The Principles of Spectrum Analysis. By THOMAS ROWNEY.

From the London Intellectual Observer, June, 1862.

Sixty years or more ago Dr. Wollaston detected in the spectrum obtained from solar light a series of dark bands crossing it throughout its entire length. These lines may be easily seen through a prismatic telescope, of which Mr. Crookes has contrived a simple form. The discoverer does not appear to have thought much of the fact, and seems to have discontinued his experiments, as we have no further account of his researches in that direction. It was not until Fraunhofer of Munich announced his independent discovery of the same lines, and showed that they were constant both in number and position, and mapped them out to the extent of more than 600, with the most sedulous care, that they came to be regarded as features worth notice. He showed that these lines, which now bear his name, might be found in all spectra, by viewing them through a telescope, whether the source of light were the sun, moon, fixed stars, or planets. He also found them in the electric spark, and in flames colored by the combustion of metals. These two philosophers might justly lay claim to the honor of having laid the foundation of what is now termed spectrum chemistry. In the words of Dr. Miller :

“The inquiry thus launched by Fraunhofer has been followed in four principal branches of research, which may be described as relating to,—

“1. *Cosmical lines*, or the black lines produced in the light of the sun, the planetary bodies, and the fixed stars.

“2. *Black lines produced by absorption*, a class of phenomena discovered by Sir D. Brewster, in his observations upon the red vapors of nitrous acid.

“3. *Bright lines produced by the electric spark*, when taken between different conductors.

“4. *Bright lines produced by colored flames*, or by the introduction of different substances into flames.

“The following chronological table contains the names of those who have made the principal steps in these different subjects :—

“ Newton	.	.	1701.
Wollaston	.	.	1802.
Fraunhofer	.	.	1815.

COSMICAL.

Brewster, 1832.
 E. Becquerel, 1842.
 Draper, 1842.
 Stokes, 1852.
 Brewster and } 1860.
 Gladstone, }

ABSORPTION BANDS.

Brewster, 1832.
 W. H. Miller } 1833.
 and Daniel, }
 W. A. Miller, 1845.

ELECTRIC LIGHT.

Wheatstone, 1835.

Foucault, 1849.

Masson, 1851—55.

Angstrom, 1853.

Alter, 1854—55.

Secchi, 1855.

Plückner, 1858—59.

V. Willigen, 1859.

Kirchhoff 1859.

Kirchhoff and Bunsen 1860."

COLORED FLAMES.

Brewster, 1822.

Herschel, 1822.

Fox Talbot, 1826, 1833, 1834.

W. A. Miller, 1845.

Swan, 1857.

In order to a right understanding of the results which have been reached by the recent labors of Kirchhoff and Bunsen, it is necessary to be acquainted with the nature of the dark lines, which are so many touchstones or tests by which they have worked them out. Let us suppose a prism of blue glass to be used for effecting the decomposition of a ray of solar light. We have an elongated image, not, however, containing seven colors, as when a white prism is used. The yellow, blue, and green are all absorbed, and we have only the two extreme colors, violet and red, the latter also diminished in breadth. A comparison with the normal spectrum will make the difference at once clear. In passing through our atmosphere, or the atmosphere of the sun, similar changes may take place, and thus materially assist in producing these dark lines. Moreover, there are a class of rays in the solar spectrum which our eyes cannot see, and of which we can only judge by their effects. Of such are the chemical rays which manifest their action in the beautiful results of the photographic art. We may instance also another set found beyond the violet rays, whose presence has been demonstrated by Professor Stokes, by transmitting them through a solution of sulphate of quinine. They have a light bluish-lavender color. Thus, it will seem that certain rays have such a refrangibility that our eyes cannot take cognizance of them; and so also certain rays exist in solar light which are incapable of transmission through certain media. Applying this to the solar spectrum, we have a clue to the production of the dark lines, by supposing, with Kirchhoff and Bunsen, that the sun has the property of inducing or giving out rays of a certain refrangibility, but yet cannot produce others capable of filling the interspaces. Another interpretation has been given, by supposing an interference in the undulations of certain rays, which produce darkness; but this theory will not meet the circumstances of the case, and we can show by experiment that by making an artificial atmosphere the same or parallel results can be produced.

The natural variations in the composition of the atmosphere produce similar effects, and Brewster was the first to notice bands in the red and green spaces, whose appearance was not constant. These appearances are usually observed when the sun is not far from our horizon; and Dr. Miller mentions an instance in which he saw a group of lines

during a thunder shower. They came suddenly, and faded as the rain passed away.

The readiness with which the spectrum responds to changes in the atmosphere, or in the nature of the source of light, is shown in the following experiment of Kirchhoff and Bunsen :—

They threw up into the air of the apartment a small quantity of chloride of sodium in very fine powder. Motion was imparted to the atmosphere, to insure an equable diffusion of the salt. The spectrum in an instant demonstrated its presence, by showing a golden-yellow band in the yellow space. This effect is uniform whenever sodium is present in a state of incandescence, and is therefore called the sodium spectrum. This result might have been expected, knowing that sodium in any form always tinges flame an intense yellow; but when we come to the combustion of other metals, the bands produced by them are such as could never have been anticipated. When silver is burnt we have other colored bands brought out equally characteristic, and so with every other metallic substance. To show the relation between these colored bands and the dark lines, we will suppose the light of a pure white flame to be passed through a yellow sodium flame, and then through the prism. Now, mark the change. The spectrum is no longer continuous, and having its bright yellow band in the yellow space; but where it flashed out so conspicuously is now to be seen a dark line, known as “D.” The rationale is obvious. The yellow atmosphere has interfered with the yellow of our normal spectrum, and by that interference darkness has resulted.

Keeping these results in view, we have a key to the whole subject of spectrum chemistry. It can be shown that each metal in a state of vapor has the power to arrest particular rays with a constancy that can be relied on. The arrangement best suited for these experiments is either Dubosq’s electric lamp, or the Drummond light, but many of the spectra may be conveniently studied by using Crookes’s spectroscope, as made by Spencer Browning and Co., and now too well known to need detailed description. This instrument is well adapted for ordinary purposes, but to appreciate the full beauty and delicacy of the various spectra, we should need an apparatus as perfect as that constructed for Kirchhoff by Steinheil of Munich.

When artificial light is employed—as that of gas or lamp—the dark lines may be brought out by interposing a glass trough or bottle containing nitrous acid gas between the light and the instrument. This gas may be obtained by the action of a small quantity of nitric acid on a piece of copper; and, as we have before mentioned, it acts as an absorptive medium. If a piece of sulphur be introduced into the flame of a spirit-lamp, a good view of its dark bands may be obtained. If the subject for examination be an alkaline metal, the spirit-lamp may be used, or better still, a flame of hydrogen mixed with air and burnt on the top of a tube covered with wire gauze. We thus obtain a flame of high temperature with little light, except what is derived from the substance employed. The metal in a state of chloride is the most convenient form—it being more easily volatilized. It may be introduced

into the cotton wick ; or if the gas-burner be used, then a loop of platinum wire sliding on an upright support is the easiest to manage. The copper spectrum may be readily obtained by dipping a coil of fine wire into pure hydrochloric acid, and immediately inserting it into the gas-flame. When iron, silver, &c., are operated upon, wires of these metals should form the electrodes of a powerful voltaic battery, and be brought by its agency to an incandescent state, when a portion of their substance is volatilized, and exhibits its characteristic action through the prism.

Kirchhoff and Bunsen, while pursuing their researches on the composition of some mineral water, obtained from the combustion of the solid matter a series of bands in two spectra, which did not correspond with those produced by any of the known metals. This led them to infer the presence of some new elements which the eye of man had never yet seen. After evaporating several tons of the fluid, their labors were rewarded by obtaining two new metals, which they named Cæsium (greyish blue)—that being the color of the bands—and Rubidium (dark red). No sooner had they done this than they were off into the depths of speculation, conceiving that they had in their power a means of analysis capable of much higher application.

These ingenious and indefatigable workers found that the bright lines in the metallic spectra corresponded closely with the dark lines of the solar spectrum. Why was this ? and how could it be explained ? They found, by experiments before cited, that each color was opaque to rays of its own color.

To illustrate the point more clearly, we may suppose two pendulums of equal length to be placed side by side. If the one be made to vibrate, it will, after a time, cause its companion to do the same in consequence of its equal length or isochronous condition ; and so it is supposed that the rays of one color will be taken up by another whose vibrations are of equal length, and so be arrested in their voyage. Now look at the application of this result. If, in the rays of light from an artificial source, this principle be correct, it may also be correct with the rays of solar light. Hence they have inferred that the dark bands of the solar spectra are produced by their passage through an atmosphere containing certain metals in a state of high combustion or vapor.

Upon these grounds they have concluded that in the outermost solar envelope exist all those metals in a state of vapor, whose color-bands coincide with dark lines of the solar spectrum, as sodium, potassium, iron, and nickel ; and that it is by the more powerful light of the photosphere shining through this only feebly-luminous layer that the dark bands of Fraunhofer are produced by the process before described. They have also inferred the source from which these metals are derived to be the mass of the sun. A bold assertion, perhaps a correct one ; but we are certainly not at present justified in accepting it as if it were proved ; and we may advantageously reflect upon the words of Dr. Miller :—

“Fascinating as this theory is, it must be remembered that it is yet

upon its trial, and that it does not explain the facts at present known respecting the vapors of hydrogen, mercury, chlorine, bromine, iodine, and nitrogen. M. Morren even questions the accuracy of some of Kirchhoff's observations. Thus, he states that in a measurement which he made of the red band of potassium, conjointly with Plücker, they found that it did not correspond with the solar line A, but that it is considerably more refrangible."

There are many other important facts which will have to be considered before we can arrive at a complete theory of the spectral phenomenon. For example, chloride of lithium produces a single crimson line in the flame of a Bunsen burner; the greater heat of a hydrogen flame enables it to emit an orange ray, and the voltaic arc adds a brilliant stripe of blue. In like manner, iron and other metals furnish spectra which advance in complication as the temperature of their vapor is increased.

Professor Roscoe says that "the general rule is that *luminous solids* give off a different *quality of light* when they are differently heated, and luminous gases give off the same kind of light at all temperatures." The spectra of gases are quite as interesting as those of the metals; hydrogen, for example, giving a red and a blue band, and nitrogen beautiful violet stripes.

On the use of Mica for Preserving Gilding, &c.

From the *Mechanics Magazine*, August, 1862.

In Paris, mica has lately been applied for preserving, silvering, and gilding decorations in churches and public buildings. The mica is first cut to the desired thickness with a knife, and is then coated with a thin layer of isinglass diluted in water, and the gold or other substance is applied, after which it is allowed to dry. A pattern of copper, with a design cut out on it, is then placed on the reverse side of the mica and the superfluous parts are removed. The colors are then applied in one or several coats, and the whole afterwards coated with a solution of isinglass and diluted alcohol, by which the mica is rendered pliable. When this is effected, the mica is applied to the object, which is coated with glue or other adhesive material, and allowed to become comparatively dry, after which the surface is made smooth by rubbing it gently with an agate burnishing tool. The value of mica depends on the size of the sheets and their transparency, the clear ruby-tinged being the finest, and the cloudy grey the least valuable.

Mountain Barometer.

From the *Intellectual Observer*, July, 1862.

Under this title Messrs. Horne and Thornthwaite have produced a very excellent aneroid, especially adapted to facilitate the measurement of heights. Being only $2\frac{1}{2}$ inches in diameter, it is very portable, while from the excellent workmanship, no practical loss of efficiency is the consequence of its reduced size. The face is graduated in two