and cast itself in a corner. For an instant they could only blink. The figure wrapped its white arms about some object.

"You can have everything but this table; you can't have—this." The words ended in a frightened sob.

"*Esther!*"

"*Oh, Joe!*" She struggled to her feet, then shrank back against the wall. "Oh, I didn't know it was you. Go 'way! go 'way!"

"Why, Esther, what do you mean?" He started towards her, but she turned on him.

"Where is she?"

"Where's who?"

She did not reply, but standing against the wall, she stared at him with a passionate scorn.

"You don't mean Sarah Norton?" asked Joe, slowly. Esther quivered. "Why, she came to tell me of the trouble her father was trying to get me into. But how did you come here, Esther? How did you know anything about it?"

She did not answer. Her head sank.

"How did you, Esther?"

"I saw—you in the lane," she faltered, then caught up her veil as though it had been a pinafore. Joe went up to her, and Jonas Ingram took hold of Harry Barker, and the two stepped outside, but not out of ear-shot; they were still curious. They could hear Esther's sobbing voice at intervals. "I tried to make 'em stop, but they wouldn't, and I slipped in past 'em and bolted the door; and when you came, I thought it was them—and, oh! ain't they our things, Joe?"

The old man thrust his head in at the door. "Yes," he roared, then withdrew.

"And won't they take the table away?"

"No," he roared again. "I'd just like to see 'em!"

Esther wept harder. "Oh, I wish they would; I ought to give 'em up. I didn't care for them after I thought—that. It was just that I had to have something I wouldn't let go, and I tried to think only of saving the table for the water-set."

"Come mighty near bein' no water-set," muttered Jonas to himself; then he turned to his companion. "Young man, I guess they don't need us no more," he said.

When he regained his sister-in-law's, he encountered that lady carrying a steaming dish. Guests stood about under the trees or sat at the long tables.

"For mercy sakes, Jonas, have you seen Esther? She made fuss enough about havin' that dove fixed up in the parlor, and she and Joe 'ain't stood under it a minit yet."

"That's a fact," chuckled the old fellow. "They 'ain't stood under no dove of peace yet; they're just about ready to now, I reckon."

And up through the lane, all oblivious, the lovers were walking slowly. Just before they reached the gap in the wall, they paused by common consent. Cherry and apple trees drooped over the wall; these had ceased blossoming, but a tangle of wild-rose bushes was all ablush. It dropped a thick harvest of petals on the ground. Joe bent his head; and Esther, resting against his shoulder, lifted her eyes to his face. All unconsciously she took the pose of the woman in the Frohman poster. They kissed, and then went on slowly.

THE CENTURY'S PROGRESS IN PHYSICS.

BY HENRY SMITH WILLIAMS, M.D.

PART II.—THE ETHER AND PONDERABLE MATTER.

I.

"WHATEVER difficulties we may have in forming a consistent idea of the constitution of the ether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body which is certainly the largest, and probably the most uniform body of which we have any knowledge."

Such was the verdict pronounced some twenty years ago by James Clerk Maxwell, one of the very greatest of nineteenth-century physicists, regarding the existence of an all-pervading plenum in the universe, in which every particle of tangible matter is immersed. And this verdict may be said to express the attitude of the entire philosophical world of our day. Without exception, the authoritative physicists of our time accept this plenum as a verity, and reason about it with something of the same confidence they manifest in speaking of "ponderable" matter or of energy. It is true there are those among them who are disposed to deny that this all-pervading plenum merits the name of matter. But that it is a *something*, and a vastly important something at that, all are agreed. Without it, they allege, we should know nothing of light, of radiant heat, of electricity, or magnetism; without it there would probably be no such thing as gravitation; nay, they even hint that without this strange something, ether, there would be no such thing as matter in the universe. If these contentions of the modern physicist are justified, then this intangible ether is incomparably the most important as well as the "largest and most uniform substance or body" in the universe. Its discovery may well be looked upon as the most important feat of our century.

For a discovery of our century it surely is, in the sense that all the known evidences of its existence have been gathered in this epoch. True, dreamers of all ages have, for metaphysical reasons, imagined the existence of intangible fluids in space—they had, indeed, peopled space several times over with different kinds of ethers, as Maxwell remarks—but such vague dreamings no more constituted the discovery of the modern ether than the dream of some pre-Columbian visionary that land might lie beyond the unknown waters constituted the discovery of America. In justice it must be admitted that Huyghens, the seventeenth-century originator of the undulatory theory of light, caught a glimpse of the true ether; but his contemporaries and some eight generations of his successors were utterly deaf to his claims; so he bears practically the same relation to the nineteenth-century discoverers of ether that the Norseman bears to Columbus.

The true Columbus of the ether was Thomas Young. His discovery was consummated in the early days of the present century, when he brought forward the first conclusive proofs of the undulatory theory of light. To say that light consists of undulations is to postulate something which undulates; and this something could not be air, for air exists only in infinitesimal quantity, if at all, in the interstellar spaces, through which light freely penetrates. But if not air, what then? Why, clearly, something more intangible than air; something supersensible, evading all direct efforts to detect it, yet existing everywhere in seemingly vacant space, and also interpenetrating the substance of all transparent liquids and solids, if not, indeed, of all tangible substances. This intangible something Young rechristened the Luminiferous Ether.

In the early days of his discovery Young thought of the undulations which produce light and radiant heat as being longitudinal—a forward and backward pulsation, corresponding to the pulsations of sound—and as such pulsations can be transmitted by a fluid medium with the properties of ordinary fluids, he was justified in thinking of the ether as being like a fluid in its properties, except for its extreme intangibility. But about 1818 the experiments of Fresnel and Arago with polarization of light made it seem very doubtful whether the theory of longitudinal vibrations is sufficient, and it was suggested by Young, and independently conceived and demonstrated by Fresnel, that the luminiferous undulations are not longitudinal, but transverse; and all the more recent experiments have tended to confirm this view. But it happens that ordinary fluids—gases and liquids—cannot transmit lateral vibrations; only rigid bodies are capable of such a vibration. So it became necessary to assume that the luminiferous ether is a body possessing elastic rigidity—a familiar property of tangible solids, but one quite unknown among fluids.

The idea of transverse vibrations carried with it another puzzle. Why does not the ether, when set aquiver with the vibration which gives us the sensation we call light, have produced in its substance subordinate quivers, setting out at right angles from the path of the original quiver? Such perpendicular vibrations seem not to exist, else we might see around a corner; how explain their absence? The physicists could think of but one way: they must assume that the ether is incompressible. It must fill all space—at any rate, all space with which human knowledge deals—perfectly full.

These properties of the ether, incompressibility and elastic rigidity, are quite conceivable by themselves; but difficulties of thought appear when we reflect upon another quality which the ether clearly must possess — namely, frictionlessness. Per hypothesis this rigid, incompressible body pervades all space, imbedding every particle of tangible matter; yet it seems not to retard the movements of this matter in the slightest degree. This is undoubtedly the most difficult to comprehend of the alleged properties of the ether. The physicist explains it as due to the perfect elasticity of the ether, in virtue of which it closes in behind a moving particle with a push exactly counterbalancing the stress required to penetrate it in front.

To a person unaccustomed to think of seemingly solid matter as really composed of particles relatively wide apart, it is hard to understand the claim that ether penetrates the substance of solids—of glass, for example—and, to use Young's expression, which we have previously quoted, moves among them as freely as the wind moves through a grove of trees. This thought, however, presents few difficulties to the mind accustomed to philosophical speculation. But the question early arose in the mind of Fresnel whether the ether is not considerably affected by contact with the particles of solids. Some of his experiments led him to believe that a portion of the ether which penetrates among the molecules of tangible matter is held captive, so to speak, and made to move along with these particles. He spoke of such portions of the ether as "bound" ether, in contradistinction to the great mass of "free" ether. Half a century after Fresnel's death, when the ether hypothesis had become an accepted tenet of science, experiments were undertaken by Fizeau in France, and by Maxwell in England, to ascertain whether any portion of ether is really thus bound to particles of matter; but the results of the experiments were negative, and the question is still undetermined.

While the undulatory theory of light was still fighting its way, another kind of evidence favoring the existence of an ether was put forward by Michael Faraday, who, in the course of his experiments in electrical and magnetic induction, was led more and more to perceive definite lines or channels of force in the medium subject to electro-magnetic influence. Faraday's mind, like that of Newton and many other philosophers, rejected the idea of action at a distance, and he felt convinced that the phenomena of magnetism and of electric induction told strongly for the existence of an invisible plenum everywhere in space, which might very probably be the same plenum that carried the undulations of light and radiant heat.

Then about the middle of the century came that final revolution of thought regarding the nature of energy, which we have already outlined in the preceding paper, and with that the case for ether was considered to be fully established. The idea that energy is merely a "mode of motion" (to adopt Tyndall's familiar phrase), combined with the universal rejection of the notion of action at a distance, made the acceptance of a plenum throughout space a necessity of thought—so, at any rate, it has seemed to most physicists of recent decades. The proof that all known forms of radiant energy move through space at the same rate of speed is regarded as practically a demonstration that but one plenum—one ether—is concerned in their transmission. It has, indeed, been tentatively suggested, by Professor J. Oliver Lodge, that there may be two ethers, representing the two opposite kinds of electricity, but even the author of this hypothesis would hardly claim for it a high degree of probability.

The most recent speculations regarding the properties of the ether have departed but little from the early ideas of Young and Fresnel. It is assumed on all sides that the ether is a continuous, incompressible body, possessing rigidity and elasticity. Lord Kelvin has even calculated the probable density of this ether, and its coefficient of rigidity. As might be supposed, it is all but infinitely tenuous as compared with any tangible solid, and its rigidity is but infinitesimal as compared with that of steel. In a word, it combines properties of tangible matter in a way not known in any tangible substance. Therefore we cannot possibly conceive its true condition correctly. The nearest approximation, according to Lord Kelvin, is furnished by a mould of transparent jelly. It is a crude, inaccurate analogy, of course, the density and resistance of jelly in particular being utterly different from those of the ether; but the quivers that run through the jelly when it is shaken, and the elastic tension under which it is placed when its mass is twisted about, furnish some analogy to the quivers and strains in the ether, which are held to constitute radiant energy, magnetism, and electricity.

The great physicists of the day being at one regarding the existence of this all-pervading ether, it would be a manifest presumption for any one standing without the pale to challenge so firmly rooted a belief. And, indeed, in any event, there seems little ground on which to base such a challenge. Yet it may not be altogether amiss to reflect that the physicist of to-day is no more certain of his ether than was his predecessor of the eighteenth century of the existence of certain alleged substances which he called phlogiston, caloric, corpuscles of light, and magnetic and electric fluids. It would be but the repetition of history should it chance that before the close of another century the ether should have taken its place along with these discarded creations of the scientific imagination of earlier generations. The philosopher of to-day feels very sure that an ether exists; but when he says there is "no doubt" of its existence he speaks incautiously, and steps beyond the bounds of demonstration. He does not *know* that action cannot take place at a distance; he does not *know* that empty space itself may not perform the functions which he ascribes to his space-filling ether.

II.

Meantime, however, the ether, be it substance or be it only dream-stuff, is serving an admirable purpose in furnishing a fulcrum for modern physics. Not alone to the student of energy has it proved invaluable, but to the student of matter itself as well. Out of its hypothetical mistiness has been reared the most tenable theory of the constitution of ponderable matter which has yet been suggested—or, at any rate, the one that will stand as the definitive nineteenth-century guess at this "riddle of the ages." I mean, of course, the vortex theory of atoms — that profound and fascinating doctrine which suggests that matter, in all its multiform phases, is nothing more or less than ether in motion.

The author of this wonderful conception is Lord Kelvin. The idea was born in his mind of a happy union of mathematical calculations with concrete experiments. The mathematical calculations were largely the work of Hermann von Helmholtz, who, about the year 1858, had undertaken to solve some unique problems in vortex motions. Helmholtz found that a vortex whirl, once established in a frictionless medium, must go on, theoretically, unchanged forever. In a limited medium such a whirl may be V-shaped, with its ends at the surface of the medium. We may imitate such a vortex by drawing the bowl of a spoon quickly through a cup of water. But in a limitless medium the vortex whirl must always be a closed ring, which may take the simple form of a hoop or circle, or which may be indefinitely contorted, looped, or, so to speak, knotted. Whether simple or contorted, this endless chain of whirling matter (the particles revolving about the axis of the loop as the particles of a string revolve when the string is rolled between the fingers) must, in a frictionless medium, retain its form, and whirl on with undiminished speed forever.

While these theoretical calculations of Helmholtz were fresh in his mind, Lord Kelvin (then Sir William Thomson) was shown by Professor E. B. Tait, of Edinburgh, an apparatus constructed for the purpose of creating vortex rings in air. The apparatus, which any one may duplicate, consisted simply of a box with a hole bored in one side, and a piece of canvas stretched across the opposite side in lieu of boards. Fumes of chloride of ammonia are generated within the box, merely to render the air visible. By tapping with the hand on the canvas side of the box, vortex rings of the clouded air are driven out, precisely similar in appearance to those smoke rings which some expert tobacco-smokers can produce by tapping on their cheeks, or to those larger ones which we sometimes see blown out from the funnel of a locomotive.

The advantage of Professor Tait's apparatus is its manageableness, and the certainty with which the desired result can be produced. Before Lord Kelvin's interested observation it threw out rings of various sizes, which moved straight across the room at varying rates of speed, according to the initial impulse, and which behaved very strangely when coming in contact with one another. If, for example, a rapidly moving ring overtook another moving in the same path, the one in advance seemed to pause, and to spread out its periphery like an elastic band, while the pursuer seemed to contract, till it actually slid through the orifice of the other, after which each ring resumed its original size, and continued its course as if nothing had happened. When, on the other hand, two rings moving in slightly different directions came near each other, they seemed to have an attraction for each other; yet if they impinged, they bounded away, quivering like elastic solids. If an effort were made to grasp or to cut one of these rings, the subtle thing shrunk from the contact, and slipped away as if it were alive.

And all the while the body which thus conducted itself consisted simply of a whirl in the air, made visible, but not otherwise influenced, by smoky fumes. Presently the friction of the surrounding air wore the ring away, and it faded into the general atmosphere—often, however, not until it had persisted for many seconds, and passed clear across a large room. Clearly, if there were no friction, the ring's inertia must make it a permanent structure. Only the frictionless medium was lacking to fulfil all the conditions of Helmholtz's indestructible vortices. And at once Lord Kelvin bethought him of the frictionless medium which physicists had now begun to accept—the all-pervading ether. What if vortex rings were started in this ether, must they not have the properties which the vortex rings in air had exhibited—inertia, attraction, elasticity? And are not these the properties of ordinary tangible matter? Is it not probable, then, that what we call matter consists merely of aggregations of infinitesimal vortex rings in the ether?

Thus the vortex theory of atoms took form in Lord Kelvin's mind, and its expression gave the world what most philosophers of our time regard as the most plausible conception of the constitution of matter hitherto formulated. It is only a theory, to be sure; its author would be the last person to claim finality for it. But it has a basis in mathematical calculation and in analogical experiment such as no other theory of matter can lay claim to, and it has a unifying or monistic tendency that makes it, for the philosophical mind, little less than fascinating. True or false, it is the definitive theory of matter of the nineteenth century.

III.

Quite aside from the question of the exact constitution of the ultimate particles of matter, questions as to the distribution of such particles, their mutual relations, properties, and actions, have come in for a full share of attention during our century, though the foundations for the modern speculations were furnished in a previous epoch. The most popular eighteenth-century speculation as to the ultimate constitution of matter was that of the learned Italian priest, Roger Joseph Boscovich, published in 1758, in his *Theoria Philosophiæ Naturalis.* "In this theory," according to an early commentator, "the whole mass of which the bodies of the universe are composed is supposed to consist of an exceedingly great yet finite number of simple, indivisible, inextended atoms. These atoms are endued by the Creator with *repulsive* and *attractive* forces, which vary according to the distance. At very small distances the particles of matter repel each other; and this repulsive force increases beyond all limits as the distances are diminished, and will consequently forever prevent actual contact. When the particles of matter are removed to sensible distances, the repulsive is exchanged for an attractive force, which decreases in inverse ratio with the squares of the distances, and extends beyond the spheres of the most remote comets."

This conception of the atom as a mere centre of force was hardly such as could satisfy any mind other than the metaphysical. No one made a conspicuous attempt to improve upon the idea, however, till just at the close of the century, when Humphry Davy was led, in the course of his studies of heat, to speculate as to the changes that occur in the intimate substance of matter under altered conditions of temperature. Davy, as we have seen, regarded heat as a manifestation of motion among the particles of matter. As all bodies with which we come in contact have some temperature, Davy inferred that the intimate particles of every substance must be perpetually in a state of vibration. Such vibrations, he believed, produced the "repulsive force" which (in common with Boscovich) he admitted as holding the particles of matter at a distance from one another. To heat a substance means merely to increase the rate of vibration of its particles; thus also, plainly, increasing the repulsive forces, and expanding the bulk of the mass as a whole. If the degree of heat applied be sufficient, the repulsive force may become strong enough quite to overcome the attractive force, and the particles will separate and tend to fly away from one another, the solid then becoming a gas.

Not much attention was paid to these very suggestive ideas of Davy, because they were founded on the idea that heat is merely a motion, which the scientific world then repudiated; but half a century later, when the new theories of energy had made their way, there came a revival of practically the same ideas of the particles of matter (molecules they were now called) which Davy had advocated. Then it was that Clausius in Germany and Clerk Maxwell in England took up the investigation of what came to be known as the kinetic theory of gases—the now familiar conception that all the phenomena of gases are due to the helter-skelter flight of the showers of widely separated molecules of which they are composed. The specific idea that the pressure or "spring" of gases is due to such molecular impacts was due to Daniel Bournelli, who advanced it early in the eighteenth century. The idea, then little noticed, had been revived about a century later by William Herapath, and again with some success by J. J. Waterston, of Bombay, about 1846; but it gained no distinct footing until taken in hand by Clausius in 1857 and by Maxwell in 1859.

The investigations of these great physicists not only served fully to substantiate the doctrine, but threw a flood of light upon the entire subject of molecular dynamics. Soon the physicists came to feel as certain of the existence of these showers of flying molecules making up a gas as if they could actually see and watch their individual actions. Through study of the viscosity of gases—that is to say, of the degree of frictional opposition they show to an object moving through them, or to another current of gas—an idea was gained, with the aid of mathematics, of the rate of speed at which the particles of the gas are moving, and the number of collisions which each particle must experience in a given time, and of the length of the average free path traversed by the molecule between collisions. These measurements were confirmed by study of the rate of diffusion at which different gases mix together, and also by the rate of diffusion of heat through a gas, both these phenomena being chiefly due to the helter-skelter flight of the molecules.

It is sufficiently astonishing to be told that such measurements as these have been made at all, but the astonishment grows when one hears the results. It appears from Maxwell's calculations that the mean free path, or distance traversed by the molecules between collisions in ordinary air, is about one half-millionth of an inch; while the speed of the molecules is such that each one experiences about eight billions of collisions per second! It would be hard, perhaps, to cite an illustration showing the refinements of modern physics better than this; unless, indeed, one other result that followed directly from these calculations be considered such — the feat, namely, of measuring the size of the molecules themselves. Clausius was the first to point out how this might be done from a knowledge of the length of free path; and the calculations were made by Loschmidt in Germany, and by Lord Kelvin in England, independently.

The work is purely mathematical, of course, but the results are regarded as unassailable; indeed, Lord Kelvin speaks of them as being absolutely demonstrative, within certain limits of accuracy. This does not mean, however, that they show the exact dimensions of the molecule; it means an estimate of the limits of size within which the actual size of the molecule may lie. These limits, Lord Kelvin estimates, are about the one ten-millionth of a centimetre for the maximum, and the one one-hundred-millionth of a centimetre for the minimum. Such figures convey no particular meaning to our blunt senses, but Lord Kelvin has given a tangible illustration that aids the imagination to at least a vague comprehension of the unthinkable smallness of the molecule. He estimates that if a ball, say of water or glass, about "as large as a football, were to be magnified up to the size of the earth, each constituent molecule being magnified in the same proportion, the magnified structure would be more coarse-grained than a heap of shot, but probably less coarse-grained than a heap of footballs."

Several other methods have been employed to estimate the size of molecules. One of these is based upon the phenomena of contact electricity; another upon the wave theory of light; and another upon capillary attraction, as shown in the tense film of a soap-bubble! No one of these methods gives results more definite than that due to the kinetic theory of gases, just outlined; but the important thing is that the results obtained by these different methods (all of them due to Lord Kelvin) agree with one another in fixing the dimensions of the molecule at somewhere about the limits already mentioned. We may feel very sure indeed, therefore, that the ultimate particles of matter are not the unextended, formless points which Boscovich and his followers of the last century thought them.

IV.

Whatever the exact form of the molecule, its outline is subject to incessant variation; for nothing in molecular science is regarded as more firmly established than that the molecule, under all ordinary circumstances, is in a state of intense but variable vibration. The entire energy of a molecule of gas, for example, is not measured by its momentum, but by this plus its energy of vibration and rotation, due to the collisions already referred to. Clausius has even estimated the relative importance of these two quantities, showing that the translational motion of a molecule of gas accounts for only three-fifths of its kinetic energy. The total energy of the molecule (which we call "heat") includes also another factor, namely, potential energy, or energy of position, due to the work that has been done on expanding, in overcoming external pressure, and internal attraction between the molecules themselves. This potential energy (which will be recovered when the gas contracts) is the "latent heat" of Black, which so long puzzled the philosophers. It is latent in the same sense that the energy of a ball thrown into the air is latent at the moment when the ball poises at its greatest height before beginning to fall.

It thus appears that a variety of motions, real and potential, enter into the production of the condition we term heat. It is, however, chiefly the translational motion which is measurable as temperature; and this, too, which most obviously determines the physical state of the substance that the molecules collectively compose —whether, that is to say, it shall appear to our blunt perceptions as a gas, a liquid, or a solid. In the gaseous state, as we have seen, the translational motion of the molecules is relatively enormous, the molecules being widely separated. It does not follow, as was formerly supposed, that this is evidence of a repulsive power acting between the molecules. The physicists of to-day, headed by Lord Kelvin, decline to recognize any such power. They hold that the molecules of a gas fly in straight lines in virtue of their inertia, quite independently of one another, except at times of collision, from which they rebound in virtue of their elasticity; or an approach to collision, in which latter case, coming within the range of mutual attraction, two molecules may circle about one another, as a comet circles about the sun, then rush apart again, as the comet rushes from the sun.

It is obvious that the length of the mean free path of the molecules of a gas may be increased indefinitely by decreasing the number of the molecules themselves in a circumscribed space. It has been shown by Professors Tait and Dewar that a vacuum may be produced artificially of such a degree of rarefaction that the mean free path of the remaining molecules is measurable in inches. The calculation is based on experiments made with the radiometer of Professor Crookes, an instrument which in itself is held to demonstrate the truth of the kinetic theory of gases. Such an attenuated gas as this is considered by Professor Crookes as constituting a fourth state of matter, which he terms ultra-gaseous.

If, on the other hand, a gas is subjected to pressure, its molecules are crowded closer together, and the length of their mean free path is thus lessened. Ultimately, the pressure being sufficient, the molecules are practically in continuous contact. Meantime the enormously increased number of collisions has set the molecules more and more actively vibrating, and the temperature of the gas has increased, as, indeed, necessarily results in accordance with the law of the conservation of energy. No amount of pressure, therefore, can suffice by itself to reduce the gas to a liquid state. It is believed that even at the centre of the sun, where the pressure is almost inconceivably great, all matter is to be regarded as really gaseous, though the molecules must be so packed together that the consistency is probably more like that of a solid.

If, however, coincidently with the application of pressure, opportunity be given for the excess of heat to be dissipated to a colder surrounding medium, the molecules, giving off their excess of energy, become relatively quiescent, and at a certain stage the gas becomes a liquid. The exact point at which this transformation occurs, however, differs enormously for different substances. In the case of water, for example, it is a temperature more than four hundred degrees above zero, Centigrade; while for atmospheric air it is 194° Centigrade below zero, or more than a hundred and fifty degrees below the point at which mercury freezes.

Be it high or low, the temperature above which any substance is always a gas, regardless of pressure, is called the critical temperature, or absolute boiling-point, of that substance. It does not follow, however, that below this point the substance is necessarily a liquid. This is a matter that will be determined by external conditions of pressure. Even far below the critical temperature the molecules have an enormous degree of activity, and tend to fly asunder, maintaining what appears to be a gaseous, but what technically is called a vaporous, condition—the distinction being that pressure alone suffices to reduce the vapor to the liquid state. Thus water may change from the gaseous to the liquid state at 400° above zero, but under conditions of ordinary atmospheric pressure it does not do so until the temperature is lowered three hundred degrees further. Below 400°, however, it is technically a vapor, not a gas; but the sole difference, it will be understood, is in the degree of molecular activity.

It thus appears that the prevalence of water in a vaporous and liquid rather than in a "permanently" gaseous condition here on the globe is a mere incident of telluric evolution. Equally incidental is the fact that the air we breathe is "permanently" gaseous and not liquid or solid, as it might be were the earth's surface temperature to be lowered to a degree which, in the larger view, may be regarded as trifling. Between the atmospheric temperature in tropical and in arctic regions there is often a variation of more than one hundred degrees; were the temperature reduced another hundred, the point would be reached at which oxygen gas becomes a vapor, and under increased pressure would be a liquid. Thirty-seven degrees more would bring us to the critical temperature of nitrogen.

Nor is this a mere theoretical assumption; it is a determination of experimental science, quite independent of theory. The physicist in the laboratory has produced artificial conditions of temperature enabling him to change the state of the most persistent gases. Some fifty years since, when the kinetic theory was in its infancy, Faraday liquefied carbonic acid gas, among others, and the experiments thus inaugurated have been extended by numerous more recent investigators, notably by Cailletet in Switzerland, by Pictet in France, and by Dr. Thomas Andrews and Professor James Dewar in England. In the course of these experiments not only has air been liquefied, but hydrogen also, the most subtle of gases; and it has been made more and more apparent that gas and liquid are, as Andrews long ago asserted, "only distant stages of a long series of continuous physical changes." Of course if the temperature be lowered still further, the liquid becomes a solid; and this change also has been effected in the case of some of the most "permanent" gases, including air.

The degree of cold—that is, of absence of heat—thus produced is enormous, relatively to anything of which we have experience in nature here at the earth now, yet the molecules of solidified air, for example, are not absolutely quiescent. In other words, they still have a temperature, though so very low. But it is clearly conceivable that a stage might be reached at which the molecules became absolutely quiescent, as regards either translational or vibratory motion. Such a heatless condition has been approached, but as yet not quite attained, in laboratory experiments. It is called the absolute zero of temperature, and is estimated to be equivalent to 273° Centigrade below the freezing-point of water, or ordinary zero.

A temperature (or absence of temperature) closely approximating this is believed to obtain in the ethereal ocean of interplanetary and interstellar space, which transmits, but is thought not to absorb, radiant energy. We here on the earth's surface are protected from exposure to this cold, which would deprive every organic thing of life almost instantaneously, solely by the thin blanket of atmosphere with which the globe is coated. It would seem as if this atmosphere, exposed to such a temperature at its surface, must there be incessantly liquefied, and thus fall back like rain to be dissolved into gas again while it still is many miles above the earth's surface. This may be the reason why its scurrying molecules have not long ago wandered off into space, and left the world without protection.

But whether or not such liquefaction of the air now occurs in our outer atmosphere, there can be no question as to what must occur in its entire depth were we permanently shut off from the heating influence of the sun, as the astronomers threaten that we may be in a future age. Each molecule, not alone of the atmosphere, but of the entire earth's substance, is kept aquiver by the energy which it receives, or has received, directly or indirectly, from the sun. Left to itself, each molecule would wear out its energy and fritter it off into the space about it, ultimately running completely down, as surely as any human-made machine whose power is not from time to time restored. If then it shall come to pass in some future age that the sun's rays fail us, the temperature of the globe must gradually sink toward the absolute zero. That is to say, the molecules of gas which now fly about at such inconceivable speed must drop helpless to the earth; liquids must in turn become solids; and solids themselves, their molecular quivers utterly stilled, may perhaps take on properties the nature of which we cannot surmise.

Yet even then, according to the current hypothesis, the heatless molecule will still be a thing instinct with life. Its vortex whirl will still go on, uninfluenced by the dying out of those subordinate quivers that produced the transitory effect which we call temperature. For those transitory thrills, though determining the physical state of matter as measured by our crude organs of sense, were no more than non-essential incidents; but the vortex whirl is the essence of matter itself.

SHARON'S CHOICE.

BY OWEN WISTER.

UNDER Providence, a man may achieve the making of many things—ships, books, fortunes, himself even, quite often enough to encourage others; but let him beware of creating a town. Towns mostly happen. No real-estate operator decided that Rome should be. Sharon was an intended town; a one man's piece of deliberate manufacture; his whim, his pet, his device for immortally continuing above ground. He planned its avenues, gave it his middle name, fed it with his railroad. But he had reckoned without the inhabitants (to say nothing of nature), and one day they displeased him. Whenever you wish you can see Sharon and what it has come to, as I saw it when, as a visitor without local prejudices, they asked me to serve with the telegraph-operator and the ticket-agent and the hotel-manager on the literary committee of judges at the school festival. There would be a stage, and flags, and elocution, and parents assembled, and afterwards ice-cream with strawberries from El Paso.

"Have you ever awarded prizes for school speaking?" inquired the telegraph-operator, Stuart.

"Yes," I told him. "At Concord in New Hampshire."

"Ever have a chat afterwards with a mother whose girl did not get the prize?"

"It was boys," I replied. "And parents had no say in it."

"It's boys and girls in Sharon," said he. "Parents have no say in it here, either. But that don't seem to occur to them at the moment. We'll all stick together, of course."

"I think I had best resign," said I. "You would find me no hand at pacifying a mother."

"There are fathers also," said Stuart. "But individual parents are small trouble compared with a big split in public opinion. We've missed that so far, though."

"Then why have judges? Why not a popular vote?" I inquired.

"Don't go back on us," said Stuart. "We are so few here. And you know education can't be democratic, or where will good taste find itself? Eastman knows that much, at least." And Stuart explained that Eastman was the head of the school and chairman of our committee. "He is from Massachusetts, and his taste is good, but he is total abstinence. Won't allow any literature with the least smell of a drink in it, not even in the singing-class. Would not have 'Here's a health to King Charles' inside the door. Narrowing, that, as many of the finest classics speak of wine freely. Eastman is useful, but a crank. Now take 'Lochinvar.' We are to have it on strawberry night; but say! Eastman kicked about it. Told the kid to speak something else. Kid came to me, and I—"

A smile lurked for one instant in the corner of Stuart's eye, and disappeared again. Then he drew his arm through mine as we walked.

"You have never seen anything in your days like Sharon," said he. "You could not sit down by yourself and make such a thing up. Shakespeare might have, but he would have strained himself doing it. Well, Eastman says 'Lochinvar' will go in my expurgated version. Too bad Sir Walter cannot know. Ever read his *Familiar Letters?* Great grief! but he was a good man. Eastman stuck about that mention of wine. Remember?

So now am I come with this lost love of mine
To lead but one measure, drink one cup of wine.

'Well,' thought I, 'Eastman would agree to water. Water and daughter would go, but is frequently used and spoils the metre.' So I fiddled with my pencil down in the telegraph-office, and I fixed the thing up. How's this?

So now am I come with this beautiful maid
To lead but one measure, drink one lemonade.

Eastman accepts that. Says it's purer. Oh, it's not all sadness here!"

"How did you come to be in Sharon?" I asked my exotic acquaintance.

"Ah, how did I? How did all our crowd at the railroad? Somebody has got to sell tickets, somebody has got to run that hotel, and telegraphs have got to exist here. That's how we foreigners came. Many travellers change cars here, and one train usually misses the other, because the two companies do not love each other. You hear lots of language, especially in December. Eastern consumptives bound for southern California get left here, and drummers are also thick. Remarks range from 'How provoking!' to things I would not even say myself. So that big hotel and depot has to be kept running, and we fellows get a laugh now and then. Our lot is better than these people's." He made a general gesture at Sharon.

"I should have thought it was worse," said I.

"No, for we'll be transferred some day. These poor folks are shipwrecked. Though it is their own foolishness, all this."

Again my eye followed as he indicated the town with a sweep of his hand; and from the town I looked to the four quarters of heaven. I may have seen across into Old Mexico. No sign labels the boundary; the vacuum of continent goes on, you might think, to Patagonia. Symptoms of neighboring Mexico basked on the sand heaps along Sharon's spacious avenues — little torpid, indecent gnomes in sashes and open rags, with crowning steeple straw hats, and murder dozing in their small black eyes. They might have crawled from holes in the sand or hatched out of brown cracked pods on some weeds that trailed through the broken bottles, the old shoes, and the wire fences. Outside these ramparts began the vacuum, white, gray, indigo, fluorescent, where all the year the sun shines. Not the semblance of any tree dances in the heat; only rocks and lumps of higher sand waver and dissolve and reappear in the shaking crystal of mirage. Not the scar of any river-bed furrows the void. A river there is, flowing somewhere out of the shiny violet mountains to the north, but it dies subterraneously on its way to Sharon, misses the town, and emerges thirty miles south across the sunlight in a shallow, futile lake, a *ciénaga*, called Las Palomas. Then it evaporates into the ceaseless blue sky.

The water you get in Sharon is dragged by a herd of windmills from the bowels of the sand. Over the town they turn and turn—Sharon's upper story—a filmy colony of wheels. In some of the homes beneath them you may go up stairs—in the American homes, not the adobe Mexican caves of song, woman, and knives; and brick and stone edifices occur. Monuments of perished trade, they rise among their flatter neighbors cubical and stark; under-shirts, fire-arms, and groceries for sale in the ground-floor, blind dust-windows above. Most of the mansions, however, squat ephemerally upon the soil, no cellar to them, and no staircase, the total fragile box ready to bounce and caracole should the wind drive hard enough. Inside them, eating, mending, the newspaper, and more babies eke out the twelvemonth; outside, the citizens loiter to their errands

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really a diamond, there is nothing like it known to man!"

"Nothing indeed," said he.

She sat staring at the great piece of glowing mineral which lay in her hand. Its surface was irregular; it had many faces; the subdued light from the window gave it the appearance of animated water. He felt it necessary to speak.

"Even these little pieces," he said, "are most valuable jewels."

She still sat silent, looking at the glowing object she held.

"You see, these are not like the stones which are found in our diamond-fields," he said. "Those, most likely, were little unconsumed bits of the original mass, afterwards gradually forced up from the interior in the same way that many metals and minerals are forced up, and then rounded and dulled by countless ages of grinding and abrasion, due to the action of rocks or water."

"Roland," she cried, excitedly, "this is riches beyond imagination! What is common wealth to what you have discovered? Every living being on earth could—"

"Ah, Margaret," he interrupted, "do not let your thoughts run that way. If my discovery should be put to the use of which you are thinking, it would bring poverty, not wealth, to the world, and not a diamond on earth would be worth more than a common pebble. Everywhere, in civilized countries and in barbaric places, people would see their riches vanish before them as if it had been blighted by the touch of an evil magician."

She trembled. "And these, are they to be valued as common pebbles?"

"Oh no," said he; "so long as that great shaft is mine, these broken fragments are to us riches far ahead of our wildest imaginations."

"Roland," she cried, "are you going down into that shaft for more of them?"

"Never, never, never again," he said. "What we have here is enough for us, and if I were offered all the good that there is in this world which money cannot buy, I would never go down into that cleft again. There was one moment when I stood in that cave in which an awful terror shot into my soul which I shall never be able to forget. In the light of my electric lamps sent through a vast transparent mass I could see nothing, but I could feel. I put out my foot, and I found it was upon a sloping surface. In another instant I might have slid—where? I cannot bear to think of it!"

She threw her arms around him and held him tightly.

[TO BE CONTINUED.]

THE CENTURY'S PROGRESS IN CHEMISTRY.

BY HENRY SMITH WILLIAMS, M.D.

I.

SMALL beginnings have great endings—sometimes. As a case in point, note what came of the small original effort of a self-trained back-country Quaker youth named John Dalton, who along toward the close of the last century became interested in the weather, and was led to construct and use a crude rain-gauge to test the amount of the waterfall. The simple experiments thus inaugurated led to no fewer than two hundred thousand recorded observations regarding the weather, which formed the basis for some of the most epochal discoveries in meteorology, as we have seen. But this was only a beginning. The simple rain-gauge pointed the way to the most important generalization of our century in a field of science with which, to the casual observer, it might seem to have no alliance whatever. The wonderful theory of atoms, on which the whole gigantic structure of modern chemistry is founded, was the logical outgrowth, in the mind of John Dalton, of those early studies in meteorology.

The way it happened was this: From studying the rainfall, Dalton turned naturally to the complementary process of evaporation. He was soon led to believe that vapor exists in the atmosphere as an independent gas. But since two bodies cannot occupy the same space at the same time, this implies that the various atmospheric gases are really composed of discrete particles. These ultimate particles are so small that we cannot see them—cannot, indeed, more than vaguely imagine them —yet each particle of vapor, for example, is just as much a portion of water as if it were a drop out of the ocean, or, for that matter, the ocean itself. But again, water is a compound substance, for it may be separated, as Cavendish had shown, into the two elementary substances hydrogen and oxygen. Hence the atom of water must be composed of two lesser atoms joined together. Imagine an atom of hydrogen and one of oxygen. Unite them, and we have an atom of water; sever them, and the water no longer exists; but whether united or separate the atoms of hydrogen and of oxygen remain hydrogen and oxygen and nothing else. Differently mixed together or united, atoms produce different gross substances; but the elementary atoms never change their chemical nature—their distinct personality.

It was about the year 1803 that Dalton first gained a full grasp of the conception of the chemical atom. At once he saw that the hypothesis, if true, furnished a marvellous key to secrets of matter hitherto insoluble—questions relating to the relative proportions of the atoms themselves. It is known, for example, that a certain bulk of hydrogen gas unites with a certain bulk of oxygen gas to form water. If it be true that this combination consists essentially of the union of atoms one with another (each single atom of hydrogen united to a single atom of oxygen), then the relative weights of the original masses of hydrogen and of oxygen must be also the relative weights of each of their respective atoms. If one pound of hydrogen unites with five and one-half pounds of oxygen (as, according to Dalton's experiments, it did), then the weight of the oxygen atom must be five and one-half times that of the hydrogen atom. Other compounds may plainly be tested in the same way. Dalton made numerous tests before he published his theory. He found that hydrogen enters into compounds in smaller proportions than any other element known to him, and so, for convenience, determined to take the weight of the hydrogen atom as unity. The atomic weight of oxygen then becomes (as given in Dalton's first table of 1803) 5.5; that of water (hydrogen plus oxygen) being of course 6.5. The atomic weights of about a score of substances are given in Dalton's first paper, which was read before the Literary and Philosophical Society of Manchester, October 21, 1803. I wonder if Dalton himself, great and acute intellect though he had, suspected, when he read that paper, that he was inaugurating one of the most fertile movements ever entered on in the whole history of science?

II.

Be that as it may, it is certain enough that Dalton's contemporaries were at first little impressed with the novel atomic theory. Just at this time, as it chanced, a dispute was waging in the field of chemistry regarding a matter of empirical fact which must necessarily be settled before such a theory as that of Dalton could even hope for a hearing. This was the question whether or not chemical elements unite with one another always in definite proportions. Berthollet, the great co-worker with Lavoisier, and now the most authoritative of living chemists, contended that substances combine in almost indefinitely graded proportions between fixed extremes. He held that solution is really a form of chemical combination—a position which, if accepted, left no room for argument.

But this contention of the master was most actively disputed, in particular by Louis Joseph Proust, and all chemists of repute were obliged to take sides with one or the other. For a time the authority of Berthollet held out against the facts, but at last accumulated evidence told for Proust and his followers, and toward the close of the first decade of our century it came to be generally conceded that chemical elements combine with one another in fixed and definite proportions.

More than that. As the analysts were led to weigh carefully the quantities of combining elements, it was observed that the proportions are not only definite, but that they bear a very curious relation to one another. If element A combines with two different proportions of element B to form two compounds, it appeared that the weight of the larger quantity of B is an exact multiple of that of the smaller quantity. This curious relation was noticed by Dr. Wollaston, one of the most accurate of observers, and a little later it was confirmed by Johan Jakob Berzelius, the great Swedish chemist, who was to be a dominating influence in the chemical world for a generation to come. But this combination of elements in numerical proportions was exactly what Dalton had noticed as early as 1802, and what had led him directly to the atomic weights. So the confirmation of this essential point by chemists of such authority gave the strongest confirmation to the atomic theory.

During these same years the rising authority of the French chemical world, Joseph Louis Gay-Lussac, was conducting experiments with gases, which he had undertaken at first in conjunction with Humboldt, but which later on were conducted independently. In 1809, the next year after the publication of the first volume of Dalton's *New System of Chemical Philosophy*, Gay-Lussac published the results of his observations, and among other things brought out the remarkable fact that gases, under the same conditions as to temperature and pressure, combine always in definite numerical proportions as to volume. Exactly two volumes of hydrogen, for example, combine with one volume of oxygen to form water. Moreover, the resulting compound gas always bears a simple relation to the combining volumes. In the case just cited the union of two volumes of hydrogen and one of oxygen results in precisely two volumes of water vapor.

Naturally enough the champions of the atomic theory seized upon these observations of Gay-Lussac as lending strong support to their hypothesis—all of them, that is, but the curiously self-reliant and self-sufficient author of the atomic theory himself, who declined to accept the observations of the French chemist as valid. Yet the observations of Gay-Lussac were correct, as countless chemists since then have demonstrated anew, and his theory of combination by volumes became one of the foundation-stones of the atomic theory, despite the opposition of the author of that theory.

The true explanation of Gay-Lussac's law of combination by volumes was thought out almost immediately by an Italian savant, Amadeo Avogadro, and expressed in terms of the atomic theory. The fact must be, said Avogadro, that under similar physical conditions every form of gas contains exactly the same number of ultimate particles in a given volume. Each of these ultimate physical particles may be composed of two or more atoms (as in the case of water vapor), but such a compound atom conducts itself as if it were a simple and indivisible atom, as regards the amount of space that separates it from its fellows under given conditions of pressure and temperature. The compound atom, composed of two or more elementary atoms, Avogadro proposed to distinguish, for purposes of convenience, by the name molecule. It is to the molecule, considered as the unit of physical structure, that Avogadro's law applies.

This vastly important distinction between atoms and molecules, implied in the law just expressed, was published in 1811. Four years later, the famous French physicist Ampère outlined a similar theory, and utilized the law in his mathematical calculations. And with that the law of Avogadro dropped out of sight for a full generation. Little suspecting that it was the very key to the inner mysteries of the atoms for which they were seeking, the chemists of the time cast it aside, and let it fade from the memory of their science.

This, however, was not strange, for of course the law of Avogadro is based on the atomic theory, and in 1811 the atomic theory was itself still being weighed in the balance. The law of multiple proportions found general acceptance as an empirical fact; but many of the leading lights of chemistry still looked askance at Dalton's explanation of this law. Thus Wollaston, though from the first he inclined to acceptance of the Daltonian view, cautiously suggested that it would be well to use the non-committal word "equivalent" instead of "atom"; and Davy, for a similar reason, in his book of 1812, speaks only of "proportions," binding himself to no theory as to what might be the nature of these proportions.

At least two great chemists of the time, however, adopted the atomic view with less reservation. One of these was Thomas Thomson, professor at Edinburgh, who in 1807 had given an outline of Dalton's theory in a widely circulated book, which first brought the theory to the general attention of the chemical world. The other, and even more noted advocate of the atomic theory, Johan Jakob Berzelius. This great Swedish chemist at once set to work to put the atomic theory to such tests as might be applied in the laboratory. He was an analyst of the utmost skill, and for years he devoted himself to the determination of the combining weights, "equivalents," or "proportions" of the different elements. These determinations, in so far as they were accurately made, were simple expressions of empirical facts, independent of any theory; but gradually it became more and more plain that these facts all harmonize with the atomic theory of Dalton. So by common consent the proportionate combining weights of the elements came to be known as atomic weights—the name Dalton had given them from the first—and the tangible conception of the chemical atom as a body of definite constitution and weight gained steadily in favor.

From the outset the idea had had the utmost tangibility in the mind of Dalton. He had all along represented the different atoms by geometrical symbols—as a circle for oxygen, a circle enclosing a dot for hydrogen, and the like—and had represented compounds by placing these symbols of the elements in juxtaposition. Berzelius proposed to improve upon this method by substituting for the geometrical symbol the initial of the Latin name of the element represented—O for oxygen, H for hydrogen, and so on—a numerical coefficient to follow the letter as an indication of the number of atoms present in any given compound. This simple system soon gained general acceptance, and with slight modifications it is still universally employed. Every schoolboy now is aware that H_2O is the chemical way of expressing the union of two atoms of hydrogen with one of oxygen to form a molecule of water. But such a formula would have had no meaning for the wisest chemist before the day of Berzelius.

The universal fame of the great Swedish authority served to give general currency to his symbols and atomic weights, and the new point of view thus developed led presently to two important discoveries, which removed the last lingering doubts as to the validity of the atomic theory. In 1819 two French physicists, Dulong and Petit, while experimenting with heat, discovered that the specific heats of solids (that is to say, the amount of heat required to raise the temperature of a given mass to a given degree) vary inversely as their atomic weights. In the same year Eilhard Mitscherlich, a German investigator, observed that compounds having the same number of atoms to the molecule are disposed to form the same angles of crystallization—a property which he called isomorphism.

Here, then, were two utterly novel and independent sets of empirical facts which harmonize strangely with the supposition that substances are composed of chemical atoms of a determinate weight. This surely could not be coincidence—it tells of law. And so as soon as the claims of Dulong and Petit and of Mitscherlich had been substantiated by other observers, the laws of the specific heat of atoms, and of isomorphism, took their place as new levers of chemical science. With the aid of these new tools an impregnable breastwork of facts was soon piled about the atomic theory. And John Dalton, the author of that theory, plain provincial Quaker, working on to the end in semi-retirement, became known to all the world and for all time as a master of masters.

III.

During those early years of our century, when Dalton was grinding away at chemical fact and theory in his obscure Manchester laboratory, another Englishman held the attention of the chemical world with a series of the most brilliant and widely heralded researches. Humphry Davy had come to London in 1801, at the instance of Count Rumford, to assume the chair of chemical philosophy in the Royal Institution, which the famous American had just founded.

Here, under Davy's direction, the largest voltaic battery yet constructed had been put in operation, and with its aid the brilliant young experimenter was expected almost to perform miracles. And indeed he scarcely disappointed the expectation, for with the aid of his battery he transformed so familiar a substance as common potash into a metal which was not only so light that it floated on water, but possessed the seemingly miraculous property of bursting into flames as soon as it came in contact with that fire-quenching liquid. If this were not a miracle, it had for the popular eye all the appearances of the miraculous.

What Davy really had done was to decompose the potash, which hitherto had been supposed to be elementary, liberating its oxygen, and thus isolating its metallic base, which he named potassium. The same thing was done with soda, and the closely similar metal sodium was discovered—metals of a unique type, possessed of a strange avidity for oxygen, and capable of seizing on it even when it is bound up in the molecules of water. Considered as mere curiosities, these discoveries were interesting, but aside from that they were of great theoretical importance, because they showed the compound nature of some familiar chemicals that had been regarded as elements. Several other elementary earths met the same fate when subjected to the electrical influence, the metals barium, calcium, and strontium being thus discovered. Thereafter Davy always referred to the supposed elementary substances (including oxygen, hydrogen, and the rest) as "undecompounded" bodies. These resist all present efforts to decompose them, but how can one know what might not happen were they subjected to an influence, perhaps some day to be discovered, which exceeds the battery in power as the battery exceeds the blow-pipe?

Another and even more important theoretical result that flowed from Davy's experiments during this first decade of the century was the proof that no elementary substances other than hydrogen and oxygen are produced when pure water is decomposed by the electric current. It was early noticed by Davy and others that when a strong current is passed through water, alkalies appear at one pole of the battery and acids at the other, and this though the water used were absolutely pure. This seemingly told of the creation of elements—a transmutation but one step removed from the creation of matter itself—under the influence of the new "force." It was one of Davy's greatest triumphs to prove, in the series of experiments recorded in his famous Bakerian lecture of 1806, that the alleged creation of elements did not take place, the substances found at the poles of the battery having been dissolved from the walls of the vessels in which the water experimented upon had been placed. Thus the same implement which had served to give a certain philosophical warrant to the fading dreams of alchemy banished those dreams peremptorily from the domain of present science.

Even though the presence of the alkalies and acids in the water was explained, however, their respective migrations to the negative and positive poles of the battery remained to be accounted for. Davy's classical explanation assumed that different elements differ among themselves as to their electrical properties, some being positively, others negatively, electrified. Electricity and "chemical affinity," he said, apparently are manifestations of the same force, acting in the one case on masses, in the other on particles. Electro-positive particles unite with electro-negative particles to form chemical compounds, in virtue of the familiar principle that opposite electricities attract one another. When compounds are decomposed by the battery, this mutual attraction is overcome by the stronger attraction of the poles of the battery itself.

This theory of binary composition of all chemical compounds, through the union of electro-positive and electro-negative atoms or molecules, was extended by Berzelius, and made the basis of his famous system of theoretical chemistry. This theory held that all inorganic compounds, however complex their composition, are essentially composed of such binary combinations. For many years this view enjoyed almost undisputed sway. It received what seemed strong confirmation when Faraday showed the definite connection between the amount of electricity employed and the amount of decomposition produced in the so-called electrolyte. But its claims were really much too comprehensive, as subsequent discoveries proved.

IV.

When Berzelius first promulgated his binary theory he was careful to restrict its unmodified application to the compounds of the inorganic world. At that time, and for a long time thereafter, it was supposed that substances of organic nature had some properties that kept them aloof from the domain of inorganic chemistry. It was little doubted that a so-called "vital force" operated here, replacing or modifying the action of ordinary "chemical affinity." It was, indeed, admitted that organic compounds are composed of familiar elements—chiefly carbon, oxygen, hydrogen, and nitrogen—but these elements were supposed to be united in ways that could not be imitated in the domain of the non-living. It was regarded almost as an axiom of chemistry that no organic compound whatever could be put together from its elements—synthesized—in the laboratory. To effect the synthesis of even the simplest organic compound it was thought that the "vital force" must be in operation.

Therefore a veritable sensation was created in the chemical world when, in the year 1828, it was announced that the young German chemist Friedrich Wöhler, formerly pupil of Berzelius, and already known as a coming master, had actually synthesized the well-known organic product urea in his laboratory at Sacrow. The "exception which proves the rule" is something never heard of in the domain of logical science. Natural law knows no exceptions. So the synthesis of a single organic compound sufficed at a blow to break down the chemical barrier which the imagination of the fathers of the science had erected between animate and inanimate nature. Thenceforth the philosophical chemist would regard the plant and animal organisms as chemical laboratories in which conditions are peculiarly favorable for building up complex compounds of a few familiar elements, under the operation of universal chemical laws. The chimera "vital force" could no longer gain recognition in the domain of chemistry.

Now a wave of interest in organic chemistry swept over the chemical world, and soon the study of carbon compounds became as much the fashion as electro-chemistry had been in the preceding generation.

Foremost among the workers who rendered this epoch of organic chemistry memorable were Justus Liebig in Germany and Jean Baptiste André Dumas in France, and their respective pupils, Charles Frédéric Gerhardt and Augustus Laurent. Wöhler, too, must be named in the same breath, as also must Louis Pasteur, who, though somewhat younger than the others, came upon the scene in time to take chief part in the most important of the controversies that grew out of their labors.

Several years earlier than this the way had been paved for the study of organic substances by Gay-Lussac's discovery, made in 1815, that a certain compound of carbon and nitrogen, which he named cyanogen, has a peculiar degree of stability which enables it to retain its identity, and enter into chemical relations after the manner of a simple body. A year later Ampère discovered that nitrogen and hydrogen, when combined in certain proportions to form what he called ammonium, have the same property. Berzelius had seized upon this discovery of the compound radical, as it was called, because it seemed to lend aid to his dualistic theory. He conceived the idea that all organic compounds are binary unions of various compound radicals with an atom of oxygen, announcing this theory in 1818. Ten years later, Liebig and Wöhler undertook a joint investigation which resulted in proving that compound radicals are indeed very abundant among organic substances. Thus the theory of Berzelius seemed to be substantiated, and organic chemistry came to be defined as the chemistry of compound radicals.

But even in the day of its seeming triumph the dualistic theory was destined to receive a rude shock. This came about through the investigations of Dumas, who proved that in a certain organic substance an atom of hydrogen may be removed, and an atom of chlorine substituted in its place without destroying the integrity of the original compound—much as a child might substitute one block for another in its play-house. Such a substitution would be quite consistent with the dualistic theory, were it not for the very essential fact that hydrogen is a powerfully electro-positive element, while chlorine is as strongly electro-negative. Hence the compound radical which united successively with these two elements must itself be at one time electro-positive, at another electro-negative—a seeming inconsistency which threw the entire Berzelian theory into disfavor.

In its place there was elaborated, chiefly through the efforts of Laurent and Gerhardt, a conception of the molecule as a unitary structure, built up through the aggregation of various atoms, in accordance with "elective affinities" whose nature is not yet understood. A doctrine of "nuclei" and a doctrine of "types" of molecular structure were much exploited, and, like the doctrine of compound radicals, became useful as aids to memory and guides for the analyst, indicating some of the plans of molecular construction, though by no means penetrating the mysteries of chemical affinity. They are classifications rather than explanations of chemical unions. But at least they served an important purpose in giving definiteness to the idea of a molecular structure built of atoms as the basis of all substances. Now at last the word molecule came to have a distinct meaning, as distinct from "atom," in the minds of the generality of chemists, as it had had for Avogadro a third of a century before. Avogadro's hypothesis that there are equal numbers of these molecules in equal volumes of gases, under fixed conditions, was revived by Gerhardt, and a little later, under the championship of Cannizzaro, was exalted to the plane of a fixed law. Thenceforth the conception of the molecule was to be as dominant a thought in chemistry as the idea of the atom had become in a previous epoch.

JOHN DALTON.

V.

Of course the atom itself was in no sense displaced, but Avogadro's law soon made it plain that the atom had often usurped territory that did not really belong to it. In many cases the chemists had supposed themselves dealing with atoms as units where the true unit was the molecule. In the case of elementary gases, such as hydrogen and oxygen, for example, the law of equal numbers of molecules in equal spaces made it clear that the atoms do not exist isolated, as had been supposed. Since two volumes of hydrogen unite with one volume of oxygen to form two volumes of water vapor, the simplest mathematics shows, in the light of Avogadro's law, not only that each molecule of water must contain two hydrogen atoms (a point previously in dispute), but that the original molecules of hydrogen and oxygen must have been composed in each case of two atoms—else how could one volume of oxygen supply an atom for every molecule of two volumes of water?

What, then, does this imply? Why, that the elementary atom has an avidity for other atoms, a longing for companionship, an "affinity"—call it what you will—which is bound to be satisfied if other atoms are in the neighborhood. Placed solely among atoms of its own kind, the oxygen atom seizes on a fellow oxygen atom, and in all their mad dancings these two mates cling together—possibly revolving about one another in miniature planetary orbits. Precisely the same thing occurs among the hydrogen atoms. But now suppose the various pairs of oxygen atoms come near other pairs of hydrogen atoms (under proper conditions which need not detain us here), then each oxygen atom loses its attachment for its fellow, and flings itself madly into the circuit of one of the hydrogen couplets, and—presto!—there are only two molecules for every three there were before, and free oxygen and hydrogen have become water. The whole process, stated in chemical phraseology, is summed up in the statement that under the given conditions the oxygen atoms had a greater affinity for the hydrogen atoms than for one another.

As chemists studied the actions of various kinds of atoms, in regard to their unions with one another to form molecules, it gradually dawned upon them that not all elements are satisfied with the same number of companions. Some elements ask only one, and refuse to take more; while others link themselves, when occasion offers, with two, three, four, or more. Thus we saw that oxygen forsook a single atom of its own kind and linked itself with two atoms of hydrogen. Clearly, then, the oxygen atom, like a creature with two hands, is able to clutch two other atoms. But we have no proof that under any circumstances it could hold more than two. Its affinities seem satisfied when it has two bonds. But, on the other hand, the atom of nitrogen is able to hold three atoms of hydrogen, and does so in the molecule of ammonium (NH_3); while the carbon atom can hold four atoms of hydrogen or two atoms of oxygen.

Evidently, then, one atom is not always equivalent to another atom of a different kind in combining powers. A recognition of this fact by Frankland about 1852, and its further investigation by others (notably A. Kekulé and A. S. Couper), led to the introduction of the word equivalent into chemical terminology in a new sense, and in particular to an understanding of the affinities or "valency" of different elements, which proved of the most fundamental importance. Thus it was shown that, of the four elements that enter most prominently into organic compounds, hydrogen can link itself with only a single bond to any other element—it has, so to speak, but a single hand with which to grasp—while oxygen has capacity for two bonds, nitrogen for three (possibly for five), and carbon for four. The words monovalent, divalent, trivalent, tetravalent, etc., were coined to express this most important fact, and the various elements came to be known as monads, diads, triads, etc. Just why different elements should differ thus in valency no one as yet knows; it is an empirical fact that they do. And once the nature of any element has been determined as regards its valency, a most important insight into the possible behavior of that element has been secured. Thus a consideration of the fact that hydrogen is monovalent, while oxygen is divalent, makes it plain that we must expect to find no more than three compounds of these two elements, namely, H—O— (written HO by the chemist, and called hydroxyl); H—O—H (H_2O, or water), and H—O——O—H (H_2O_2, or hydrogen peroxide). It will be observed that in the first of these compounds the atom of oxygen stands, so to speak, with one of its hands free, eagerly reaching out, therefore, for another companion, and hence, in the language of chemistry, forming an unstable compound. Again in the third compound, though all hands are clasped, yet one pair links oxygen with oxygen; and this also must be an unstable union, since the avidity of an atom for its own kind is relatively weak. Thus the well-known properties of hydrogen peroxide are explained, its easy decomposition, and the eagerness with which it seizes upon the elements of other compounds.

JOHAN JAKOB BERZELIUS.

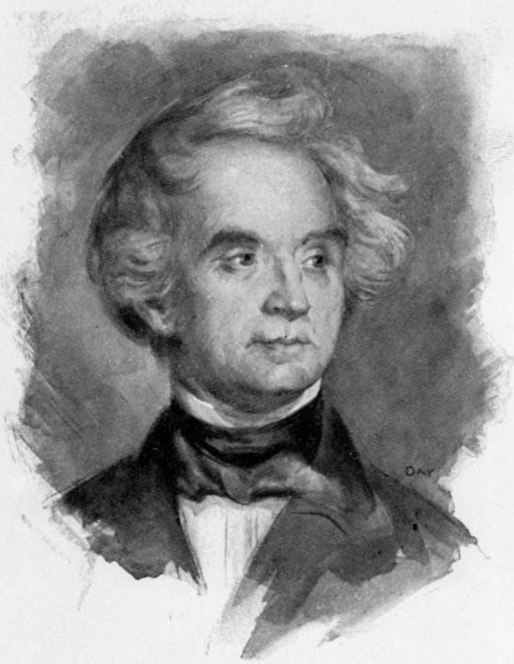
But the molecule of water, on the other hand, has its atoms arranged in a state of stable equilibrium, all their affinities being satisfied. Each hydrogen atom has satisfied its one affinity by clutching the oxygen atom; and the oxygen atom has both its bonds satisfied by clutching back at the two hydrogen atoms. Therefore the trio, linked in this close bond, have no tendency to reach out for any other companion, nor, indeed, any power to hold another should it thrust itself upon them. They form a "stable" compound, which under all ordinary circumstances will retain its identity as a molecule of water, even though the physical mass of which it is a part changes its condition from a solid to a gas—from ice to vapor.

But a consideration of this condition of stable equilibrium in the molecule at once suggests a new question: How can an aggregation of atoms, having all their affinities satisfied, take any further part in chemical reactions? Seemingly such a molecule, whatever its physical properties, must be chemically inert, incapable of any atomic readjustments. And so in point of fact it is, so long as its component atoms cling to one another unremittingly. But this, it appears, is precisely what the atoms are little prone to do. It seems that they are fickle to the last degree in their individual attachments, and are as prone to break away from bondage as they are to enter into it. Thus the oxygen atom which has just flung itself into the circuit of two hydrogen atoms, the next moment flings itself free again and seeks new companions. It is for all the world like the incessant change of partners in a rollicking dance.

JOSEPH LOUIS GAY-LUSSAC.

This incessant dissolution and reformation of molecules in a substance which as a whole remains apparently unchanged was first fully appreciated by Ste.-Claire Deville, and by him named dissociation. It is a process which goes on much more actively in some compounds than in others, and very much more actively under some physical conditions (such as increase of temperature) than under others. But apparently no substances at ordinary temperatures, and no temperature above the absolute zero, are absolutely free from its disturbing influence. Hence it is that molecules having all the valency of their atoms fully satisfied do not lose their chemical activity—since each atom is momentarily free in the exchange of partners, and may seize upon different atoms from its former partners, if those it prefers are at hand.

While, however, an appreciation of this ceaseless activity of the atom is essential to a proper understanding of its chemical efficiency, yet from another point of view the "saturated" molecule—that is, the molecule whose atoms have their valency all satisfied—may be thought of as a relatively fixed or stable organism. Even though it may presently be torn down, it is for the time being a completed structure; and a consideration of the valency of its atoms gives the best clew that has hitherto been obtainable as to the character of its architecture. How important this matter of architecture of the molecule—of space relations of the atoms—may be was demonstrated as long ago as 1823, when Liebig and Wöhler proved, to the utter bewilderment of the chemical world, that two substances may have precisely the same chemical constitution—the same number and kind of atoms—and yet differ utterly in physical properties. The word isomerism was coined by Berzelius to express this anomalous condition of things, which seemed to negative the most fundamental truths of chemistry. Naming the condition by no means explained it, but the fact was made clear that something besides the mere number and kind of atoms is important in the architecture of a molecule. It became certain that atoms are not thrown together haphazard to build a molecule,



JUSTUS VON LIEBIG.

any more than bricks are thrown together at random to form a house.

How delicate may be the gradations of architectural design in building a molecule was well illustrated about 1850, when Pasteur discovered that some carbon compounds—as certain sugars—can only be distinguished from one another, when in solution, by the fact of their twisting or polarizing a ray of light to the left or to the right, respectively. But no inkling of an explanation of these strange variations of molecular structure came until the discovery of the law of valency. Then much of the mystery was cleared away; for it was plain that since each atom in a molecule can hold to itself only a fixed number of other atoms, complex molecules must have their atoms linked in definitive chains or groups. And it is equally plain that where the atoms are numerous, the exact plan of grouping may sometimes be susceptible of change without doing violence to the law of valency. It is in such cases that isomerism is observed to occur.

By paying constant heed to this matter of the affinities, chemists are able to make diagrammatic pictures of the plan of architecture of any molecule whose composition is known. In the simple molecule of water (H_2O), for example, the two hydrogen atoms must have released one another before they could join the oxygen, and the manner of linking must apparently be that represented in the graphic formula $H-O-H$. With molecules composed of a large number of atoms, such graphic representation of the scheme of linking is of course increasingly difficult, yet, with the affinities for a guide, it is always possible. Of course no one supposes that such a formula, written in a single plane, can possibly represent the true architecture of the molecule: it is at best suggestive or diagrammatic rather than pictorial. Nevertheless it affords hints as to the structure of the molecule such as the fathers of chemistry would not have thought it possible ever to attain.

VI.

These utterly novel studies of molecular architecture may seem at first sight to take from the atom much of its former prestige as the all-important personage of the chemical world. Since so much depends upon the mere position of the atoms, it may appear that comparatively little depends upon the nature of the atoms themselves. But such a view is incorrect, for on closer consideration it will appear that at no time has the atom been seen to renounce its peculiar personality. Within certain limits the character of a molecule may be altered by changing the positions of its atoms (just as different buildings may be constructed of the same bricks), but these limits are sharply defined, and it would be as impossible to exceed them as it would be to build a stone building with bricks. From first to last the brick remains a brick, whatever the style of architecture it helps to construct; it never becomes a stone. And just as closely does each atom retain its own peculiar properties, regardless of its surroundings.

Thus, for example, the carbon atom may take part in the formation at one time of a diamond, again of a piece of coal, and yet again of a particle of sugar, of wood fibre, of animal tissue, or of a gas in the atmosphere; but from first to last—from glass-cutting gem to intangible gas—there is no demonstrable change whatever in any single property of the atom itself. So far as we know, its size, its weight, its capacity for vibration or rotation, and its inherent affinities, remain absolutely unchanged throughout all these varying fortunes of position and association. And the same thing is true of every atom of all of the sixty-odd elementary substances with which the modern chemist is acquainted. Every one appears always to maintain its unique integrity, gaining nothing and losing nothing.

All this being true, it would seem as if the position of the Daltonian atom as a primordial bit of matter, indestructible and non-transmutable, had been put to the test by the chemistry of our century, and not found wanting. Since those early days of the century when the electric battery performed its miracles and seemingly reached its limitations in the hands of Davy, many new elementary substances have been discovered, but no single element has been displaced from its position as an undecomposable body. Rather have the analyses of the chemist seemed to make it more and more certain that all elementary atoms are in truth what John Herschel called them, "manufactured articles"—primordial, changeless, indestructible.

And yet, oddly enough, it has chanced that hand in hand with the experiments leading to such a goal have gone other experiments and speculations of exactly the opposite tenor. In each generation there have been chemists among the leaders of their science who have refused to admit that the so-called elements are really elements at all in any final sense, and who have sought eagerly for proof which might warrant their scepticism. The first bit of evidence tending to support this view was furnished by an English physician, Dr. William Prout, who in 1815 called attention to a curious relation to be observed between the atomic weight of the various elements. Accepting the figures given by the authorities of the time (notably Thomson and Berzelius), it appeared that a strikingly large proportion of the atomic weights were exact multiples of the weight of hydrogen, and that others differed so slightly that errors of observation might explain the discrepancy. Prout felt that this could not be accidental, and he could think of no tenable explanation, unless it be that the atoms of the various alleged elements are made up of different fixed numbers of hydrogen atoms. Could it be that the one true element—the one primal matter—is hydrogen, and that all other forms of matter are but compounds of this original substance?

GUSTAV ROBERT KIRCHHOFF.

Prout advanced this startling idea at first tentatively, in an anonymous publication; but afterward he espoused it openly and urged its tenability. Coming just after Davy's dissociation of some supposed elements, the idea proved alluring, and for a time gained such popularity that chemists were disposed to round out the observed atomic weights of all elements into whole numbers. But presently renewed determinations of the atomic weights seemed to discountenance this practice, and Prout's alleged law fell into disrepute. It was revived, however, about 1840, by Dumas, whose great authority secured it a respectful hearing, and whose careful redetermination of the weight of carbon, making it exactly twelve times that of hydrogen, aided the cause.

Subsequently Stas, the pupil of Dumas, undertook a long series of determinations of atomic weights, with the expectation of confirming the Proutian hypothesis. But his results seemed to disprove the hypothesis, for the atomic weights of many elements differed from whole numbers by more, it was thought, than the limits of error of the experiments. It is noteworthy, however, that the confidence of Dumas was not shaken, though he was led to modify the hypothesis, and, in accordance with previous suggestions of Clark and of Marignac, to recognize as the primordial element, not hydrogen itself, but an atom half the weight, or even one-fourth the weight of that of hydrogen, of which primordial atom the hydrogen atom itself is compounded. But even in this modified form the hypothesis found great opposition from experimental observers.

In 1864, however, a novel relation between the weights of the elements and their other characteristics was called to the attention of chemists by Professor John A. R. Newlands, of London, who had noticed that if the elements are arranged serially in the numerical order of their atomic weights, there is a curious recurrence of similar properties at intervals of eight elements. This so-called "law of octaves" attracted little immediate attention, but the facts it connotes soon came under the observation of other chemists, notably of Professors Gustav Hinrichs in America, Dmitri Mendèleeff in Russia, and Lothar Meyer in Germany. Mendelèeff gave the discovery fullest expression, expositing it in 1869, under the title of "periodic law."

ROBERT WILHELM BUNSEN.

Though this early exposition of what has since been admitted to be a most important discovery was very fully outlined, the generality of chemists gave it little heed till a decade or so later, when three new elements, gallium, scandium, and germanium, were discovered, which, on being analyzed, were quite unexpectedly found to fit into three gaps which Mendelèeff had left in his periodic scale. In effect, the periodic law had enabled Mendelèeff to predicate the existence of the new elements years before they were discovered. Surely a system that leads to such results is no mere vagary. So very soon the periodic law took its place as one of the most important generalizations of chemical science.

This law of periodicity was put forward as an expression of observed relations independent of hypothesis; but of course the theoretical bearings of these facts could not be overlooked. As Pro-

LOUIS JACQUES MANDÉ DAGUERRE.

From a daguerreotype made in Paris for Meade Brothers, New York, now in possession of Abraham Bogardus, New York.

fessor J. H. Gladstone has said, it forces upon us "the conviction that the elements are not separate bodies created without reference to one another, but that they have been originally fashioned, or have been built up from one another, according to some general plan." It is but a short step from that proposition to the Proutian hypothesis.

But the atomic weights are not alone in suggesting the compound nature of the alleged elements. Evidence of a totally different kind has contributed to the same end, from a source that could hardly have been imagined when the Proutian hypothesis was formulated, through the addition of a novel weapon to the armamentarium of the chemist—the spectroscope. The perfection of this instrument, in the hands of two German scientists, Gustav Robert Kirchhoff and Robert Wilhelm Bunsen, came about through the investigation, toward the middle of the century, of the meaning of the dark lines which had been observed in the solar spectrum by Fraunhofer as early as 1815, and by Wollaston a decade earlier. It was suspected by Stokes and by Fox Talbot in England, but first brought to demonstration by Kirchhoff and Bunsen, that these lines, which were known to occupy definite positions in the spectrum, are really indicative of particular elementary substances. By means of the spectroscope, which is essentially a magnifying lens attached to a prism of glass, it is possible to locate the lines with great accuracy, and it was soon shown that here was a new means of chemical analysis of the most exquisite delicacy. It was found, for example, that the spectroscope could detect the presence of a quantity of sodium so infinitesimal as the one two-hundred-thousandth of a grain. But what was even more important, the spectroscope put no limit upon the distance of location of the substance it tested, provided only that sufficient light came from it. The experiments it recorded might be performed in the sun, or in the most distant stars or nebulæ; indeed, one of the earliest feats of the instrument was to wrench from the sun the secret of his chemical constitution.

To render the utility of the spectroscope complete, however, it was necessary to link with it another new chemical agency, namely, photography. This now familiar process is based on the property of light to decompose certain unstable compounds of silver, and thus alter their chemical composition. We have seen that Davy and Wedgwood barely escaped the discovery of the value of the photographic method. Their successors quite overlooked it until about 1826, when Louis J. M. Daguerre, the French chemist, took the matter in hand, and after many years of experimentation brought it to relative perfection in 1839, in which year the famous daguerreotype first brought the matter to popular attention. In the same year Mr. Fox Talbot read a paper on the subject before the Royal Society, and soon afterward the efforts of Herschel and numerous other natural philosophers contributed to the advancement of the new method.

JOHN W. DRAPER.

In 1843 Dr. John W. Draper, the famous English-American chemist and physiologist, showed that by photography the Fraunhofer lines in the solar spectrum might be mapped with absolute accuracy; also proving that the silvered film revealed many lines invisible to the unaided eye. The value of this method of observation was recognized at once, and as soon as the spectroscope was perfected, the photographic method, in conjunction with its use, became invaluable to the chemist. By this means comparisons of spectra may be made with a degree of accuracy not otherwise obtainable; and in case of the stars, whole clusters of spectra may be placed on record at a single observation.

As the examination of the sun and stars proceeded, chemists were amazed or delighted, according to their various preconceptions, to witness the proof that many familiar terrestrial elements are to be found in the celestial bodies. But what perhaps surprised them most was to observe the enormous preponderance in the sidereal bodies of the element hydrogen. Not only are there vast quantities of this element in the sun's atmosphere, but some other suns appeared to show hydrogen lines almost exclusively in their spectra. Presently it appeared that the stars of which this is true are those white stars, such as Sirius, which had been conjectured to be the hottest; whereas stars that are only red-hot, like our sun, show also the vapors of many other elements, including iron and other metals.

In 1878 Mr. J. Norman Lockyer, in a paper before the Royal Society, called attention to the possible significance of this series of observations. He urged that the fact of the sun showing fewer elements than are observed here on the cool earth, while stars much hotter than the sun show chiefly one element, and that one hydrogen, the lightest of known elements, seemed to give color to the possibility that our alleged elements are really compounds, which at the temperature of the hottest stars may be decomposed into hydrogen, the latter "element" itself being also doubtless a compound, which might be resolved under yet more trying conditions.

Here, then, was what might be termed direct experimental evidence for the hypothesis of Prout. Unfortunately, however, it is evidence of a kind which only a few experts are competent to discuss—so very delicate a matter is the spectral analysis of the stars. What is still more unfortunate, the experts do not agree among themselves as to the validity of Mr. Lockyer's conclusions. Some, like Professor Crookes, have accepted them with acclaim, hailing Lockyer as "the Darwin of the inorganic world," while others have sought a different explanation of the facts he brings forward. As yet it cannot be said that the controversy has been brought to final settlement. Still, it is hardly to be doubted that now, since the periodic law has seemed to join hands with the spectroscope, a belief in the compound nature of the so-called elements is rapidly gaining ground among chemists. More and more general becomes the belief that the Daltonian atom is really a compound radical, and that back of the seeming diversity of the alleged elements is a single unique form of primordial matter. But it should not be forgotten that this view, whatever its attractiveness, still lurks in the domain of theory. There is no proof that the Daltonian atom has yet been divided in the laboratory.

THE KENTUCKIANS.*

BY JOHN FOX, JR.

PART FOURTH.

XIII.

TO meet death, a rat goes to his hole, a lion to his lair; the same instinct perhaps, in the shadow of a lesser crisis even, sends a man home. Marshall took the train with Anne's face still haunting him like the face of the dead. Chance had rent the veil, and he had turned away, as he would have turned had chance as suddenly bared the girl's breast as it had seemed to bare her soul. The stupefying calm that held him broke slowly as the train rushed through the winter fields; and slowly his hold on himself began to loosen. By the time he was climbing into his buggy he was asking himself fiercely what the use of it all was; and a moment later he pulled his horse to her haunches before his club door, in answer to an old voice within him that had been still for a long while. He had always stopped there in the old days, and it was the habit of resisting the impulse since those days, perhaps, that made him suddenly lash his horse on now. The mare sprang ahead with a frightened snort, and Marshall, with a half-curse on himself for his thoughtless cruelty, called kindly to her several times to make recompense. Then he settled back into his big coat, and a little later he was on the white turnpike again speeding home, with his chin on his breast and the same fight in his soul that was there on that other drive, when Stallard first came into his life and into Anne's. Only the yellow evening light was almost gone now. There was not a bird-note from the darkening brown fields. The sun was a sullen blotch of fire when he reached his gate, and the woods behind the house were black and still. But his mother was waiting for him, and he was very tender with her that night. She knew something was wrong—she always knew; but she waited for him to tell, as she always did; and there were things that he had never told and could never tell, which she never knew nor guessed; and he was grateful, whatever the shame her faith and his weakness brought to him. The pantry door was open when he went to his room, but there was no glisten of glass-ware from within. That temptation had been removed long ago, and it was well for him that night that it was. His room was cold; the white moon through the window looked cold, and the dead fields and the gaunt moonlit woods. The whole

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* Begun in July number, 1897.

world was cold, and every riotous drop in the veins of his reckless forefathers was running wild in his, when he went sleepless to bed and to an all-night struggle that sent him groping back through his past for the things that were the stay of his unthinking childhood. For the first time in years he was ready to go with his mother to church next morning when the carriage drove before the door. It was a sign to her of some unusual distress of mind, and a grateful surprise that she was too wise to show. Instinctively she took him to the old country church where she used to take him when he was a boy; and, going and coming, the little schoolhouse where he and Anne had been playmates gave him a sharp pang; but the old church that had brought its brick walls and sturdy faith down from the pioneers, the saddle-horses hitched to the plank fence, the long stiles, with the country girls dismounting in their long black skirts, the atmosphere of reverence, the droning old hymns—all helped little by little to draw him back to the faith from which he had started adrift; to stir memories that were good for him and would make easier what was to come. From church several neighbors went home with them to dinner, after a custom of the neighborhood; and it was after they were gone that a negro boy brought the morning paper to Marshall's room. He opened it, and read one paragraph on the first page twice. Then he threw the paper on the table and rose. It was a terse telegram from Stallard to the Governor. The fight was over. Stallard was safe and successful, and he was coming back. Marshall's acceptance of the fact and its probable significance was quick, proud, and fiery. Only he picked up his hat and got quickly out into the open air. His mother was in the front yard, and he did not want to see her quite yet; so he went into the parlor, where a fire was still burning, and sat down by the window—forestalling the days that were at hand. He was before Anne now, paying her his tribute to Stallard; and from the depths of his unworthy satire rose the bitter fact that what he was saying to himself, and mentally to Anne, was literal truth. The mountaineer *was* worthy. And with this realization he suddenly lost the power to feel the thousand subtleties that he had always believed would prevent Anne from joining her life to Stallard's, no matter what her admiration for him, her respect, her pity, or even her love.

Then, for the first time in his life, jealousy started throbbing through him, and he knew the hell of two passions fighting his soul at once. It stretched him out on the sofa where he sat, and he lay there a long time dully watching the evening sunlight as it rose slowly to the face of his boyish uncle on the wall, whose life and death was a tragedy that seemed meant for him to play again. He looked with a deeper sympathy now behind the smiling lips and the reckless smiling eyes, and with a throb of pity for him which was half for himself he hurried out into the woods and the dusk.

It was startling to realize that nothing, not even religion nor his mother, had governed his life as had his love of Anne. Without her it seemed as though he must lose anchor and go adrift. And once, in the night, sick with fever and mad for a little relief, he sprang from his bed to take his buggy and go back to town and lose himself in the old way. This time it was the swift vision of his mother's face that stopped him in the middle of the floor—his duty was to her now—and forced him in an agony of helplessness to his knees in the first prayer that had been wrung from him in years. That was his crucial hour, and he faced the morning grateful; but he staid at home that day through distrust of himself—and to keep away from the capital.

Life had almost begun anew for him a year ago; he believed now that without Anne it must begin quite new. It was like walking back into childhood when he started out after breakfast on foot, and every memory was a healing comfort. When he passed the spring-house, the geese raised their wings with a reedy cackling, and, with the ducks, went swinging down the riffles, as though they yet expected him to throw pebbles at them. At the stone fence beyond he stopped to look at the water bubbling over the water-gap, through which he used to drop his hook for perch and catfish. Then he followed the winding branch by a pig-path through the thickly matted long grass that was crisscrossed by tiny beaten roads that used to lead many a musk-rat to death in his traps. A hawk was sweeping the field with his wings, hovering close to the grass in his hunt