[From the Galaxy.]

THE SPECTROSCOPE AND ITS REVELATIONS.

BY PROF. HENRY DRAPER.

Within the last few years a new form of chemical analysis has arisen, which ascertains substances by observation upon the color and properties which they impart to flames during combustion. It has been long known that the combustion of certain bodies gave certain colors to flames; strontia, for example, affording the beautiful crimson so well known in pyrotechny But no sure method existed of using the facts of combustion for chemical investigations, until the invention of the spectroscope. Spectrum analysis enables us to detect the minutest trace of the constituents of substances burnt. It has already discovered several unsuspected new metals; has given us the power of analyzing bodies whose composition we had not the means of ascertaining, and has proved to us that many of the elements of the earth are present in the inaccessible sun, and even in those more remote stars whose distance the most refined researches of astronomy cannot determine.

The spectroscope is merely a prism to which light can be admitted through a slit $\frac{1}{32}$d of an inch wide, with apparatus for examining microscopically the spectrum or decomposed ray beyond the prism. When this is done, the spectrum is found to be crossed by an infinite number of lines perpendicular to its length, as shown in the upper part of Fig. 2. These lines are called, from the name of the distinguished optician who discovered them, Fraunhofer's lines.

When the light, coming from a white-hot mass of metal is examined by the spectroscope, its spectrum is found to be perfectly continuous and unbroken by any Fraunhofer lines. This fact was demonstrated by my father, Prof. J. W. Draper. in 1847. What is the cause of the lines in the solar light, and in what does that luminary differ from the incandescent mass ?

In order to fathom this question, we must investigate for a few moments the case of artificial lights, such as ordinary flames, and those in which there are purposely introduced various elementary or compound bodies. The construction of the spectroscope must also be described.

The spectroscope is some times a very complicated instrument, but, for ordinary analysis, quite a simple form may be used. The one represented in Fig. 1 is commonly found in laboratories. It consists of a prism, P, supported on a stand, F. Two telescopes of low magnifying power, A and B, are attached by suitable supports. One of these, B, is furnished with an eye-piece like any common spy-glass, but the eye-piece of the other, A, is removed, and in its place is put a vertical slit, *e*. Opposite this slit the flame to be examined is placed. The light coming through the slit from the flame falls upon the object glass of the first telescope, and its rays are rendered parallel; it then passes through the prism, is refracted and decomposed, and enters the second telescope, whence it falls upon the eye. Any flame may be put opposite the slit, and its peculiarities examined, or, by the aid of a reflector, the sunlight may be cast on part of the slit so that we can see a solar spectrum alongside of the flame spectrum. Or we may have the spectra of the two flames, D and E, at once and compare them. The third telescope carries a scale.

The use of a spectroscope merely involves placing the substance to be examined in a spirit or gas flame, and then looking through the telescope to examine the spectrum. The number, position, and color of the transverse lines are always the same from the same substance. A person soon becomes experienced enough to state in a moment what bodies are present.

If, for example, a piece of soda be suspended in the flame, at once a double yellow line makes its appearance, as shown in Fig. 2, by the double line near the right-hand end of the third spectrum from the top. The wood cut shows also the lines characteristic of the elementary bodies, potassium, lithium, rubidium, cæsium, strontium, calcium, barium, thallium. The spectrum at the top is that of the sun, and is inserted for the sake of comparison. By noticing where the lines in the lower spectra fall, and collating them with the solar spectrum, their color may be ascertained from this cut. Those at the right-hand end are red, those at the left violet, those in the intermediate parts of the intermediate colors.

Understanding, then, that various elementary bodies, when volatilized in a flame and examined by a spectroscope, give spectra distinguished by bright-colored lines, soda by yellow, strontia by red, etc., the reader is ready to grasp the next idea in the investigation.

If the light coming from such a source as a mass of white-hot iron, which is free from all Fraunhofer lines, be passed through a flame where soda is volatilizing, before it is analyzed by the prism, instead of seeing the bright yellow lines characteristic of the soda, we shall find in their place two dark lines. In other words, the soda flame has interfered with the continuity of the spectrum of the white-hot body, and produced therein two Fraunhofer lines. If a number of substances are burning in the flame at once, we shall get in the spectrum an increased number of lines. A flame refuses to permit the passage of rays of the same kind as it emits. White light passing through a soda flame has the yellow rays sifted out of it.

It is obvious at once, from such considerations, that we can ascertain the constitution of the sun, both as regards his physical character and chemical composition. From the fact that the lines in his spectrum are dark, we infer that he has an intensely hot solid or fluid nucleus, emitting light and surrounded by an atmosphere of flame in which there are many volatilized bodies. If he were solely an ignited gas or flame, the lines of his spectrum would be bright instead of dark.

As regards chemical composition, it is only necessary to ascertain what elementary substances can produce lines corresponding to those in the solar spectrum. We can then at once be sure that those bodies exist in their luminary. The presence of iron, sodium, and a variety of other materials familiar to us here, has thus been proved.

The reader will at once perceive what an important bearing these facts have on the construction and unity of the solar system. We have shown that on two members of it—the sun and the earth—the same substances are found, and may, therefore, infer that all the rest are similarly composed—for no other two, at first sight, seem more unlike. The sun, and all his attending planets, with their satellites, are composed of the self-same elements.

In this place, it is interesting to refer to a theory by which such facts may be accounted for, and the reason of the similarity shown. The nebular hypothesis assumes that our solar system was at one time a gaseous mass, extending beyond the orbit of the furthest planet, Neptune. Its composition was necessarily uniform throughout, for the tendency of gases to diffuse into one-another, or intermingle, would have free play. In this nebula the temperature was very high, for the elementary bodies were in a vaporous state in it, just as they are at present in the sun. But as soon as the mass commenced to lose its heat, there were established currents and a general movement of rotation, and on the exterior a shell, or, rather, equatorial band of condensed materials, began to form. The cooling and consequent contraction still continuing, the band was left behind, but it sooner or later broke, in one or more places, and aggregated into one or more globular masses, which continued their rotation as planets.

The same thing occurring several times in succession, and rings of molten matter being left behind by the contracting gaseous mass, as it lost its heat, eventually all the planets, as we now see them, were formed, and the remainder of the nebula is the sun, still preserving the form partly of ignited gas, and partly, probably, of a liquid or solid. It is, however, even now radiating its heat away and cooling, though slowly. After, perhaps, giving off a few more planets, whose orbits will not exceed in diameter his present size, the sun, according to the hypothesis, will be no longer visibly hot, and life on the planets will come to an end.

This celebrated hypothesis has been very freely discussed, and has received much adverse criticism. Many strong objections have been urged against it, but the spectroscope confirms it. The reader will not be able to appreciate the full value of this support until the constitution of the nebulæ visible in the heavens has been spoken of. It will, therefore, be reserved for that place.

But let us not confine ourselves in these observations to our own solar system. Let us see whether this little instrument, which is scarcely any thing more than a small triangular piece of glass, will not enable us to establish a relationship with more distant bodies than the sun and planets—with other solar systems far away in the abysses of space.

To the naked eye, there appear scattered over the sky at night a multitude of stars of various colors. Even in our best telescopes they are only glittering points, and no glimpse of their chemical constitution could be presented before the spectroscope was applied to investigate them. We were satisfied that they shone by their own light, that they were suns, that they presented many analogies to our solar system, and also many dissimilarities.

How strange a sunlight, for instance, there must be in a world lighted by a pair of differently colored suns, for such must be the case if planets revolve around some of the binary stars. At one season of the year, a blue sunrise, followed by a yellow one, then a day of the intermingled lights—a yellow evening and dark night. At another season the reverse order of illumination; while at intermediate times there may be continuous day, first of one color, then of the other; a yellow day inciting the growth of plants, a blue one delighting the photographers. Can we establish a connection with such worlds?

The stars, both single and double, when examined by the spectroscope, are observed to contain substances well known to us. One of them, Arcturus, closely resembles our sun, as has been shown by Rutherford. At once we perceive a fellowship between them and our own earth, and are led to the noble idea that Nature constructs everywhere out of the same materials. Bodies, so distant that the astronomer fails to give us an idea of their remoteness are brought, as it were, into our grasp, and are analyzed with certainty. We recognize the same elements in them, that compose the soil we tread, the water we drink, the air we breathe.

And what are these materials? Chemists enumerate to us sixty-eight elementary bodies, that is, substances not composed of anything else, and that cannot be further decomposed. Such are the gases: oxygen, nitrogen, hydrogen, etc.; the liquids: mercury, bromine, etc.; the solids: sulphur, iron, gold, etc One is fifteen times lighter than the air, another twenty-one times as heavy as water. Truly, Nature has variety enough to choose from, for out of sixty-eight elements how many combinations may not be made? But this very variety creates at once a suspicion that the ultimate elimentary bodies are not in fact so numerous.

Among the reasons for doubting the multiplicity of elementary bodies, it may be stated: 1st, That many of them are so nearly identical that it requires a good chemist to distinguish one from another. 2d, That in our own times a number of elements have been stricken from the list, having been found to be compound bodies. 3d, That by quite trivial means one elementary substance may be made to assume a form having properties totally distinct from those it originally possessed. 4th, That we can form, from two or more elements bodies, which have the attributes of elements, a case in point being cyanogen. 5th, That the infinite variety of organic substances, such as the various tissues of the bodies of animals and plants, diverse as they are, are all formed principally from four elementary bodies. A multitude more of such arguments might be advanced; but the general conclusion which they indicate can be summed up in a line. All the sixty-eight elements may be compounds of perhaps only two or three elements—may even be modifications of a single type of matter. But any further consideration of this part of the subject would lead us into an examination of the nature of matter, and its atomic constitution, and with that we have not room to deal.

But we will penetrate yet a step further into space. The stars, it has been stated, are exceedingly remote. Let us examine bodies so distant that the stars are near neighbors compared with them. Clusters, resolvable nebulæ, true nebulæ, shall carry us as far from the earth into space as the eye can see.

To the naked eye, or in a telescope of low magnifying power, there are visible in the sky certain patches of diffused light, differing in appearance from the glittering stars. Some, when examined with a higher power, are seen to be resolved into an aggregation of stars; some, by the use of the highest attainable magnifying power, on the finest nights, are with difficulty resolved, while some resist every attempt. It is with the last that we are more particularly concerned.

The great reflecting telescope of Lord Ross is well known. It is six feet in aperture and fifty-four feet in focal length. By its aid, nebulæ that had, up to his time, been unresolved, were separated into stars, and from this circumstance the argument was advanced that all nebulæ would yield to a sufficient increase of power and be demonstrated to consist of stars, which, while in reality separated by immense distances, yet seem so closely packed together that their light is blended into one mass.

We have spoken of solar systems; there are, according to these statements, also stellar systems where, instead of a sun and planets, there are groups of suns. Our sun belongs to such a group of resolvable nebulæ, the stars that we see individualized, and those of the milky way, being his companions.

Seen at a great enough distance, our nebular or stellar system would present a flattened or lima-bean-like shape, somewhat elliptical from one point of view, and like a narrow band from another. Is this group arrangement the only form in which luminous matter is found in the universe?

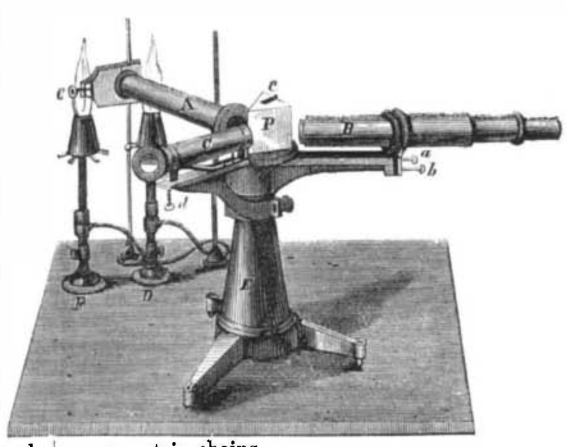
Here, again, the power of means apparently trivial, but rightly applied, is shown. Once more the prism of glass solves a question which hundreds of thousands of dollars expended in telescopes could not have settled. On applying the spectroscope to the investigation of the irresolvable nebulæ, Huggins finds that some of them present the spectra characteristic of an ignited gas, that is, of a flame. The Fraunhofer lines in that case are, as we have said, bright instead of dark, as in the solar spectrum, and the evidence is of a very tangible and unmistakable kind.

There are, then, in space, masses of ignited gaseous matter of prodigious extent, shining by their own light, containing no star and resembling the nebulæ, which the nebular hypothesis declares to have been the original state of our solar system.

Now we can appreciate the assistance which the spectroscope has lent in establishing that noble conception of Herschel and Laplace. It has demonstrated the unity of the solar system by establishing the existence throughout it of the same elements; it has shown the same unity in the materials of the universe; and, lastly, it fortifies us in the belief that that theoretical conception is in process of realization before our eyes; that we may see worlds in the act of formation. The spectroscope has also a bearing on a great geological hypothesis: the former heated state of our globe. Geologists assert, from the presence in high latitudes of the fossil remains of tropical plants, that the earth was once in a molten condition; that it cooled gradually, and at one time reached such a temperature that the internal heat sufficed to maintain a warm climate on every part. The polar regions were not then dependent on the sun for their supply of heat, but needed that luminary only for light. Vegetation was somewhat like that of a hothouse in the north in winter, with plenty of heat, but lacking light for part of the year.

By this hypothesis, a great variety of facts, such as the formation of some mountain ranges, may be satisfactorily explained. For example, when the heated mass of the earth was cooling it was also shrinking, but as soon as an inflexible crust had formed over the liquid ball, that exterior could no longer gradually diminish in circumference, but was forced to pucker into ridges, just as we see in the case of an apple drying up. The apple assumes a wizened appearance, so did the earth. The wrinkles

Fig. 1.

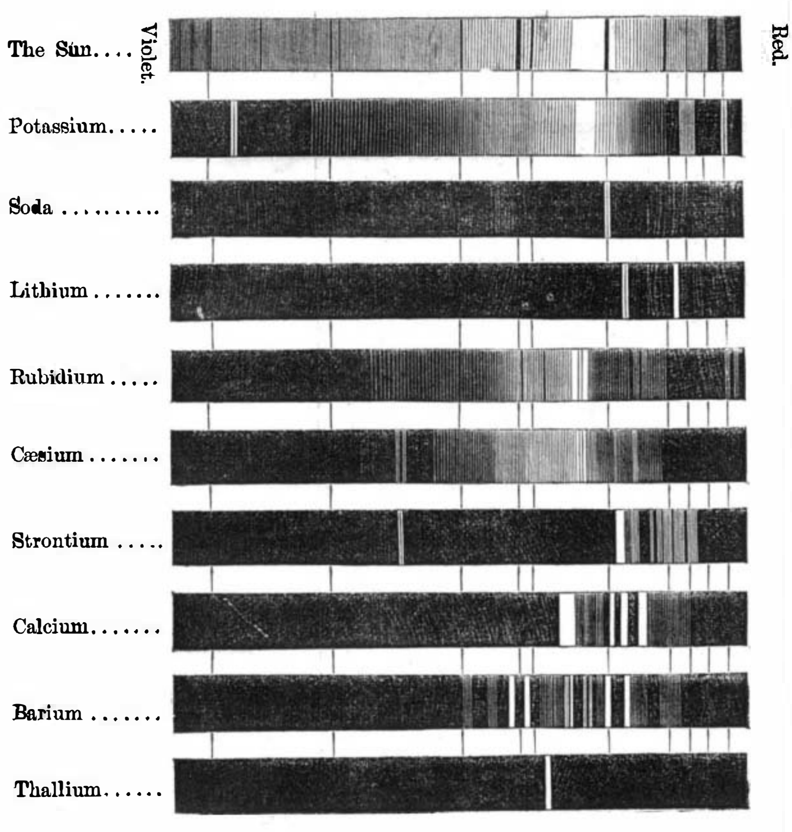


are mountain chains.

The spectroscopic confirmation of these ideas, though indirect, follows necessarily from the support which that instrument lends to the nebular hypothesis. If the earth was once an ignited gas, it is certain that it also presented subsequently a molten form. And its geometrical shape, that of an oblate spheroid, the figure naturally assumed by a rotating liquid mass, is an important link in the chain of evidence.

Another reflection naturally suggests itself to any one thinking about these matters. We know that heat was the force concerned in keeping the materials of our solar system in the gaseous state, for by its aid we can again bring most of them into that form.

Fig. 2.



The escape of heat was the cause of the solidification of the present crust of the earth. Where has all that immense amount of heat gone to?

It escaped altogether as radiant heat, moving in straight lines. Is it lost in the abysses of the universe, or is it somewhere collected together to melt worn-out worlds into nebulæ again, and cause them to run again the course they have before pursued? Can we discover the scheme by which perishing systems are replaced by new ones, and the grand East Indian idea, of a multiplicity of worlds in an infinity of time, realized? How, when the light of our sun has faded out, shall our solar system be revivified, and re-supplied with the force it has lost? These are questions that remain to be solved. We are satisfied that matter and force are eternal, but what their laws of distribution and operation in space and time are, the intellect of man has yet to discover.

And if there has been a gradual formation of planets within our solar system, beginning at its confines, one after another losing its internal heat and becoming dependent on the sun for warmth, does not another thought occur to us? Has not life followed the inward march of heat? Is it not possible that there was a time when plants and animals, such as we have here, were able to exist on the exterior planets, favored by their genial heat? The last traces may not have disappeared from them. And may not the types of low forms of organized things, that inhabited this earth in early geological times, have passed inward toward the sun, where surrounding physical conditions favored them in a manner that has ceased here? Are there on Venus the radiata, mollusca, etc., belonging to our planet ages ago? Do types of life exist in the more distant planets, of some grade higher than our own? We see on the earth the migrating animals that cannot stand the vicissitudes of summer and winter, follow the sun southward in winter, and driven before him northward in the summer. Is there in the solar system a similar obedience to heat and its effects, and an ever inward flowing tide of life?

A Great Railway Enterprise.

The Imperial Mexican Railway, connecting the capital city with Vera Cruz, a distance of 350 miles, is one of the greatest railroad enterprises ever undertaken. In a distance of 55 miles an elevation of 7,000 feet is to be overcome, corresponding to 119 feet per mile, or 2 feet in every 44½ feet throughout the whole distance. The most abrupt ascent ever before achieved was that on the Copiapa line in Chili, 196 feet per mile in 17 miles; but the chief incline of the Mexican Railway, at Maltrata, will overcome 211 feet per mile in a distance of 23 miles. In achieving this part of the work, the engineers have been called upon to construct over the river Metlac, midway between the cities of Orizaba and Cordova, a viaduct which, when completed, will surpass any structure of the kind now existing in the world, and will, of itself, be worth a trip to Mexico to see. This viaduct, to consist, of an iron bridge, now nearly completed in England, will carry the road over the Barranca de Metlac, at the enormous hight of 380 English feet, being nearly 150 feet higher than any such work now extant. One hundred and sixty miles of this road will be opened this month, and the whole is under contract to be completed on the 30th of April, 1869. The road is built under the superintendence of Col. Andrew Talcott, an eminent American engineer.

Variable Star.

In a recent issue we noticed the discovery of a variable star in the Constellation of the North Crown. Rear-Admiral Davis, in a communication to the Secretary of the Navy, gives full credit to Mr. Farquhar, of the Patent Office, for the first discovery of this star. The *Compte Rendus* states that the same star was observed at Rochefort, France, on the night of the 13th of May—only one day later than its discovery by Mr. Farquhar.

A GLASS-MAKERS' convention was recently held at Philadelphia, all the leading concerns being represented. It is said that the glass-manufacturing business has been so much injured by the low rate of tariff put upon imported manufactured glassware, that many shops have been compelled to suspend operations entirely, and the others have so little encouragement to continue the business that but a small number of hands are employed. The ware can be imported, and after payment of duties, sold at a less price than our manufacturers can afford to make it. It is desired by them that Congress raise the tariff on this article of importation.

AT the recent meeting of the American sharpshooters association, at Chicago, Gottlieb Fahlni, of Morgansfield, Ky., won the first prize, making twenty-five shots within a circle four inches in diameter at a distance of 700 feet.