"The Spectroscope."

1870 The Atlantic Almanac, 1870, Boston: Fields, Osgood & Co., p. 62.

THE SPECTROSCOPE.

As several wonderful discoveries have lately been made in astronomy by means of the spectroscope, an account of this instrument and of its applications will not be without interest.

Since an early period in the history of chemistry, it has been known that the different alkalies and alkaline earths can be distinguished by the different colorations which they give to the flame of alcohol. Soda turns the flame yellow, potassa violet, lithia crimson, strontia crimson, lime orange, and baryta green. Magnesia does not color the flame. Many years ago, Sir John Herschel and others experimented upon these lights with a prism. It is well known that when a ray of light from the sun or a lamp, after passing through a narrow slit, is refracted in a direction perpendicular to the slit, it is not all equally bent, but that part is bent less and part more, so that the light is dispersed and spread out into a rainbow-colored spectrum. The red light is the least refracted, and the violet light the most. This experiment is a part of the proof that white light is composed of red, yellow, green, blue, indigo, and violet. Now, when Herschel and other investigators passed the light from the alcohol flame, colored by alkalies, through a slit and a prism in the same way, they found that the light was not spread out into a continuous spectrum from red to violet. The yellow light derived from soda was not dispersed at all, but was all equally refrangible. Such light is called monochromatic, or single-colored, because it is not composed of light of different colors; and in a room illuminated by such light it is impossible to distinguish colors in the least degree; but objects which by daylight present the strongest contrasts in colors, by such a light are precisely alike in that respect. In the case of the other substances the spectrum is not reduced to a single line, nor is it continuous, but it consists of several narrow lines of different colors, separated by black spaces. These were the first chemical experiments with the spectroscope; they did not immediately lead to any great discoveries, on account of the imperfect methods in which further investigations were conducted.

Accordingly, this instrument never attracted much attention until 1860, when the researches of Kirchhoff and Bunsen were published. From this time may almost be dated a new era in chemistry and astronomy. Kirchhoff was a young physicist, little known before; Bunsen, an eminent chemist. The flame they made use of was that of the Bunsen gas-burner, which is much better suited to spectroscopic work than that of alcohol, both on account of its greater heat and also from its freedom from sodium and other impurities, which impart a color to the flame. They proved, in a more rigorous manner than former experimenters had done, that the lines of the spectrum depend solely on the constituents of the flame, and not upon its temperature. They also showed the extreme delicacy of spectroscope-test in many cases. A platinum wire, which has been cleaned by being kept at a white heat until all that could be volatilized in the flame has been driven off, if after cooling it is passed once through the fingers or any cloth, or even is allowed to remain untouched for some time, will, when put into the flame, impart to it the pure yellow light which is characteristic of sodium. This shows that there is common salt floating about in the air of all our houses, and resting upon everything,--a fact quite unsuspected before.

But what drew the most particular attention to these researches was the discovery by Bunsen, by means of the spectroscope, of two new metals. For many years no new elements had been discovered, but, on the contrary, great doubt existed as to the existence of those last added to the list,--pelopium, norium, and terbium. The establishment of the existence of another element was regarded as a labor of many years; yet in one year rubidium and caesium, the metals discovered by Bunsen, were better understood in their chemical relations than a dozen others. The reason of this was that the spectroscope afforded a means of securing the purity of the new substances, which is always the most difficult part of such investigations. Furthermore, the small proportion (about 1-50000th of one per cent) in which the new elements occurred in the mineral water in which they were found made their discovery very surprising. Of course, all this created a great sensation in the scientific world, and the spectroscope was soon found in every laboratory. Two other metals, thallium and indium, have since been discovered by means of it; with the same circumstances of being found in extremely small proportions, and of becoming quickly very well understood. But the chemical discoveries of the spectroscope were soon to be outdone by its performances in the realm of astronomy.

The optician Fraunhofer, in 1814, upon observing the spectrum of the sun with a carefully constructed spectroscope, had observed that it was crossed everywhere with very fine black lines, irregularly distributed, of which he mapped some six hundred. It had been asserted that the most conspicuous of these lines, called D, corresponded in position with the yellow line of sodium. Kirchhoff found that this was precisely true, and demonstrated by a long mathematical process that, in general, a body cannot be transparent to the same rays as those with which it shines. Consequently, the precise coincidence of the yellow sodium line and the line D of the sun's spectrum could be accounted for by supposing that incandescent sodium vapor existed in the atmosphere of the sun, which absorbed this yellow part of the light emitted from the solid sun beneath.

In order to obtain the spectra of the heavier metals they were made the electrodes of a Ruhmkorf coil, whereby a heavy electric spark was made to pass from one piece of such metal to another. This spark gives the spectrum of the metal in the greatest perfection. By comparing the spectra of the metals thus obtained with the solar spectrum, fourteen of them have been detected in the solar atmosphere, which also contains hydrogen.

Fraunhofer had remarked that the lines in the spectra of several fixed stars were not the same with those in the spectrum of the solar light. As soon, therefore, as the cause of these lines became known, several observers began to study the spectra of the stars. Only a few of the stars have been subjected to a thorough examination. In Aldebaran have been found hydrogen, sodium, magnesium, calcium, iron, bismuth, antimony, tellurium, and mercury. In Betelgeux (α Orionis) have been found sodium, magnesium, calcium, iron, and bismuth. Both of these are red stars. The white stars, such as Sirius and Wega, have much fewer and fainter lines. Betelgeux shows some singular shaded bands besides its lines. It is a variable star, and the same bands are shown by several other variables. This circumstance does not afford us an explanation of the variability of stars, but it is supposed that it is owing to a phenomenon like that of sun-spots on a much more exaggerated scale. The sun-spots increase in number for five and a half years, and then diminish for five and a half years.

We are still far from being able to explain the solar spots, and the periodicity of their frequency. But the beginning of an explanation seems to have been made by Mr. Lockyer by means of the spectroscope. Among other points observed by him is a thickening of some of the dark lines in a spot, and this effect would be produced by a greater atmospheric pressure in the spot. He regards a spot as the seat of a down-rush in the atmosphere of the sun.

The variety of information afforded by the spectroscope is illustrated by an observation made some time ago by Mr. Huggins. He found that the lines in Sirius (or at least one of them) were displaced; and this displacement is explicable by supposing that Sirius is moving away from our sun with a velocity equal to four times the velocity of the earth in its orbit. Similar displacements have been observed by Mr. Lockyer in some lines in the solar spectrum, and are explained by the supposition of currents in the solar atmosphere.

The nebulas also have been subjected to spectroscopic examination, and have been found to be of two distinct kinds. The shapeless ones, the "rays," round nebulosities about stars, and the great nebula in Andromeda, show extremely faint continuous spectra, which probably show that these nebulas are really clusters of stars. On the other hand, those which have the form of rings, spirals, and disks, together with the great nebula in Orion, have spectra which consists of one, two, three, or four bright lines, and therefore are certainly gaseous. Several of these, however, show a faint continuous spectrum in addition to their gas-lines. There is little or no reason for thinking that any of these distant gases are such as are known to us on earth, and some of them are certainly different from any that we know.

Since the application of the spectroscope to astronomy no great comet has appeared; but several minute faint and tailless telescopic objects moving in eccentric orbits about the sun have been examined. These have all shown a gaseous spectrum, the gas in two cases containing carbon, and in another showing a line apparently coincident with one of the nebula-lines.

The spectrum of the aurora borealis has often been examined. It is not always the same, but it usually shows a greenish-yellow bright line. In addition to this, six other lines or bands have been seen in this spectrum at the Observatory of Harvard College. All this indicates that the luminous substance is some gas unknown to chemists. The aurora is connected with the earth, but is above the ordinary atmosphere. This gas must, therefore, be very light to extend up so high, but by the laws of gaseous diffusion it must reach down to the surface of the earth. Owing to a law of chemistry, called the law of vapor-volumes, a very light gas enters into combination in very small proportions, and it is by no means improbable that the small proportions in which this gas exists in its compounds may account for its not having been discovered by the chemists.

THE SPECTROSCOPE.

As several wonderful discoveries have lately been made in astronomy by means of the spectroscope, an account of this instrument and of its applications will not be without interest.

Since an early period in the history of chemistry, it has been known that the different alkalies and alkaline earths can be distinguished by the different colorations which they give to the flame of alcohol. Soda turns the flame yellow, potassa violet, lithia crimson, strontia crimson, lime orange, and baryta green. Magnesia does not color the flame. Many years ago, Sir John Herschel and others experimented upon these lights with a prism. It is well known that when a ray of light from the sun or a lamp, after passing through a narrow slit, is refracted in a direction perpendicular to the slit, it is not all equally bent, but that part is bent less and part more, so that the light is dispersed and spread out into a rainbow-colored spectrum. The red light is the least refracted, and the violet light the most. This experiment is a part of the proof that white light is composed of red, yellow, green, blue, indigo, and violet. Now, when Herschel and other investigators passed the light from the alcohol flame, colored by alkalies, through a slit and a prism in the same way, they found that the light was not spread out into a continuous spectrum from red to violet. The yellow light derived from soda was not dispersed at all, but was all equally refrangible. Such light is called monochromatic, or single-colored, because it is not composed of light of different colors; and in a room illuminated by such light it is impossible to distinguish colors in the least degree; but objects which by daylight present the strongest contrasts in colors, by such a light are precisely alike in that respect. In the case of the other substances the spectrum is not reduced to a single line, nor is it continuous, but it consists of several narrow lines of different colors, separated by black spaces. These were the first chemical experiments with the spectroscope; they did not immediately lead to any great discoveries, on account of the imperfect methods in which further investigations were conducted.

Accordingly, this instrument never attracted much attention until 1860, when the researches of Kirchhoff and Bunsen were published. From this time may almost be dated a new era in chemistry and astronomy. Kirchhoff was a young physicist, little known before; Bunsen, an eminent chemist. The flame they made use of was that of the Bunsen gas-burner, which is much better suited to spectroscopic work than that of alcohol, both on account of its greater heat and also from its freedom from sodium and other impurities, which impart a color to the flame. They proved, in a more rigorous manner than former experimenters had done, that the lines of the spectrum depend solely on the constituents of the flame, and not upon its temperature. They also showed the extreme delicacy of spectroscope-test in many cases. A platinum wire, which has been cleaned by being kept at a white heat until all that could be volatilized in the flame has been driven off, if after cooling it is passed once through the fingers or any cloth, or even is allowed to remain untouched for some time, will, when put into the flame, impart to it the pure yellow light which is characteristic of sodium. This shows that there is common salt floating about in the air of all our houses, and resting upon everything, — a fact quite unsuspected before.

But what drew the most particular attention to these researches was the discovery by Bunsen, by means of the spectroscope, of two new metals. For many years no new elements had been discovered, but, on the contrary, great doubt existed as to the existence of those last added to the list, — pelopium, norium, and terbium. The establishment of the existence of another element was regarded as a labor of many years; yet in one year rubidium and cæsium, the metals discovered by Bunsen, were better understood in their chemical relations than a dozen others. The reason of this was that the spectroscope afforded a means of securing the purity of the new substances, which is always the most difficult part of such investigations. Furthermore, the small proportion (about 1-50000th of one per cent) in which the new elements occurred in the mineral water in which they were found made their discovery very surprising. Of course, all this created a great sensation in the scientific world, and the spectroscope was soon found in every laboratory. Two other metals, thallium and indium, have since been discovered by means of it; with the same circumstances of being found in extremely small proportions, and of becoming quickly very well understood. But the chemical discoveries of the spectroscope were soon to be outdone by its performances in the realm of astronomy.

The optician Fraunhofer, in 1814, upon observing the spectrum of the sun with a carefully constructed spectroscope, had observed that it was crossed everywhere with very fine black lines, irregularly distributed, of which he mapped some six hundred. It had been asserted that the most conspicuous of these lines, called D, corresponded in position with the yellow line of sodium. Kirchhoff found that this was precisely true, and demonstrated by a long mathematical process that, in general, a body cannot be transparent to the same rays as those with which it shines. Consequently, the precise coincidence of the yellow sodium line and the line D of the sun's spectrum could be accounted for by supposing that incandescent sodium vapor existed in the atmosphere of the sun, which absorbed this yellow part of the light emitted from the solid sun beneath.

In order to obtain the spectra of the heavier metals they were made the electrodes of a Ruhmkorf coil, whereby a heavy electric spark was made to pass from one piece of such metal to another. This spark gives the spectrum of the metal in the greatest perfection. By comparing the spectra of the metals thus obtained with the solar spectrum, fourteen of them have been detected in the solar atmosphere, which also contains hydrogen.

Fraunhofer had remarked that the lines in the spectra of several fixed stars were not the same with those in the spectrum of the solar light. As soon, therefore, as the cause of these lines became known, several observers began to study the spectra of the stars. Only a few of the stars have been subjected to a thorough examination. In Aldebaran have been found hydrogen, sodium, magnesium, calcium, iron, bismuth, antimony, tellurium, and mercury. In Betelgeux (α Orionis) have been found sodium, magnesium, calcium, iron, and bismuth. Both of these are red stars. The white stars, such as Sirius and Wega, have much fewer and fainter lines. Betelgeux shows some singular shaded bands besides its lines. It is a variable star, and the same bands are shown by several other variables. This circumstance does not afford us an explanation of the variability of stars, but it is supposed that it is owing to a phenomenon like that of sun-spots on a much more exaggerated scale. The sun-spots increase in number for five and a half years, and then diminish for five and a half years.

We are still far from being able to explain the solar spots, and the periodicity of their frequency. But the beginning of an explanation seems to have been made by Mr. Lockyer by means of the spectroscope. Among other points observed by him is a thickening of some of the dark lines in a spot, and this effect would be produced by a greater atmospheric pressure in the spot. He regards a spot as the seat of a down-rush in the atmosphere of the sun.

The variety of information afforded by the spectroscope is illustrated by an observation made some time ago by Mr. Huggins. He found that the lines in Sirius (or at least one of them) were displaced; and this displacement is explicable by supposing that Sirius is moving away from our sun with a velocity equal to four times the velocity of the earth in its orbit. Similar displacements have been observed by Mr. Lockyer in some lines in the solar spectrum, and are explained by the supposition of currents in the solar atmosphere.

The nebulas also have been subjected to spectroscopic examination, and have been found to be of two distinct kinds. The shapeless ones, the "rays," round nebulosities about stars, and the great nebula in Andromeda, show extremely faint continuous spectra, which probably show that these nebulas are really clusters of stars. On the other hand, those which have the form of rings, spirals, and disks, together with the great nebula in Orion, have spectra which consists of one, two, three, or four bright lines, and therefore are certainly gaseous. Several of these, however, show a faint continuous spectrum in addition to their gas-lines. There is little or no reason for thinking that any of these distant gases are such as are known to us on earth, and some of them are certainly different from any that we know.

Since the application of the spectroscope to astronomy no great comet has appeared; but several minute faint and tailless telescopic objects moving in eccentric orbits about the sun have been examined. These have all shown a gaseous spectrum, the gas in two cases containing carbon, and in another showing a line apparently coincident with one of the nebula-lines.

The spectrum of the *aurora borealis* has often been examined. It is not always the same, but it usually shows a greenish-yellow bright line. In addition to this, six other lines or bands have been seen in this spectrum at the Observatory of Harvard College. All this indicates that the luminous substance is some gas unknown to chemists. The aurora is connected with the earth, but is above the ordinary atmosphere. This gas must, therefore, be very light to extend up so high, but by the laws of gaseous diffusion it must reach down to the surface of the earth. Owing to a law of chemistry, called the law of vapor-volumes, a very light gas enters into combination in very small proportions, and it is by no means improbable that the small proportions in which this gas exists in its compounds may account for its not having been discovered by the chemists.