mechanical factor deserves to be set apart from the others in importance. However, the special carbureter, which makes possible the application of the new system, is of sufficient novelty to warrant especial attention. Fig. 1 shows the top view of a two-cylinder tractor motor equipped with the system in question. The cam shaft is gear driven and in turn drives both governor and magneto through bevel gears. The fly-ball governor, through a first-class lever and a link coupling, operates a sliding brass valve which is clearly shown in Fig. 2. The carbureter sits above the cylinders, with the short inlet manifold presenting little opportunity for the mixture to stratify before it is completely vaporized. It contains constant-level chambers for kerosene and water, an overflow being provided for each. It has also, for starting purposes, a chamber for gasoline which is filled by hand pump. This chamber, which holds about a pint, is connected by a siphon with the mixing chamber. Turning the engine over creates suction enough to draw upon the contents of this chamber, but a vent is provided so that if a start is not made immediately the siphon will not continue to act and drain the chamber.

Fig. 3 shows the position of the valve plate at light load. Two air inlets are then open, providing a large ratio of admission to outlet area and thus greatly reducing the relative vacuum in the mixing chamber. As the load increases, the governor throws the sliding valve forward, increasing the area of the outlet to the cylinder, increasing the air inlet in the middle, and decreasing or entirely closing the air opening at the right. Thus the ratio of admission to outlet area decreases, the relative vacuum becomes greater, and more fuel in quantity, though not in proportion, is picked up by the incoming air and carried to the cylinder.

A sectional view from the side (Fig. 4) shows the arrangement of the kerosene and water needle valves, the overflow, etc. It will be noted that the water level is lower than the kerosene level. The suction therefore is not great enough, until the engine reaches about half load, to lift the water to the point (H₂) where it can flow down the tube surrounding the needle valve. From half to full load, the ratio of water to fuel increases rapidly until the amounts of fuel and water used are practically equal.

The carbureter is so designed that the fuel needle-valve (K) should be adjusted at the full-load position, when the plate is farthest to the right. This order of procedure is important, since at this position the adjustable plate has no effect upon the area of the air inlet openings. The adjustment of the air should be made at the "no-load" position and after once made, need never be changed, unless the engine enters a very different altitude. This adjustable plate allows each carbureter to be adjusted to the engine it is to serve, hence the slight variations in manufacturing are fully taken care of. The sliding plate is the only moving part in the carbureter, and that is positively controlled. There are no springs, floats, or check valves. Wear cannot affect the size of the air open-

ings which control the relative vacuum in the mixing chamber, therefore the accuracy of the carbureter will never be interfered with by any ordinary cause.

Ignition is necessarily electric, and in large engines where the speed variation is great, means have been developed for automatically advancing the spark as the speed increases. On ordinary engines, however, only such manual adjustments are needed or provided as will take care of the starting and normal speeds.

One of the most noted gas-engine builders in the country has adapted this system to a line of stationary kerosene and distillate engines which will eventually range in size from 50 to 170 horse-power. His factory tests show an efficiency of over 15 brake horse-power hours per gallon of kerosene on 50 horse-power single cylinder engines at all loads from about one third to shortly below the maximum. The manufacturer's literature places a guarantee of within 2 per cent on speed regulation. One other large licensee making stationary engines in sizes from 3 to 15 horse-power is achieving considerable success through a series of electric lighting and power outfits suitable for the country home or small business. The generators are direct-connected, yet give steadier power than the average public service in the smaller towns. The U. S. Government is using a number of engines fitted with this system to drive air compressors for foghorns in life-saving stations on the Great Lakes.

A six-cylinder marine engine using the system here described develops a brake horse-power hour from 0.9 pint of kerosene. A large number of these engines are being used by the Japanese government for operating electric lighting and wireless telegraph stations, and these engines have been adapted to a great variety of uses in this country where safety and close speed regulation are essentials. Naturally, insurance rates are much lower where a non-volatile fuel is used.

The widest use of this system, however, has been made in connection with farm tractors. One factory built more than 50 tractors a week as an average for the year 1912 with a total of more than 115,000 horse-power. These engines are meeting with universal success, operating on the kerosene and distillates of the United States, on gasoline in South America, and on the lighter grades of crude oil found in the United States and Southern Russia. One tractor recently ran for four months on Montana crude oil without cleaning or even inspection. A two-cylinder tractor, 10-inch bore by 12-inch stroke, running at 375 revolutions per minute, recently developed in an official contest at Winnipeg, Manitoba, 51 brake horse-power in an economy test with a consumption of 0.71 pound of fuel per horse-power hour, and 76.5 horse-power in a maximum test on 0.85 pound of fuel. This is a grade of fuel which sells at 5½ to 7 cents in barrel lots in country towns throughout the Central States, and weighs nearly 7 pounds to the United States gallon.

In the Winnipeg Motor Contest of 1911, a single-cylinder engine of the same type averaged 0.85 of a pint

of fuel per brake horse-power hour on kerosene and 0.93 of a pint per brake horse-power hour on gasoline. The kerosene contained 16 to 20 per cent more heat units than gasoline, hence the engine running on kerosene, while a trifle more economical as regards volume of fuel used, was a trifle less efficient thermally. In the last three such competitions, the fuel cost of the tractors operated under these patents has been consistently lowered and has remained at or near the lowest point recorded, while the speed regulation has been scored perfect in nearly every instance. The recent winning of a gold medal and sweepstakes over more than 20 other tractors, including 4 steam and 14 gasoline, indicates that the desirable oil-burning feature has been achieved without sacrificing any points of excellence. These tractors are being used by ordinary farm hands in every condition of climate and altitude without further adjustment than is provided for in the simple carbureter.

The owners of the patents are proceeding carefully in their efforts to adapt the new system to a wide variety of popular power uses. No serious attempt has been made as yet to adapt it to automobile or motor truck use, and the marine engines referred to are of the heavy-duty type designed more particularly for coastwise trade. The farm market has so far occupied the attention of the manufacturers to the practical exclusion of all others, but strong efforts are now being put forth to occupy the irrigation and cotton gin fields. The rice fields of Louisiana and Texas are taking a large number of these motors, and they are becoming popular in western mining districts.

The new system is the result of one man's close attention for the last 28 years to the problem of burning oil without in the least changing the essentials of the most popular type of internal combustion engine. For nearly 15 years practicable engines embodying the system have been on the market, but the perfection of the present form of carbureter gave the method a decided impetus. Basic patents have invited the investment of capital by a number of manufacturing concerns and three are now marketing engines that with three-cent fuel are capable of supplying power at a fuel cost of one third of a cent or less per horse-power per hour. The system has been applied to both two-cycle and four-cycle engines, and to engines running above 1,100 revolutions per minute.

With the production of kerosene out-running that of motor gasoline nearly four to one, the world-wide introduction of this process comes at an opportune time.

While this article was being written, not many weeks ago, a tramp steamer from Singapore was discharging a cargo of gasoline at Montreal. The prevailing state of affairs, even in oil-producing countries, is indicated by the fact that the Russian government has recently offered a bounty for the production of industrial alcohol to supplement the gasoline supply. However, the problem of burning oil in a gas engine—one that has been in the minds of engineers for the last 20 years—seems to have been finally and satisfactorily solved.

The Significance of Spectroscopy for the Atomistic Theory*

A Rational Theory Wanted to Correlate Observed Facts

By Prof. C. Runge

ALTHOUGH Bunsen and Kirchhoff employed the term spectrum analysis in the narrow sense of "chemical analysis by means of spectra" they should be regarded as the founders of the whole modern science of spectroscopy, for they appreciated the significance of the fundamental facts—that atoms and molecules are vibratory systems and that their periods of vibration are indicated by the variously colored rays emitted by glowing vapors.

In Bunsen's words, these periods "condition chemical characters as constant and fundamental as atomic weight, and they can be measured with almost astronomical precision." The qualification "almost" can now be omitted, for the periods of the cadmium lines whose wave-lengths have been compared with the standard meter by Michelson are known to less than one millionth of their value.

A relation between the periods of vibration and the other properties of an element, analogous to the relation between the musical tones emitted by a vibrating body and its mass, form and elasticity, must have suggested itself to the founders of spectrum analysis, although they gave no expression to this idea, probably because the spectra which they observed showed no trace of order or regularity.

At first glance, indeed, the spectra of the elements appear utterly irregular, and some of them are so complex that the task of reducing them to law and order seems hopeless. An example is the spectrum of iron, in which Kayser and I have measured more than 4,000

lines. Stoney, in 1870, first discovered a semblance of order, although he failed to find, as he expected, simple numerical relations among the spectral lines of an element, analogous to the relations that connect the overtones of a musical note. He did find that three of the four strong hydrogen lines have vibration-frequencies proportional to the whole numbers 20, 27 and 32, but this discovery bore no fruit until Balmer, in 1885, discovered the true mathematical form of the relation. According to this law, the vibration-frequencies of the hydrogen lines are proportional to the expression $1 - \frac{4}{n^2}$ in which the whole numbers 3, 4, 5, etc., are successively substituted for n . The ratio 20:27:32, is obtained by making n equal successively to 3, 4 and 6, and all other hydrogen lines can be found by substituting other whole numbers for n . The formula gives the vibration-frequencies of the 29 hydrogen lines now known, to within one part in 100,000.

In the search for analogous laws applicable to the spectra of other elements it was found that the essential property common to such spectra is not a simple numerical relation among vibration-frequencies but the probable existence of an infinite series of frequencies, gradually approaching a finite limit, with steadily diminishing intensity. Such series of lines are found in many spectra and, in numerous instances, the law of formation of the series has been discovered and an apparently chaotic spectrum has been resolved into a number of superimposed, regular series of lines. The spectrum of helium,

for example, contains eight such series. The complete helium spectrum is represented in the uppermost section of Fig. 1, and the component series are shown separately in the other sections. The regular arrangements of the lines in each series is apparent at a glance, but the regular progressive diminution in intensity with increase in vibration-frequency, in going toward the right or violet end, is not well shown in the drawing. The eight series of lines may be divided into two groups, each comprising four series, connected by relations which can be shown more effectively by comparing the spectra of the alkali metals, each of which is composed of four series of lines.

The spectra of the alkali metals are illustrated in Fig. 2. The first four sections, beginning at the top, represent the component series of the lithium spectrum. The remaining groups of four sections represent the component series of sodium, potassium, rubidium and cesium. All five spectra are found in exactly the same way, so that every line of each spectrum corresponds to a line in each of the other four spectra. All of the lines shown in the figure (except those of lithium, which are still in doubt) are resolved into double lines by increasing the dispersion. Bunsen and Kirchhoff observed many of the lines here shown, but they failed to detect the relations among the various spectra, because they did not know the law of formation of the individual spectra. For example, the dark red double line to which rubidium owes its name corresponds, in the cesium spectrum, to a double line in the ultra-red which is invisible, although

* Translated from *Zeitschrift für Elektrochemie*.

its energy exceeds that of all other cesium lines. Hence Bunsen and Kirchhoff regarded the next line of the series, which falls in the blue, as the principal line of cesium, and named the element accordingly. In the sodium only the double line and the yellow was known to Bun-

Fig. 1.—The Spectrum of Helium and Its Eight Component Series.

sen and Kirchhoff. The next line of this series lies in the ultra-violet, but forty-eight lines of the series have been photographed, with the aid of quartz prisms, by Wood, who expresses the conviction that an indefinitely great number of lines of still higher refrangibility can be discovered if the pressure of the sodium vapor and the dispersive power of the apparatus can be sufficiently increased.

In order to show the relations which connect the four series of each spectrum I have drawn, in Fig. 3, the four series of the cesium spectrum in such a way that their upper limits, at the violet or right end, coincide. The origin, or zero point, of the first series is at the left end of the uppermost section of the drawing. The second and third series, like the first, consist of double lines, whose origins coincide with the lines of the first pair of the first series. The origin of the fourth series coincides with the first line of the third series. Hence the interval between the lines of each pair in the second and third series is equal to the interval between the lines of the first pair in the first series. This constant difference in vibration-frequency between paired lines, which is observed in many spectra, is so exact that, despite the great and ever-increasing precision of spectroscopic measurements, the apparent deviations from constancy still lie within the limits of errors of observation. In the spectra of mercury, thallium and many other elements, the intervals in question are so large that they can be determined within 1/30,000 of their amount. Even these spectra show no deviation from the law of constant difference in the vibration-frequencies of paired lines. Many spectra show lines which have vibration-frequencies equal to the differences between the frequencies of other lines belonging to different series—for example, between the second pair of the first cesium series (Fig. 3) and both the first and second pairs of the second series. It is not improbable that every interval between two lines is represented by another line, and that only the strongest of these lines have been discovered.

These laws of formation are repeated in the spectrum of each member of a group of chemically related elements, with modifications that are evidently dependent upon the atomic weight. For example, an inspection of Fig. 2 shows that the limits of corresponding series move toward the left or red end, i. e., in the direction of slower vibration, as the atomic weight increases. This rule does not apply to analogous individual lines, such as the red lithium line and the yellow sodium line, because the series

contract and therefore shift some lines toward the right, as the atomic weight increases. This effect is shown more clearly in Fig. 4 which includes only the series of each spectrum which contains the principal line of the element. The spectral lines are indicated by small circles and the

Fig. 2.—Spectra of the Alkali Metals.

five series are so drawn that their limits coincide, and the distance of each below the top of the drawing is proportional to the atomic weight. The series contract rapidly in going from lithium through sodium to potassium, and more slowly in going from potassium through rubidium to cesium.

The connection between the atomic weight and the interval which separates the components of double lines is equally evident, except in the case of lithium, where it is yet uncertain whether the lines are doubled or not.

Fig. 5 shows a representative pair of lines of each of the other alkali metals, sodium, potassium, rubidium and cesium. The horizontal distance between the lines of each pair represents the difference in vibration-frequency, and the vertical distances between lines of different elements represent differences in atomic weight. The inter-

Fig. 4.—Spectra of Alkali Metals, Spaced According to Atomic Weight.

val, or difference in vibration-frequency, between the lines of a pair is approximately proportional to the square of the atomic weight, in the group of alkali-metals, and to the other powers of the atomic weight in other groups of elements. This law can be illustrated graphically by plotting the logarithms of the intervals as abscissæ and the logarithms of the atomic weights as ordinates. If the pair-interval were exactly proportional to a power of the atomic weight the plotted points would lie precisely in a straight line. How nearly they do so in the case of the alkaline-earth-metals is shown in Fig. 6. If the proportionality were exact it would furnish by far the most accurate method of determining atomic weights, but as it is only approximate, it may lead to serious error, especially when extrapolation is required, as is shown in Fig. 6 by the discrepancy between Mme. Curie's value of the atomic weight of radium and the value obtained by graphical extrapolation. On the other hand, it is evi-

dent from the figure that a very close approximation to the atomic weight of strontium, for example, could be obtained, by interpolation, from those of magnesium, calcium and barium.

The correct theory of the vibratory system which emits the variously colored rays of a spectrum is unknown. The displacement of spectral lines in the magnetic field suggests the presence of electrons, oscillating

Fig. 3.—Spectrum of Cesium.

about positions of equilibrium conditioned by the nature of the atom or molecule. The theories already advanced have led to very valuable results, and the rates of vibration of the lines that form a series in the spectrum of an element can be computed from each other very accurately by empirical formulæ. The most interesting characteristic of these formulæ is the presence in all of them, of a common constant, representing a rate of vibration which is independent of all the chemical elements. In the correct theory, doubtless, this rate of vibration will play a fundamental rôle as the embodiment of a law applicable to all ponderable matter. The present state of spectroscopy may be likened to the state of astronomy in the period between Kepler's discovery of the laws of motion and Newton's discovery of the law of universal gravitation.

The Micro Indicator

With increasing speed it became necessary to restrict the movements of the pencil lever and the paper drum of the indicator so as to make smaller diagrams. Some makers of indicators furnish small drums for high-speed work. This means of avoiding distortion due to inertia has been carried to a limit in the micro indicator invented by a German by the name of O. Mader. This instrument traces on smoked glass, a minute diagram which is magnified 40 diameters by means of a microscope for measurement and analysis, or may be reproduced upon an enlarged scale photographically, or by means of a special reflecting and magnifying device. It is said that the instrument may be used upon internal combustion engines running at a speed as high as 3,000 revolutions per minute.—Power.

Legibility of Colored Advertisements

The French publication *Le Courrier du Livre* reports on some interesting experiments which have been made regarding the most favorable color combinations for reading at a distance. It was found that the most legible print was black upon yellow background. The order of merit obtained for different combinations is somewhat surprising, and is as follows: (1) Black on yellow; (2) green on white; (3) red on white; (4) blue on white; (5) white on blue; (6) black on white; (7) yellow on black; (8) white on red; (9) white on green; (10) white on black; (11) red on yellow; (12) green on red; (13) red on green.

It will be noticed, among other things, that the customary combination of black upon white comes sixth in the list, about half way down.—Cosmos.

Na
K

Rb

Cs

Fig. 5.—Intervals Between Parts of Lines of Sodium, Potassium, Rubidium, and Cesium.

Fig. 6.—Pair-intervals and Atomic Weights of Alkaline Earth Metals.