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SMALLEST OF OBJECTS.

WHAT THE ATOM IS AND WHERE SUBDIVISION CEASES.

Atoms so Minute that Millions Together Would be Hardly Large as a Grain of Sand—Their Motion and Their Way of Working in Steam.

The man of science is at one time exploring the depths of space and becoming there conversant with magnitude so vast as to tax his power of conception to the utmost. At another time he is engaged in the study of objects far too minute to admit of their direct perception by any of his senses. That potent weapon for the investigation of nature which is supplied by the laws of mathematics is equally available for the discussion of the phenomena presented in such a mighty system as the Milky Way, or for tracing the movements of those atoms of matter so exceedingly small that they must necessarily elude every endeavor to perceive them.

It was at one time supposed that every substance must be susceptible of infinite subdivision. If we took a material object, say, for example, a sheet of paper, and cut it in half and repeated the operation again and yet again, ever halving one of the portions which was left by the proceeding division, it used to be thought that though the fragments of paper must be ever growing less and less, yet it should be possible to continue this subdivision indefinitely if only sufficient delicacy of manipulation were forthcoming. In other words, the idea was entertained that there could be no piece of paper so small but that it would admit of division again into two other pieces, each of which was still the substance possessing the qualities of paper. But now we know that the indefinite divisibility which is here postulated is not the property of matter as it is in nature. Only a finite number of divisions could be made or conceived before the fragment which is arrived at, though perhaps itself veritable paper, could not receive any further subdivision with ceasing to be paper. Of course it may be said that in the case supposed we are operating upon a substance which is manifestly of a composite character. The result of the subdivision, when carried on sufficiently far, must therefore necessarily disclose the ultimate ingredients of which the composite material known as paper is formed. Let us therefore take for our illustration some substance which, as far as we can tell, is absolutely homogeneous, inasmuch as it consists only of a single element. I select for this purpose a piece of iron, and suppose it to be divided into two portions. Let each portion be subdivided again, and yet again, until at last it shall have been reduced to the minutest portion of which our senses can take cognizance. Each one of the little pieces so obtained will still possess all the qualities of iron. We shall further imagine that we are provided with some means for carrying on the subdivision of an iron particle to a point much beyond that which any mechanical appliance at our disposal can affect. We shall even suppose that we are able to continue the subdivision of the iron long after the particles have become too minute to be visible, even in the most powerful microscope. Modern science has, however, taught us that though this subdivision can be carried on so far, yet it cannot be protracted indefinitely. A point would at last be reached where each of the little particles, though still possessing all the qualities of iron, would refuse to admit of any further subdivision. The particle in question may, no doubt, be composed of parts, but if we could seperate those parts they would not be iron, they would not in fact be anything like iron. This piece of iron which cannot be further reduced is called an atom. The derivation of this word indicates that the object to which it is applied is a something which cannot be cut. We are thus led to the conception that all matter on the earth or throughout the universe is constituted of aggregations of atoms. The sun itself is no more than an enormously great though quite definite number of those ultimate atoms out of which all material objects must be composed.

There is perhaps no other department of scientific research which shows so strikingly man's tremendous ignorance of nature. Any Adequate information as to what these atoms of matter really are has been hitherto denied us. A few facts may be stated. We know, at all events, that the atoms are so minute that millions of them would be required to be put together to form the bulk of a small grain of sand. It would, however, be quite erreneous to suppose that because these objects are so minute their structure is therefore simple. This is by no means the case. Some phenomena prove unmistakably that the atoms of certain elements, such, for instance, as those of iron, which I have already used as an illustration, must be anything but simple objects. They should rather be regarded as possessing a highly complex character and as elaborately formed from many different portions, these portions being in many cases animated by rapid and intricate movements. Indeed, it would seem that no experience of the grosser objects, which alone are perceptible to our senses, would be capable of affording any adequate conception of the extraordinary liveliness of atoms. I must try to explain some of their varied activities.

Let us think of the steam in the cylinder of a steam engine. The steam presses upon the piston and thus forces it up to accomplish its work. In our ordinary language we say that this work is done by the pressure of the steam on the piston and everybody understands what is meant when we thus speak of high pressures and low pressures. If, however, we look a little more closely into the matter we shall find that what the engineer understands by the pressure of the steam has to be regarded in a somewhat unexpected light when the ultimate constitution of steam is considered. The water from which the steam is made is, of course, produced by the chemical union between two gases, oxygen and hydrogen. Each molecule of steam is, in fact, the result of the union between two atoms of hydrogen and one of oxygen. Steam thus consists of molecules too small to be subdivided into lesser particles of the same subtance, namely, water. If any subdivision of a molecule of steam were affected, then the parts into which it would be separated would not be water, they would be the atoms of the constituent gases from which that water was made. The steam in the cylinder of the engine is to be regarded as consisting of a vast multitude of molecules of water. Each of each molecules is in a state of rapid motion. It is hurrying along with a speed which is sometimes slower and sometimes faster than that of a rifle bullet. Even in a very small portion of space the multitudes of these molecules are prodigious. The number of them which are required to form as much steam or atmospheric pressure as would suffice to fill a lady's thimble, are to be represented by many billions. As these mulecules are in such close contiguity, and as they are incessantly darting about. It will not be surprising to find that collisions frequently take place between them. The effect of a collision will be to divert each of the impinging molecules from the path in which it was proceeding before the collision took place, so that it bounds off again in some other direction. This new direction is similarly pursued until the molecule is turned aside by the next collision. These operations take place so rapidly that each of the molecules will experience millions of collisions in each second.

As the molecules of steam in the cylinder dash about with their tremendous velocity, they rain incalculable myriads of little blows upon the bottom of the piston. The effect of these imparts is to push the piston upward. Indeed, what the engineer calls the pressure of the steam is merely the result of the myriads of little impulsive shocks which are given by the blows of the rapidly-moving molecules. If the heat from the boiler is still applied, while the steam generated is not allowed to escape, then, of course, the pressure of the steam rises. But we may state what this means in a different manner. The increase of pressure arises from the fact that the temperature increases, the rate at which the little molecules hurry along also becomes greater. There is, in fact, a definite relation between the temperature of the steam and the average rate at which its molecules are moving. The greater the temperature, the greater the speed the less the temperature, the less the speed. The increase of the pressure within the boiler is equivalent to an increase in temperature of the steam, and this correaponds to an increase of the average speed with which the molecules are animated. But with increased velocities of the molecules there would be a coresponding increase in the vehemence of the blows which they administer to the inside of the boiler, and consequently, as we say, the pressure of the boiler is augumented. Under certain circumstances those blows may become so numerous and energetic that the tension of the iron or steel of which the boiler is constituted may no longer be able to withstand the strain to which it is exposed, in which case an explosion will be the result. This illustration will show to a certain extent how the temperature of a gas is connected with the average speed by which its molecules are initiated.

When two liquids, such as brandy and water, are placed together in a tumbler a complete fusion takes place No doubt in this case the act of fusion is generally accelerated by the was in which one liquid is poured into the other. Fusion, would however, proceed without such assistance; indeed it could not be prevented if the two liquids are in any way brought into contact. Suppose the water had been placed first in the glass and the spirit, being the lighter liquid has been carefully poured on the top There will be at first a marked difference between the two strata; a gradual blending of the two liquids, by what chemists call diffusion, will, however, at once commence Notwithstanding the relative lightness of the spirit, it cannot remain permanently distinct from she water as a covering of oil would do under the same circumstances. In due time the spirit descends through the water and the water ascends through the spirit, so that the mixture will ultimately become as complete as if the two liquids had been shaken together in a bottle. Thus we see that the spirit, though actually lighter than the water, gradually sinks downward, while the water, though heavier than the spirit, gradually makes its way upward.

The explanation of this phenomenon can be readily obtained when we remember that each of the two liquids in question is made up of molecules in motion. Across the boundary which at first divides the upper from the lower stratum, a molecule of either liquid occasionally dashes, and by the incessant repetition of this process the blending is ultimately accomplished. It is quite true that the movements of the molecules in matter in the liquid state are not so unrestrained as they are when the matter is in the geseous state. Each molecule in a gas has, so to speak, a free run between one of its collisions with other molecules and the next. It seems, however, that the molecules of matter when in the liquid state enjoy a much more limited degree of freedom. In this case each molecule can only be detached from its association with some neighboring molecule, in order to become associated with a third molecule. Such interchanges of alliance among the liquid molecules are, however, incessantly taking place, and thus it happens that the molecules of the spirit become gradually dispersed through the water, while on the other hand the molecules of the water gradually penetrate through the spirit, until at last the two fluids become completely blended.

A solid substance, such as a piece of cold iron, may seem to our senses to be quite devoid of movement in its ultimate parts. We have, however, the best reasons for knowing that if we had organs of sense some millions of times more acute than those with which nature has been endowed us, we should find that the molecules even of a piece of cold iron were animated by the liveliest movements. In the case of such a body, or of anybody which may be termed solid, the movements of the molecules are of much more restricted character than they are in the case of gas or even of a liquid. The extent of the movements of the particles of a solid are confined within very narrow limits. Each molecule, in fact, remains, generally speaking, in permanent association with the the other molecules with which it was originally connected. This is illustrated by the obvious truth that if a piece of solid copper and a piece of solid zinc are placed even in the closest contact, no fusion of the two substances will take place. The movements of the molecules in the zinc are so narrowly restrained that they do not cross the boundary to any appreciable extent. The molecules of copper are also confined in their movements within the mass to which they originally belonged. If, however, these two metals, instead of being in the solid form, have been melted into a fluid state, then the two fluids, if placed in contact, will speedily diffuse one into the other, for under the influence of heat the amplitudes of the movements of the molecules have been so much increased that they are now able to shake themselves free from their original attachments. The atoms of the zinc can thus cross the boundary and enter into the copper and the atoms of the copper also cross and enter the zinc, so that the homogeneous material known as brass is the result.

Lord Kelvin has given a striking illustration to show how extremely minute must be the actual magnitudes of the molecules of matter. Imagine that a rain drop the size of a pea were to be magnified into a globe as large as the earth. Let us suppose that each of the molecules in the drop of water were to be at the same time magnified in the like proportion, then we know that the dimensions of the molecules thus increased would make them larger than shot, but smaller than cricket balls.

We may also illustrate the fineness, so to speak, of the ultimate texture of matter in the following way: Think of a plate of copper possessing the same thickness as the page on which this is printed. It is perfectly certain that if we had machinery by which we could beat out that copper until the plate was reduced to the thousandth part of its present thickness, the thin sheet so produced would still be found to present all the characteristics of copper. Even if the sheet could be beaten out ten more, so that its thickness were ultimately reduced to one ten-thousandth part of that of the original sheet of paper, the substance in the plate would still possess the characteristics, chemical and physical, of actual copper. It can, however, be inferred by an ingenious line of reasoning, given by Lord Kelvin, that if the plate thus attenuated were to undergo a yet further reduction, which would make it to have no more than the millionth part of the thickness of this sheet of paper, then the substance would have ceased to be copper in the sense in which we understand the word. It would approximate to a layer of individual molecules, further subdivision of which would be impossible.

Some very interesting results illustrating the minute subdivision of matter can be derived from certain beautiful experiments made by Prof. Boys. Having melted the common mineral quartz at an exceedingly high temperature, he has succeeded in drawing out extremely fine fibres of the remarkable substance. The method he employed in this delicate operation is one of great ingenuity. To produce the fibres he used a little crossbow wherewith he discharged a light arrow which had been previously attached to the melted quartz. As the arrow flew through the air it drew out behind it a filament of the fused mineral. In this way Prof. Boys succeeded in obtaining fibres possessing more tenuity and delicacy than had ever been before attained by human art with any material whatever. The fibres of quartz produced in each discharge of the arrow are about forty or fifty feet long. They are remarkably uniform in diameter, and the strength of these fibres, due allowance being of course made for their dimensions, is truly astonishing. Drawn quartz thus appears to have a tenacity not less than that of ordinary steel.

The thickness of a fibre of silk as wound from the cocoon is about one-five-thousandth of an inch. Prof. Boys has drawn fibres of quartz so fine that if a hundred of them were twisted into a cable, its thickness would be about the same as that of a fibre of unspun silk. But this statement, remarkable as it may seem, is by no means adequate to express the highest order of fineness which has been obtained in certain of the quartz filaments. They have indeed been drawn with such exceeding delicacy, that they can no longer be perceived by the naked eye. Indeed, Prof. Boys has assured us that where the end of the fibres gradually tapers off its thickness has become so small that it cannot even be perceived by the microscope. It is thus certain that some of these fibres are so fine that they do not possess a thickness of a hundred thousandth part of an inch. This extraordinary tenuity is strikingly illustrated by Prof. Boys when he says that a lump of quartz of the size of a walnut contains sufficient material for a fibre long enough to wrap six or seven times around the whole earth.

These results demonstrate in a striking way the extreme sublety of the molecular texture of matter. The quartz fibre, though only one hundred thousandth part of an inch in thickness, still seems to be as veritable quartz as was the original lump of mineral before it was fused for the operation of drawing out. In other words, so vast a number of molecules are contained within the thickness of the one hundred thousandth part of an inch that the physical properties of the substance remain the same in the delicate filament as in the large mass.

Many illustrations might be given of the significance of molecules in connection with the visible operations of nature. Let us take for instance the supreme beneficience of the sun itself. We shall, I think, be able to demonstrate that we are indebted to the smallest material objects for conferring on the sun its ability to send us light and heat. We receive the solar radiation in the form of waves transmitted through that mysterious fluid—the ether—which seems to fill all space. The vibrations of the ether enter the eye, and falling on the retina, produce the sensation of light. These waves start from the sun and they have there been endowed with the energy which is to carry them across the 93 000 000 miles which separate the earth from the great luminary. If we inquire into the actual method by which the necessary waves seem to have been imparted to the other, we shall soon learn the extent to which we are indebted to the movements which takes place within the atoms. The sun is at a temperature so high that, in its outrr regions at all events, it is actually in a gaseous state. The molecules of these gases are continually dashing about with speed corresponding to the exaulted temperature which they possess. It must be understood that although an atom is so minute an object, it is still in some cases, at all events, of a highly complex character. Portions of an atom are found to be free to move relatively to other portions, so that in consequence of the collisions with which one atom strikes against another vibration in the several parts are kept up. The atoms may be said to quiver under the influence of the repeated shocks which they receive just as elastic bodies do. Indeed, it would seem that the most perfect type of an elastic body may be illustrated by the deportment of these little atoms. The rapidity of their vibrations differs somewhat for molecules of different substances. The molecules have, it would seem, the power of transferring part of the energy of their vibrations to the ether, and thus of originating waves which speed on their way to the earth to be interpreted by us either as light or as warmth, according to the senses to which they make their appeal. Though the internal energies of the atoms ever tend to be reduced in the process of giving rise to vibrations in the ether, yet those energies are ever and anon recuperated by the fact that as the atoms are dashing about they come into collision with other atoms. In consequence of these collisions, part of the energy which is due to the translation of the molecule as a whole is transmitted into that internal energy due to the motion of the parts of the molecules, which has the capacity of producing ethereal vibrations.

Such is an outline of the physical cause of those wondrous natural phenomena, the radiation of light and heat. When we come to examine into the details of the subject, multitudes of interesting points arise which are connected with some of the most remarkable developments of modern science. Let us take, for instance, one of the most important elements, namely hydrogen, that gas which we know so well on this earth, and one which is diffused far and wide throughout the universe. The sun, like many other celestial bodies, contains large quantities of hydrogen, and its atoms are of course vibrating in the way that I have suggested. But these vibrations are known to be a manifold character. They do not all seem to be performed in the same time, and consequently the undulations through the ether which are originated by the molecular vibrations of hydrogen are not all of one type. There are a large number of quite distinct ethereal waves produced by the hydrogen molecules. In the ordinary way in which these waves are received by our eyes, we have no means of discriminating between them. Modern science has, however, at its disposal a beautiful instrument called the spectroscope, which enables us to take a complex bundle of ethereal waves and, so to speak, to sort them out into their different types. We can discover by the spectroscope the several waves which are blended in a beam of light. Thus, to take the the case of hydrogen, already mentioned, we find that among the solar beams which reach our eyes there are quite a number of distinct rays due to to the presence of hydrogen in the sun. Besides those waves from this gas, which produce effects visible to the eye, there are also many other ethereal waves transmitted from the atoms of solar hydrogeu which are unable to appeal directly to any organ of sense which we possess, but which nevertheless possess the power of making themselves manifest on the photographic plate. The photographic spectrum of hydrogen, as it is called, contains a multitude of lines. Each one of those lines corresponds to a distinct form of ethereal undulation, and thus we obtain some idea of the extraordinary complexity of that atom of hydrogen gas, which, itself so exceedingly minute, is still able to give rise to so many different forms of ethereal agitation.

Every other element besides that one which I have named is also able to produce waves in the ether when suitable conditions as to temperature and pressure are present. It is a remarkable fact that the waves which arise from each element are generally speaking so entirely distinct from those produced by any other element that we have, with the aid of the spectroscope, a method of ascertaining what the actual substances may be which are present in the sun. In some cases the spectra of the elements are extremely complicated, thus indicating a corresponding complexity in the atom belonging to the element. The molecule of iron must, for example, be of very elaborate character, for the spectrum which it produces contains far more lines than are to be seen in the spectrum which is due to hydrogen. Thousands of lines, indicating the existence of thousands of distinct waves, take their origin from this little atom belonging to the most common of metals. The more we learn of the ultimate texture of matter the more amazing seem the properties of those atoms which are the smallest of natural objects.—Robert S. Ball.

A MODEST HERO.

He Boldly Disclaims Credit for a Brave Deed Attributed to Him.

Recently in Gloucester, Mass., a member of the Free Press staff became acquainted with Capt. Bickford, whose experience as first gunner on the Kearsarge in the celebrated engagement with the Alabama are of considerable interest. The captain is now residing in the old fishing town. He wears a medal, one of the few presented by Uncle Sam to his brave sailors in the war, upon which appears words showing that it is a testimonial for valor performed in the noteworthy engagement. This battle royal took place on Sunday, June 19, 1864. The armament of the Kearsarge was seven guns and that of the Alabama eight guns, including a 100 pound Blakely rifle. The Kearsarge had 163 men and the Alabama 149. This was the most important sea fight of the war between two ships, the Alabama being sunk after an engagement lasting an hour and twenty minutes. But three men were wounded on the Kearsarge.

It is tradition at Gloucester that Capt. Bickford received his medal for throwing overboard one of the enemy's shells which lighted upon the deck of the Kearsage. The captain was asked about this and laughed heartily:

"Throw a shell overboard?" he repeated. "Now that is good. Yet I have read about such things in books written about sea-fights and histories of heroic deeds furnished to children in the schools, but I believe such a thing is impossible. In the first place, a shell is timed to explode in a certain brief interval, a fraction of a second after striking. In the next place a shell is a very heavy article to handle. Did you ever try to lift one? If you have you won't believe all that is said about people throwing an enemy's shell overboard.

'Suppose a shell rested on the deck, how long do you think it would wait for a man to come and pick it up, stagger to the side beneath its weight and then heave it out into the ocean? By the time he took three steps toward it, off it would go. He had better jump overboard himself and let the shell take care of itself."

'What did you get the medal for, Captain?'

'Danno; never found out. It wasn't for heaving shells overboard, though. That would make a nice story to tell landsmen, but a sailor aboard a man-of-war would have his own opinion about the yarn."

A Type-Written Love Letter.

When a person becomes accustomed to doing a thing in a certain manner nothing is harder than to break the old habit. A certain young newspaper man in this city has been in the habit of writing all his copy with the aid of a typewriter, and last week he sat down and wrote a very lengthy letter to his girl, and then scoring a dash under the writing laid it on the city editor's desk just as he would a piece of copy. When the man who handles the blue pencil came to look over the copy lying on his desk, he was amazed to find one which started 'Dear ——,' and ended, 'Your loving——.' It is needless to say that the author of this endearing epistle was unmercifully twitted for some time, and now he writes his love letters at home.—Pittsburg Chronicle-Telegraph.