QUANTITATIVE SPECTRUM ANALYSIS.

The subject of spectrum analysis has of late been so frequently and prominently brought before the public that it is only necessary briefly to recapitulate what has been done in order to understand the most recent tendency of investigation with this wonderful instrument, to which science already owes so much.

We must remember then, to begin with, that chemical substances, when volatilized in a flame, make known their composition by causing certain light lines to appear in the spectrum produced by making the light from the flame pass through a prism. Every chemical element has lines peculiar to itself, and their relative position in the spectrum is so constant that their appearance enables the observer at once to recognize the presence of substances. We can tell whether a light to be examined is due to a glowing gas, or proceeds from a liquid or solid body. A gas will produce bright colored bands separated by dark spaces, while a liquid or solid will give rise to a spectrum containing every shade of color without gaps. Thus the nature of the light coming from heavenly bodies is revealed to us, and it has been found, for example, that about one third of the nebulæ are composed of incandescent gas. A glowing vapor will absorb the same kind of light as that which it emits; if therefore a brilliant source of light is surrounded by a glowing vapor, that vapor will not permit certain portions of the light behind it to pass through, and the absorption will be indicated by dark lines in the spectrum. These dark lines will be in the same places where the glowing vapor alone would produce bright ones. Hence it is that the spectrum of the sun, which is surrounded by an envelope of glowing gas, contains a great number of dark lines whose position reveals to us the substances present in the incandescent envelope. The same is true of the fixed stars, whose spectra are also characterized by dark lines.

When a luminous body is approaching us with great velocity, the waves of light crowd upon each other, become more rapid and shorter, and hence more refrangible, than if the body were stationary. Any given line in the spectrum of such a body will therefore be found nearer the more refrangible or violet portion of the spectrum than its normal position. If the luminous body is receding, the line will move towards the less refrangible or red end of the spectrum. The displacement of the line being accurately measured, we can calculate, from its known wave length and the velocity of light, the rate at which a fixed star is approaching or receding from the earth.

Terrific hydrogen storms are constantly taking place on the surface of the sun. On account of the glare of the light, these could only be seen formerly around the edge of the moon's disk during a total eclipse. Now they can be observed at any time by means of a spectroscope of high dispersive power, which extinguishes the blaze of the sun sufficiently to allow them to be seen. The enormous velocity of the currents of glowing hydrogen projected upwards from the sun's surface can be measured on the same principle as that of a star approaching the earth.

If the light passing through colored solutions is examined by the spectroscope, certain portions of it will be found to be absorbed, and their spectra will be characterized by dark bands, whose position and arrangement varies with the nature of the solution. It is thus that we can distinguish between different dyes, detect artificial coloring of wines (as, for example, by means of logwood), and decide upon the important question, likely to arise in criminal cases, whether a substance to be examined is human blood or not.

The fluorescent light produced, in a large class of substances, when illuminated by blue and violet light affords, on examination by the spectroscope, a ready and most delicate means of determining their composition and even their state of hydration. Fluorescing substances, moreover, by rendering visible the actinic rays, increase the effective length of the spectrum and hence the delicacy of analysis.

Among many practical applications of spectrum analysis, one of the most important is in the manufacture of steel by the Bessemer process. A blast of air is forced through the melted iron to deprive it of a certain proportion of carbon. If this blast is continued a few minutes too long or stopped a few minutes too soon, the whole operation is vitiated. By examining the flame of the converter with the spectroscope, the proper time to stop the blast is clearly indicated by the disappearance of the carbon lines and the change to a continuous spectrum.

But the uses of the spectroscope do not stop here. Scientific men have of late been turning their attention in a new direction, that of quantitative analysis by means of the spectrum. Not content with discovering what substances are contained in a given compound, they are devising means to determine the quantity of these substances.

In a session of the French Academy of Science held November, 7, 1870, Janssen stated that he believed he would soon be able to determine sodium quantitatively by means of the spectroscope. In his analyses, he was much annoyed by the constant presence of the sodium line, caused by the sea salt in the air; so he directed the slit of the spectroscope upon the most brilliant portion of the flame of an ordinary gas burner instead of a Bunsen burner, in order to get a continuous spectrum in which the D line did not appear sensibly, because of the abundance of the neighboring lines. Sometimes he had to interpose several flames between the testing flame and the spectroscope. This led him to conceive the possibility of estimating the quantity of sodium by the number of flames necessary. He also stated that the length of time it takes the sodium to volatilize might serve as a criterion of its quantity.

These crude ideas formed the basis of a series of experiments undertaken quite recently by MM. Champion, Pellet and Grenier. After substituting colored glasses and colored solutions for Janssen's flames, and making a great many experiments, they constructed the "spectronatrometer," an instrument of considerable delicacy, but rather complicated in its arrangement. We will therefore confine ourselves to a description of its principles.

The soda in the substance to be analyzed is converted into the sulphate, the volatility of which is found to be intermediate between that of the chloride and the phosphate. Into the solution obtained a wire, of platinum-iridium ·04 of an inch thick, is dipped and dried. It is then carried into a flat Bunsen flame with a perfectly regular motion by means of clockwork; and the intensity of the sodium line, produced in the spectroscope directed upon the flame, is compared with that of a line produced from a solution containing a known quantity of sodium or from the volatilizing of solid pure sulphate of soda. The comparison is effected by causing the rays of the substance to be examined to pass through a glass prism containing a colored solution. This prism, being wedge-shaped, permits the experimenter to make the light pass through different thicknesses of the absorbing liquid (that is, from ·04 to ·60 inch) until he gets a sodium line equal in intensity to that of the standard of comparison. The inventors have made a large number of observations on solutions of known strength, and constructed a curve, whose abscissas represent the thickness of the layer of the solution in the prism through which the light has to pass, and whose ordinates correspond to the quantity of sodium present.

Dr. K. Vierordt, of Tübingen, the inventor of a delicate method of photometry by means of the spectroscope, solves the problem of quantitative analysis of bodies giving an absorption spectrum in the following way: The slit of the spectroscope, adjusted to a certain width, is divided into two parts. Opposite one half is placed a solution of the body to be determined, and opposite the other a solution of the same body whose strength is known. The first slit is then narrowed or widened until the absorption is the same in both halves of the spectrum, when the width is read off. By using a series of solutions varying decimally in strength, from the weakest to the strongest through which light will pass, curves may be constructed, in which solutions of unknown strength can be interpolated and their value ascertained. When a certain point is reached, further concentration of a solution will not affect its absorbing power regularly, and it is therefore necessary to dilute liquids which are very concentrated. Tables to facilitate calculation have been computed by Dr. Vierordt.

The most recent and perhaps the most important method yet discovered is due to Lockyer of England. It is based upon the following principles: When an alloy is introduced into the electric arch, the most volatile metal will be carried across to the other pole first, and its vapor will form so good a conductor that but little of the less volatile metal will get into the arch. To make the principle perfectly plain, we will quote an explanation given by Tyndall. When showing his audience the characteristic lines of silver and thallium, he found that the latter were far brighter, and that the former were diminished, when a bit of thallium was put in with the silver in the electric arch. "It is the resistance," he went on to say, "offered to the passage of the electric current from carbon to carbon that calls forth the power of the current to produce heat. If the resistance were materially lessened, the heat would be materially lessened; and if all resistance were abolished, there would be no heat at all. Now thallium is a much more fusible and vaporizable metal than silver; and its vapor facilitates the passage of the current to such a degree as to render it almost incompetent to vaporize silver." The more, therefore, of the more volatile metal is present in an alloy, the less of the other can be vaporized by the arch.

Now on examining the arch by means of the spectroscope, Lockyer found lines extending across the whole width of the spectrum and shorter ones reaching only part of the way. The former corresponded to the more volatile, and the latter to the less volatile, metal. Now, as the length of the latter increases with the quantity of the metal present, it is evident that by measuring them we can ascertain that quantity. In these determinations, the electric current is obtained either from a powerful battery, a Ruhmkorff coil or a magneto-electric machine; and the heat of the spark is intensified and at the same time rendered constant by means of Leyden jars of constant surface. Instead of placing the alloy to be tested in one of the carbon electrodes, we might have the electrodes themselves composed of the metals. Suppose we make one of pure gold and the other of some alloy whose percentage of gold we wish to ascertain. Then by separating the electrodes sufficiently, we finally arrive at a point where the gold lines from the alloy no longer meet the lines from the pure gold, but will extend only part of the way, leaving a gap on their half of the spectrum. If we now keep the same distance between the electrodes, and experiment on alloys containing different percentages of gold, the length of their gold lines will be found to vary with that percentage. The length of the lines can easily be measured by causing the reflection of a graduated scale to fall upon the spectrum. In assaying, where we frequently have to do with samples of gold whose fineness differs but little, a series of electrodes of known composition may be prepared; and by comparing them with alloys of unknown fineness, it is easy to tell, by simple inspection of the spectrum, which is the finer. The lines of the one containing less gold will not extend all the way across.

The attention of the United States Mint has been called to this discovery of Mr. Lockyer's; and while this article was in course of preparation, an officer from the Philadelphia branch was experimenting in the Stevens Institute of Technology with a view of testing its practical utility.

Photometry of Colors.

Mr. Wm. M. Lockwood, a practical photographer, read a paper before the National Photographic Association at the recent meeting in Buffalo, N. Y., in which he explains in an interesting and philosophical manner some of the mathematics of light, and the difficulties connected with the photographic production of colors. He says:

"I closed up my window so as to exclude all solar light; then, with a small gimlet, I bored two holes through this covering to my window, about half an inch apart, one over the other. By placing the ground glass so as to cover both these holes, I noticed that the two rays of light, passing through the holes and glass, seemed to unite at a distance of nearly five inches; the same trial with the purple glass made the rays unite at about seven inches; deep blue glass, at nearly ten; red glass, fifteen; and yellow glass, over twenty inches. To me this was a real discovery, because it settled in my mind that colors were of different focal length, and, being so, affected or reduced the iodide of silver, in sensitive films, each in a different way. I subsequently ascertained that Tyndall and others had established the focal length of colors, but have not, to my knowledge, determined their respective actinic force. I have another theory beside the above mentioned that goes to more fully establish the relative focal length of colors, and at the same time determines, to a certain extent, their actinic capabilities. Dr. Young and Augustin Fresnel, both eminent philosophers, were the first to establish the basis of what is called the wave theory of light. According to data arrived at by these gentlemen, a wave of pure solar light, in a clear atmosphere, is $\frac{1}{75000}$ of an inch in length; that of violet light, $\frac{1}{57500}$; that of blue, $\frac{1}{49500}$; red, $\frac{1}{39000}$; yellow, $\frac{1}{27500}$. In fact, 'the color of light is determined solely by its wave length.' Now the velocity of light being 192,000 miles in a second, if we ascertain the number of waves of each color in a mile and multiply this by 192,000, we obtain the number of waves that enter the eye, or attack the surface of iodide of silver, in a second of time.

Thus the waves of pure solar light amount to 913,384,192,-375,000. In the same interval of time 699,000,000,000 waves of violet light enter the eye or attack the sensitive film of your plate.

As violet light stands next to pure solar light in its actinic capabilities, you can easily understand what a large percentage the reflection of solar (white) light has over that of any other, the difference in this instance being 214,384,192,375,-000 in favor of white light in a second of time. Now, gentlemen, do you fully understand how it is that the human face, which is possessed of from three to seven distinct colors, tends to solarization in what we term the 'high lights?' Do you see how futile it is to attempt to photograph a red face with white draperies, a yellow face with purple clothing, a sunburnt and freckled face in white linen and laces? Do you not now see at what a fearful discount you work when you attempt to make a finely modeled picture under these circumstances? Do you wonder that so many otherwise good pictures are so flat, white, and chalky in the high lights? Seven eighths of all photographs made, which are failures in lighting and likeness, are attributable to this phenomenon alone. * * My cure is homœopathic; '*similia similibus curantur*,' or words to that effect. I use different colored reflectors, according to complexions. If red predominates in the face, use red as a modifier; if blue, yellow, or brown, use blue, yellow, or brown. The rule is: Look for the most non-actinic color in a face, and select the colors of your reflectors accordingly. Why? Because, by flooding the face with any color, you thereby tend to reduce all colors to a mean focus, or to reduce the difference in the length of the waves to an approximate length.

"I tried this theory for several months and find it works nicely, and will do away with seventy-five per cent of retouching, which is an item now-a-days.

"I give you these thoughts, and the use of my system of lighting, free of charge. I have no patent. I have given you the particulars of my theory, not so much to provoke criticism as to provoke thought."

Persimmon Coffee.

The Commissioner of Patents has lately issued a patent to to Edward Dugdale, of Griffin, Ga., for a new article of coffee, consisting of roasted persimmon seeds. Verily there is no end to the vagaries of the Patent Office.

That special SIXTY THOUSAND edition of the SCIENTIFIC AMERICAN, which is to issue about the 15th instant, is nearly ready for the press. Orders for advertisements on the back page came in so quickly, after the announcement of our intention to print a special edition, that the space was all taken some time ago.

One inside advertising page and the Business and Personal column will be left open for a few short advertisements till the morning of November 15. For terms, see inside page of this paper.

The SPECIAL number will be copiously illustrated, varied in contents, and full of useful information, which will insure its preservation by those who receive it.

After the sixty thousand are printed, orders from advertisers and others will be executed, for any number of copies of the paper desired, at reduced rates. When writing for terms, state the number of papers wanted. The larger the order, the less will be the price per hundred or thousand.

THE Danbury *News* man has discovered that car wheels are being made out of paper. He is now desirous of finding out whether that paper is *Iron*.