody then that temperature alone is in question.

Finally, then. The similar changes in the spectra of certain elements, changes observed in laboratory, sun and stars are simply and sufficiently explained on the hypothesis of dissociation. If we reject this, so far no other explanation is forthcoming which coordinates and harmonises the results obtained along the different lines of work.

NORMAN LOCKYER.

[1] *Proc. Roy. Soc.*, vol. xxiv. p. 352.
[2] *Ibid.*, vol. xxviii. p. 171.
[3] *Ibid.*, vol. xxxvi. p. 444.

HIGHER COMMERCIAL EDUCATION AND THE UNIVERSITY OF LONDON.

OUR knowledge of what is needed for the improvement of commercial education has undoubtedly been amplified and better defined by the action of the London Chamber of Commerce and of the Technical Education Board of the London County Council. The important conference held in June last at the Guildhall settled certain points beyond further controversy, and cleared the way for a new departure in those directions in which improvement is practicable and possible. The "Summary of Results" published by the Chamber will serve as a useful guide to educational authorities desirous of adapting school teaching to the requirements of our mercantile classes. The special Committee, appointed in May 1897 by the Technical Education Board, were actively engaged during the greater part of the year 1898 in taking evidence from merchants, bankers, teachers, and organisers of commercial classes, and their valuable report, recently published, gives some interesting extracts from the evidence of the expert witnesses they consulted, together with their own conclusions and recommendations. The report also contains a summary of the notices, previously published in various other reports, of the facilities provided in foreign countries for commercial education of different grades.

For many years there has been a growing feeling in this country, that the mercantile classes are placed at a disadvantage in competition with their foreign neighbours, owing to the absence of any specialised schools of commerce, such as exist in other parts of Europe. The reports of our consuls abroad went to show, that in the distant markets of the world agencies were being established with continental manufacturing firms, and that England was being gradually driven to the wall, in consequence of the greater activity, and the special aptitudes of commercial travellers, representing mercantile firms in Germany, Belgium, and Switzerland. It was also shown, that owing to their special business qualifications and to their knowledge of foreign languages, foreigners were preferentially employed in business houses in this country, and it was generally assumed, that although there might be other causes of an industrial and economic character, which helped this result, the defects of our educational system were mainly responsible for the gradual displacement in many important markets of English wares for those produced in other countries.

It is possible there may have been some exaggeration in the facts on which these conclusions were based; but there is no doubt that a strong *à priori* case for inquiry was established, and the report of the London County Council, and of the conference at the Guildhall, supplemented by further evidence from our consuls, and from other persons who have independently investigated the subject, has shown the extent to which foreign nations have benefited by their special schools, and the directions in which improvements may be looked for in our own methods. A very important item of evidence was furnished by Mr. Powell in his consular report on this subject of November 1898, which has undoubtedly modified the views of some of our educational reformers. Mr. Powell brought into prominence the fact, that the alleged pre-eminence of Germany was in no way due to her commercial schools; but that the movement, now in progress, for developing commercial education had followed, and had not preceded the rapid advance in her industrial operations. The wide publication of this fact has been useful in directing attention to other causes than the absence of special commercial schools in this country, for the explanation of the undoubted ability of German clerks and commercial agents to succeed where Englishmen too often fail. The inquiry instituted last year will serve to prevent the repetition of vague statements about the comparative excellence of commercial schools abroad, and shows the extent of the changes that are needed in our present educational system to give us all the advantages that commerce can be expected to gain from special schools or new methods of instruction.

The recommendations in the report of the London County Council are in general agreement with the con-