

THE CHEMICAL “ELEMENTS”



By

M. M. Pattison Muir

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THE CHEMICAL ELEMENTS

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PREFACE.

I HAVE made an attempt to put forth in some kind of orderly sequence a few of the chief guiding conceptions of chemistry ; endeavouring, on the one hand, to avoid technical details, and, on the other hand, to illustrate these conceptions by describing many common facts. I have tried to keep the attention of the reader fixed on the great generalisations of chemistry ; and I have done my best to shew that these generalisations find constant application in the occurrences of everyday life.

M. M. PATTISON MUIR.

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THE STORY OF THE CHEMICAL ELEMENTS.

CHAPTER I.

INTRODUCTION.

ANYONE who observes with some care the material occurrences which are constantly taking place around him must notice, that although these events differ much from one another, very many of them have this in common that in them there is change of substance, or change of form, or change of properties. As a fire burns there is a change of coal, or wood, to smoke, flame, and ashes; although we see no new thing produced when coal gas is burning, yet our sense of smell helps our sense of sight, for we know that if the gas were not changed into some other thing when it is burnt we should smell the unchanged gas; when an oil lamp is burning badly some of the substances that are formed from the oil make known their presence by unbearable odours. From the dry and winter-stricken trees the return of spring calls forth green buds, and summer changes these to leaves, and autumn dyes those leaves in crimson, purple, and gold; the blossoms on the fruit-trees that herald the

near approach of a milder season change after a time into fruits, and on the surface of these fruits the colour deepens as under the influence of the sun new substances are produced within them; the fields are ploughed and the seed is sown, and from these seeds corn and other kinds of grain spring up in due time, and then the pale green ears acquire a warmer hue till the waving of the golden grain tells that the time has come for this cycle of changes to be completed. Water changes to ice, and rain to hail and snow; the mountain side that to-day is dry and silent to-morrow is vocal with the sound of dashing brooks; and the mountains themselves crumble slowly and their rocks are changed to the dust of the plains.

And if we turn to man's dealings with material nature outside himself we shall find that it is hardly an exaggeration to say that the whole of these dealings consist in taking advantage of changes of substance, properties, or form that occur in material things without his intervention, or in accomplishing novel changes by creating conditions different from those that prevail where he does not interfere.

The timber which is used in making houses, furniture, ships, and many other things that enter into our daily lives, is one product of those complicated changes that are brought about by the growing tree in the food it obtains from the air by its leaves and from the soil by its roots. There are plants which change the substances they absorb by their roots and leaves into sugar, and when these plants are crushed and the liquid

part of the sweet juice which exudes is boiled away sugar remains. In the living laboratories of other plants are produced, from materials the same as, or very like, those that the sugar-cane changes into sugar, dye stuffs such as madder and indigo, or sweet-smelling resins such as frankincense and myrrh, or essential oils as cedarwood oil, oil of bergamot, and attar of roses, or gums as gum tragacanth and gum arabic, or such things as guttapercha and indiarubber, or substances such as quinine, morphine, and salicylic acid that afford some relief to those who suffer pain.

Most of the substances that are used as human food are the products of changes that occur in those living organisms, plants and animals. The plants absorb comparatively simple substances from the air and the soil, and from these they build up more complex things such as starch and sugar ; plants are eaten by animals which carry further the building up processes that the plants began ; and both vegetable and animal substances are consumed by man and are changed into the highly complex materials that form the organism which is for ever synthesising itself from simpler kinds of matter, and is constantly being resolved into less complex forms of substance.

The manufacturing industries are so many examples of the intelligent direction to definite ends of changes in material things. Iron ore is brought in the blast furnace under such conditions that the red earthy stone is converted into lumps of cast iron ; and when this iron is melted and air is blown into the fluid mass it undergoes another transmutation into hard, lustrous, malle-

able steel. Sulphur, or it may be pyrites, is burnt in a stream of air, and the suffocating gas so produced is conducted into large leaden chambers where it mixes with steam and with another reddish coloured gas from which it removes oxygen; the product of these changes is oil of vitriol, an acrid, corrosive, liquid that is used in almost every manufacturing process.

Common salt is heated with oil of vitriol, and a mixture of the product with coal and chalk is melted in a furnace; the black solid formed by this operation is lixiviated with water, and when the liquid is evaporated carbonate of soda is obtained. Carbonate of soda is transformed into caustic soda by boiling with milk of lime; and when caustic soda is heated with fat, olive oil, or cottonseed oil, the products are glycerin and soap. Scrap iron is heated with pearl ash and hoofs, horns, or fragments of hides or leather; the product is treated with water, and large, yellow, transparent crystals of yellow prussiate of potash are obtained by filtering this liquid and evaporating it. The yellow prussiate is dissolved in water and a solution of iron in an acid is added to this liquid; the result is the deep blue pigment called Prussian blue. Sand, or finely ground quartz, is mixed with carbonate of soda, or pearlash, and the mixture is melted in pots placed in a very hot furnace; when the melted mass is poured on to a flat metal table a sheet of transparent, colourless, glass is formed.

Coal tar is distilled; a portion of the colourless liquid which distils over is mixed with *aqua fortis*, and the heavy reddish oil, smelling like oil

of almonds, which is produced by this treatment is warmed for some time with iron filings and concentrated vinegar, and is then distilled. The colourless liquid that distils over is called aniline; and from that liquid is produced, by suitable treatment, a vast number of coloured substances wherewith cotton, woollen, and other goods may be dyed every shade and variety of colour, both beautiful and crude.

The juice of grapes acquires new properties after being exposed to the air for a time; the liquid loses some of its sugar, and in place thereof a volatile liquid, endowed with strange powers and potencies, is produced; the juice of the fruit has changed into "wine that maketh glad the heart of man." When barley that has begun to germinate is heated to a proper temperature, and is then mashed with water, and the liquid so produced is mixed with yeast and kept slightly warm, a change occurs similar to that which happens in grape juice exposed to the air; sugar disappears, and alcohol and carbonic acid gas are formed: the decoction of malted barley has been transmuted into beer.

And what is the art of cooking but the intelligent direction of certain possible transmutations in the substance and properties of food-stuffs so as to produce new materials that nourish the body, please the palate, and enliven the wits of man?

The story of chemistry is the story of the unravelling of such changes and transmutations of material things as those that have been referred to in the preceding paragraphs.

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It was supposed in former days that anything might be changed into anything else, provided the proper conditions could be arranged. On this supposition was based the tedious art of alchemy ; for it was not on a vague guess, but on what they took to be a universal law, to wit, the infinite mutability of material things, that the long-suffering, much-enduring, alchemists rested their strange processes. Noticing the profound and unexpected transmutations that occur so frequently in things, the alchemists gave an affirmative answer to the question which these transmutations kept dinning in their ears ;—Can any material thing be changed into any other thing ? And then driven to seek for some stable, unchanging, reality, by the innate longing of humanity for rest, the alchemists hit upon the enticing hypothesis of The One Thing, which they called also the Essence, the Stone of Wisdom, the Blessed Water, the Philosopher's Stone, and many other names.

Those early readers of the story of the changes of material nature found that a language had to be constructed wherein they might express their reading of the legend ; and the fundamental conception of their rendering found expression in such sentences as these :—“ 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.”

“ . . . For 'twere absurd
To think that nature in the earth bred gold

Perfect in the instant ; something went before.
There must be remote matter.

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, basing their work on this conception of a perfect matter which was able to convert to itself all imperfect bodies, the alchemists recognised that much labour was required to gain that perfect matter ; they recognised, as one of themselves stated, that "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." In setting their hands to supply the material conditions favourable to the movement of nature, they were convinced that nature moved in the direction they thought she ought to move in and by ways which they were able to mark out for her progress.

Many centuries passed before the investigators of nature shewed some willingness to accept their true position as parts of the nature they sought to comprehend. Most of the earlier seekers after a knowledge of nature began by building walls each of which marked off one portion of natural occurrences from the rest. I do not suppose they built these walls consciously, rather they thought they saw walls where no barriers were. The alchemists were very busy within their intellectual sheep-pens, as the chemists of to-day are most active in the larger walled

gardens of their intellectual domain; but the alchemists made fewer breaches in their encircling barriers than we make now in ours. And I think we recognise, what our predecessors could not acknowledge, that the territorial divisions which must be established are of our own making, and are made only for the purpose of helping us to understand the infinitely complex whole.

The history of science may be described as the history of the breaking down, and the crumbling away, of artificially constructed barriers. All the great men of science have been famous wall-breakers. The instruments of demolition which these men wielded have been derided by the ignorant wise men who declared the walls would never fall; the noise of the crashing barriers has travelled slowly to the ears of those who did not wish to hear, and in the vacant places solid constructions have continued to be evident to the eyes which did not desire to see.

It is worthy of remark that the central conception of the alchemists, which, nevertheless, led to their pigeon-holed representation of nature, was the unity of natural phenomena. If their arguments were translated into the language of to-day they would be somewhat as follows—Plants grow from seeds, and the plant is a very different thing from the seed; animals become larger, stronger, and more complete as they grow older; the plant may well be called more perfect than the seed, and the full grown animal more perfect than the immature animal; both plants and animals grow, come to their prime, and decay; and there are degrees of perfection in

the animal and vegetable worlds. Now—we may suppose the argument of the alchemist to continue—nature works in simple ways ; man is the crown and glory of creation, and it is foolish to suppose that man cannot understand nature ; to preserve the unity of nature it is necessary that minerals and metals and all inanimate things should grow, and change, from less perfect to more perfect forms ; as there are degrees of perfectness and dignity among living things, so must there be degrees of perfectness and dignity among all things ; some metals disappear in acrid liquids, and these metals are generally easily worn away, they are readily melted and burnt to dross ; but some other metals are not swallowed up by corrosive liquids, nor are they worn away with ease, nor readily changed in the fire ; there are evidently noble and base metals, perfect and imperfect metals ; and as the less perfect seed under proper conditions produces the more perfect plant, and the plant is rendered yet more perfect by cultivation, so the imperfect metals change slowly into those which are more perfect, and this slow process of change can be hastened by man's art and device.

The argument from analogy was pushed by the alchemists further than this. What they said may be rendered somewhat in this way :—It is evident that living things are more perfect than inanimate things ; if therefore there are changes from less perfect to more perfect forms among living things, much more must changes from immature to mature forms be constantly proceeding among dead things like minerals and

metals; and as these minerals and metals are less perfect than plants and animals, it is probable that the plasticity of the minerals and the metals will be greater than the plasticity of living animals and living plants; hence there will not be those marked lines of demarcation in the mineral world which we find in the animal and vegetable worlds; it will be a comparatively easy thing to grow a noble metal like gold from ignoble metals like lead or copper, although it is an impossible thing to change one kind of animal into another or one sort of plant into another sort of plant.

A vague conception of the unity of nature of this kind led to little accurate knowledge; the conception could not be applied strictly and in detail to natural occurrences; all that could be done was to perform a vast number of inaccurate and incomplete experiments, and to state the results in the loose and slipshod language of the vague but sonorous hypothesis which prompted the experiments. And so although the hypothesis postulated the unity of nature there was no unity in the experimental results which were collected to support the hypothesis. The resemblances and the dissimilarities between natural occurrences are not to be discovered by reasoning about an order of nature which exists only in the brain of the reasoner. A man who sets out to discover what is must endeavour to put aside all his notions of what ought to be; it is only when he has gained a solid foundation of verified and accurately stated facts that he may venture to make a definite guess concerning the cause of

the facts he has collected, but unless he makes clearly stated guesses—that is, scientific hypotheses—he will remain a mere collector of half facts and will never become a scientific investigator.

We shall endeavour in the following chapters to trace the methods which chemists have used to elucidate a certain class of changes that material things undergo, and to state and illustrate some of the more important general results they have attained by the application of these methods.

CHAPTER II.

THE CHARACTER OF CHEMICAL CHANGE.

As the changes which material things undergo were examined with some care, a distinction came to be made between those changes wherein the properties and also the composition of the matter affected are modified, and those wherein the composition of the matter is not altered, although its properties are changed.

A few simple experiments will illustrate the more prominent differences between these two kinds of changes.

If a piece of thin, clean, iron wire is held in the hot, non-luminous flame of a Bunsen burner,*

* The Bunsen burner is an ordinary gas jet over which fits a cylindrical metal tube pierced near the lower end with two large holes ; the mixture of air and gas is lighted at

the iron glows and emits light. If the wire is removed from the flame after a few seconds, an examination of the wire will show that the iron has not been changed into anything else so far as can be judged by the senses of sight and touch.

When a few chips of wood are placed in a dry test tube which is then gradually heated by a Bunsen burner, the wood soon darkens in colour, and after some minutes moisture is seen forming on the upper parts of the tube, and something is given off with a very decided odour. If the heating is continued for a few minutes, and a lighted taper is then brought to the mouth of the tube, the vapours that are coming off take fire. The senses of sight and smell assure us that the wood has been changed by heating it, into things which are quite different from wood ; and this conclusion is verified by the test of the lighted taper.

If a few small pieces of sugar are heated in a dry test tube, in the same way as the chips of wood were heated in the last experiment, the sugar chars and gives off badly-smelling vapours, which ignite when a lighted taper is brought to the mouth of the tube after the heating has been continued for some minutes. The sugar is evidently destroyed, and things which are not sugar are formed in its stead.

When a few grains of dry salammoniac are the top of this tube. A considerable volume of air enters through the holes in the metal tube, and when the mixture of gas and air which issues from the top of the tube is ignited, the whole of the gas is completely burnt and a flame is obtained which is very hot, and is not luminous as it is free from particles of unburnt carbon.