With compliments
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CONCEPTIONS OF MATTER: ANCIENT AND MODERN.

THE science that deals with the constitution of matter has occupied the time and energies of countless generations of men since the time of Adam, who, possibly, was himself an alchemist, as one might be led to believe when he reads of

> "A book where Moses and his sister,
> And Solomon have written of the art."(1).

The quest of the alchemist was the production of new substances and the conversion of one form of matter into other forms by a process of transmutation. This was possible, he argued, because, in nature, plants and animals were seen to grow, change, develop, and die, and that therefore the same growth and development ought to proceed in the mineral kingdom. Just as a grain of seed in the ground died, and from its dead body arose the perfect plant or tree, so, in the earth, the metals were looked upon as undergoing a growth and becoming more perfect—in time reaching the highest stage of all, namely, gold.

Alchemy did not give place to chemistry proper until the eighteenth century, and, in its long life, experienced many vicissitudes. Its students and followers were not merely natural but also moral philosophers; they regarded nature from both standpoints, watched and studied the course of nature as exemplified by the growth of living things, vegetable and animal, endeavoured to discover the secret of her workings, and trusted to be able to apply this secret to the transmutation of the baser into the nobler metals, to the production of an *Elixir Vitae*, which would be the cure of all ills, and, as a result of this, hoped for the mental happiness which would follow from the practical knowledge of the supreme secret of nature. Their quest was for an undefinable something, called by various writers "*the one thing*," "*the philosopher's stone*," "*the essence*," "*the soul of all things*," and by many other names.

(1) *The Alchemist*: by Ben Jonson, 1610.

Though some alchemists believed in the power of this "essence," (which was presumed to have a dual nature, material and spiritual), to create things, yet the best writers seem to have had a real belief in the Supreme Being as alone having power to create and destroy: they hoped only to make one form of matter into a different form, not to create it. That this could be done they believed implicitly, and a simple illustration will show in how far their belief was justified. The mineral galena, which is a sulphide of lead containing some silver, has somewhat the appearance of the metal lead itself. This, when subjected to treatment, yields lead; and the lead in turn, on heating and removing the "calx," or earthy material formed, disappears, leaving a small portion of the precious metal silver. The alchemist took no consideration of the relative *quantities* of original material and the residual silver obtained: he used his results to confirm his preconceived theory of the transmutation of the baser metal, and did not, as would have been more logical, deduce a theory from his experimental results. The alchemist's belief remained firmly fixed in his mind, was a part of his system of ethics, indeed not only from the example just given but from his observation of nature. That lead could not, by one wave of the alchemistic wand, be converted at once into gold he quite understood; a series of purifications, of "trying in the fire," was required before the perfect metal was obtained. In *The Alchemist* this view is expressed in these lines:—

> Nor can this remote matter suddenly
> Progress as from extreme unto extreme,
> As to grow gold, and leap o'er all the means,
> Nature doth first beget the imperfect, then
> Proceeds she to the perfect.

It was a far cry from the earlier alchemist to the chemists of the nineteenth century, or to the time when the ideas of transmutation had to give way,—thanks to Priestly, Lavoisier, and others,—to theories evolved from the results of careful investigation of the quantitative changes occurring during chemical operations. The enunciation of Dalton's hypothesis of atoms placed chemistry on a new basis, and was the commencement of an era of phenomenal progress in chemical science. According to this theory, matter is composed of combinations of the atoms of elementary substances with one another, which unite together, by reason of their chemical affinity, to form molecules of new substances. Matter, therefore, is composed of minute indivisible particles of the same or of different elements, and of these everything that is apparent to the senses is made up. Cut and carve down these particles as you may, in the end there is left the uncuttable particle or atom of each element.

This hypothesis of Dalton's was by no means new; indeed he merely resuscitated a theory put forward more than two thousand years previously. These early philosophers—Democritus (B.C. 460), Lucretius, the Latin poet who was born about a century before the Christian era—attempted to connect the differences of size, shape, and qualities of various forms of matter with the diffe[illegible] of size, shape, position, and movements of what th[illegible] the *atoms* of matter. Everything material, they he[illegible]posed of "a coalescence of certain unchangeable and [illegible]ble particles": no atom of anything could either be cre[illegible] destr[illegible]ed; when substances ceased to exist, another was formed; no destruction of matter took place, merely a rearrangement of the atoms. The ancients were evidently as fully alive to the soundness of the doctrine of the indestructibility of matter as we are now. Their conception of its various forms coincides with the modern ideas also; a solid body consisted of a vast number of atoms squeezed closely together, a liquid of a less number more loosely connected, and a gas of a still smaller number able to move freely and distributing themselves uniformly throughout the space containing them.

The atomic theory, as enunciated by the Manchester schoolmaster (Dalton), was based on observations of the manner in which the elements combined with one another, namely in fixed and definite proportions:—the atoms of each element had a definite weight peculiar to all the atoms of that particular substance. This theory has served the purposes of chemists for the past century, and has been, and still is a convenient quantitative method of expressing chemical changes as they occur. The chemist can calculate the amounts of material necessary for the formation of new combinations—alike in the factory as in the laboratory—and can prophesy the yield he will obtain from the union of known quantities of different elements or compounds. But though the atomic theory has for so long been a perfect working hypothesis from the chemist's point of view, recent researches, depending mostly on the study of electricity and radio-activity, have led to the displacement of the atom from its position as the unit form of matter. [illegible] atom is slowly but surely being proved to consist of an aggregation of still smaller units, (electrons, corpuscles or ions,—call them what you will) incapable of detection by ordinary chemical methods, but readily recognisable by the physicist, on account of their influence in rendering dry air a conductor of electricity. Professor J. J. Thomson, of Cambridge, claims to be able to detect with certainty, by electrical methods, quantities of radio-active substances less than one hundred-thousandth part of the least quantity which the chemist could detect by any method of analysis known. He stated in his lectures delivered at Yale College, some eighteen months ago, that the quantity of these radiations which could be detected electrically were to the quantity of any known element (so-called), which could be detected by ordinary chemical analysis, in the proportion of a second to a thousand years!

Since the discovery of the Röntgen rays, in 1895, the properties of emanations from the mineral substances uranium, thorium, and radium, have occupied the attention of scientific investigators; and it is to them that we owe the new ideas and conceptions of matter as capable of existence in even a more attentuated condition than the atom. From phenomena connected with the emission of rays and emanations from these radioactive bodies, it is evident that they consist of particles infinitely more minute than atoms. The emission of atoms themselves seems quite intelligible, as matter, in many forms, can evaporate, and some substances emit a perfume, if not always appreciable to human beings, certainly to the lower order of animals. No one has seen a smell, nor the wind, nor the minute particles worn away from a pavement, yet no one doubts the existence of these particles. But, in the case of the emissions from radioactive bodies, their speed is found to be enormous, and their atomic weight something like one-thousandth of the atomic weight of hydrogen. The atom of matter must therefore be considered as complex, not simple, and composed of a number of smaller bodies interleaved and interlocked, and in a state of rapid motion. Occasionally an atom loses one of these minute constituent parts, which becomes separated from it, chipped off, as it were, and which flies away at a speed which Sir Oliver Lodge has calculated as being many thousand miles a second: these portions thus separated are known as the α rays. But this rupture of the atom is immediately followed by a further splitting off of other parts of it, which are so minute as to be able to penetrate through solid bodies; and yet a third or ethereal emanation, called the γ rays, follows as a consequence of the break up of the atom. What, then, are these minute portions which the experimental physicist can recognise, handle and investigate? They may be called the corpuscles, or electrons, and are of the order of many thousandths of the magnitude of an atom of matter, which is commonly estimated as being about one fifty-millionth of an inch in diameter. Sir Oliver Lodge has given an illustration of the size of these corpuscles by asking one to imagine an atom of matter magnified to the size of an ordinary church, when its constituent ions would be represented in size by this full .

This research into these striking but obscure forms of radiation has laid the foundation of a new hypothesis regarding the constitution of all matter. The phenomena of radio-activity have been found not to be confined entirely to the elements uranium, thorium, etc., which possess this property to a remarkable degree, but to be common to a great number of things, possibly to all things material. It has been found that certain mineral springs are radio-active: rain, snow, hail, the air of cellars, and the air contained in many soils, possess the same properties: the atmosphere itself has been shown to exhibit this property, the experiments leading to this result having been made in our own Physical Department by Professor McLennan and his assistants. Indeed, it might be said that corpuscles or electrons are everywhere about, incessantly streaming from the earth, from the ends of branches, from rails, from telegraph poles, and from the sun itself. These particles, too, are all of the same nature, size and kind, no matter from where they may come; and it seems likely that they constitute the primordial form of matter, various combinations of which, interlocked together, go to make up what, up to now, have been looked upon as the elements, of which some seventy or eighty are recognised by chemists. And does this mean that the ancient alchemists were not so very far wrong after all in their belief that one form of matter could be converted or transmuted into another? It seems so, for, in experiments conducted in London by Sir William Ramsay, the emanation from radium was found to have lost its characteristics on standing for a week, and to have developed the properties of a known elementary substance, the gas helium! The radium emanation had become destroyed, altered,—degenerated, one might call it,—into another form of matter entirely!

What interpretat then, can be put on these results regarding the fundamental constitution of all material things? The existence of bodies infinitely smaller than the smallest atom, has been clearly demonstrated, and, for many reasons, it has been concluded that they are akin to electricity. Sir Oliver Lodge holds that electricity possesses two of the fundamental properties of matter, namely mass and inertia; light and electricity have been shown to be closely allied to one another in their mode and speed of propagation. Is electricity matter and is matter electricity? Evidently they are closely related, and if the corpuscles or electrons emitted are not electricity, they at least are the carriers of electricity. The new conception of matter seems to indicate that it and electricity are one and the same thing, and that the chemist's atoms consist of systems of positive and negative electrons, and of nothing else. If the simplest atom, that of hydrogen, consists of, say, 350 positively and 350 negatively charged electrons, interleaved together and in a state of violent motion within themselves, . n some sixteen times as many constitute the atom of oxygen, and other multiples of this, the atoms of other elements.

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