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THE SCIENTIFIC AMERICAN SUPPLEMENT

No. 179.

For the Week ending June 7, 1879.

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THE TRAJECTORY OF MOLECULES.

In "The Fourth State of Matter," SCIENTIFIC AMERICAN, January 25, last, an account was given of the experiments made by Mr. William Crookes, showing the high probability of a fourth state of matter, more ethereal than the gaseous, in which matter take on an entirely new set of properties. At a social meeting of the British Royal Society, April 30, Mr. Crookes exhibited a series of experiments illustrating still further the curious behavior of electrified molecules in extremely rare media.

By the improvements made in the Sprengel pump by Mr. C. H. Gimingham it is now possible to produce vacua in which the pressure is measured in millionths of an atmosphere. It is with vacua so produced, in the more perfect of which the pressure is as low as one millionth of an atmosphere, that Mr. Crookes' investigations were conducted.

It will be remembered that the discoveries in question were made in the dark space around the negative pole within a vacuum tube and separating it from the luminous glow. This dark space was found to be a region of molecular activity similar to that in front of the vanes of a radiometer, by which activity the negative pole, when free to move, is set in motion.

The phenomena exhibited in his first published experiments—the phosphorescent effects produced by molecular impact, the illumination of lines of pressure, the casting of molecular shadows, the magnetic deflection of molecular streams, and the like—were shown anew, and supplemented by even more beautiful effects, though nothing absolutely new was developed.

In some of the experiments variously-shaped poles were used, causing the molecular streams to converge to a focus, to diverge, or to move in parallel lines. By one apparatus the four principal phenomena of molecular physics in high vacua—namely, the phosphorescent light of molecular impact, the projection of molecular shadows, the magnetic deflection of the trajectory of molecules, and the mechanical action of molecules projected from the negative pole—were beautifully illustrated.

The vacuum tube inclosed a circular concave negative electrode, and at its center of curvature a light wheel was pivoted upon a horizontal axis. The wheel was a disk of thin mica, carrying around its periphery a number of equidistant radial vanes of aluminum, making the wheel look like a waterwheel. When the tube was placed in connection with an induction coil, the stream of molecules concentrated upon the wheel fell in line with its axis, in which case no motion resulted. But on bending the stream of molecules up or down by magnetic action the focus of impact would fall above or below the axis, and the wheel would be set to spinning at a lively rate.

Very brilliant effects were also produced by causing the molecular stream to fall on naturally phosphorescent substances, as, for example, diamonds. At such times different sorts of diamonds were distinguished by different colors—blue, pale blue, orange, red, green, and pale green—African diamonds emitting a blue phosphorescence. Rubies, on the other hand, whatever their normal tint, all assumed under the molecular hail the deep "pigeon's blood" red, characteristic of a fine ruby. Even white precipitated alumina gave under the molecular stream the same ruby color, though normally without a trace of color.

Thus far these researches of Mr. Crookes seem to be brilliant rather than instructive in their results; but it is altogether too early to pronounce upon their possible value.

THE INTERNATIONAL CANAL CONGRESS.

An international canal congress, for discussing projects for the construction of an interoceanic ship canal across the American isthmus, met in Paris May 15. M. Ferdinand de Lesseps was fitly chosen president. Since the main object of the convention was to compare routes and decide upon the one to be recommended as a practical enterprise, the principal interest naturally centered in the Committee on Technique.

Up to this writing, May 22, six routes have been under examination and discussion, namely, the Nicaragua route, the Panama route, the San Blas route, the Tiati-tolo route, the Tuyra-Caquirri-Atrato route, and the Atrato-Napipi route. At first the Tiati-tolo route, known as Lieutenant Wyse's lockless canal and tunnel route, seemed to have the brightest prospects, from the strong party and personal influence known to be working in its favor. The Sub-Committee on Tunnels, however, found that its probable cost had been greatly underrated, and that under the most favorable conditions it would cost $160,000,000. This discouraging blow was followed by such an able presentation of the impracticability of the scheme by the English engineer, Sir John Hawkshaw, that the project was abandoned.

Already the choice seems to be narrowed to two projects, the Nicaragua route and the Panama route, and a decision will probably be reached in the course of a week.

A Medal for Peter Cooper.

At the late meeting of the British Iron and Steel Institute in London, the Bessemer Medal of the institute was presented to the venerable Peter Cooper as "the father of the iron trade in America." In his presentation speech the President spoke of Mr. Cooper's half-century connection with the iron trade, his Baltimore rolling mill in 1830, his building and running the first American locomotive, his extensive iron works at Trenton, and especially the founding and direction of the great Cooper Institute in this city. In view of the fact that it is through the efforts of Mr. Cooper and other leaders in the American iron trade that England's greatest rival in iron production has almost reached supremacy, this recognition of his labors by the English iron and steel producers is particularly handsome.

SCIENCE AS A DETECTIVE.

A correspondent tells at greater length than we have space for the story of an attempted fraud which was exposed by chemistry.

An emery wheel guaranteed to stand 600 revolutions was run at the speed, of 1000 revolutions, and burst, doing a large amount of damage. A suit to recover was instituted, based on a letter written by the seller of the wheel, in which the strength of the wheel was rated at 1,600 revolutions. While in the office of the prosecutor endeavoring to effect a settlement, the defendant observed that a certain make of ink was used, and he learned by a casual inquiry that the same ink was used exclusively by the prosecutor. The defendant had for several years used another ink. Taking samples of the two inks to a chemist, he was able after analysis to secure a solvent for the one which would not affect the other.

The case came to trial. Evidence was taken as to the kind of ink each party employed. Then the chemist was called, and in the presence of the jury applied the solvent, which removed the interpolated "1," and left the rest of the writing untouched. The proof of the forgery was sufficient, and the case was dismissed, leaving the dishonest prosecutor to defend himself from a criminal charge.

A NEW REFRIGERATING LIQUID FROM BEETS.

In Europe the principal supply of sugar is derived from beets; the annual production of beet sugar being now seven hundred thousand tons. Besides this a large quantity of beet molasses is produced, a portion of which is distilled and a coarse sort of whisky made; the stuff remaining in the retort yields potassium salts, which are employed as fertilizers. Sugar, spirits, and potash have heretofore been the chief products manufactured from beets. But Mr. Vincent has now succeeded in realizing from the refuse that remains after the beet molasses distillation, a combustible gaseous body, which is easily condensed into liquid form, and is called chloride of methyl.

This liquid, obtained as stated from beets, is used in the preparation of some of the aniline colors; but it is now found to be especially valuable as a refrigerating agent. By its rapid evaporation a temperature of—55° C., or 67° F. below zero, may be maintained, which is far below the freezing point of mercury. Prof. Huxley says that by this means mercury (which freezes at 39° F. below zero) may be frozen by the pound. For the manufacture of ice this new beet root product promises to become of much importance.

MAGNETIC MOTORS.

Is there an available source of energy in magnetism? There are very many inventors who believe that there is, and every year many attempts are made to produce economical magnetic motors. A short comparison between the force of magnetism and other natural forces will answer our question.

An iron steamship plies between New York and Liverpool; it is more or less a magnet under the influence of the earth. Yet the helmsman does not allow for the attraction of the north or south poles of the earth upon this magnetic matter. This attraction is immensely inferior, even if the steamship were made of steel and been magnetized to saturation, to the drift of the tides, or even to the effect of the gentlest breeze. The force of gravitation, however, sinks the heavy vessel deep in the water, and is ready to draw it with all on board to the very bottom of the ocean. While the force of magnetism decreases or remains constant when the masses of the attracting magnetic bodies are increased, the attracting force of gravity steadily increases with the masses of the two bodies, between which this attraction acts.

It is sometimes proposed to utilize the magnetism of the earth in magnetic motors by supplying any waste in the energy of a permanent magnet from the store in the earth. Let us see how much this force of the earth's magnetism is in comparison with the force of gravity, which is our universal measuring force, so to speak. Suspend in a vertical position from one end a cylindrical bar of iron which is about one foot in length. It should be hung by a very short wire or thread from its north pole. Hang beside it a brass rod of the same dimensions, and provide it with the same length of suspension. Then set the two rods to swinging, and count the number of swings which each makes in a given number of seconds. It will be found that the two rods will accomplish very nearly the same number of swings in the same time. The rods will differ very little in weight, and their moments of inertia will be very nearly alike. The vertical force of the earth's magnetism, therefore, must be small in comparison with the force of gravitation; for the iron bar is acted upon by both gravity and the earth's magnetism, and yet it vibrates at nearly the same rate as the brass bar. An iron bar, such as we have used in the above experiments, will be rendered feebly magnetic by the earth's magnetism, and could hold a light cambric needle at its extremity; but nothing more. This is the force from the earth which we can count upon to renew the magnetism of steel when it has been deprived of it.

It has been said that it is possible to lower the energy of a magnet by vibrating an armature composed of a thin plate of iron in front of the magnet. An experiment will speedily convince those who have no theoretical convictions upon the subject that it is not possible to do this. Having measured in any way the lifting effect of a magnet or its action upon a compass needle placed at a fixed distance, cause a thin plate of iron to vibrate by any automatic arrangement very rapidly in front of the magnet; and after some time has elapsed examine the strength of the magnet: it will be found as strong as before. The rate of vibration can be carried as high as 3,000 vibrations per minute, and still the magnet will be unaffected. If one endeavors to use the magnetic energy of the earth as a source of motive power, disappointment will surely result; for the earth's magnetism is too feeble to do an appreciable amount of work. Moreover the energy stored up in permanent magnets is feeble, compared with that of other forces. A horseshoe permanent magnet, the strongest that can be made, will not lift 200 pounds; and the lifting force does not increase with the size of the magnet, except to a very limited degree. Very strong electric magnets, however, can be made. Prof. Henry succeeded in lifting 640 pounds by one that he constructed. It might be supposed that there is no limit to the amount that an electro-magnet can lift; for we can increase the strength of the current which circulates about the iron to a very great amount. There is a limit, however, to the amount of magnetism which can be imparted to soft iron. This limit has been placed at a lifting power of 354 pounds to the square inch.

Let us now inquire into the expense of producing this effect. One pound of coal yields 7·200 thermal units; one pound of zinc yields 1·200 thermal units. One pound of zinc costs ten times as much as a pound of coal. It will be seen, therefore, that any magnetic motor will be sixty times as expensive as a steam motor of the same horse power; for we have no better agent for producing electricity in batteries than zinc. The inventors of magnetic motors should therefore turn their attention to the discovery of a cheaper source of electricity than zinc. The modern dynamo-electric machine affords another source of magnetism. This machine, however, requires a powerful steam engine to run it, and its useful effect is necessarily less than that of the steam motor which is employed to generate the current of electricity. If the useful effect of such a machine for producing electric currents was greater than the work of the steam motor, we should have perpetual motion.

Let us now turn our attention to other agents which we can use as sources of power. A pound of water converted into steam occupies about 1,250 times its former volume at the ordinary pressure of the atmosphere. This would give over 18,000 pounds pressure on the square inch, if the water when converted into steam was not allowed to expand. Liquid carbonic acid at 86° C. in assuming the gaseous form exerts over 1,000 pounds on the square inch. The explosion of gunpowder can exert pressures from 5,000 to 20,000 pounds on the square inch, and the explosive force of nitro-glycerine has not even been estimated with any precision, so tremendous is the energy developed. It can readily be seen that a motor which is driven by the expansion of steam, by the explosion of gas and common air, or by the explosion of gunpowder or nitro-glycerine affords with the feeblest of these agencies work which far surpasses what the most sanguine inventor of magnetic motors can even dream of.

Electro-magnetism is a swift and nimble servitor ready to convey ideas from mind to mind around the world in an instant. The attempt to yoke Pegasus to a plow and to make him perform the work of oxen has often been delineated by artists. We remember to have seen a series of cartoons which represented the mournful attempt. There was the delicate, highly-strung steed beside the sturdy beasts whose true province was to drag the heavy weight, and the various stages of the agony of Pegasus were vividly depicted. The cartoons could have been called "Electricity in Harness," and would equally well have illustrated the attempts of the inventors of magnetic motors.

UNDERGROUND TELEGRAPH WIRES.

In a late issue of the SCIENTIFIC AMERICAN notice was taken of the difficulties experienced in England in the use of telegraph wires underground. Notwithstanding the apparent success of the system in Germany, the electrician of the British telegraphs pronounced decidedly against underground wires as less efficient, less durable, and much more costly than the ordinary system. The system of insulating underground wires patented by Mr. David Brooks, of Philadelphia, is said to be open to none of the usual objections, being at once cheap, durable, and efficient. This plan is substantially as follows: The wires are wrapped in cotton and bundled together in a tight netting, to the number of 50 or less, then inclosed in a pipe and laid in the ground. Insulation is effected by oil which is poured into the pipe after it is laid, and the pipe is kept full by having the source of supply in an elevated vessel. A mile of line was thus laid about two years ago in West Philadelphia, with complete success. A line across the Schuylkill, in 35 feet of water, has been in operation since April, 1877, with increasing insulation. It is said that a line on this system will be laid between New York and Philadelphia this summer, and that the system will soon be generally adopted in this city. The exclusive right to construct telegraph lines in the United States under Mr. Brooks' patent was purchased a short time since by General Stager, of Chicago, one of the vice-presidents of the Western Union Telegraph Company, and president of the Western Electric Manufacturing Company. The purchase was made, however, for General Stager's personal benefit, and not on account of the Western Union Telegraph Company, as first reported.

LOCALIZING TELEPHONE CALLS.

The district telephone companies employ various kinds of alarms by which attention can be called to messages about to be sent. Vibrating reeds and magneto-call bells of many patterns are found to be most efficient devices. A summons, however, sent to one house will necessarily be heard in all the houses or offices on the same circuit. In some localities this has been found to be very objectionable. There are many theoretical ways in which a call can be localized, so to speak. The most obvious way is to employ a set of reeds or tuning forks which will only respond to definite notes. At the sending office the proper reed or other vibrating means is set in action, and the reed or tuning fork at one station responds only. There are, however, certain practical difficulties in the use of this method: it is comparatively costly and requires accurate adjustment. Niemoller, in a late article in Wiedemann's *Annalen der Physik und Chemie*, describes a simple method of setting a wire in vibration, which might be also turned to account in localizing calls on telephone circuits.

A steel wire stretched between two points is provided with a platinum point at its middle; this point dips into a vessel containing mercury. A current of electricity is passed over the half length of the wire, and a magnet placed above the middle point of the half length through which the current passes serves to maintain the vibration of the wire. The application of this simple interrupter to telephone circuits is obvious. At the sending office a wire could be stretched with definite weights over a long channel of mercury, and the length of the wire could be readily altered by simple bridges. In each office or station wires could be stretched on suitable sounding boards, provided with electro-magnets placed above their quarter lengths, and tuned to respond to the note of the wire at the central office. Only the wire which is of the proper length and tension would respond to the same length and tension of the wire at the central office. The wires could vibrate between bells or could strike when their amplitude of swing was at its greatest upon some sounding substance. This method also requires careful adjustment, but it is much cheaper than any system of reeds.

MOLECULAR CHEMISTRY.—NO. II.

The discovery that bodies combine in constant definite proportions by weight was followed by one of almost equal importance. At the beginning of the present century, Gay Lussac and Alexander von Humboldt found that one part by measure (one volume) of oxygen combines with exactly two parts by measure (two volumes) of hydrogen, and that the water so formed occupies two volumes when it is measured in a state of vapor. After numerous experiments, Gay Lussac announced that all gases and vapors combine in definite proportions by volume, and also that the combining volumes have simple numerical relations to each other as well as to the volume of the resulting compound, the latter being compared while in a state of vapor.

While the 100 grains of water in our last paper contained eight times as much oxygen as hydrogen by weight, this hydrogen takes up twice as much room as the oxygen. Still, we are not able to answer the question, How many atoms of each does it take to make the smallest possible quantity of water? At the first glance it would seem as though we needed to know either the number of atoms contained in a given volume, say a cubic inch, or else their size, and information on these points appears to be no more accessible than on the number or the size of the atoms contained in a given weight. Nevertheless the problem was most beautifully solved by the Italian physicist, Avogadro.

Reasoning on the remarkable fact that all gases undergo very nearly the same diminution of volume, when subjected to the same pressure, or to the same degree of cold, Avogadro concluded that this could be accounted for most simply by supposing that all gases have their particles separated by equal spaces, or, what is the same thing, that equal volumes contain the same number of particles.

Armed with this important deduction, we may now return to the study of the composition of water and reason as follows: The hydrogen in water occupies twice the space of the oxygen; therefore it contains twice as many particles, or in other words, water contains two particles of hydrogen for every particle of oxygen, and we may write H_2O as a formula representing its composition by weight and measure. The combining weight of H being taken as unity, that of oxygen will be 2×8, or more accurately, 15·960; for the O in H_2O was found to weigh eight times as much as two volumes of H, consequently it weighs sixteen times as much as one volume.

As equal volumes of different gases contain the same number of particles, the weights of these particles must be the same as the densities of the gases, when hydrogen is taken as the unit both of weight and volume. This follows directly from the definition that density is the amount of matter contained in a given space. The densities of a very great number of gases, as well as of vapors, have been determined by independent methods with the utmost care, and the correctness of Avogadro's deduction has been again and again corroborated.

Whenever, therefore, an element forms either gaseous combinations or such as may be reduced to a state of vapor, we have two trustworthy means of determining its atomic weight: we can ascertain the percentage composition by chemical analysis, and we can determine the density of the gas or vapor into whose composition it enters.

The atomic weights of elements that do not form gaseous combinations are ascertained from the results of chemical analyses, aided by two important laws, which need only be briefly stated here, as they are not essential to our chain of reasoning. The first, discovered by Dulong and Petit, is that all atoms have the same specific heat, a conclusion deduced from the fact that the products of the specific heats of the elements by their atomic weights differ very little from the number 6·4. The second law is that of Mitscherlich, that the crystalline form of substances furnishes an indication of their atomic structure. When two bodies are isomorphous, that is, when they have crystals of the same form, their composition may be expressed by analogous formulas. The latter law is true within certain limits only.

Let us now test our formula for the composition of water by the discovery of Gay Lussac, stated at the beginning of this paper. Suppose, for convenience of illustration, that the unit volume of hydrogen contains one thousand particles; then an equal volume of oxygen must contain one thousand particles, and so must one of water, vapor, or of any other gaseous substance. But two volumes of hydrogen containing two thousand particles combine with one volume of oxygen containing one thousand particles to form two volumes of water vapor containing two thousand particles, which is equivalent to saying that two particles of water vapor consist of two atoms of hydrogen plus one atom of oxygen. Now, what does one particle of water vapor consist of? We cannot divide by 2, or else we shall obtain a half atom, which is impossible. The only way out of the difficulty is to conclude that the particles of hydrogen and oxygen are all double, *i. e.*, that they consist of an undetermined but even number of atoms. Then we shall see that two volumes of hydrogen containing two thousand HH, combine with one volume of oxygen containing one thousand OO, to form two volumes of water vapor containing two thousand H_2O.

The combination of two atoms of hydrogen among themselves is called a molecule of hydrogen, that of two atoms of oxygen among themselves a molecule of oxygen, and the union of two molecules of hydrogen with one molecule of oxygen forms a molecule of water. To resume, one volume of water vapor occupies two volumes, consists of three double atoms, and weighs 17.960 times as much as one volume (= one double atom) of hydrogen.

Our standard of comparison for molecules is the hydrogen molecule H_2, whose density is 1, and whose molecular weight is 2. Hence we must multiply the densities of other gases by 2 to obtain molecular weights comparable to that of hydrogen. For example:

The density of arsenic vapor is about 150·2 times that of hydrogen. Its molecular weight is therefore $2 \times 150{\cdot}2$, or 300·4. A study of its compounds shows that this molecule is composed of AS_4, or of 4 atoms each weighing $\frac{300{\cdot}4}{4} =$ 75·1. The correctness of this atomic weight may be tested as follows, by the law of Dulong and Petit: The specific heat of arsenic ·0814 multiplied by 75 = 6·113, which is sufficiently near the average.

The density of chlorine is about 35·25 times that of hydrogen. Its molecule then weighs $2 \times 35{\cdot}25$, or 70·5. A comparison of the analyses of its compounds shows this molecule to be composed of Cl_2, or of two atoms, each weighing 35·368.

The density of mercury vapor is about 100 times that of hydrogen; its molecule is, therefore, about 200 times as heavy as that of hydrogen. A comparative study of its compounds indicates that this molecule contains but a single atom; or, speaking more accurately, half as many atoms as the hydrogen molecule. This view satisfies the law of Dulong and Petit; for $200 \times {\cdot}03332$, the specific heat of mercury = 6·66.

A similar study of ozone assigns to it a molecule composed of three atoms of oxygen, O_3.

On the supposition that the hydrogen molecule contains only two atoms—the lowest even number—the other elements have molecules consisting of one, two, three, and four atoms. It is evidently of no consequence to our reasoning whether the hydrogen molecule contains two atoms or a multiple of two, because all our other molecular weights, being only ratios, are affected proportionally.

We are now prepared to begin the study of the relative sizes of the molecules of simple and compound bodies.

We have found that a given volume of oxygen contains as many particles as an equal volume of hydrogen, and that these particles weigh 16 times as much; therefore each particle of oxygen weighs 16 times as much as each particle of hydrogen. If these particles occupied the whole space, that is, if there were no interstices, we could conclude that the particles of oxygen and the particles of hydrogen are equally large.

As we have not, however, any means of knowing the real or absolute size of these particles, we shall be obliged, at the outset of our investigations, to define a molecular volume, or the volume of a molecule, as the cubical space of which, at a given moment, it occupies the center—a definition that involves no hypothesis. There is no difficulty in conceiving a given volume as divided up into equal cubes, each containing a molecule. C. F. K.

THE Fall River (Mass.) *News* relates the following as a fact: Two men were conversing about the anticipated strike the other day, when one of them, a mule spinner, remarked that he had been in 26 strikes during his lifetime. "Well," said the other, "did you ever make anything by it?" "Not once," was the reply; "lost every time."