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THE ALCHEMICAL ESSENCE

AND THE

CHEMICAL ELEMENT

AN EPISODE IN THE QUEST OF THE UNCHANGING

BY

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'Nature moves not by the theorie of men, but by their practice, and surely wit and reason can perform no miracles unlesse the hands supplie them' THOMAS VAUGHAN

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This essay is written in the hope that some of the men who exercise their 'wit and reason' in examining the problems of life may help to answer the questions that nature propounds to those of her students who follow the quest of the unchanging.

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Amid the rush of changing appearances, and the shifting scenes wherein they move, men have always dreamt of the unchangeable, and have sought for some sure resting-place. Their conceptions of human life, and duty, and suffering, have assumed different forms at different times; and as they have represented their various ideals as shadowings forth of an immutable reality, so they have pictured the movements of matter as superficial manifestations of an underlying unity.

To write the history of the endeavours that men have made to give definiteness to the conception of the unity of material phenomena, and to represent these phenomena as the harmonious outcome of a pervading and definable principle, would be to write the history of natural science.

The results of the changes that material things undergo are so manifold and perplexing that students of natural events have been compelled to divide into bands, and each band of searchers has been forced to tread its own path; but all the bands hope to meet at the goal, that is yet far off.

The chemists form one of the bands. The path that they have trodden, and which still they tread, is a pleasant way; no one complains of lack of variety; at every turn new vistas are opened, and the prospect of new delights beckons the travellers on. But there are side paths that lead backwards, or lead nowhere, and it is easy to stray down one of these; many a man who began the journey with high hope and good promise has found himself in the forest at the end of a blind alley, unable to go on because the trees are many and grow close, and unable to go back because weeds have sprung up and choked the way. There are short cuts also, to be discovered by the keen-eyed and the men of quick wit; sometimes a traveller who started with shambling steps finds a shorter way, and soon is far ahead of those who refuse to leave the beaten path.

It is along this path, worn by the feet of many who have joined the quest of the unchanging, that I ask you to walk for a little while.

'There abides in nature a certain form of matter which, being discovered and brought by art to perfection, converts to itself, proportionally, all imperfect bodies that it touches.' Belief in this proposition, that I have quoted from one of the alchemists, was the root whence sprang many searchings into nature's ways of working in the olden days before chemistry had become a science.

'In chemistry we recognise how changes take place in combinations of the unchanging;' these are the words of one of the greatest of living chemists.

The two forms of words are somewhat alike; it is not, however, as verbal statements, but as science-producing doctrines, that they demand our attention. We must ask,—

What fruit did the alchemical proposition concerning the one perfect form of matter bring forth? And we must inquire what have been the results of examining the 'changes that take place in combinations of the unchanging.'

The changes of the seasons, the waxing and waning moon, the ebb and flow of tides, the gradual wearing away of the land by the sea and by rivers, the melting and disappearance of ice and snow, the growth and the decay of trees and plants; these changes, and changes like these, have always forced themselves on men's notice. Men, too, have long been used to manufacture clothing from wool, or cotton, or silk; they have obtained dyes from plants; from plants also they have distilled oils, and essences, and perfumes; they have extracted metals from minerals found in the rocks, and they have melted these metals together to obtain harder, or softer, or differently coloured, or more workable, materials wherewith to make weapons, or domestic utensils, or on which the craftsman might fitly exert his skill.

All these handicrafts rest on the possibility of effecting changes in the properties of material things.

On the readiness with which the properties of substances can be changed depend also many processes that have long been in common use.

When Odysseus had made an end of slaying the suitors, he called to the nurse:

> Quickly, O Nurse, bring fire that I may burn
> Sulphur, the cure of ills.

Eurycleia wished to bring

> a rich robe and tunic clean,

but

> Wary-wise Odysseus quick replied;
> First of all now bring sulphur and the fire provide.
> (*The Odyssey*, Worsley's translation.)

The production of a deodorising substance by burning sulphur was evidently well known to the early Greeks.

Ages ago the discovery was made that the juices of many fruits by exposure to the air acquired the property of 'making glad the heart of man.' Noah's preservation of this process has helped us to realise our kinship with the unconscious chemists who practised it before the flood.

Pliny tells us that some Phœnician merchants, returning by sea from Egypt, put ashore on the sandy bank of a river, and, for lack of better supports, rested their cooking vessels on lumps of the *natron* (soda) wherewith their ship was laden. The fire melted the supports; and where the molten soda mingled with the sand, the rough dull sand disappeared, and a clear and transparent substance came in its place. After this discovery the production of glass by melting together sand and soda became a common handicraft.

Those who in bygone times examined the changes brought about in the properties of things by changing the conditions to which things were subjected, made many curious discoveries. They noticed that a yellowish-red powder was produced when lead was heated for some time in the air, and that lead was reproduced by heating this yellow powder with charcoal or wheat. They saw that lead gradually disappeared when it was melted in a dish made by kneading burnt bones and was burnt there by blowing air over it; and sometimes they were astonished to find a little silver on the support when the lead had vanished. As they calcined bluestone in an earthen vessel with a neck, they noticed an oily, acrid, burning liquid dropping from the open end of the neck, and they found a blackish solid left in the vessel. By heating this oily, burning liquid with nitre they obtained another liquid, pale yellow in colour, fuming, corrosive, and very sour, which destroyed parchment, skin, and leather, and dissolved silver, lead, iron, quicksilver, chalk, and many other substances. They placed a piece of copper in this fuming fluid, and the copper disappeared with great frothing and bubbling; they boiled the pale blue fluid thus formed in an open dish, and after a time there remained a blue solid quite unlike either the copper or the corrosive yellow fluid in which the copper had disappeared; they poured water on to this solid, the water became blue, but the solid vanished; they dipped a piece of bright iron into the blue water, the iron gradually grew less and less, and red flakes of shining copper were seen adhering to it. The yellow, fuming liquid from nitre, and also the acrid oil from bluestone, were found to destroy most metals; the metals were worn, eaten through and through, broken, and at last swallowed by the liquids, generally with much frothing and bubbling.

The old chemists looked on the fuming liquid obtained from nitre as a kind of water with very masterful properties, and so they called it *aqua fortis.*

Quicksilver too was found to have the power of swallowing many metals; tin, zinc, and lead disappeared in the running mercury which still retained its lustre and mobility. But when melted sulphur was poured on to quicksilver, sulphur and quicksilver both disappeared, and a substance was produced black as the raven's wing.

One metal however remained unchanged in *aqua fortis*, and in the corrosive oil from bluestone; that metal was gold. No change was effected in gold by heating it, nor was it altered by contact with the sulphur that stopped the movement and quenched the brightness of quicksilver. Acids that dissolved other metals were without effect on gold; heat did not change it; liquids that altered the common metals left gold untouched; hence gold was called, in the old days, the noble metal. And when a liquid was discovered wherein the noble metal disappeared, as the baser metals disappeared in *aqua fortis,* that liquid was hailed as the royal water, or *aqua regia.*

Considering the different degrees of durability of metals, knowing that some were easily corroded and worn away, or even destroyed by liquids which had but a slight and tardy action on others, the men who observed these differences of behaviour supposed that the metals which resisted the action of corrosive liquids must be more perfect than those which quickly disappeared in these liquids. According to the degree of perfectness or purity of a metal, so, they thought, did it resist the action of fire, sulphur, acids, and other things.

As a seed, buried in the earth, in time sends forth a green shoot which grows into a plant, whereon blossoms appear and fruit ripens; or as more and more pungent oils are obtained by distilling and redistilling the juices that exude from certain plants; so, it was supposed, might one metal in process of time grow into another, or a metal might be freed from impurities by repeated distillations which at last should yield a substance wholly different from the impure material with which the experiment was commenced.

In Ben Jonson's 'Alchemist,' when *Surly*, who is not to be cozened into accepting *Subtle's* tricks as genuine, is arguing with *Subtle* about the transmutations of metals, we read:

Subtle. No egg but differs from a chicken more
Than metals in themselves.
Surly. That cannot be.
The egg's ordained by nature to that end,
And is a chicken *in potentia*.

Subtle. The same we say of lead and other metals,
Which would be gold if they had time.
. . . .
. . . . for 'twere absurd
To think that nature in the earth bred gold
Perfect in the instant ; something went before.
There must be remote matter.

To discover, and 'bring by art to perfection,' this *remote matter* was the aim of the alchemist. But what was this remote matter supposed to be? We can have no better answer to this question than that which *Subtle* gives to *Surly* in Ben Jonson's play :—

It is, of the one part,
A humid exhalation, which we call
Materia liquida, or the unctuous water ;
On the other part, a certain crass and vicious
Portion of Earth ; both which, concorporate,
Do make the elementary matter of gold ;
Which is not yet *propria materia*,
But common to all metals and all stones ;
For, where it is forsaken of that moisture,
And hath more dryness, it becomes a stone,
Where it retains more of the humid fatness,
It turns to sulphur or to quicksilver,
Who are the parents of all other metals.

The alchemists, those ancient searchers for the unchanging, were imbued with the notion of growth and change ; they saw that plants and animals grew, developed, and decayed ; and they thought that minerals also might suffer change into new forms, and progress through the less perfect to the more perfect, through the changing to the unchangeable. Nature worked slowly; but surely, they thought, man could aid nature and hasten the steps of her going.

Subtle, in the play, says:

> Nor can this remote matter suddenly
> Progress so 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.

And he gives some hints of the way by which 'the parents of all other metals' may be produced from the two parts of the 'remote matter,' namely 'the unctuous water' and 'the crass and vicious portion of Earth.'

> . . . . of that airy
> And oily water mercury is engendered;
> Sulphur of the fat and earthy part;
> . . . . these two
> Make the rest ductile, malleable, extensive.
> And even in gold they are; for we do find
> Seeds of them, by our fire, and gold in them;
> And can produce the species of each metal
> More perfect thence, than Nature doth in Earth.

I beg the attention of the reader to the following lines wherewith *Subtle* concludes his argument:—

> Besides, who doth not see in daily practice
> Art can beget bees, hornets, beetles, wasps,
> Out of the carcases and dung of creatures;
> Yea, Scorpions of an herb, being rightly placed?
> And these are living creatures, far more perfect
> And excellent than metals.

Although *Subtle* was a knave, his argument was unanswerable until the skilled mechanician gave the balance to the chemist, who used it as a mighty engine wherewith to batter down the walls of the alchemical citadel. *Surly* does not attempt to answer the argument of *Subtle*. When *Mammon*, a believer in alchemy, and in *Subtle's* claim that he could make gold from pewter, exclaims to *Surly*,

> Nay, if he take you in hand, Sir, with an argument
> He'll bray you in a mortar ;

Surly only replies

> Rather than I'll be bray'd, Sir, I'll believe
> That alchemy is a pretty kind of game,
> Somewhat like tricks o' the cards, to cheat a man
> With charming.

Grant that 'art can beget bees . . . . out of the carcases and dung of creatures,' and the production of gold by properly combining the seeds of gold, sulphur and quicksilver to wit, becomes a simple task; for is it not true that living creatures are far more perfect and excellent than metals, if by 'perfect and excellent' we mean having many functions and many parts?

It is somewhat remarkable that at a later stage of their search for the unchangeable men became convinced that nature had placed impassable barriers between each species of living things, but that she had drawn no sharp boundary lines between one kind of mineral substance and another ; and that as the quest has progressed they have found that living organisms are more plastic than the fundamentally different kinds of matter of which minerals are composed.

The alchemists said that mercury and sulphur were 'the parents of all other metals.' But what were mercury and sulphur?

By mercury and sulphur the alchemists did not mean the two kinds of matter that we are accustomed to designate by these names. The terms were given to two principles supposed to be present in metals; the principle of malleability and lustre was called mercury or quicksilver, and the principle of changeability was called sulphur. The malleability and lustre of different metals, and also their greater or less readiness to change, were supposed to depend on the quantities, and on the degrees of purity and of fixation, of these principles present in the metals. The mercury and sulphur of the alchemists were intellectual abstractions clothed in material garments, which fitted very loosely, and were constantly being put off and on.

We cannot now form a clear conception of what a principle of malleability, or a principle of changeability, may be. We have discovered that to say that similar occurrences are similar because there is a principle common to them all is merely another way of saying that they are alike because they are alike. The days have gone when patients were expected to be contented and impressed if their medical man, in prescribing opium, assured them that the drug contained a soporific principle, and for that reason it induced sleep.

The difficulty of attaching a definite meaning to the expression, *the principle of malleability*, is increased when we are assured that the principle in question is mercury; not, however, the mercury we are familiar with, but a more refined and more subtle substance.

The properties of metals were considered by the alchemist to depend not only on the quantities of mercury and sulphur they contained, but also on the purity of the mercury and sulphur and on the degree of fixation of these in the metals. It is not possible to discover what exactly an alchemist meant when he spoke of the purity of a substance; the nearest we can get to understanding what a pure substance was to the alchemist is to think of it as a substance which had been repeatedly heated and distilled. And when we consider that mercury was another name for the principle of malleability, and sulphur was another name for the principle of changeability, we are more than ever at a loss to understand what a more or less pure principle of malleability or of changeability can mean. It does not help us to be told that mercury and sulphur became pure when they were neither too hot nor too cold, too moist nor too dry; and that the effect of a superabundance of dryness on these principles was to produce a stone.

Then, again, one cannot quite discover what *fixation* meant in alchemical language. The greater the degree of fixation of the mercury in a metal the more infusible did the metal become; and the colour of a metal varied according to the degree of fixation of the sulphur, or principle of changeability, in it. But even with the help of such a statement as this we cannot translate the notion of degrees of fixation of semi-material principles into language that is descriptive and clear to us.

Our ways of thinking about the things around us are so different from those that prevailed in the alchemical days that much of the language of these days is meaningless now. But it does not therefore follow that it was meaningless to the men who invented it as a vehicle for expressing their thoughts. The only way for us to judge of the value of the alchemical conceptions is to find out what results flowed from applying these conceptions to the study of nature.

We are able however to form some general notion of the alchemical scheme of things. I think we may recognise at the root of it the notion of constant mutability, coupled with the notion of the existence of one unchangeable thing. We see that the alchemists thought of all things, save *The One Thing*, as slowly growing, changing, developing, and coming to maturity; that they deemed it possible to hasten the slow growth of substances by their art; and that they firmly believed in the reasonableness of the quest of *The One Thing* which was the master-key of all mutations.

The names given by the alchemists to substances often used by them are very suggestive. The strongest acids they employed they called *aqua fortis* and *aqua regia*, names which tell that the alchemists regarded these liquids as water endowed with very powerful properties. They did not attempt, with their appliances they could not successfully have attempted, to find out the compositions of substances. The study of composition was nothing to them, the study of properties was everything. This or that substance was of importance only as it was a vehicle for putting into their hands the command of certain properties or powers of doing. They supposed that a solid substratum existed; but they were able to speak and think of this only as an essence or a principle, a quint-essence or a subtle spirit. On this vague foundation they thought to fix manifold properties which could be re-arranged and exchanged by their art. Dross and refuse and decaying matter were burnt up by fire; heat caused the lighter parts of bodies to ascend, and cold condensed these tenuous particles into matter that was perceptible to the senses of touch and sight; and so, naturally, the chief instruments in the laboratories of the alchemists were the furnace and the alembic. By repeated passages through the fire, and many distillations in the alembic, they fondly hoped to drive out the grosser properties of common metals, and to secure, at last, the pure and perfect gold.

In performing these processes, the alchemists worked hard in their laboratories. Paracelsus says of them: 'They are not given to idleness, nor go in a proud habit, or plush and velvet garments, often showing their rings on their fingers, or wearing swords with silver hilts by their sides, or fine and gay gloves on their hands; but diligently follow their labours, sweating whole days and nights by their furnaces. They do not spend their time abroad for recreation, but take delight in their laboratory. They put their fingers amongst coals, into clay and filth, not into gold rings. They are sooty and black like smiths and miners, and do not pride themselves upon clean and beautiful faces.'

It was needful for the alchemists to work laboriously and constantly, for they were convinced that only very slowly, and by long-continued processes, could the essence that they sought for be brought to perfection. A small error in any part of these processes might spoil all; a little too much mercury, or a trifle too little sulphur, too rapid a distillation, or too feeble a fire,—any of these would upset the due admixture of properties and stop the purification of the stone of wisdom. As this wonderful essence contained the properties of all substances in a refined or attenuated state, it was necessary to gather as many diverse things as possible and to endeavour to retain their properties while driving away the grosser parts of the things themselves. Hence the strange ingredients that were thrown into the furnace for the perfecting of the stone. In 'The Alchemist' *Surly* flouts *Subtle*, and scornfully flings in his face

> Your marchesite, your tutie, your magnesia,
> . . . .
> With all your broths, your menstrues, and materials,
> Of lye and egg-shells; man's blood,
> Hair o' the head, burnt clouts, chalk, merds, and clay,
> Powder of bones, scaldings of iron, glass,
> And worlds of other strange ingredients
> Would burst a man to name.

It would be extremely absurd for any one now to make himself 'sooty and black' by putting his fingers into such 'coals, clay and filth' as these, in the hope that he might in this way manufacture the one original and fundamental kind of matter; but the alchemists were able to make out a strong case in justification of their potterings in such nasty messes.

In his work the alchemist was necessarily hemmed in by the conceptions of his age, as the modern chemist is bound by the ways of thinking about nature that belong to his time.

In the alchemical times men imagined the world as a group of appearances resting on the foundation of certain universal principles. White objects were said to be white because there was a universal principle of whiteness, and this was imaged forth more or less perfectly in all white things; round objects were the material shadows of roundness; sweet things were sweet because of the presence in them all of some portion of the sweetness that existed apart from all sweet things but became known to the senses only as it was embodied in these things. When a soft object was hardened by mixing it with something harder than itself, it was supposed that the soft object communicated to the mixture a portion of the universal softness that was its attribute, while the hard object carried into the thing formed some part of the universal hardness that existed even if all hard things were destroyed. 'The life of metals,' said

Paracelsus, 'is a secret fatness; of salts the spirit of *aqua fortis*; of pearls, their splendour; of marcasites and antimony, a tingeing metalline spirit; of arsenics a mineral and coagulated poison.' Each particular substance had its own properties; as an English adept said, 'God hath seal'd it with a particular idea;' but transcending all, although manifested in all, was the universal essence.

The essence, or stone of wisdom, as being the perfect *One Thing*, must needs reflect all the universal principles some of which were made manifest in one kind of matter and some in another; but as some principle that was not embodied in any common substance might be very essential to the perfecting of the stone, it was necessary to make trial of all kinds of things that the ingenuity and knowledge of the worker suggested, so that the best chance might be given for securing the wished-for combination of qualities in the product.

In selecting the substances whose properties were to be blended harmoniously in the universal essence, one golden rule was that *like attracts like.* Thus in 'The triumphal chariot of Antimony' it is written:[1] 'So great is the attraction of like for like in nature that poison always draws towards it irresistibly

[1] The quotation is from an English translation, published recently by A. E. Waite.

all that is poisonous, and substances that are free from venom exert the same influence over substances which enjoy a similar immunity. Hence poison can be removed in two ways; firstly, by its contrary which repels it, as the unicorn repels the spider; secondly, by its like which attracts it by magnetic power.' As an example of like attracting like, we are told that to get rid of poison, 'You may take a venomous toad, dry it in the sun, reduce it to ashes in a carefully closed pot, pulverise, and apply the powder to any poisonous wound, whereupon it will attract to itself all the poison of the wound. Why? Because by the combustion or calcination of the toad its inward efficacy is called out and becomes operative.'

The conception of the Essence was vague because it was an outcome of the vague ways of thinking about nature that prevailed in alchemical times. The essence was many-sided; it embodied in itself the properties that were distributed over a thousand different substances; hence the names given to it, and the descriptions of the processes by which it might perhaps be attained, were hard to understand even by the initiated, and to us, who have travelled far from the 'specular mount' whence the alchemists surveyed the world, they seem as foolish jargon and idle tales.

As regards the names of the Essence, we read in a translation recently published of a work that appeared in 1608:—'This Virgin and Blessed water have philosophers in their books called by a thousand names; as a heaven, celestial water, heavenly rain, heavenly or May dew, water of Paradise . . . a sharp vinegar and brandy, a quintessence of wine . . . a waxy mercury, a water becoming green, and green lion . . . a menstruum . . . white arsenic . . . a fiery burning spirit . . . a basilisk which kills everything . . . a dragon . . . a sharp salt, a sharp soap, lye, and viscous oil . . . a vulture and hermetic bird . . . a smelting and calcining stove.'

And again:—'I am the old dragon that is present everywhere on the face of the earth; I am father and mother; youthful and ancient; weak and yet more strong; life and death; visible and invisible; hard and soft; descending to the earth, and ascending to the heavens; most high and most low; light and heavy; in me the order of nature is oftentimes inverted, in colour, number, weights and measure. . . . I am the carbuncle of the sun, a most noble clarified earth, by which thou mayest turn copper, iron, tin, and lead into most pure gold.'

No wonder that one who had joined the quest, but had been distracted by the perplexities of the path, once exclaimed: 'This horrid beast has so many names that unless God direct the searcher it is impossible to distinguish him.'

As a specimen of the directions given for preparing 'the horrid beast that has so many names,' I give the following:—'Take our two serpents, which are to be found everywhere on the face of the earth; tie them in a love-knot and shut them up in the Arabian *caraha.* This is the first labour; but the next is more difficult. Thou must encamp against them with the fire of nature, and be sure thou dost bring thy line round about. Circle them in and stop all avenues that they find no relief. Continue this siege patiently, and they turn into an ugly venomous black toad, which will be transformed to a horrible devouring dragon, creeping and weltering in the bottom of her cave without wings. Touch her not by any means, for there is not on earth such a vehement transcending poison. As thou hast begun so proceed, and this dragon will turn into a swan. Henceforth I will show thee how to fortify thy fire till the phœnix appear; it is a bird of a most deep colour, with a shining fiery hue. Feed this bird with the fire of his father and the ether of his mother; for the first is meat, and the second is drink, and without this last he attains not to his full glory;'—and so on.

The English adept, Thomas Vaughan—who wrote in the middle of the seventeenth century under the name of Eugenius Philalethes—gives many mystical directions for preparing *The One Thing.* These directions are hard to understand, but in charity to the reader he says :—‘But because I will not leave thee without some satisfaction, I advise thee to take the Moone of the Firmament, which is a middle nature, place her so that every part of her may be in two elements at one and the same time; these elements also must equally attend her body, not one further off, not one nearer than the other. In the regulating of these two there is a twofold geometrie to be observed, natural and artificial. But I may speak no more. . . . As for the work itself, it is no way troublesome; a lady may reade the “Arcadia,” and at the same time attend this philosophie without disturbing her fancie. For my part I think women are more fitter for it than men, for in such things they are more neat and patient, being used to a small chemistrie of sack-possets, and other finicall sugar-sops.’

There are two expressions in these words of Eugenius Philalethes that call for comment. He says of the ‘Moone of the Firmament’ that it is ‘a middle nature;’ and when one expects that something definite is about to be announced, one is disappointed by the words ‘but I may speak no more.’ The alchemists were chary of divulging their secrets; partly no doubt because men who studied nature in the old days were suspected of tampering with the devil—for in these times the belief was prevalent that the earth belonged to the spirit of evil; and partly from a conscientious dread of revealing to the vulgar the mysteries which they held to be sacred. The same Eugenius Philalethes thus translates a passage from Raymond Lully:—'I swear to thee upon my soule that thou art damn'd if thou shouldest reveal these things . . . Thou shalt reserve and keep that secret which God only should reveal, and thou shalt affirme thou doest justly keep back those things whose revelation belongs to his honour. For if thou shouldest reveale that in a few words which God hath been forming a long time, thou shouldest be condemned in the great day of judgement as a traytor to the majestie of God, neither should thy treason be forgiven thee.' The expression 'middle nature,' or 'middle substance,' embodies a fundamental conception of the more subtle alchemy, which taught that everything is a trinity 'having a body and a soul held together by the spirit, which is the cause and the law,' and that ordinary material things may be raised into higher, that is more refined or attenuated, states, by contact, under proper conditions, with things of a 'middle nature,' that is things more refined than themselves but less lifted up in the scale of existence than the universal elements. 'To grasp the invisible elements, to attract them by their material correspondences, to control, purify, and transform them by the living power of the spirit—this is true alchemy' (Paracelsus).

'The art of divine magic consists in the ability to perceive the essence of things in the light of nature, and by using the soul-powers of the spirit to produce material things from the unseen universe; and in such operations the Above and the Below must be brought together, and made to act harmoniously. . . . Gold is of a threefold nature, and there is an ethereal, a fluid, and a material gold. It is the same gold, only in three different states; and gold in one state may be made into gold in another state' (Tritheim, Abbot of Spanheim). Eugenius Philalethes speaks of a certain kind of reduction which is 'vital and generative, resolving bodies into their sperm or middle substance, out of which nature made them; for nature makes not bodies immediately out of the elements, but of a sperm which she draws out of the elements.'

The same author, translating from 'the oracle of magick, the great and solemn Agrippa,' says:—'There are then . . . four Elements, without the perfect knowledge of which we can effect nothing in Magick. Now each of them is threefold. . . . Of the first order are the pure Elements, which are neither compounded nor changed, nor admit of mixtion, but are incorruptible, and not of which but through which the vertues of all naturall things are brought forth into act. No man is able to declare all their vertues, because they can do all things upon all things. . . . Of the second order are elements that are compounded, changeable, and impure, yet such as may by art be reduced to their pure simplicity, whose vertue, when they are thus reduced to their pure simplicity, doth above all things perfect all occult and common operations of Nature, and these are the foundations of the whole naturall Magick. Of the third order are those elements which originally, and of themselves, are not elements, but are twice compounded, various, and changeable one into the other. They are the infallible medium, and therefore are called the middle nature, or Soul of the middle nature. . . . In them is . . . the perfection of every effect in what thing soever, whether naturall, cœlestiall, or super-cœlestiall; . . . for from these, through them, proceed the bindings, loosings, and transmutations of all things. . . . Whosoever shall know how to reduce those of one order into those of another, impure into pure, compounded into simple, and shall know how to understand distinctly the nature, vertue, and power of them in number, degrees, and order, without dividing the substance, he shall easily attain to the knowledge and perfect operation of all naturall things, and cœlestiall secrets.'

I have said enough, and quoted sufficiently from alchemical writings, to give some notion of the meaning that the older seekers after the unchangeable attached to the assertion—'There abides in nature a certain form of matter which, being discovered and brought by art to perfection, converts to itself, proportionally, all imperfect bodies that it touches.'

In its grosser aspects alchemy was a futile attempt to transmute all things into gold; in its more refined aspects it was a mystical system of occult theology, and it used a language like that used by theologians in every age. And there was a third aspect of alchemy in which it appeared as an art or handicraft. Thomas Vaughan said—'Nature moves not by the theorie of men, but by their practice, and surely wit and reason can perform no miracles unlesse the hands supplie them.' The knowledge of natural events, and of ways of preparing and examining different substances, that the practice of the alchemists brought to light, has proved of much more service to humanity than all the fantastic theories that their 'wit and reason' invented.

Let us go back to some of the operations practised by the alchemists, and endeavour to take these changes to pieces, that we may follow the steps of the processes.

The alchemist made a solution of bluestone in water, dipped a piece of iron into this solution, obtained a deposit of copper on the iron, and triumphantly declared he had transformed iron into copper. He boiled water in an open dish, and when the water had disappeared he pointed to the earthy matter in the dish as proof of the transmutation of water into earth. And the alchemist was justified in drawing these conclusions from the data which he had. He might have concluded that the copper existed in the bluestone and was drawn out by the iron, and that the water he boiled down contained earth which became visible when the water was removed; but had the alchemist come to this conclusion it would have been as much an unverified guess as the conclusion was whereat he actually arrived.

It was impossible to understand such occurrences as these, even superficially, two or three centuries ago. The minds of men in these days were saturated with certain conceptions of the world and their own relations to the seen and the unseen; and they had not invented the balance. Until delicate balances had been made and used, no clear conceptions regarding the changes that matter undergoes were possible; and until clearer conceptions of material changes were gained than those that prevailed in the middle ages, it was impossible to construct delicate balances. The mechanician, the naturalist, and the philosopher worked together, unconsciously in most cases, to bring about the emancipation of the human mind from the trammels of alchemy. The words of Eugenius Philalethes, that I have quoted, are profoundly true—'Nature moves not by the theorie of men, but by their practice, and surely wit and reason can perform no miracles unlesse the hands supplie them.'

When a piece of copper was weighed, and dissolved in oil of vitriol, the solution was evaporated and the blue crystals thus obtained were weighed and then dissolved in water, a piece of iron was immersed in this liquid and kept there as long as the liquid retained any shade of blue colour, and the copper that was deposited was collected, washed, dried and weighed; when these operations were finished the alleged transmutation of iron into copper was found to be incapable of explaining the facts. When the facts were known the explanation was also known. When the dream was told the interpretation followed. The weight of copper obtained from the blue solution was the same as the weight of the copper that was converted into bluestone by solution in oil of vitriol. The copper could not be detected by looking at the bluestone; but it is one part of the business of the student of nature 'to bring the invisible full into play.'

A quantity of water was weighed, and boiled in a vessel wherein the steam could be condensed to water; when all the water had been thus converted into steam and the steam changed back to water, the condensed water was weighed, and the earthy matter in the vessel wherein the water had been boiled was also weighed; the condensed water weighed less than the water before it was boiled, but the sum of the weights of the condensed water and the earthy matter was equal to the weight of the water before boiling. After these experiments, wherein the quantities of matter taking part in the occurrence were determined, the only conclusion that could be come to was that the earthy matter existed in the water that was boiled down.

The interpretation of such quantitative experiments as these assumes that the relative quantities of matter in two substances can be determined by the balance, and that if two pieces of matter have the same properties they are the same kind of matter. The very conception of quantities of this or that kind of matter was impossible until *accurate* weighings had been made. After that was done it was possible to compare one quantity of matter with another. If two pieces of matter have the same properties they are the same kind of matter. Such a statement as this could not have been made by the alchemist; that two pieces of matter have identical properties could not be asserted without the use of a delicate and accurate balance. The notion of definite kinds of matter, each having fixed properties, and each being recognisable by these properties, is one of those comparatively modern conceptions that have been forced on us quite as much by the hands, as by the 'wit and reason,' of men.

The substance we call copper is always copper. Every piece of copper has the same properties as every other piece; we know some of the properties that distinguish copper from every other kind of matter; we do not know all the properties of copper; but we know that any substance that has not all the properties that characterise copper is not copper. For the name copper is used to distinguish a certain group of properties, that we always find associated together, from other groups of associated properties; and if we do not find the group of properties connoted by the term copper we do not find copper. The discovery of new properties always associated with the group of properties we call copper would not invalidate the statement that copper is always copper. The separation of copper into two or more unlike kinds of matter would not invalidate this statement, for what we had before called copper would still be copper, that is, would still have the properties for which the word *copper* is a convenient abbreviation.

At present we know about sixty-five distinct kinds of matter none of which has been separated into parts that are unlike the original kind of matter and unlike one another. These kinds of matter are called *elements*. These elements combine in various fixed proportions, and thus produce a vast number of distinct kinds of matter called *compounds*. Every compound has its own properties, and is as definitely an individual and distinct kind of matter as the elements that compose it. But every compound can be disintegrated into at least two different substances; and the proof of this disintegration is that the quantity of each different kind of matter obtained from a compound is less than the quantity of the compound from which these different kinds of matter are obtained, and that the sum of the quantities of the different substances obtained is equal to the quantity of the compound from which they are obtained.

Iron, lead, silver, copper, gold, tin, mercury, sulphur, and carbon are some of the commoner elements. Water, sulphuric acid, common salt, nitric acid, silica, Epsom salts, iron rust, chalk, saltpetre, carbonic acid, sugar, and alcohol are some of the commoner compounds.

Elements are often spoken of as simpler forms of matter than compounds. The terms simpler and more complex are not used now as such terms were used by the alchemists. A definite kind of matter is said, nowadays, to be simpler than another, when it can be obtained by separating the less simple into the more simple substance and one or more other substances, and when the less simple can be formed by combining the more simple substance with one or more other substances. The test of separation is that the sum of the weights of the different things obtained from another thing is equal to the weight of that thing from which the different things have been obtained. The process of simplification has resulted in the recognition of about sixty-five different substances by combining which all the other definite kinds of matter we are acquainted with can be produced.

The most simple kinds of matter, that is the elements, readily suffer change, but only by combining with other elements or with compounds; the less simple kinds of matter, that is the compounds, undergo change both by combining with other compounds or with elements, and also by separating into simpler compounds, or into elements.

The classification of definite kinds of matter into elements and compounds could not have been attained without the constant use of a delicate instrument for determining the relative quantities of matter in substances. The balance has enabled chemists to give a definite meaning to the conception of an element, and to substitute this for the hazy notion of the alchemical essence.

When a house is being built of bricks, every one can see the bricks being added one to another, and when the house is finished every one can see the bricks in the completed building. But when iron is dissolved in oil of vitriol mixed with water, the solution is evaporated and crystals of green vitriol are obtained, no one can see the particles of iron coalescing with the particles of the acid, and no one can distinguish by the sense of sight, or smell, or touch, or taste, the particles of the constituents—iron and oil of vitriol—in the substance formed by their interaction. The iron seems to be destroyed; but it can be obtained again from the green vitriol, and the quantity so obtained is exactly the same as the quantity that disappeared in the acid. The iron seems to be destroyed; it is destroyed, said the alchemists; but the balance declares it is only hidden.

When lead is kept molten in a stream of air the metal is changed into a reddish-yellow powder, and when this powder is mixed with charcoal, and a flux, and heated, lead is obtained again. The alchemist said that lead was destroyed by heating it in air, and that it was brought to life again by heating its ashes with charcoal. The balance has enabled the chemist to trace the lead through these changes; it has made it possible for him to see things that are invisible; he sees the molten lead combining with oxygen in the air that is passed over it, and he sees the oxide of lead torn into parts by the hot charcoal, and one part—the oxygen—carried off in company with the carbon of the charcoal and forming carbonic acid gas, while the other part—the lead—remains. The balance enables the chemist to see these changes occurring, for it tells him that the quantity of lead that is transformed into litharge is the same as the quantity of lead that is obtained by heating this litharge with charcoal, and it tells him that the quantity of litharge formed by burning a definite quantity of lead in air is equal to the sum of the quantities of lead burnt and oxygen taken out of the air that is passed over the burning lead.

When the alchemist poured molten sulphur on to mercury, both substances disappeared and a black substance came in their place. He did not know, he had no means of knowing, that the quantity of the black substance was exactly equal to the quantity of the mercury added to the quantity of the sulphur he had used. But the balance has revealed to the chemist that the formation of the black solid consists in an extremely intimate union of the mercury with the sulphur that was poured on to it.

In a sense the alchemist was right. Neither mercury nor sulphur can strictly be said to exist in the black body formed by the union of mercury with sulphur; nor is it altogether accurate to say that lead and oxygen exist in the litharge that is produced by burning lead in oxygen. Black sulphide of mercury and litharge are definite and individual kinds of matter; we cannot recognise mercury or sulphur in one, nor lead and oxygen in the other, by means of any of the properties which these substances exhibit when they are separated from all other substances. Nevertheless we can separate sulphide of mercury into sulphur and mercury, and litharge into lead and oxygen, and we can form sulphide of mercury by combining sulphur with mercury, and oxide of lead by combining lead with oxygen; moreover the quantity of sulphide of mercury formed is equal to the sum of the quantities of sulphur and mercury used, the quantity of litharge formed is equal to the sum of the quantities of lead and oxygen used, the quantities of sulphur and mercury obtained, when added together, are equal to the quantity of sulphide of mercury from which they are obtained, and the sum of the quantities of lead and oxygen obtained from litharge is equal to the quantity of litharge that is separated into these two substances. Moreover we have failed to separate lead, sulphur, mercury, or oxygen into any simpler kinds of matter; hence we are justified in speaking of the processes that occur when litharge is formed by combining lead with oxygen, and sulphide of mercury is formed by combining mercury with sulphur, as 'changes in combinations of the unchanging.'

When very finely divided copper is strongly heated in air, a black solid is obtained; when this black solid is heated in a stream of hydrogen gas, copper appears again, and water is also produced. The black solid weighs more than the copper did; but the copper that remains when the black solid is heated in hydrogen weighs the same as the copper weighed before it was burnt in air. Water can be separated into two gases, oxygen and hydrogen, and water can be formed by passing electric sparks through a mixture of oxygen and hydrogen; the sum of the weights of oxygen and hydrogen obtained from water is equal to the weight of water from which they are obtained; and the weight of water formed by causing oxygen and hydrogen to combine is equal to the sum of the weights of oxygen and hydrogen that disappear. The weight of the water that is produced by passing hydrogen over black oxide of copper—formed by burning copper in air—exceeds the loss of weight undergone by the oxide of copper by as much as is equal to the weight of hydrogen used in the conversion of the oxide of copper into water and copper. Hence, when copper is burnt in air it combines with oxygen in the air; and when oxide of copper, or burnt copper, is heated in hydrogen the oxygen that was combined with the copper is removed and is combined with hydrogen to produce water. By combination of the elements copper and oxygen, oxide of copper is formed; and by tearing away oxygen from oxide of copper and combining it with hydrogen, water is produced, and copper remains. These changes also are 'changes in combinations of the unchanging.'

When we apply the epithet *unchanging* to the elements, we mean that these kinds of matter are not separated into unlike parts in any processes that have yet been performed; and when we speak of *changes occurring in combinations of the elements*, we mean that compounds can be taken to pieces, and that the unlike, and as far as we know unresolvable, pieces thus obtained can be re-arranged to form new compounds.

The meaning that is now given to the term *un-*

changing is seen to be very different from the meaning that the alchemists attached to their unchangeable essences or elementary principles.

When coal or wood is burnt, carbonic acid gas is produced, and this gas is composed of carbon that is taken from the wood or coal, and oxygen that existed in air before the burning took place. When a green plant is brought into moist carbonic acid gas, and exposed to sunshine, it gradually separates the gas into the elements of which that gas is composed; the plant keeps the carbon and combines it with other elements, the chief of which are hydrogen, oxygen, and nitrogen, and sends back the oxygen, or a portion of the oxygen, into the air. If the plant is eaten by an animal, the compounds of carbon with hydrogen, oxygen, and nitrogen that are in the plant are disintegrated by the animal, portions of these elements are built up in new combinations to form parts of the animal structure, and portions of them are excreted by the animal. The continuance in life of the animal is intimately connected with the continual re-arrangement of the elements that compose the compounds in the food consumed by the animal. A portion of the carbon in these compounds is burnt in the animal organism to carbonic acid which is sent into the air, to be, perhaps, absorbed by plants and by them torn into carbon and oxygen; or the carbonic acid may enter into combination with lime, and so produce chalk or marble, which may, in turn, be decomposed by acids in water percolating through it, with reproduction of carbonic acid that is returned once more to the atmosphere. Throughout these cycles of change the carbon is never separated, so far as we know, into dissimilar parts; it undergoes change by combining with oxygen, hydrogen, and nitrogen; and, although the compounds thus produced are unmistakably distinct kinds of matter in whose properties the properties neither of carbon or oxygen, nor of hydrogen or nitrogen, appear, yet we certainly recognise in these cycles of change 'how changes take place in combinations of the unchanging.'

The elements carbon, hydrogen, oxygen, and nitrogen combine in different proportions, and an innumerable host of different but definite substances is thus produced. The compounds that are formed by combinations of these four unchanging things exhibit the most diverse properties; some are colourless gases, some are brilliantly coloured solids; some are limpid liquids, some are liquids that are oily, sluggish, and heavy; many of them enter readily into reactions with other compounds, while others are inert, unimpressionable, and immovable. The compounds formed by the union of carbon, hydrogen, oxygen, and nitrogen, or of some of these elements, include many most virulent poisons, such as prussic acid, strychnine, and morphine; many potent drugs, such as chloral, sweet spirit of nitre, the active ingredients of laudanum, quinine, and other medicines; many common food-stuffs, such as sugar, starch, the compounds present in butter, milk, bread, and flour, and also the active ingredients of tea, cocoa, and coffee; among these compounds are alcohol, and acetic acid or the acid of vinegar; tartaric and citric acids, that are used in calico printing, are compounds of three of these four elements; large and increasing trades rest on the manufacture of compounds of these elements, —among these are the preparation of aniline dyes, the making of leather and perfumes, the purification and preparation of gelatin and starch, the fermentation of grape juice into wine, the manufacture of beer, and the baking of bread. The production of these compounds, and of a great multitude of others, consists in effecting changes in the combinations of the four unchanging things carbon, hydrogen, oxygen, and nitrogen. The foundations of a thousand manufactures have been formed by tracing the changes in the quantities of these elements that are combined in different compounds, and by connecting these changes with changes in the properties of the compounds.

It was impossible to weigh or measure any one of the alchemical principles, and so it was impossible to connect the properties of substances with the presence in them of more or less of these principles. It may be convenient sometimes to speak of the *principle of sweetness*, if one desires to class together different things that are alike in the one respect that all are sweet to the taste; but to say that the substances all contain the principle of sweetness is merely an awkward and inaccurate way of expressing the fact that they all are sweet; by affirming that they all contain this principle we do not advance a single step in accurate knowledge of the things that are sweet. But to be able to connect the property of being sweet to the taste with the compositions of the substances that exhibit this property is to have advanced in the accurate knowledge of these substances. And to be able to do this means that we have attained to some accurate knowledge of the compositions of different kinds of matter; it means that we have attained to some clear, definite, and workable conception of the structure of many material things; it means a step forward in solving a great natural problem.

The alchemist asked—why are some things sweet? and he supposed he had answered the question when he replied, 'because they contain the principle of sweetness.' The chemist asks— what is the composition of the things that are sweet? and he knows he has made some progress towards finding the answer when he is able to name the kinds of matter that are present in all sweet things, and the quantities of them in each thing that is sweet. The alchemist's question was, *why?* and his answer was merely a re-statement of the question in more grandiloquent terms. The chemist's question is, *how?* and his answer forms a foundation on which he rests other questions.

The phrases which the alchemist coined and then mistook for natural principles led him to confuse facts with fancies; the chemist too is often led astray, but he has learnt not to trust in phrases, but from time to time to review his vocabulary that he may make his terms more clearly express well-grounded truths.

There is a note in Hartmann's 'Life of Paracelsus' that is most suggestive of the difference between the alchemist's words and the chemist's facts. Hartmann says, 'Each metal has its elementary matrix in which it grows. Mines of gold, silver, &c. become exhausted, and after centuries (or millenniums) they may be found to yield again a rich supply; in the same way the soil of a country, having become infertile from exhaustion, will after a time of rest become fertile again. In both cases a decomposition and a development of lower elements into higher ones takes place.' The chemist knows nothing of the 'decomposition and development of lower elements into higher ones;' the terms lower and higher are meaningless when applied to the elements. But experience has proved to the chemist that an exhausted soil regains fertility after a time of rest, because the food that plants require has found its way into that soil from the rain or air, or from other soils, or from decaying plants left in the soil; and, should gold or silver be found after centuries, or millenniums, in a mine that had been exhausted, the chemist would know either that the mine had not really been exhausted, or that the gold or silver found there had been brought by some natural agency from another place, or had been produced by the gradual decomposition of compounds of gold, or silver, that existed in the mine but had not been found by the earlier searchers.

It is much easier to talk about principles, and to call some of these fancied causes of things higher than others, than to investigate facts and to reason accurately on the results of the investigation. There was much excuse for the alchemist, for he had not the means of making accurate investigation into natural facts; but there is no excuse for the spiritualist, who is the modern copier of alchemical methods.

Accurate and systematised investigation has brought to light the infinite complexity of nature, the fineness of the dovetailing of every event into many others, the never ending response of all things to changes in the conditions that encompass them, the universal orderliness of natural occurrences, the immutability of sequences, and the absolute interdependence of cause and effect; and it has also made known the great plasticity of the material wherein these sequences and that interdependence are exhibited. The study of chemistry is, in an especial way, the study of the plasticity of matter. Very many of the changes that occur in combinations of the unchanging occur when one substance is brought into contact with another, or when the conditions to which substances are subjected are altered. A colourless oil is mixed with a little bleaching powder and a brilliantly purple-violet coloured substance is formed; a little hot oil of vitriol is poured on to sugar and a quantity of charcoal is produced and steam passes into the air; a dry piece of phosphorus is placed in a dish, after a time it begins to smoke, and then it catches fire and changes into a white, snow-like powder; iron filings are moistened and hung, in a bag of muslin, in an enclosed quantity of air standing over water, the air gradually becomes less and the surface of the filings changes into rust; a lighted taper is brought to a small quantity of a white solid (called *sulphocyanide of mercury*), and from the little piece of white solid there gradually emerges a long, brownish black, crumbly, snake-like substance which occupies twenty or thirty times the space that was filled by the white solid before the lighted taper touched it; flowers of sulphur and very finely divided iron are mixed in the proportion of one part of sulphur to one and three-quarter parts of iron, the mixture is moistened with water, made into a paste, and buried beneath some earth, after a time there is heard a slight sound, the earth is driven upwards and scattered, and beneath the scattered earth is found a black solid in which neither iron nor sulphur can be detected by their ordinary properties. When the pink liquid known as *Condy's fluid* (*permanganate of potash*) is added to water containing products of the decay of animal or vegetable matter, the colour of the liquid is discharged, and some of the products of decay are changed into new substances. When cotton-wool is rubbed with cold concentrated oil of vitriol, and the semi-liquid substance thus formed is poured into water and boiled, and the water is then removed by evaporation, a sweet syrup is obtained in which is present the sugar found in grape juice. When sulphur is burnt the sulphur disappears, and a choking, colourless gas comes in its place.

These changes show how comparatively easy it is to take to pieces some of the buildings that are formed by putting elements together, and to rearrange the building stones—the elements—in new combinations. If a chemical compound is compared to a building constructed of two or more different kinds of stones, the changes that may be effected in the arrangement of the building stones, and hence in the appearance of the building, by changing the conditions to which the building is subjected, may be likened to the changes that take place in fairy tales, when, by a wave of her wand, the good fairy makes a pumpkin into a coach or a walnut-shell into a palace. But the change from one chemical building to another is always perfectly orderly; there is a definite number of each kind of building stones in both buildings; and in the process no single stone is either broken to pieces or destroyed. The plasticity of many material things is associated with the permanency of the simpler materials of which these changing structures are composed. The great and striking changes in properties accompany changes in composition, but the latter changes consist in variations in combinations of the unchanging.

There are some changes wherein no variation occurs either in the kind or in the quantities of the elements that compose the matter whose properties are altered. There is a white solid called *ammonium cyanate*; when this is heated for some time by steam coming from boiling water, another substance is produced called *urea*. Both these substances are perfectly definite kinds of matter with fixed properties and unvarying composition. The properties of ammonium cyanate are very different from the properties of urea; nevertheless, both compounds are composed of 20 per cent. of the element carbon, united with 26·6 per cent. of the element oxygen, 46·7 per cent. of the element nitrogen, and 6·7 per cent. of the element hydrogen. Such a change of properties as marks the passage from ammonium cyanate to urea demonstrates, in a way not to be mistaken, the plasticity of some of the material structures with which chemistry is concerned.

Accurate investigation has brought to light many other instances of plasticity like that exhibited by the conversion of ammonium cyanate into urea. Three compounds are known, composed of 83·3 per cent. of carbon and 16·7 per cent. of hydrogen; each of these compounds has properties that distinguish it from all other kinds of matter, but all have identically the same composition. Five distinct compounds can be produced by combining 83·72 parts by weight of carbon with 16·28 parts by weight of hydrogen; the properties of these compounds are different, but their composition is the same.

At first sight it would seem that the variations in properties that occur without variations in composition, in such cases as those cited, cannot justly be described as changes in combinations of the unchanging. Does not the chemist's formula break down in such cases? Would it not be better to go back to the alchemical explanation, and to say that ammonium cyanate and urea have different properties because they contain different principles, and that the differences between the properties of the five compounds of carbon and hydrogen, all of which have the same composition, are due to differences in the principles that permeate these compounds? Would it not get over the difficulty to assert that each of these compounds embodies some portion of a universal principle that exists in nature, and that the presence of this principle is the determining cause of the properties which we recognise? A modern commentator on Paracelsus has said—'If a certain element that goes to form the legs of men were suddenly taken away from the universal storehouse of the Macrocosm (the Limbus), human beings would be born without legs; if no principle of reason existed, there would be no use for brains, &c.' Shall we adopt this explanation, and affirm that there is a certain element, or principle, in the universal storehouse that 'goes to form' ammonium cyanate, and another principle that goes to form urea?

That some satisfaction is to be obtained by affirming the existence of universal principles is evident when we remember that many people are ready to accept the assertion of the existence of a 'principle of reason' as a sufficient explanation of the power of reasoning. We all have our favourite *Mesopotamias* that we roll under our tongues, and by frequent sucking we derive much comfort from them.

The modern alchemist is conceited and lazy, so he allows himself to be deceived by his own fancies clothed in the false finery of sounding phrases. Chemistry prefers the harder task; by experiment and reasoning she seeks to know the facts, and then, by more experiment and more reasoning, she tries to find facts that are like those she knows, that by slow steps she may at last arrive at a true explanation.

Have we then arrived at a sufficient knowledge of the composition of compounds? Let us examine the composition of compounds and endeavour to ascertain whether the facts concerning composition can be expressed in general statements that hold good always.

The elements carbon and oxygen combine to form two distinct compounds; the quantity by weight of oxygen that combines with a determinate quantity by weight of carbon to produce one of these compounds is exactly double the quantity of oxygen that combines with the same determinate quantity of carbon to form the other compound. The elements nitrogen and oxygen combine to form five different compounds; the quantities by weight of oxygen that combine with one and the same quantity by weight of nitrogen are to one another as 1 : 2 : 3 : 4 : 5. Statements similar to these can be made regarding all the compounds formed by the union of any two elements. If A represents a determinate weight of one element, and B represents the smallest weight of another element that is found to combine with A, then the compositions of all the compounds formed by the union of the two elements are expressible by the symbol A_xB_y, where x and y are small whole numbers.

Considering the compositions of all compounds, we find that a generalisation may be made similar to that which expresses the compositions of the compounds of any pair of elements. The compositions of all compounds can be expressed by such symbols as $A_aB_bC_c$, $D_dE_eF_fG_g$, $H_hI_iK_kL_lM_m$, &c. In these symbols A represents a fixed weight of one element, B a fixed weight of another element, C a fixed weight of a third element, and so on; and a, b, c, d, e, f, &c. are small whole numbers varying from 1 to not greater, in very many cases, than 8. This generalisation may be stated in another form, as follows. A number can be attached to each element, expressing a certain weight of that element; the elements combine in the proportion of these numbers, or in the proportion of whole multiples of these numbers. Thus to hydrogen is attached the number *one*, to oxygen the number 16, to carbon the number 12, to sulphur the number 32, to nitrogen the number 14, to iron the number 56, to lead the number 207, to mercury the number 200, and so on:—hydrogen and oxygen always combine in the proportion $n\,1 : m\,16$; oxygen and sulphur in the proportion $n\,16 : m\,32$; lead and sulphur in the proportion $n\,207 : m\,32$; hydrogen, oxygen, and nitrogen in the proportion $n\,1 : m\,16 : p\,14$; nitrogen, carbon, and oxygen in the proportion $n\,14 : m\,12 : p\,16$; and so on; and n, m, and p are always small whole numbers.

This general statement applies accurately to all compounds.

The process of forming compounds of the elements might be likened to men building with about 65 different kinds of unbreakable bricks; all the bricks of one kind are of the same weight; but the bricks of one sort are 16 times heavier than the lightest kind of bricks; the bricks of another sort are 32 times heavier, the bricks of a third sort are 56 times heavier, the bricks of a fourth sort are 200 times heavier than the lightest kind of bricks, and so on;

the buildings are constructed each of two, three, four, five, or perhaps six, different kinds of bricks. As the bricks cannot be broken, at least one brick, of any kind, must be used in every building operation. An enormous number, practically an infinite number, of edifices may be built, each different in some respects from all the others. The bricks are the unchanging materials, and the various structures are put together by effecting changes in combinations of the unchanging.

It is evident that the differences between the edifices constructed of these bricks will depend, not only on how many different kinds of bricks are used, and how many bricks of one kind are put into each building, but also on the arrangement of the bricks that are employed. When it is said that the various structures are put together by effecting changes in combinations of the unchanging, the word *combinations* includes the notion of arrangement.

This analogy suggests the question :—is it possible that the properties of compounds may be connected with the arrangement of the elementary substances of which these compounds are formed?

Before attempting to answer this question we must get some clearer notions about the building of compounds.

Why do the elements combine in certain definite and simply expressible proportions by weight? Why is it possible to express the composition of all compounds by such a symbol as $A_aB_bC_cD_d$, . . . where A, B, &c. represent determinate weights of different elements, and a, b, &c. are small whole numbers? These questions may be put in another form; we may ask—can a simple, definite, and descriptive conception be attained of the combining together of elements, from which those generalisations that are universally applicable concerning the quantities by weight of elements that combine can be deduced as necessary consequences, and which conception suggests other deductions that are capable of being put to experimental proof?

Such a simple, definite, descriptive, and suggestive conception has been attained. According to this conception of chemical combination, we are to picture a piece of any definite kind of matter as consisting of a vast number of extremely minute particles, all identical in mass and properties, and each separated from the others. We are to think of the combination of elements as the combination of two, three, or more, different kinds of these minute particles; and we are to realise the ultimate particle of every compound to be a structure formed by putting together definite numbers of particles of different kinds of elementary substances.

Consider water, for instance. This conception of chemical combination bids us see a quantity of water in a vessel as if it were a heap of small shot, each shot being a particle of water. The vessel is not entirely filled by the particles of water, for there are interstices between the particles. Each particle is identical with all the others, and each is a particle of water. Water is formed by the combination of hydrogen and oxygen, and, therefore, if chemical combination consists in the close juxtaposition of very small particles of elements, each particle of water must be formed of particles of both hydrogen and oxygen. If a particle of water is separated into parts, these parts are not water, but some of them are hydrogen and some are oxygen. We have good grounds for asserting that the ultimate particle of water, that is the smallest portion of water that is still water, is formed of two particles of hydrogen united with one particle of oxygen.

So far as we know, the ultimate particles of an element cannot be separated into parts that are unlike each other; these minute portions of about 65 different kinds of matter mark the limits reached, at present, in the separation of less simple into more simple things. The ultimate particles of compounds are represented by this conception of chemical combination as formed by putting together the unchanging particles of the elements. All the particles of an element weigh the same, but all differ in weight from those of any other element.

If this conception is adopted, it necessarily follows that the composition of all compounds must be expressible by such a symbol as $A_aB_bC_cD_d$, . . . where A is a particle of one element, B a particle of another element, C a particle of a third element, and so on, and where a, b, c, d, &c. are whole numbers; for if more than a single particle of one element combines with the particles of another element, then at least two—it may be three, or four, &c.—particles of the first element must combine, because the particle of an element has never been separated into parts. Hence the universally applicable generalisations concerning the quantities by weight of elements that combine are deducible as necessary consequences from this conception of chemical action.

If the properties of a compound are conditioned by the kind of elements that form the compound, the properties of an ultimate particle of a compound are conditioned by the properties of the particles of the elements that form the particle of the compound. Now it is probable that the properties of the compound particle will depend not only on the kind of elementary particles that form it, but also on the number of each kind of these particles, and also on the way in which these particles are arranged. Hence the conception of chemical action we are considering makes possible the existence of compound particles having different properties but all formed by putting together the same number of the same kinds of elementary particles. In other words this conception would lead us to expect that two or more compounds might have the same composition but different properties. We know that compounds exist having the same composition but not the same properties.

Provided that the notion of composition is widened, so as to include the notion of arrangement of the particles of elements that form the ultimate particles of compounds, then we are justified in asserting that the formation of compounds, by putting various elements together, consists in changes in combinations of the unchanging. We are still able to form a clear mental picture of the formation of compounds; we are still able to connect the properties of compounds with changes in the combinations—that is, with changes in the relative quantities, and in the arrangement—of the elements whereof the compounds are composed. We do not require the vague notion of principles, disseminated through compounds, to enable us to bind into a mental unity the facts about composition and properties. The unifying conception grows clearer as the facts are made more definite and more numerous by investigation; and the growth in clearness and applicability of the unifying conception suggests new lines of investigation that lead to the discovery of important facts.

There is no greater mistake than to suppose that the man of science is merely a fact-finder, or that all facts are equally important that come to his net. He works under the guidance of general conceptions that have arisen from the study of facts; these conceptions constantly grow clearer, and the range of their applicability constantly widens; and as they become wider and clearer they suggest relations between facts that before were unrelated, and they indicate directions wherein the search for facts is likely to yield important results. The acquirement of facts that were before unknown necessitates modifications in the general conceptions of science. These conceptions are never final; they help men to realise the unity and the diversity of nature; they are stages in the advance towards truth; like things in nature they are, or ought to be, distinct; but, like natural objects, they are, or ought to be, 'never defined into absolute independent singleness.'

If we are to think of the chemical combination of elements to form compounds as the putting together of definite numbers of extremely minute particles of different kinds of matter, and if the properties of these groups of particles are conditioned not only by the qualities, and the quantities, but also by the arrangement, of the different kinds of particles that compose them, then surely it ought to be possible to form very many compounds with different properties but composed of the same quantities of the same elements. A very great number of such compounds is known, and the list of them lengthens every day. Nevertheless, the conception of properties as dependent, among other conditions, on the arrangement of the elementary particles that compose the ultimate particles of these compounds has been found a sufficient basis for a clear, workable, and most suggestive, classification of all the compounds of this description that have been produced hitherto.

How could the alchemist attain an intelligible and suggestive conception of the existence of kinds of matter differing in properties but not in composition? He could not form any distinct mental image of a *kind of matter*; he could not connect composition with properties, because he had no means of finding out anything definite about composition. He was forced to construct an intangible, indefinable, *principle* which he tacked on to each thing he dealt with, and which, he said, explained the properties of that thing. As many substances, so many principles. Not seeing the terrible complexity of nature, he must needs invent a complicated system of *principles* outside and surrounding nature. In the middle ages even the ardent student of nature could not escape from a supernatural explanation of inaccurately known natural facts. But the modern alchemist might move, if he chose, in a freer atmosphere. And yet there are now many people who prefer to give what they call an explanation of natural facts by an unwieldy, creaking, rusty machinery of supernatural imaginings, rather than take the trouble to understand even the fringe of the facts that they profess to explain. Many a man to-day who calls himself by some sounding name—it may be theosophist or theologian—is a near mental relative of the alchemist of the middle ages; like his ancestors, he has a very mean equipment of facts in his armoury, but unlike his ancestors, he might have many more if he would trouble to collect them; his facts are so few that they rattle against one another and make noises that frighten timid souls: and like his alchemical predecessors, he insists that the man who seeks, patiently and with perseverance, to know the world he lives in is a mean-spirited and owl-eyed creature, while he declares that he himself seeks an explanation of material things on what he is pleased to call a 'higher spiritual plane.' This is the kind of man who hinders the progress of the race; he says he seeks the unchangeable, and he finds it in the shifting creations of his own fancy. It is the duty of every man who desires to advance towards the goal of tried and abiding knowledge to put aside the methods and the results of the modern alchemist, by whatever title he call himself, or however he may seek to dignify his vanities by giving them the name of science.

The notion of the elements that has been attained, after long-continued labour, is that of certain distinct kinds of matter, each of which has properties that distinguish it from every other kind of matter, no one of which has been separated into portions unlike one another and unlike the original substance, and which combine together to produce new kinds of matter that are called compounds. All the portions of any one element must then be identical in properties. Any piece of pure iron must be identical, except in mass, with any other piece of pure iron; every specimen of pure lead must be identical, in every respect saving mass, with every other specimen of pure lead; and a statement like this must hold good for each of the 65 or 70 elements.

Now the chemist is accustomed to say that pure charcoal and diamond are the same element, namely, carbon; he is accustomed to speak of three or four forms of the element sulphur, and of two forms of the element phosphorus; and he often asserts that the element oxygen exists in more than one modification. He makes similar statements regarding a dozen or so of the elements.

If the elements are unchanging kinds of matter by the combinations whereof compounds are formed, how can it be correct to say that two or more varieties of the same element sometimes exist?

Let us first of all try to see clearly what facts are expressed when it is said that there is sometimes more than one variety of the same element. Diamond can be changed to charcoal by heating it out of contact with air; the weight of charcoal obtained is equal to the weight of diamond used. A piece of pure roll sulphur is a mass of small yellow crystals. By melting roll sulphur and suddenly cooling it, a plastic yellowish-red substance is formed, somewhat like caoutchouc; the weight of the caoutchouc-like substance obtained is equal to the weight of ordinary sulphur that was melted and cooled. Again, if 1 grain of diamond is completely burnt in air, $3\frac{2}{3}$ grains of carbonic acid gas are obtained; and if 1 grain of pure charcoal is burnt $3\frac{2}{3}$ grains of carbonic acid gas are obtained. If 1 grain of either ordinary sulphur or of the caoutchouc-like substance produced by melting sulphur and suddenly cooling is completely burnt in air, 2 grains of a choking gas, called sulphur dioxide, are obtained. Similar results are obtained with other elements that are said to exist each in more than one form. These results may be stated in general terms by saying that the change of one form of any of these elements into another form of the same element is accomplished without any alteration of weight ; and that, in making compounds of any of these elements, it does not matter which form of the element is used, as the same compounds are always obtained, and equal weights of the various forms of the element produce the same weights of the same compounds.

The existence of several varieties of an element is probably similar to the existence of different compounds with the same composition. We think of the ultimate particles of compounds that have the same composition but different properties as consisting of the same numbers of elementary particles arranged in different ways ; so we may think of the ultimate particles of the various varieties of the same element as consisting of the same number of yet smaller particles, all of which are the same but which are arranged differently. If this conception is adopted, we must see a quantity of ordinary sulphur as a collocation of a vast number of very minute particles each of which has the properties of ordinary sulphur, and we must think of each of these particles as a structure formed of a definite number of yet smaller particles arranged in a definite way; we must see a quantity of plastic sulphur as a collocation of many very minute particles, each of which has the properties of plastic sulphur, and we must think of each of these particles as a structure formed of the same number of the same smaller particles as compose a particle of ordinary sulphur, but arranged differently from the way in which these smaller particles are arranged when the collocation of them presents the properties of ordinary sulphur.[1] This conception leads us to picture the ultimate particles of many elements—that is the smallest particles that have the properties of these elements—as composed of definite numbers of yet smaller particles all of which have the same properties and the same mass, and to regard the properties of the ultimate particles of these elements as conditioned, to some extent, by the arrangement of these yet smaller particles.

This conception obliges us to recognise two orders of minute particles: heavier particles that exhibit the properties of the elements as we know

[1] It may be that the ultimate particle of ordinary sulphur is composed of a number of very minute particles different from the number of the same very minute particles that compose an ultimate particle of plastic sulphur.

them, and lighter particles that may be arranged in different ways, and so may form two or more kinds of heavier particles with somewhat different properties.

The close and deep study of the elements leads to the recognition of finer and more subtle shades of difference than could be imagined by speculating about elementary principles. This study leads us to recognise some 65 or 70 different kinds of extremely minute particles. It leads us to think of two, or three, or perhaps more, particles of one kind as arranged in a definite way and so forming a particle which has the properties of a certain element as we commonly know that element, and to think of the same number of the same particles as arranged in another way and so forming a particle which has somewhat different properties from those that characterise the element as we commonly know it; and this study leads us to think of two, or three, or more very minute particles of different kinds as arranged in different but definite ways and so forming particles which have the properties of certain compounds as we know these compounds.

More refined methods of study may compel us to recognise that the very minute particles of one kind which, being differently arranged, form different varieties of the same element, are themselves composed of yet minuter particles; but until we are compelled to do this we shall regard these very minute particles as the unchanging portions of different kinds of matter which, by changes in their combinations, produce the various substances found in the earth or manufactured in the laboratory.

The conception of two orders of minute particles has sufficed hitherto to bring together and co-ordinate the facts that are accurately known concerning what are generally called varieties of the same element, and also the facts concerning compounds of different elements. The conception has enabled us to represent all the manifold and surprising changes in the composition and properties of definite kinds of matter as changes in combinations of the unchanging. When the combinations are combinations of the same kind of unchanging particles, the results are elements; when the combinations are combinations of different kinds of unchanging particles, the results are compounds.

If the properties of compounds are conditioned by the qualities, the quantities, and the arrangement, of the unchanging elementary particles that by their union form the smallest particles which have the properties of the compounds, we might fairly expect to be able to connect, in some general way, the properties of compounds with the properties of the unchanging particles of the elements. Such a connexion has been established within recent years.

The relative weights of the unchanging particles of the elements are known; it is known that one of these minute particles of oxygen weighs 16 times more than one of the particles of hydrogen, that one of the particles of sulphur weighs 32 times more than a particle of hydrogen; and so on.

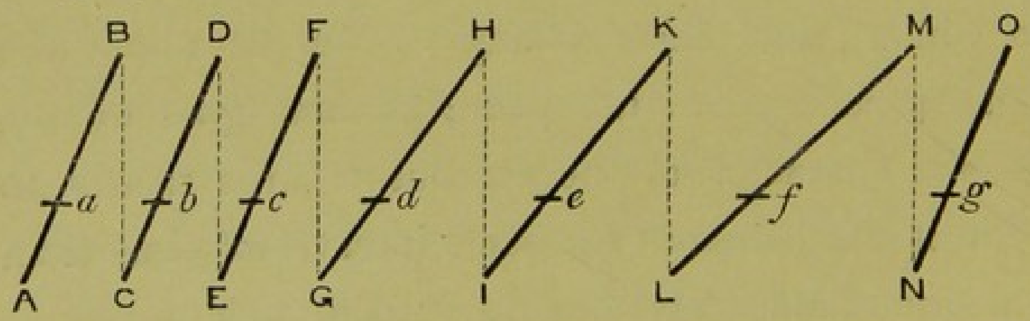
Let us apply to these minute unchanging particles of elements the name *atoms*, and let us call the relative weights of these particles the *atomic weights* of the elements.

The generalisation has been established that the properties of the elements, and the properties and compositions of compounds, vary periodically with variations in the atomic weights of the elements.

The regular waxing and waning of the moon is a periodic occurrence. At definite intervals of time the moon is full, and at definite intervals of time the moon is new. The return of the seasons is a periodic occurrence. Winter changes to spring, spring to summer, summer to autumn, and autumn to winter; and these changes occur at about the same periods year after year; as time goes on the general character of the seasons returns nearly to what it was before at the same interval of time from a definite date selected as the starting point.

As the atomic weights of the elements vary, the properties of the elements and the properties and the compositions of their compounds are repeated in more or less regular cycles. If the elements are arranged in ascending order of atomic weights, then the compositions and properties of the compounds of the elements, as well as the properties of the elements themselves, vary in a regular way from the first to the seventh element, and this variation is repeated in its general character in the second set of seven elements, and is again repeated, approximately, in the third set of seven elements, and so on. In some cases the variation spreads itself over more than seven elements; in other words, more than seven elements are required before the limit of variation is reached.

If the variations in the properties of the elements and in the compositions and properties of their compounds are represented by a number of sloping lines, the nature of the connexion between these variations and the regularly increasing values of the atomic weights of the elements may be shown, roughly, by the following figure.



There are seven elements between A and B, seven between C and D, and the same number between E and F, and between N and O; but more than seven elements, perhaps fourteen or seventeen, are required to exhibit the range of variation between G and H, I and K, and L and M. The properties of the elements, and the properties and compositions of the compounds of the elements, placed at A, C, E, G, I, L, and N, are very alike; and the properties and compositions of the compounds of the elements, and also the properties of the elements themselves, placed at B, D, F, H, K, M, and O, are also very similar. The element at B is more unlike the element at A than any element that comes between A and B; the element at D is more unlike the element at C than any element that comes between C and D, and so on; the elements placed, respectively, at A and B, C and D, E and F, G and H, I and K, L and M, and N and O, mark the extreme points of each cycle of variation of properties. Suppose that *a* marks the position of the element that comes next but one to that at A, in order of atomic weights, *b* marks the position of the element next but one to that at C, *c* marks the position of the element next but one to that at E, and *d*, *e*, *f*, and *g* mark the positions of the elements next but one, respectively, to those at G, I, L, and N; then the elements at *a*, *b*, *c*, *d*, *e*, *f*, and *g* are very similar, both in respect of their properties and also in respect of the properties and the compositions of their compounds.

This generalisation of facts—the properties of the elements and the properties and compositions of their compounds vary periodically with variations in the atomic weights of the elements—shows how accurate the statement is that chemical changes are changes in combinations of the unchanging.

The unchanging things are the atoms of the elements; when these combine, new substances are produced, and the changes of properties and composition that are thus brought about repeat themselves approximately at fairly regular intervals. The results of the prolonged and painstaking examination of a vast number of compounds have been vivified by the penetrating imagination of a great student of nature who has discovered and made manifest the rhythmic order that pervades the changes from compound to compound brought about by combining the unchanging atoms of 65 or 70 different elements.

How far away is this from the vague alchemical speculations about the unity of nature, or the gradual growth of all things from a few principles! In some ways the alchemical essence was a productive conception; but it necessarily lacked suggestiveness and applicability. In place of an essence that could not be clearly conceived, that could not be named, chemists have connected the myriad changes that occur among material objects with variations in the qualities, quantities, and arrangement of about 65 distinct kinds of extremely minute portions of matter. The notion of the alchemical essence incited men to investigate nature, and therefore it bore fruit; but it could not pass into the clearer and more suggestive conception of the chemical element until the investigation of nature, which it incited, had become accurate and searching.

Now that the nebulosity of the alchemical way of looking at material changes has been replaced by the comparative clearness of the chemical conception of changes in combinations of the unchanging, it is worse than foolish to talk, as some people talk, of the old uncertain, uncritical, and unstable methods as higher, and nobler, and more inspiring than the accurate and penetrating methods of science. The man who asserts, as many do assert nowadays, that he can find out the secrets of nature by thinking about them, is making himself the measure of all things; he prates about gaining knowledge of the essence of things, but he forgets to inquire what the facts are that he is so ready to explain, and, therefore, although his explanations may be very pretty, they are quite valueless and altogether superficial.

Until a man realises by actual contact with natural phenomena the overwhelming complexity, and also the absolute regularity, of the occurrences around him, he is easily led away by phrases about the meanness and barrenness of science; and, such is the credulity of the untrained mind, he readily persuades himself that his fancies about nature are much finer, and more worthy of credence, than nature herself. As a man learns more of the realities among which he moves, he begins to realise how transcendently more wonderful these realities are than any dreams that his untutored fancy can create; and instead of thinking that it is a fine thing to explain the natural by aid of the supernatural, he discovers that the natural is quite sufficient for him, and that he can gain the outlines of knowledge only by subjecting his imagination to the discipline of the real.

The alchemists spoke of perfect and imperfect metals; they fancied that imperfect metals grew more perfect. They carried over into material nature ideas that arose from a study of human nature; they read themselves into the universe. One great aim of science is to prevent men reading themselves into the universe. But the lesson takes long to learn. It is so easy to boast of the greatness of the mind, and the inferiority of matter; it is so simple to draw a broad distinction between what we call the material and what we call the spiritual, and to praise the spiritual and decry the material; all this comes so naturally to men that those who walk in the well-trodden path are sure of a welcome and certain of a following. It is for this reason, I think, that the inaccurate and slipshod methods of alchemy always find acceptance with many who cannot be troubled to examine natural occurrences for themselves, but, judging nature by their own standard, declare that her ways of working must be simple.

As a matter of fact it is much easier to accomplish what Paracelsus declared to be the end of alchemy—'to grasp the invisible elements, to attract them by their material correspondences, to control, purify, and transform them by the living power of the spirit,' it is much easier to do this than to trace one of the fundamental kinds of matter that chemistry calls an element through the changes it undergoes by combining with other elements. For when a man declares he has grasped the invisible elements and attracted them by their material correspondences, it is impossible to prove he has not; as it is impossible for the man himself or for any one else to know what an 'invisible element' is, or to tell whether he has grasped it or not, considering that after the grasping his hands are as empty as they were before. If a man asserts he can control, purify, and transform the invisible elements by the living power of the spirit, there is no good telling him he can't; for he will continue to assert he can, and from the very nature of the case there is no test that can be applied to detect the purified invisible element. But every trained chemist can repeat the experiments whereby a man asserts he has prepared certain compounds of a definite element, and if the experiments are repeated the same results will be obtained under the same conditions. 'Invisible elements' and 'material correspondences' and 'purifications of elements by the living power of the spirit,' and such phrases, are merely phrases now, whatever they may have been in the days when first they were coined.

To illustrate the difficulties that must be overcome before a natural occurrence that seems simple can be explained in terms that convey definite knowledge, and also to illustrate how ready men are to explain such occurrences by sounding phrases that represent no realities, I will sketch the development of the explanation of the phenomena of burning.

The earliest attempts to find a common cause of the phenomena of combustion seem to have been made in the 16th and 17th centuries. In the 17th century, especially, much attention was given to the changes that are produced by heating substances. Glaser prefixed to his treatise, published in 1663, the motto *Sine igni nihil operamur.* In the later years of the 17th century, those who studied material changes announced that all combustible substances contain a common principle, and that when these substances are burnt this principle rushes out, and the escape of the *principle of fire* is made apparent by the light that is seen and the heat that is felt.

Some substances, it was said, contain very much of the *principle of fire*, and by their aid the principle may be restored to the incombustible ashes that remain after burning. A piece of lead was burnt to a yellowish-red powder; this burnt lead, or *calx of lead* as it was called, was mixed with charcoal and the mixture was heated; the powder disappeared and lead came again. The men of the 17th century said that the *principle of fire* rushed out of the burning lead, and that the burnt lead was dull and lustreless because it contained no 'living power of the spirit' of fire; but that, as the 'invisible element' of fire was attracted and retained by charcoal, which was one of its 'material correspondences,' it was only necessary to heat the burnt lead with charcoal in order to 'purify' the dross, and transform it by the 'living power' of fire into lustrous lead.

As this explanation was in harmony with the ways of thinking about nature at the time, it met with general acceptance. All processes of combustion were labelled *outrushings of the principle of fire*, and were put into the pigeon-hole marked *thoroughly explained cases*.

At the time when combustion was thus comfortably explained, inquiries were being made by men who were not content to think about nature, but who insisted on investigating natural facts by varied experiments; and these inquiries showed that the volume of the air wherein a substance is burnt is diminished during the burning, and also that the burnt substance weighs more than the substance weighed before burning. The conclusion seems to follow from these results that a burning substance absorbs some of the air wherein it burns, and that the burnt substance is composed of the absorbed air and the original substance. But the facts were not sufficiently varied nor sufficiently accurate to force this conclusion on men's minds. And as much careful inquiry was needed to elucidate the changes that actually occur during burning, while it was comparatively easy to frame a theory that seemed to account for the striking phenomena of these processes, and especially as the superficial explanation was couched in language that men were accustomed to use, while the results of deeper research required new terms and new conceptions for their expression, the explanation of those parts of the phenomena of combustion that strike every observer, and that jumped with the thought of the time, was adopted by almost every one, and investigation was stopped for many years.

In August 1774 Priestley was wandering about his laboratory with a burning lens in his hand, concentrating the sun's rays on to various substances, 'without any particular view,' he says, 'except that of extracting air from a variety of substances,' by means of the burning lens—'which was then a new process with me, and which I was very proud of.' He extracted from *red precipitate* an air wherein a candle burnt with a 'remarkably vigorous flame;' this 'surprised me more than I can well express,' says Priestley; 'I was utterly at a loss how to account for it.' But he soon accounted for the properties of the new air. He found that it possessed 'all the properties of common air only in much greater perfection;' he said it was common air deprived of the *principle of fire*; and he called it *dephlogisticated air*, *phlogiston* being the name then generally given to the fancied principle of fire.

The reasoning whereby Priestley came to the conclusion that he had extracted *dephlogisticated air* from red precipitate is very instructive. The argument began by assuming that burning is the outrush of *phlogiston* from the burning body. If a substance is burnt in a closed vessel, the burning stops after a time. Why does the burning cease before the whole of the combustible substance is burnt? Because, said the upholders of the principle of fire, the *phlogiston* that comes out of the substance accumulates and hinders the outrush of any more, just as a crowd in a doorway stops the egress of people from the room. Common air, they said, contains *phlogiston*; it will hold a little more but not much more; but if you surround a burning body with air that has been deprived of all *phlogiston*, it is evident that the *phlogiston* in the burning body has a splendid opportunity to escape; it does escape with great haste, that is to say, the body burns very rapidly and brilliantly.

Grant the assumption that burning is the outrush of *phlogiston* from the burning body, and the argument is satisfactory, provided you are contented with a superficial examination of the facts.

If Priestley's reasoning was admitted, then any process by which common air could be charged with *phlogiston* must render common air less capable of supporting combustion. Priestley was acquainted with an air, or gas, obtained from nitre and called by him *nitrous air*, wherein combustible substances refused to burn; when he mixed this nitrous air with common air, combustible substances burnt very slightly, or not at all, in the mixture—in the language of the time the ordinary air had been rendered noxious. It is evident, said Priestley, that nitrous air contains a large quantity of *phlogiston*; mixing this air with common air is charging common air with more *phlogiston* than it usually contains; hence, of course, a combustible body refuses to burn in this mixture, because the *phlogiston* in the body can't get out. 'If any opinion,' said Priestley, 'in all the modern doctrine concerning air be well founded, it is certainly this, that nitrous air is highly charged with phlogiston, and that from this quality only it renders pure air noxious. . . . If I have completely ascertained anything at all relating to air, it is this.'

Priestley's explanation was of the alchemical kind; it explained nothing; it predicated a principle of fire about which exact knowledge was impossible. Priestley did not accurately distinguish one kind of air from other kinds; he thought of one kind as more or less perfect than others, but not essentially different from the others. He did not connect the properties with the compositions of substances. He looked on different substances merely as vehicles for showing forth the properties of hypothetical principles.

Lavoisier discarded the will-o'-the-wisp principles of the alchemists, and set himself to determine what actually does take place when a substance is burnt.

Working about the same time as Priestley, he proved that the product of burning sulphur, or phosphorus, in air weighed more than the sulphur, or phosphorus, which he burnt. He concluded that 'this augmentation of weight arises from a great quantity of air which becomes fixed during the combustion, and which combines with the vapours [of sulphur or phosphorus].'

If this conclusion is correct, the gain in weight during burning must equal the weight of air that enters into combination with the burning body. Lavoisier proved that when tin had been calcined in a closed glass vessel, the weight of air that rushed in when the vessel was opened was equal to the excess of the weight of the calcined tin over the weight of tin put into the vessel at the beginning of the experiment.

But Lavoisier was not contented until he had got back, from the product of burning, the air which he asserted had combined with the burning substance in the process of combustion. He knew that *red precipitate*, from which Priestley had extracted an air wherein a candle burnt vigorously, was prepared by calcining mercury. He thought it was likely that Priestley's *dephlogisticated air* was a constituent of ordinary air, and that the calcination of mercury consisted in the absorption by the heated metal of this constituent of air. To prove, or disprove, this hypothesis, Lavoisier heated a weighed quantity of mercury, for many days, in a closed apparatus arranged so that if air disappeared during the process the volume thereof could be measured ; he obtained a quantity of *red precipitate*, and the volume of air in the vessel decreased; he then weighed the *red precipitate*, and heated it strongly in a small tube arranged so that any gas that came off could be collected and measured. The quantity of gas obtained by heating the *red precipitate* was the same as the quantity of air that had disappeared during the formation of the *red precipitate* by calcining mercury. And, moreover, when the heated *red precipitate* had ceased to give off gas, mercury remained in the little tube ; and the weight of this mercury added to the weight of gas collected was equal to the weight of *red precipitate* that had thus been separated into mercury and a gas wherein a burning candle burnt very vigorously.

A complete statement of the changes of composition that occur when mercury is calcined was now possible. Lavoisier said that the process of calcination consists in the absorption of a constituent of air by the heated mercury, that the product of calcination is composed of mercury and this constituent of the air, and that this constituent of the air is the same as the gas that Priestley called *dephlogisticated air*.

When a substance burns in air, there is not an outrush of anything or any principle, said Lavoisier; on the contrary there is an inrush of something present in the air that surrounds the burning substance. The presence of this something is a necessary condition of combustion. Air contains other things besides this gas that is a supporter of combustion. If this gas is separated from everything else, and a combustible substance is burnt in it, the burning substance does not require to pick out the thing that is needed for its combustion from the other things that are in air, and that are not required to maintain combustion; every particle of the gas surrounding the burning body is a particle of the gas that the burning body requires, and therefore the process of combustion is rapid.

The change in properties, from the properties of the combustible body to the properties of the product of combustion, was connected with a definite change of composition. An exact statement was made which applied, without any modification, to every case of combustion. There was no longer any need to invent 'principles,' or 'living powers of the spirit,' or 'invisible elements' with their 'material correspondences,' or to talk about more or less 'perfect kinds of air,' or about 'purification of dross.' These phrases were seen to be meaningless, and they were given up.

Most unhappily they have been revived in recent times by men who are too untrained to investigate natural events themselves, and too conceited to study and grasp the investigations of others, and who suppose that to shut one's eyes and fill one's mouth with big words is a proof of wisdom and an indication of ability.

The alchemist studied properties; but he could not gain the conception of a measurable something that remains unchanged in total quantity through all changes of properties. Of course it is most important to study the properties of things, but this study leads to a very superficial explanation of natural facts unless it is accompanied by the study of the compositions of things. The examination of composition has led to the recognition of a number of distinct kinds of matter that have not been separated into dissimilar portions, and to the recognition of all other definite kinds of matter as composed of determinate and unchangeable quantities of some of those substances that are regarded as essentially homogeneous. The examination of properties has led to the recognition of a measurable thing the total quantity of which is not changed in the changes of composition that matter undergoes. This thing is called *energy*, or power of doing work.

Two changes of composition may be very different, and the properties of the kinds of matter concerned in the two changes may be very different, and yet the quantities of work that can be done by making use of the two changes—say the weight that can be lifted 10 feet into the air from the surface of the earth—may be the same. If 100 tons of water are allowed to fall from a mill-race through a wheel, a certain amount of work may be done by the revolving wheel; if 100 tons of alcohol were allowed to fall from the same height, through the same wheel, under the same conditions, the same amount of work would be done by the revolving wheel.

Every change in the composition of matter is accompanied by a change in the quantity of work that can be done by the matter; the collocation of different kinds of matter formed by the change is able to do either more work, or less work, than the matter could do before the change. If the products of the change can do more work than could be done by the material system before the change, then some other material system has suffered a loss of energy equal in amount to the gain in the energy of the material system under consideration. If the products of the change can do less work than could be done by the material system before the change, then some other material system has gained energy equal in amount to the quantity of energy lost by the material system under consideration. If the material system considered is taken as the whole material universe, then there is very strong evidence in favour of the statement that the amount of energy lost to any part of this system in any change of composition is exactly compensated by an equal gain of energy in some other part, so that the total energy of the whole system is always the same.

If attention is concentrated on the energies of different material systems, under defined conditions, the changes of composition that are required to pass from one system to another may be thought of only as opportunities for exhibiting changes of energy.

The constancy of the total quantity of energy in the material universe, and the transportation of measurable quantities of energy from one material system of definite composition to another, are, perhaps, the conceptions after which the alchemists dimly felt. These conceptions have been gained by methods entirely opposed to those that the modern descendants of the alchemists wish to pursue; they have been gained by long-continued and laborious investigations into realities, not by imagining essences or speculating about principles.

I have already said that alchemy and chemistry must be judged by their fruits. What fruit did alchemy produce, and what have been the results of examining material changes accurately and critically?

The practice of alchemy added much to the stock of useful information about natural objects, and led to the discovery of many things, and many processes, that have been serviceable to mankind. But alchemy did not help men to a true insight into nature; it did not make clearer, nor did it establish on a firmer foundation, the relations of the universe to human ideals. Alchemy encouraged superficiality of observation and looseness of thinking; it filled the mental vision of its disciples with fancies, and taught its followers to mistake these fancies for realities; it hid the wonders of nature by the stage-wonders of its own creation; it dazzled men's eyes by fireworks so that they could not see the sun; the noise of the machinery it set in motion dulled men's ears to the silent sounds of nature. By trying to explain nature supernaturally, alchemy contracted the universe to a speck, and called this folly wisdom. Alchemy lulled men to sleep by persuading them that nature is simple. It made up natural things in little parcels that were easily handled, and neatly labelled them; and this shopkeeper's work it performed with an air of profound mystery that made people think the work was great. The fundamental error of alchemy was that it explained natural facts, by wit and reason, before it had ascertained what the facts were that required explanation.

Chemistry has added much more than alchemy to the stock of useful information about natural objects, and it has discovered a great number of things, and processes, that have been serviceable to mankind. But it has done far more than this. It has made the universe vastly larger than it used to be. It has brought a thousand new interests into life, and thus it has widened the range of human sympathies and hopes. Our conceptions of the relations of man to the whole scheme of things have been changed by the progress of accurate knowledge of nature, and in this progress chemistry has borne a considerable part. Every branch of human activity has felt the influence of the closer contact with reality that is the mark of the time since alchemy gave place to chemistry. The method that is used in chemistry has made some advance in the work of placing man in his true position in the universe. The application of this method—which consists in accurate and tested examination, and accurate and tested reasoning on the results of examination—has already made the world a more wonderful place than undisciplined fancy ever pictured it; and every day this method is opening up new prospects that promise fullest scope for the exercise of intellect and richest material for the realising grasp of imagination.

All science is suggestive; chemistry is pre-eminently suggestive. The results of investigating the composition of compounds show that at present we must recognise about 65 or 70 different kinds of matter no one of which has been separated into dissimilar portions, and that we must look on all other definite kinds of matter—and there are hundreds of thousands of other definite kinds of matter—as formed by combining determinate quantities of two or more of the 65 or 70 fundamentally different elements. This result of accurate inquiry at once suggests a question. As compounds are formed of elements, and as compounds are as distinctly individual substances as elements are, may not elements be composed of a few yet simpler kinds of matter? In casting about for facts whereon some kind of answer to this question may be rested, we remember that some elements exist in more than one form or modification, and we recall the explanation that is given of this fact by the theory of atoms, namely, that one arrangement of a certain number of identical atoms has certain properties and a different arrangement of the same number of these atoms has other properties. This recollection suggests another question. Can the ultimate particles of all those kinds of matter called elements be composed of yet smaller particles all of which are identical, and may the differences between the ultimate particles of elements be connected with differences either in the number, or in the arrangement, of these (hypothetical) very minute particles of one kind? Chemical inquiry brings us face to face with the question of the unity of matter. Are the elements fundamentally different? Are there about sixty-five absolutely distinct and mutually unchangeable kinds of matter; or are the differences between elements the same in kind, although not in degree, as the differences between compounds?

Chemistry raises a question which is very like *the* question of alchemy. Is there in nature one primary kind of matter of which, and of which only, all those things we are accustomed to call different kinds of matter are composed? This question is like the fundamental question of alchemy, but the two are separated by a wide and deep gulf. The alchemical question was put in words that had, and could have, no exact meaning; the terms that express the chemical question are definite, because they represent the results of accurate investigation. The question must be answered, if answered at all, by chemical, not by alchemical, methods of inquiry.

An attempt was made, a good many years ago, to answer the question concerning the essential unity of the apparently different kinds of matter by tracing relations between the values of the atomic weights of the elements. It was argued that if the atomic weights of many elements should be proved to be whole multiples of the atomic weight of the lightest element, taken as unity, this would be strong evidence in favour of the view that the atoms of these elements are composed of different numbers of atoms of the lightest element. For instance, if an atom of oxygen is found to be exactly sixteen times heavier than an atom of hydrogen—hydrogen being the lightest element known—then, the argument was, it is probable that an atom of what we call oxygen is really a group of sixteen atoms of the kind of matter we call hydrogen, associated together so closely that the group of sixteen atoms acts and reacts as if it were a single indivisible particle of matter.

The result of inquiries on the lines suggested by this argument is that the atomic weights of very few, if any, elements are exactly whole multiples of the atomic weight of the lightest element.

It seems to me that the conclusion drawn from this argument is not so binding as has generally been supposed. No atomic weight of an element has been determined with certainty to more than the second decimal place; if the values now generally accepted for the atomic weights of the elements are multiplied by 100, all these values become whole numbers, the value for the atomic weight of the lightest element—hydrogen—becoming, of course, 100, in place of one as at present. Then it is only necessary to assume that an atom of hydrogen is composed of 100 atoms of a primary kind of matter, and the values of the atomic weights of the elements are all whole multiples of the atomic weight of this primary element.

The old argument is based on the assumption that hydrogen is the primary element, and this assumption is made because no kind of matter lighter than hydrogen is known at present. But surely attempts to progress towards a solution of the problem of the unity of matter should not start by burdening themselves with supposing that any kind of matter at present known is necessarily the simplest kind of matter.

The facts, that every element is distinctly different from every other element, and that the properties of the elements do not vary continuously but by jumps, have been urged as strongly militating against the conception of the essential unity of matter. But the properties of compounds also vary by jumps, and each compound is as definitely an individual kind of matter as each element is; yet we know that compounds are formed by putting elements together. There are many pairs of compounds of two elements that differ markedly in properties, but differ in composition only by one compound having a single atom more of one of the elements than the other compound; why then should not the addition to a group of atoms of one kind of one, or a few, more atoms of the same kind be accompanied by a very marked change of properties? The change from oxygen to ozone is very definite; but the ultimate particle that possesses the properties of oxygen is composed of two atoms of one kind, and the ultimate particle that possesses the properties of ozone is composed of three atoms of the same kind as those that compose the ultimate particle of oxygen. Reasoning from analogy, we should expect a collocation of 100 atoms of the (hypothetical) primary matter to have properties very distinct from those belonging to a collocation of 150 atoms of the same primary matter.

The fact that the properties of the elements do not vary continuously, but by jumps, seems to me to be as much in keeping with the view that postulates the unity of matter as with that which asserts its essential want of homogeneity.

The question of the nature of the elements is not yet ripe for decision; we cannot give an answer to the question—are the elements really elementary?

But we have advanced sufficiently to see that the answer will be found only by proceeding steadily along the path of accurate observation and experiment, and careful and constantly tested reasoning on the results of experiment.

Some ignorant people find fault with science because it vouchsafes no answers to the conundrums they choose to propound. And the same kind of people often complain that science is dogmatic, and assertive, and thinks she can explain everything. Both complaints are untrue. Nature is infinite; our powers are finite. Strive as we may we are able to comprehend only a few small portions of nature's ways; the essential thing is that the comprehension should be clear as far as it goes. The light that suffices to show us the path to-day will be too dim for those who shall tread the same path to-morrow. Yet it is possible to make sure that the light comes from realities, and is not a creation of the fancy.

To explain the changes of material things, alchemy invented principles or essences that were supposed to manifest themselves more or less fully in this or that kind of matter. These essences served some good purpose; they brought together, in a rough way, many natural occurrences that had a superficial likeness, and so encouraged investigation. But when close attention was paid to natural occurrences themselves it was found that the rough and ready alchemical classification of them had slurred over many essential features, and had put together some events that were totally unlike while separating other events that were really similar. When the 'wondrous veil' that alchemy had spread over nature was hesitatingly withdrawn by chemistry, the 'material laws' of nature were found to be much more wonderful than the veil which human fancy had manufactured and then supposed to be of nature's weaving.

The great business of alchemy was to prevent men from coming into close contact with external realities. Alchemy was a manufacturer of blinkers that shut off the objects on either side and so distorted the vision. The great business of chemistry is to force men into close contact with some aspects of external realities, and, with the help of her sister sciences, to remove everything that prevents the full vision of nature.

There certainly was a romance about alchemy; but the romance rested on an insecure foundation, and was itself false, glaring, and hard. The romance of chemistry is a part of the romance of nature, and it is suffused with the glow that is on the whole face of nature.

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Mr Muir's premises and conclusions may, from passages scattered throughout the text, be summarised as follows:—The fundamental article of the alchemical creed was that nature is in a state of constant mutability, so that one substance might and did, in process of time, grow into another as a seed grows into a plant. But it was conceived that there existed one essence which, containing all the properties of all substances in a refined state, was the original form of matter and the master-key of all mutations—the *one unchangeable thing.* This unchangeable thing, it was supposed, could be made by art, and the alchemists tried to make it. Furthermore, "in alchemical times men imagined the world as a group of appearances resting on the foundation of certain universal principles." There was a universal principle of whiteness with which all white objects were imbued; round objects were imbued with the principle of roundness *(sic)*; sweet substances owed their sweetness to a principle of sweetness conceived to exist apart from the substance, but made manifest to human sense when embodied in the substance. Actuated by these crude and unscientific notions, the alchemist succeeded only

the head of some Jove who, whoever he might be, was at least not an alchemist. No hint is given of the gradual development of chemistry, or of the fact that it was not until the first half of the sixteenth century that alchemical doctrines began to be thrown aside; nor is there any hint that another hundred years elapsed before Boyle declared that the experimental method of investigation was the only sure basis for speculations. The reader finds Mr Muir on one page flouting the old alchemists, and on the next plunging into a discussion of elements and their compounds, without any preface to the effect that in the middle of the seventeenth century the four Aristotelian and alchemical elements were still accepted, until Boyle applied to the term "element" the meaning which chemists now attach to it. Was there no chemist before Boyle? Or was even he a chemist? If a belief in the transmutation of metals be Mr Muir's touchstone for discriminating between alchemist and chemist, then Boyle believed in transmutation, and so did many of his contemporaries and successors — for example, Glauber, Homberg, Kunkel, Stahl, and Boerhave—"of whose earnest desire to arrive at the truth there can be no doubt," observed Von Meyer in his well-known "History of Chemistry." Or if Mr Muir ranks Boyle as a chemist, in spite of his alchemy, how much chemical "bread" must be added to an "intolerable deal" of alchemical "sack" in order to make a chemist? To find the first chemist may we go back to Basil Valentine, who, in his "Triumphwagen des Antimonii," gives what is acknowledged to be a surprising description of an element and its compounds, or must we besmirch with the opprobrious name of alchemist every devotee of "the science" until we come to Lavoisier, leaving poor Priestley a martyr to error and phlogiston by the way? Is it not rather the fact that modern chemistry owes its existence to evolution, the steps in which it would fill many a portly volume to recount? It may be that the mistaken theories of the alchemists had but slight influence on the development of chemical science; but it is incontestable that

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