Lastly, the spiral $\frac{5}{22}$, series $\frac{1}{4}, \frac{2}{9}, \frac{3}{13}, \frac{5}{22}$, &c., which Dr Dickson formerly noted as occurring in a cone of *Pinus Pinaster*, in the Museum, Edinburgh Botanic Garden, may readily be derived, as MM. Bravais have suggested,* from a spiral of the series $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}$, &c., thus,

TABLE G.—*Showing possible derivation of a $\frac{5}{22}$ Spiral from the System $\frac{1}{4}, \frac{1}{5}$, &c.*

D	S	D	S	D	V
—	1	4	9	13	$22 = \frac{5}{22}$
1	4	5	9	14	$23 = \frac{5}{23}$

The following Gentleman was admitted a Fellow of the Society:—

Rev. Professor CRAWFORD.

Monday, 15th May 1871.

PROFESSOR CHRISTISON, President, in the Chair.

At the request of the Council, Professor Tait gave an Address on Spectrum Analysis.

(*The following is a brief Abstract, consisting mainly of the Lecture Notes*):—

I should not have thought of appearing before you to-night to lecture on so hackneyed a subject, had I not been assured by several members of the Council that such an address was really desired by many Fellows of the Society. It is a subject to which I have not paid very special attention, partly because it is in so many and such good hands, and partly because (except from the point of view of theory) it requires for its extension, especially to

* *L. c.* p. 103.

astronomy, very costly instrumental appliances and a great sacrifice of time. And the difficulty of transporting to the Society's rooms from the College the large amount of bulky and delicate apparatus required for its proper illustration, is (as I have just found) so great, that if on any future occasion the Society desire me to give such an address, I shall have to make it a condition that the meeting for that evening be held in my class-room in the University buildings.

The subject of spectrum analysis must always possess great interest for this Society, inasmuch as many of its most distinguished promoters have been, or are, among our Fellows, ordinary as well as honorary, and several of the most remarkable memoirs on various parts of the subject are to be found among our publications.

The objects of spectrum analysis may be briefly enuntiated as follows:—*To make, by optical methods, the qualitative chemical analysis of (1) a self-luminous body ; (2) an absorbing medium, whether self-luminous or not.*

It is difficult now-a-days, when so many philosophers are engaged almost simultaneously at the same problem, to decide which of their successive steps in advance is that to which should really be attached the title of *discovery* (in its highest sense) as distinguished from mere *improvement* or *generalisation*. You have only to look at the recent voluminous discussions as to the discoverer of the Conservation of Energy, to see that critics may substantially agree as to facts and dates, while differing in the most extraordinary manner as to their deductions from them.* Some of these writers, no doubt, put themselves out of court at once by habitually attributing the gaseous laws of Boyle and Charles to Mariotte and Gay-Lussac. Men who persist in error on a point so absolutely clear as this, show themselves unfit to judge in any case of even a little more difficulty. Others, who strongly support the so-called claims of Mayer in the matter of Conservation of Energy, and who should (to be consistent) therefore far more strongly advocate the real claims of Talbot, Stokes, Ångström, Stewart, &c., to the discovery of spectrum analysis, are found to uphold Kirchhoff as alone en-

* Some frantic partisans of Papin, &c., deny almost all credit to Watt in the matter of the steam-engine! No farther examples need be cited.

titled to any merit in the matter. As a paper by Mr Talbot, on the early history of the subject, is to be read this evening, I shall content myself for the present with the remark, that, of the two objects of spectrum analysis above named, Talbot and Herschel were unquestionably foremost in the enunciation of the first; Brewster, Ångström, and especially Stokes and Balfour Stewart, in that of the second. Why some of their statements were incomplete or inexact, and what was required to complete or to correct them, will be more usefully stated after I have given some preliminary explanations.

SPECTRUM.—Newton's fundamental experiment.

Reason of separation of colours.

Reason of impurity.

How to obtain a pure spectrum.

Object of trying to do so.

Effect of Additional Prisms.

Note that the source of light in all these experiments has been carbon heated to incandescence by resistance to a powerful current of voltaic electricity.

I. Incandescent solids and liquids give *generally* a continuous spectrum.

Its highest radiation, and the amount of radiation of each wave length, depend on the temperature.

Hence the necessity of using the highest temperature we can obtain.

Illustrate by different lengths of platinum wire heated by current.

II. Gaseous bodies, incandescent, give generally a (limited) number of perfectly definite wave lengths (though under certain circumstances of pressure, &c., they give a continuous spectrum). The number depends for each substance on its temperature and pressure, and their appearance is *characteristic of the substance*. For, under the same physical circumstances, we have always the same effect—as, indeed, must be assumed to be the case, if we think physics can be studied at all. This remark was virtually made by Carnot, and is all that was wanting in Talbot's earliest paper to make it the complete statement of this first part of the subject.

Illustrate by the spectra of the incandescent vapours of

Thallium,

Lithium,

Magnesium,

Sodium.

Illustrate the conductivity of the vapour of the latter by the increased breadth of the spectrum when it is present; also by its effect in improving the spectra of other substances when a weak battery is used.

Hydrogen—by induction-coil.

(Here refer again to Talbot's paper, presently to be read.)

SPECTROSCOPES.—Swan's paper, in *Edinburgh Transactions*—Introduction of Collimator—estimation of the excessively minute amount of sodium required to give the D line.

UNIVERSAL PREVALENCE OF SODIUM, LITHIUM, &c.

DISCOVERY OF NEW METALS.—Bunsen—Rubidium, Cæsium.

Crookes and Lamy—Thallium.

Reich and Richter—Indium.

DISCOVERIES IN ASTRONOMY AND METEOROLOGY.

Lightning.

Aurora.

Solar prominences and corona.

Nebulæ.

Comets.

Zodiacal light.

Temporary stars.

Huggins, Janssen, Lockyer, Secchi, &c.

III. Absorption by glowing gases, from otherwise continuous spectra.

Fraunhofer's lines (Wollaston).

Reversal of sodium line (exhibit).

Hence *atmospheres* of sun, stars, &c.

Brewster (in *Edinburgh Transactions*).

Nitric peroxide—effects of heat and pressure.

Atmospheric lines.

Foucault.—Spectrum of incandescent carbon points, seen (by reflection) through the voltaic arc (which itself gives them bright) shows the D lines reversed.

Stokes—about 1850, gave, in consequence of W. H. Miller's very accurate verification that the double bright line of sodium exactly corresponds in refrangibility with the double dark line D, the correct mechanical explanation of the phenomenon, with the mechanical illustrations still very often employed. Given, with general theory of solar and stellar chemistry, ever since (annually) by Thomson in his lectures. Give it.

Ångström—1853.—“Un gaz à l'état d'incandescence émet des rayons lumineux de la même réfrangibilité que ceux qu'il peut absorber.”

B. Stewart (*Edinburgh Transactions*, 1858–9).

Extension of the Theory of Exchanges—The radiating power of a body is equal to its absorbing power, and that for every ray. Based on experimental facts.

Heated pottery ware, with marked pattern, looked at in the dark.

Coloured glasses lose their colour in the fire.

Kirchhoff, Oct. 1859.—Introduction of reasoning more *directly* based on the Second Law of Thermodynamics.

Proof that the absorbing flame must be colder than the source—Exception for Fluorescence.

Kirchhoff and Stewart.—Tourmaline, which polarises common light by absorbing polarised light, gives off, when hot, polarised light like that which it absorbs..

(Note that the discussion of the question of priority on this subject, in papers by Stokes, Thomson, Kirchhoff, and Stewart, in the *Phil. Mag.* 1863, is very interesting, and may still be read with profit).

Fluorescence is Degradation of Energy.

Exhibit Stokes' fundamental Experiments.

The question of priority just alluded to illustrates in a very curious way a singular and lamentable, though in one sense honourable, characteristic of many of the highest class of British scientific men; *i.e.*, their proneness to consider that what appears evident to them *cannot but* be known to others. I do not think that this can be called modesty; it is rather a species of diffidence due to their consciousness that in general their accurate knowledge of the published developments of science is confined mainly to those branches to which they have specially devoted themselves. Their foreign competitors, on the other hand (especially the Germans), are often profoundly aware of all that has been done, or, at least, have some one at hand who is, and can thus, when a new idea occurs to them, at once recognise, or have determined for them, its novelty, and so instantly put it in type and secure it. Neither Stokes nor Thomson, in 1850, seems to have had the least idea that he had hit on anything new, especially as they had a vague recollection that Foucault had previously attacked the problem—the matter appeared so simple and obvious to them—and, but for the fact that Thomson has given it in his public lectures ever since (at first giving it as something well known), they might have thus forfeited all claim to mention in connection with the discovery. I could mention many other striking instances of this peculiarity; one, in fact, appeared in our own *Proceedings* a few months ago; but to consider it more closely would lead me away from the subject of my lecture. It is sufficient to have called attention to a want which could easily be supplied, if we

had anything in this country equivalent to the *Fortschritte der Physik*, but published with considerably less delay.

Detailed study of Solar Spectrum—mainly due to the labours of two men.

Maps by Kirchhoff and Ångström, with the number of elements proved to exist in the sun's atmosphere.

According to Ångström, the following numbers of bright lines given by elements are found exactly coincident with dark lines in the solar spectrum :—

Hydrogen,	4	Manganese,	57
Sodium,	9	Chromium,	18
Barium,	11	Cobalt,	19
Calcium,	75	Nickel,	33
Magnesium,	4 + (3 ?)	Zinc,	2 (?)
Aluminium,	2 (?)	Copper,	7
Iron,	450	Titanium,	118

He notes that Thalén has found 200 coincidences with Titanium lines.

TYPES OF STARS—Secchi.

- I. White stars—Scarcely any absorption lines, except those due to Hydrogen, which are strongly marked. Sirius, Vega, &c.
- II. Yellow stars—The Sun, Arcturus, Aldebaran, &c.—multitudes of fine lines.
- III. Nebulous bands in addition to the fine lines— α Herculis, α Orionis, &c. In Mira Ceti these bands vary with the apparent magnitude. Similar appearances are observed in the spectra of sun-spots. On the contrary, Algol retains the first type through all its periodic changes.
- IV. Feeble spectrum crossed by bright lines. The stars of this type are all of small apparent magnitude (*i.e.* of feeble luminosity), and usually of a blood-red colour. Temporary Stars—bright lines of hydrogen.

If to these be added

- V. Resolvable Nebulæ—Continuous spectrum, as are those of the nebula in Andromeda, and of many others *not* resolvable; and
- VI. Planetary Nebulæ, and others irresolvable, such as those of Orion, Lyra, &c., where the spectrum consists of a very few bright lines only.

it seems to me that we have a series of indications of what (for want of a better phrase) may be called the *period of life* of a star or group; beginning with the glowing gases developed by the impacts of the agglomerating cold masses (VI.), * then the almost perfect spectrum of white-hot liquid or compressed gas (V., I.), which (as it becomes colder) suffers absorption by the rise of still colder vapours (II.); then, as it farther cools, nebulous bands take the place of sharp lines (III.); anon the bursts of glowing gases are

* See the Abstract of my paper on Comets, Proc. R.S.E., 1868–9.

brighter than the photosphere (IV.), and, finally, no light but that of these gases is intense enough to reach us (VI.) That there is energy enough to produce these successive developments is obvious from the fact that, even at their immense distance, the *visible* portions of the nebulæ of Orion and of Argus subtend an angle of nearly *four degrees*.

Application of the spectroscope to determine the RELATIVE VELOCITY OF A STAR, OR OF A GASEOUS CURRENT IN THE SOLAR PHOTOSPHERE, WITH REGARD TO THE EARTH.

Analogy from sound.

Railway whistle.

Tuning-fork experiment.

Similar experiment with organ-pipe.

Finally, ABSORPTION BY BODIES AT ORDINARY TEMPERATURES.

Coloured glasses.

Chlorophyll.

Detection of blood, changes of the blood-spectrum by oxidation, &c., &c.

Microscopic spectroscope.

The following Communications were read :—

1. Note on the Early History of Spectrum Analysis. By
H. Fox Talbot, Hon. F.R.S.E.

Newton, in his observations on the spectrum, appears never to have used a narrow aperture. In fact there was nothing, in the existing state of knowledge in his day, to lead him to suppose that this would alter the phenomena.

Wollaston was the first who observed some obscure bands in the spectrum, by viewing with a prism the aperture left by the shutters of his room when nearly closed. It is surprising that this acute philosopher did not follow up the hint thus accidentally presented to him, but contented himself with the rude observation above mentioned.

Fraunhofer was the first who detected the wonderful system of dark lines in the solar spectrum, by viewing a very narrow and accurately formed aperture with an excellent prism, aided by a small telescope. He likewise gave names to the principal dark lines which have been generally adopted, and he measured accurately their refractive indices by mounting the prism on a graduated brass circle movable round a centre.

After completing his observations on the solar spectrum, he