LITTLE BLUE BOOK NO. 679
Edited by E. Haldeman-Julius

Chemistry
For Beginners

Hereward Carrington, Ph.D.

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Author of the following Little Blue Books: No. 491, "Psychology for Beginners;" No. 419, "Life: Its Origin and Nature;" No. 524, Death and Its Problems;" No. 493, "New Discoveries in Science;" Nos. 445-446, "Psychical Research" (2 vols.), etc., etc.

HALDEMAN-JULIUS COMPANY
GIRARD, KANSAS

PRINTED IN THE UNITED STATES OF AMERICA

CHEMISTRY FOR BEGINNERS

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PART I

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CHEMISTRY FOR BEGINNERS

PART I

The ancient Greeks, when they looked about them on the world in which they lived, came to the definite conclusion that everything is in a constant state of flux, or change. Things animate and inanimate gradually disintegrated and tended either to disappear (apparently) or to change into other forms of matter. With their true æsthetic sense, they felt it necessary that there should be some *one* permanent thing in the world, underlying all the changes which they saw going on about them, and many of their early speculations were devoted to the nature and constitution of this one "permanent thing." Thales, of Myletus, who flourished about 585 B. C., and who was, perhaps, the first great philosopher and physicist, contended that the essential principle of things,—the substance, or stuff, of all things,—must be *water*. He held the view that, by condensation and rarefaction of water all things rise, and he actually attempted an evolutionary account of the Genesis of Man, Plants and Animals, with this idea as a basis for his thought.

Anaximenes said that *air*, or *ether*, must be the substance of things. Heraclitus regarded *fire* as the most primary element in the universe,—from which all else arises. Anaximander said that the "unlimited"—a sort of boundless, animated mass—is the ultimate substance. Plato, as we know, contended that the permanent reality of things was not anything material at all, but was mind, or *spirit*. Empedocles, (495-435 B. C.) advanced the theory that there are four elements—Earth, Air, Fire and Water. Anaxagoras contended that nothing changed of itself, but that it is caused or made to change, and that *that* which produces these changes is the permanent reality. This he believed to be a sort of mind or universal intelligence (*Nous*), but he regarded this mind as strictly impersonal, as well as immaterial, and did not attempt to answer the difficulty as to how mind can affect matter in any detailed manner.

It was only natural that, prior to the discovery of the laws of the indestructibility of matter and energy, that this sense of "change" should have struck these early thinkers very forcibly, since they had no means of ascertaining that, when matter disappears from our sight, it is not actually destroyed. We now know that, when we burn a candle, the candle disappears, but that the elements composing the candle are merely changed into invisible gaseous compounds, which are no longer visible to the human eye. Lacking delicate instruments of precision, the ancients could not know this; to them, the matter of the candle would have disappeared. Hence, it was only natural that they should seek the ultimate reality behind these changes, and speculate as to its origin and nature.

ALCHEMY

The modern science of chemistry is relatively new. It gradually emerged from alchemy, which practically constituted the chemistry of the middle ages. The objects of alchemy were various: (1) the transmutation of the base metals into gold, by means of the so-called "Philosopher's Stone"; (2) The fixation of Mercury; (3) The discovery of the elixir of Life, etc. These were the purely chemical aspects of alchemy, but we now know that the alchemists had much more than this in mind, in their experimental work, and that they hinted at their true meaning in many of their veiled writings. Many of the higher types of alchemists were also mystics, and when they wrote in chemical symbols, they really concealed their inner meaning; they referred, very largely, to the inner spirit of man, and the methods by which this could be changed or transformed into some higher spiritual being (See "Alchemy Ancient and Modern," by H. Stanley Redgrove; "Alchemy, Its Scope and Romance," by the Rev. J. E. Mercer, etc.) Mr. Foster Damon has lately published a series of articles in which he has brought forward a mass of evidence tending to prove that the alchemists were also deep students of psychic phenomena, and that their experiments relative to the "First Matter" were really experiments in so-called "Materialization!" He has published his findings in a series of articles in the "Occult Review."

MODERN CHEMISTRY

Modern chemistry may be said to begin with Robert Boyle (1626-1691). He defined an element as a substance which could not be decomposed, but which could enter into combination with other elements, giving compounds capable of decomposition into these original elements. The number of elements which were thought to exist varied greatly,—some contending that they were but few in number, others that they were numerous. It must be remembered that all this was before the time of Dalton, and that the atomic theory had not yet been advanced as a scientific hypothesis, since the days of the ancient Greeks, when Democritus and Epicurus had defended this view. The swing of science, at that time was, therefore, toward the materialism of those older writers, and the atomic theories which they had then proposed.

Chemistry is that branch of science which investigates the nature and properties of matter in all its forms. It is, perhaps, the most materialistic of all the sciences, since it deals essentially with matter. Physics deals with forces or energies, or the energies manifested by and through matter, but the two are more or less inter-related—especially of late years, as we shall see. Chemistry is essentially an *experimental* science, and practically everything which has been learned about it has been acquired by means of laboratory experimentation. But here as elsewhere theories have woven together the mass of separate facts, and of them made a consistent and philosophical science.

There are two main divisions of chemistry—inorganic and organic; that is to say, the chemistry of "dead" matter, and the chemistry of "living" or organic substances, Chemical experiments may be for the purpose of *analysis*—discovering the constituents of a given substance; *synthesis*, in which a compound substance is "created" from several simpler ones; or purely *experimental*, in which certain tests are made, and the results or reäctions noted.

MEDIAEVAL CHEMISTRY

As before stated, Chemistry is more or less the direct child of Alchemy; but before the modern, scientific period of chemical research had been reached, two transitional stages were first of all passed through. These were (1) The so-called "Iatro-Chemical" period — the period of medical mysticism; and (2) the "phlogistic" period. A few words will be necessary to explain each of these terms, and the period of chemical development which they covered.

As may be inferred from the name, the iatro-chemical period was one in which attempts were made to combine chemistry and medicine, and make the former serve the latter. All kinds of weird concoctions were tried, and attempts were made to explain, on chemical principles, all the changes and reactions occurring in the body—an attempt which was necessarily futile for the chemistry of that day. However, many important results were achieved, as the consequence of experimentation, and chemical science was on the whole enriched, even though the workers of that day were inspired by totally erroneous views.

The Phlogistic Period takes its name from a hypothetical substance denominated "phlogiston." This was supposed to be an invisible principle or entity, constituting the basis of Fire, and corresponds to the "pure fire" of Zoroaster. The Phlogiston theory was propounded and championed by Stahl, and it was defined by him as follows:

"Phlogiston is . . . a very subtle matter, capable of penetrating the most dense substances; it neither burns, nor glows, nor is visible; it is agitated by an igneous motion, and it is capable of communicating its motion to material particles apt to receive it. The particles when indued with this rapid motion constitute visible fire . . . ."

This conception dominated the whole scientific world for many years. The experimental work undertaken by Scheele and Priestly, however, finally enabled Lavoisier to discover the true nature of "fire"—combustion. In a famous "Memoir," published in 1783, entitled "Reflections Concerning Phlogiston," he showed that all the observed phenomena could be accounted for without the presence of any hypothetical phlogiston; in fact, as he himself says, they "can be better explained without phlogiston than by means of it." His discovery of oxygen, in the atmosphere, was a fundamentally important step in modern chemical science. Hitherto, the air was thought to be a single gas, or a mixture of various gases; but oxygen was unknown as its most important constituent. Lavoisier's discovery finally disposed of the phlogiston idea, and ushered in the new era of scientific chemisty.

It may be thought that undue space has been devoted to this theory of Phlogiston; but anyone reading the history of Chemistry will realize the extent to which this idea completely dominated the minds of men at that time, and how all chemical researches were perverted by it. The discovery of the true nature of combustion was one of the fundamental turning-points in the history of scientific thought.

The material world in which we live is very evidently composed of a variety of substances. At least some of these were soon seen to exist in at least three different states—solid, liquid and gaseous. These seemed to differ radically from one another; ice, water and steam are as different as one can imagine; and yet, somehow, they were the same thing after all; for ice melts and becomes water, and water, when heated, becomes steam. On the contrary, steam cools and becomes water again, and when it is sufficiently cold, will again form ice. There must be some fundamental Thing, therefore, of which water is composed. What is this Thing? How many such Things are there in the world? Are there a limitless number, or only a few? If a certain, limited number, how many? And how discover them? These were questions which naturally occupied the minds of men throughout the ages. No answer was found, however, and it remained for John Dalton to discover and formulate the Law which enabled men to obtain their first glimpse of the nature of the ultimate constitution of matter.

JOHN DALTON

John Dalton (1766-1844) was born in Eaglesfield, in Cumberland (England), and was the son of a poor weaver. Endowed with natural aptitude and an indomitable will, he utilized all possible opportunities for the study of mathematics and natural philosophy. He taught school, while devoting all his spare time to his beloved scientific researches. In fact, he earned his living as a private teacher to the end of his life, never having enough money to pursue his investigations unhampered by material considerations.

It was, of course, well known that mere *mixtures* were entirely different things from chemical *compounds.* We can mix sand and sugar together, but they remain sand and sugar, and can be separated again, having undergone no change. Or we can mix together two liquids or two gases, and they also can again be separated by suitable means. But when two substances chemically combine one with another, then we have some third thing which is entirely different from the original two, and which possesses properties dissimilar from either. Now, what has happened when substances thus combine? What are the laws of such combinations? And what are the ultimate constituents of matter, which render these combinations possible? Dalton was the first to undertake an explanation of these phenomena, backed up by experimental evidence. The historic importance of this cannot be overestimated. As Dr. Raphael Meldola says, in his "Chemistry":—

"The doctrine of equivalence, even in its most elastic form, is still nothing more than a quantitative expression of the facts of chemical composition. Of course, there must be some underlying principle—some explanation of this simplicity of multiplicity. Such explanation was first definitely formulated in 1807-08 by John Dalton, who not only discovered the law of Multiple Proportions, but suggested a theory, the introduction of which marks one of the greatest epochs in the history of Chemistry. The reason why combination takes place in definite proportions by weight, and why, when the same element has more than one equivalent the principle of integral multiples is maintained is, according to Dalton's explanation, because the combination is between the ultimate particles of which elementary matter is composed. This is the notion of the discontinuity or discreteness of matter. The "particles" of which matter is composed—whatever its state of aggregation—are, from Dalton's point of view, ultimate in the sense of being indivisible. For this reason he called them *atoms*."

THE ATOMIC THEORY

Here, then, we have at last the Atomic Theory—the theory, that is, that all matter, in all its stages, is built-up of extremely small particles which are so small, indeed, that they can no longer be sub-divided. They are the ultimate of matter—the "building stones of the Universe"—of which everything, animate and inanimate, is composed.

These atoms were held to be spherical in shape, of a certain definite weight and figure, according to the element or substance in question. Thus: "every particle of water is like every other particle of water, every particle of hydrogen is like every other particle of hydrogen, etc." These ultimate particles—atoms—were held to be indestructible. These atoms all had their own particular *weights*, which might be denoted by number. Hence "atomic weight"

These atoms, then, combine, forming molecules, or compounds of atoms; and molecules make up matter as we see and know it.

Further, most of the matter in the world is composed of a variety of elementary substances, limited in number. When more complex bodies are analyzed or broken-down, these elementary substances are always found. The number of these in Dalton's day was unknown; but they had long been known as *elements*. Elements were, of course, composed of their own particular atoms; while all other substances were made-up of combinations of elements.

THE ELEMENTS

Dalton's views ushered in a new era in chemistry. Prolonged researches were at once undertaken, in order to determine the precise atomic weights—investigations which are being carried on even today. The exact size, shape, texture, etc., of the atom was subject to endless investigation. The nature of chemical combinations (how two elements combine with one another) held the fascinated attention of chemists for a hundred years, and it is only within the past few years that a definite solution has been found, and this has only been rendered possible by the newer views of matter, entirely different from those maintained during the past century.

During the hundred years which have elapsed since Dalton's time, a number of new elements have been discovered, and there are reasons for supposing that there are some yet to discover. It is now believed, however, that there are 92 primary elements, of which Hydrogen has the lowest atomic weight, and Uranium the highest. Typical elements are: Oxygen, Iron, Fluorine, Silver, Sodium, Sulphur, Gold, Zinc, Copper, etc. A complete list may be found in any standard Chemistry.

ATOMIC WEIGHTS

When work was undertaken, to discover the exact atomic weights of these various elements, it was soon found that these could not be expressed in *exact*, whole numbers. Fractions or decimal numbers were nearly always found to exist. Thus, the atomic weight of Hydrogen was not exactly 1, but 1.008; copper was 63.57, etc. For long it was thought that these variations were due to errors of experiment, and renewed attempts were made to reach more accurate conclusions, in which these apparently annoying fractions were absent. But the most painstaking experimental work only served to confirm these results, and still later researches have shown us *why* this is so. It would take us too far afield, however, to go into that question at present.

The various elements were given symbols. for the sake of brevity; some of these represented the first letters of the name of the element; some were the first letters of the Latin word for that element. Thus, Co=Cobolt, S=Sulphur, Ne=Neon, Bi=Bismuth, On the other hand, Fe=Iron (Latin, ferrum), etc. This served greatly to abbreviate chemical language, and at the same time simplified chemical formulæ and equations.

VALENCY

We must now explain one or two terms which are extremely important for understanding what is to follow. The first of these is *Valency*. We know that chemical combinations take placed in fixed proportions by weight; this is known as the "Constancy of Composition." There is always an equivalence noted. This doctrine of equivalence is merely the numerical expression of the definiteness of chemical change. Calculations are made from the point-of-view of combining with a unit-weight of hydrogen (the Unit element). In chemical compounds, then, the doctrine of equivalence says that these atomic weights represent quantities of different elementary substances which are of the same chemical value as measured by their capacity for displacing the same weight of hydrogen.

A new property of the atom is thus brought out, *viz.*, its value as measured by the number of atoms with which it can combine. This property is appropriately described as the "Valency" of the atom. If the atomic weight contains the equivalent once, *i. e.*, if the equivalent and atomic weight are identical, that atom can combine only with one atom of hydrogen, or of chlorine, bromine, etc. The formulæ of the compounds, HCl, HBr, etc., expresses this fact. If the equivalent is contained twice in the atomic weight, then that atom can obviously combine with two atoms of hydrogen, chlorine, etc.; if it is contained three times in the atomic weight, the combining capacity or valency of the atom is three; and so forth.

THE PERIODIC LAW

The work which had been done upon the atomic weights rendered possible one of the most brilliant generalizations of modern times, in this field. This was the *Periodic Law*. In the year 1864, Newlands published a Table containing the various elements arranged in the order of their atomic weights. In a side column the differences between these weights were given, each being deducted from the one next higher in the scale. The next year, Newlands announced his "law of octaves," which he deduced from his arrangement of the elements. He said in part that: "If the elements are arranged in the order of their equivalents, with a few slight transpositions . . . it will be observed that elements, belonging to the same group usually appear on the same horizontal line. . . . It will also be seen that the number of analogous elements generally differ either by seven or by some multiple of seven; in other words, members of the same group stand to each other in the same relation as the extremities of one or more octaves in music."

This pioneer work of Newlands rendered possible the Periodic Law, as finally formulated and worked out in detail by Mendeleeff. Briefly, the Law states that "the properties of an element are a periodic function of its atomic weight."

This is merely another way of saying that if you know the atomic weight of an element, you also know its properties, since these are fixed or invariable. Mendeleeff arranged the elements in various "Groups," according to their atomic weights, and it was found that the properties of the elements periodically recur as the weights of the atoms rise. There were certain empty spaces in Mendeleeff's Table, waiting for new elements which should fit into these empty spaces, if discovered. At the time they had not been discovered; but several of them have been since, and it is a remarkable fact that they invariably fit into his table exhibiting all the properties which they should theoretically exhibit, and might have been predicted to, years before. This is one of the surest confirmations of the accuracy of Mendeleeff's general Law, and is one of the finest generalizations ever made in science.

The conclusion which we may draw from this Law is that there is a definite *relationship* between the chemical elements. How or why this relationship existed was not known at the time, and only became clear half a century later, when the newer discoveries concerning the ultimate constitution of matter rendered this clear.

EARLIER DISCOVERIES

Mendeleeff's Law could not have been formulated had not an immense amount of research work preceded it, and a number of new elements been discovered. Such was, however, the case. Immediately following the great work of Lavoisier, a host of brilliant chemists appeared, and rapid and important advances were made in consequence. Cadmium was discovered by Stromeyer in 1817; lithium in the same year by Arfvedson. Silicon was isolated in 1810 by Berzelius. In 1827, Wohler isolated aluminum; and the same scientist also isolated beryllium the following year. Bromine was discovered by Balard in 1826; iodine, in 1811, by Courtois. Tellurium had been discovered by Muller von Reichenstein in 1782; Berzelius discovered an element closely analogous to it —selenium—in 1817. Elements continued to be added to the list—and then no more! Had every element been discovered? Some were inclined to think so. With the discovery of Radium, by the Curies, however, another whole list of elements was brought to light—all of which have been added to the Table of the Periodic Law.

Meanwhile, further discoveries of the curious properties of matter were being made. For example, it had been noticed that at least three distinct varieties of sulphur existed: (1) A pale yellow, brittle solid; (2) translucent needles; and (3) soft and rubber-like sulphur. These were all different physical varieties of one and the same substance—nevertheless they are all sulphur! This element, then, can assume more than one form, and because of this, the term "allotropic" has been applied, to signify the varieties of appearance which the same substance can be made to assume. A good example of this afforded by charcoal, graphite (or black-lead) and diamond,—which would hardly be suspected of being all the same substance; and yet they are!

ANALYSIS AND SYNTHESIS

Compounds may be broken up into their constituents, during the process of analysis, or they may be made to combine one with another, in synthesis. All the resources of modern science have been brought to bear, in efforts to effect these various alterations or changes. Great heat, extreme cold, chemical reägents, enormous pressures, high vacua, electrical currents and sparks, bombardment with radio-activity, etc.—all have been employed in these chemical investigations. Suitable laboratories have been constructed, encasing immense boilers, huge refrigeration machines, electrical contrivances of all kinds, etc. What tremendous strides have been made in this field during the past century—from the simple grass retorts, flasks and apparatus of a century ago! But this only shows us how tremendous would be our progress could men but learn to work together, in harmony, welded together by a common interest,—instead of butchering one another, or wasting their precious lives and energies in scandals and political intrigues!

But let us return to earth again—to matter —the subject of chemistry!

FORMULAE AND EQUATIONS

We have seen that the various chemical elements combine with one another in certain proportions. In order to express these varied reactions, chemical formulæ have been devised, which can be read at a glance, showing the changes which have taken place in any given combination. When one atom of one element combines with one atom of another, the letters signifying these elements are simply written side by side, thus: HCl. When, however, two atoms of one element combine with one of another, a small figure is placed under and to the right of the element, thus: H_2O. Here we see at a glance that two atoms of hydrogen have combined with one of oxygen, forming water. This is the simplest type of formula, and is often known as the *empirical* formula. There is, however, another way of writing a formula, which is more expressive, thus: $A{=}C{=}{}^{B}_{B}$ This is known as a *structural* or *constitutional* formula, and from it we can see at a glance that A is bivalent, C is quadrivalent, and B univalent. This type of formula shows us more readily than the other the structure of the molecule in question. The complexity of such formulæ naturally increases with the complexity of the molecules, and in many cases may be extremely intricate. Ordinary chemical formulæ, however, are written empirically. Any chemical changes which take place as the result of some reaction are expressed in this manner.

ORGANIC VS. INORGANIC CHEMISTRY

As before stated, chemistry has been divided into two categories—organic and inorganic. It was stated at the time that these divisions represented the chemistry of living and dead matter, respectively. As a matter-of-fact, this description is not quite accurate. This was the older view of the observed facts, because it was believed that some mysterious "vitality" was responsible for the peculiar substances found in living bodies, but the chemist has now succeeded in making, in the laboratory, a number of these substances which were thought to be the result of life only; and in addition has succeeded in making great numbers of organic compounds not found in the living body. Over 150,000 "organic" compounds are now known to the chemist, only a small fraction of which are known to be the product of "vitality." All living things—animal and vegetable—contain carbon, as their most important constituent, so that the modern view of organic chemistry is that it is, very largely, the chemistry of carbon compounds. Whether or not any form of "vitality" exists aside from the living matter studied is a question usually passed over by chemists as beyond their province.

There is no doubt, however, that the human body presents many problems still unexplained by modern chemistry. Take, for example, the miracle of digestion. A potato, a cabbage, an apple, a chicken running about the yard, a piece of candy—all these are eaten by little Mary Jones, and are somehow turned into the body of little Mary Jones, making hair, teeth, eyes, lungs, liver, nerves, brain, etc. The food material is somehow transformed into the living body of the person eating it! Much has been discovered as to the innumerable changes which the food undergoes during the various stages of digestion, but the final result—how this pabulum is converted into bodily tissue—is still largely a mystery. We know, for example, that proteins are broken-up into simpler compounds, the most important of which are the amino-acids. Fats are broken up into fatty acids and glycerine, and substances resembling soaps are formed in the body. Carbohydrates are resolved into levulose, glucose, maltose, etc., which are utilizable by the human system. But just how these substances are converted into bodily tissue is still largely a problem.

ORGANIC COMPOUNDS

The living matter of the body is composed of a variety of substances, of which protoplasm may be taken as typical. This is highly complex, and while it can be imitated by the chemist, its living properties have not been reproduced. (See my book on "Life: Its Origin and Nature," in the present series.) The various secretions and excretions of the body have been studied exhaustively by physiological chemists. *Plants* have also been studied minutely from a similar point-of-view.

A number of important discoveries have resulted from this work, however, and nearly all the essential animal and vegetable substances are at present accessible to artificial synthesis from their very elements. Even protein matter seems to have lost much of its mystery since we have learned from Emil Fischer's work that amino-acids can be combined in the same way as they occur in protein. Compounds of Amino-acids can be obtained, which show all the main reactions of protein substances. Emil Fischer, of Berlin, was the same chemist who, in 1886, discovered how to prepare grape-sugar from glycerine. A considerable number of plant alkaloids have also been artificially prepared in the course of the last five or six decades. The most important coloring matters of plants—for instance, alizarin and indigotin,—are no longer extracted from plants for technical purposes, but are accessible from the products of coal-tar.

CATALYSIS

We now come to a remarkable series of chemical phenomena, which have been much studied during the past century, and which have a bearing upon both organic and inorganic chemistry. More than a century ago, it was discovered that certain chemical substances, which will not normally combine with one another, can be made to do so, if another substance is brought into contact with them. This third substance does not in any way enter into the combination, or share in the reaction; its mere presence seems to bring it about. Thus, oxygen and hydrogen may be mixed together; but if a small amount of "platinum black" be introduced, an explosion of the gases at once occurs. Hydroperoxide is rapidly split into oxygen and water when in contact with "platinum black," etc. These contact-effects are very curious, and have engaged the attention of chemists for a long time. Berzelius is responsible for the term now generally used—*catalysis*. We now speak of catalytic power, catalytic reactions, and so forth.

These catalytic reäctions soon became very important factors in organic chemistry and biology, as well as in the field of inorganic chemistry. In 1833, Payen and Persoz in Paris made the discovery that germinating seeds contain a peculiar contact-substance, which transforms starch into sugar. This substance they named

Diastase. Similar effects were noted to occur elsewhere,—particularly in the protein digestion in the stomach of man and the higher animals. We now know that many such reäctions occur in the living cells, and the chemical phenomena of life have had an entirely new light thrown upon them by these findings.

ENZYMES

They led, in short, to the discovery of the so-called *Enzymes.* Until relatively recently, the expression "Ferment" was used, as the phenomena were akin to fermentation. Soluble ferments are termed Enzymes, and the phenomena connected with living protoplasm are now known to be largely due to the action of a group of Enzymes. These are catalytic substances, are of a limited field of action, of colloidal nature, and very little resistant to heat. When injected into the veins of animals, other substances are at once manufactured, which have been called "anti-enzymes," which have the effect of offsetting their action. Sunlight and ultra-violet light destroy enzymes. Their importance in the field of biology may be discerned when it is stated that researches have shown us that, *e. g.*, the amount of protein digested in a certain time is not proportional to the quantity of the enzyme itself, but to the square root of the quantity of the enzyme.

HORMONES

These enzymes must not be confused with other internal secretions, such as the *hor-*

mones. These are substances generated by the so-called ductless glands,—such as the thyroid, the pituitary, the adrenals, etc. These ductless glands secrete substances which when absorbed into the blood-stream greatly affect the life of the body, its functions, its structure and its growth, and to a certain extent at least the mental life. Researches in this field are of relatively recent origin, but of extreme importance. I have mentioned this subject at greater length in my little book on "Life: Its Origin and Nature," in the present series, and the interested reader may refer to such a work as Dr. Louis Berman's "The Glands Regulating Personality," for further details.

There is no matter anywhere in the universe, living or dead, which modern chemistry does not attempt to analyze. Not only in the laboratory are these tests undertaken, with minute particles of matter. The very earth on which we dwell has been subjected to chemical analysis, and so have the stars, the planets and suns which circle around us in space,—perhaps separated from us by many millions of miles. The ability to do this is assuredly one of the greatest achievements of the mind of man, and represents one of the greatest conquests over nature, over time and space.

CHEMISTRY OF THE EARTH

The water constituting our seas, lakes, rivers and oceans; the air constituting our atmosphere; the materials of the earth on which we dwell—clay, rock, mud, granite, metals—

all have been analyzed, and their chemical composition accurately determined. It has even been possible to measure the density and weight of our earth, and to calculate its age, from the salinity of its oceans. (Of this more anon.) But when it comes to ascertaining with great accuracy the chèmical constitution of distant stars, *that* seems a feat well-nigh impossible, and unless the process by means of which it is accomplished were explained, it might very well be disbelieved.

How, then, can this be accomplished?

For our explanation, we must go back to a classical experiment made by Sir Isaac Newton. He proved that white light, when made to pass through a glass prism, is split up into a variety of colors. There are seven primary colors, constituting the visible spectrum. These are red, orange, yellow, green, blue, indigo and violet. We now know that there are both "ultra-violet" and "infra-red" rays, invisible to the eye, above and below the spectrum, but this was not known until long after. The essential fact is that light, when passed through a prism, is split up into its primary colors.

THE SPECTROSCOPE

The instruments employed were necessarily soon refined, and the modern "spectroscope" resulted,—a piece of apparatus of great delicacy, capable of studying these effects with exactitude.

The function of the spectroscope is to receive a sample of light and to separate its different components. In a broad sense, everything that can be seen has a spectrum—flame, blue sky, red hot metal, the sun, the electric spark, etc. We can at once divide these things into two classes, (1) those that are visible because they emit light of their own; (2) those that can be seen only by virtue of their reflecting, diffusing or transmitting light that falls upon them from other sources. The former are called "emission spectra" and the latter "absorption spectra."

Now, when practically any spectrum be examined in this way, it will be seen that certain bands of shadow, or dark lines, cut across the light spectrum, in absorption spectra, these are the things which are studied. Thus, when we observe the spectrum of the sun, or of many of the stars, we find that the spectrum may be described as a continuous spectrum, from which a number of narrow lines are omitted. The lines consequently appear dark on a bright ground. These are called "absorption lines."

Just why these dark lines appear would take us too far afield to explain here; suffice it to say that every chemical element has been found to yield a different spectrum; that is to say, the number and arrangement of these dark lines will indicate the presence of the element in question. Whenever certain lines appear on the spectrum, we may be sure that such-and-such an element is present. Thus, Kirchhoff first proved that two of these dark lines were caused by the white light of the solar photosphere having suffered absorption at the sun, by passing through a stratum of glowing sodium vapor. Sodium was thus shown to be present in the sun. Other elements were similarly identified, not only in the sun, but in the millions of stars in the heavens. By means of spectrum analysis, therefore, it has been possible to detect and identify the various chemical elements present in any given sun or star in space.

ASTRO-PHYSICS AND CHEMISTRY

In this manner, about forty terrestrial elements have been shown to exist in the sun. Carbon, oxygen, iron, silicon, nickel, etc., exist in the sun just as they do on our earth. On the other hand, many elements, such as mercury, nitrogen, sulphur, and boron do not appear, although they are found in abundance on the earth. Yet several elements were shown to exist in the sun which up to that time had not been discovered here. Helium is an example. (From the Greek, *Helios*, the Sun). And yet, when attention was directed to this element, it was soon found in our earth, and is today so common that helium gas is employed to inflate balloons, in preference to hydrogen, on account of its non-combustibility.

SPECTRUM ANALYSIS

Spectrum analysis, then. tells us the precise chemical constitution of the various suns, or stars, in space, and it also tells us that these stars are incapable of supporting life such as we know it. As Dr. E. Walter Maunder says, in his book, "Are the Planets Inhabited?":

"The application of the spectroscope to astronomy is not confined to the sun, but reaches much further. The stars also yield their spectra, and we are compelled to recognize that they also are suns; intensely heated globes of glowing gas, rich in the same elements as those familiar to us on the Earth and known by their spectral lines to be present on the sun. The stars, therefore, cannot themselves be inhabited worlds any more than the sun, and at a stroke the whole of the celestial luminaries within the furthest range of our most powerful telescopes are removed from our present search (*i. e.*, whether or not life may exist upon them). Only those members of our solar system that shine by reflecting the light of the sun can be cool enough for habitation, the true stars cannot be inhabited, for, whatever their quality and order, they are all suns, and must necessarily be in far too highly heated a condition to be the abode of life. Many of them may, perhaps, be a source of light and heat to attendant planets, but there is no single instance in which such a planet has been directly observed; no dark, non-luminous body has ever been actually seen in attendance on a star. Many double or multiple stars are known, but these are all instances in which one sun-like body is revolving round another of the same order. We see no body shining by reflected light outside the limits of the solar system. Planets to the various stars may exist in countless numbers, but they are invisible to us. . . ."

Thus has the science of chemistry been wafted across hundreds of millions of miles of space, and has enabled us to tell, not only the composition of these distant bodies, but also the degree of their habitability, and their possible sources as abodes of life.

INDUSTRIAL CHEMISTRY

But if all this is of purely theoretical interest, the chemistry of our earth and its products is of immense practical importance. It may be *applied*, and the day of "industrial chemistry" is here. By studying the chemistry of soils, the farmer has been enabled to increase both the quality and the quantity of his crops. By employing artificial fertilizers, production has been greatly increased. An analysis of the earth's strata has thrown great light upon geology. Analytical chemistry has proved of service in criminology,—by enabling experts to detect poisons, blood-stains, etc. (Unfortunately, it has also been applied detrimentally, in the manufacture of explosives, poison gases, etc., employed in war.) Dentistry and surgery have been rendered painless by the discovery of anæsthetics. The wholesale manufacture of illuminating gas has been instrumental in lighting millions of homes. The manufacture of steel, paper, ink, dyes, stains, paints, perfumes, bread, and a thousand-and-one useful articles of our daily lives has been rendered possible by the progress of chemical research. Artificial preservatives have enabled us to keep foodstuffs for long periods of time. By the discovery of the nature of iron rust, bridges, buildings, etc., have been preserved intact. Our food, our clothes, our very lives themselves, may be said to depend upon modern chemistry for their maintenance and preservation.

Let us pass in rapid summary a few of these results. Let us take, for example, *glass*.

Glass is made from silica. What is silica? It is a substance of remarkable infusibility, and is the oxide of silicon, which is a near neighbor of carbon. Glass is made by mixing sand, limestone and carbonate of soda or potash in large pots, and melting them together at a temperature of 3,500° F. The sand, being silica, combines with the lime of the carbonate of lime, to give silicate of lime, and with the soda (or potash) of the carbonate of soda (or potash) to give silicate or soda (or potash). These two silicates become intimately fused and form the glass, which remains liquid in the pot. It is then blown into various shapes or rolled into thin sheets for window glass. We know what an effect windows have had upon the comforts of modern life!

By mixing together several metals, *alloys* are obtained which very often have properties quite different from those of the substances which compose them. Thus: Bronze is a mixture of copper and tin; plumber's solder is an alloy of lead and tin; brass is an alloy of copper and zinc; ferro-silicon is a union of silicon and iron, etc. Many of these alloys are of great utility in the various arts and sciences, as well as in manufacture.

Gilding, silvering and electroplating have been rendered possible by modern chemistry. Alumina and porcelain have been produced. Alumina is the oxide of aluminum. One variety of clay known as "kaolin" is employed in the manufacture of porcelain. China and earthenware are made by very similar processes. Alcohol, wine and beer have depended upon scientific chemistry for their production. Ice can be manufactured artificially by means of freezing mixtures. The manufacture of oxygen gas has rendered possible high altitude flights by aviators. Camphor can now be manufactured, instead of depending upon nature's resources for this valuable substance. Woodpulp, starch and sugar owe much to modern chemistry. Artificial silk is manufactured on a large scale. Soaps and fats have likewise been developed in vast quantities. The perfume milady uses has been developed by the chemist. Colors and dyes now constitute an enormous industry. For our medicines we depend upon the chemist, when visiting the nearest drug store. These are but a few examples, which might be lengthened almost indefinitely, illustrating the extent to which we are dependent upon modern chemistry, in our daily lives.

And chemistry is capable of explaining many things which would be unintelligible without its aid. Let us take a simple example by way of illustration. You have probably noticed that a frozen potato has a characteristic sugary taste. The cause of it is this: the potato contains in its tissues a great quantity of starch, as well as a diastase capable of transforming this starch at the moment of its sprouting. These two substances are kept apart by the membrane of the tissue. But if a frost occurs, the ice tears this membrane, and the starch comes in contact with this diastase and is, therefore, transformed into sugar, just as it is when the sprouting of the potato begins.

INSTRUMENTS OF RESEARCH

These applications of chemistry have been rendered possible by improved methods of investigation, a greater knowledge of the nature of matter itself, and the perfection of scientific instruments of precision. These instruments are so much finer and more delicate than our senses that they have been the means of disclosing the actual constitution of matter. A man might sit and "meditate" upon the nature of matter for years, but he would be no nearer an actual *proof* as to its constitution than he was at the beginning. It is generally conceded that Aristotle possessed one of the finest minds the world has ever known; yet any school boy today knows more of the ultimate constitution of matter than did Aristotle. The reason for this is that instrumental methods of research have enabled us to see and measure the ultimate properties of matter,—which our unaided senses would never permit us to do. The development of science in other fields, therefore, has rendered possible the rapid growth of chemistry, during the past century; and chemistry, in turn, has assisted the other sciences. Thus does all knowledge work hand in hand, when co-operation is rendered possible!

SALINITY OF THE OCEANS

I referred some time ago to the calculations which had been made as to the age of the earth, based upon researches as to the salinity of the ocean. As we know, the water of all the oceans is salt water; only that of rivers and lakes is "fresh." But the degree of the ocean's saltness is not quite constant. It varies, since evaporation is constantly taking place; sediments are deposited; and above all vast quantities of water are being poured into the ocean by the hundreds of rivers which flow into it, carrying all kinds of earthy deposits which have been washed away by their passage through the river-beds over which they flow.

In 1715, the famous astronomer Edmund Halley published a paper entitled "A Short Account of the Saltness of the Ocean . . . . With a Proposal by Help Thereof to Discover the Age of the World." No definite progress was made, however, until 1899, when Joly pointed out that of the many elements which enter into the composition of salt water, sodium alone tends to accumulate. All the others are sooner or later rejected, associating themselves with the detrital sediments, or forming chemical or organic sediments by their ultimate precipitation. He accordingly used sodium as the index of the age of the oceans. He assumed that the annual increase of sodium has been more or less constant, being added to every year by the quantity washed into the ocean by the rivers. How long a period of time would it require to reach its present degree of saltness? Taking all the oceans as one, the volume of the ocean is approximately 320,000,000 cubic miles. Its density (according to Murray) is 1.026. On the basis of these figures, Joly, and after him Sollas and others, calculated that it would require from 80 to 150 million years for the present degree of salinity to be reached. Ninety or a hundred million years would be a fair estimate. Indirectly therefore, the study of the salinity of the oceans has thrown light upon the age of our earth, and its chemical constitution throughout geological ages.

THE NEWER CHEMISTRY

It will be seen, therefore, that chemistry has not only proved of the utmost practical value to mankind, but that it has been instrumental in solving some of the greatest enigmas confronting the mind of man, and in settling some philosophical and even theological questions. (The age of the earth, the composition and habitability of distant stars, etc.) Attempts have been made to account for life itself along purely physico-chemical lines. And all this was attempted—and in part even rendered possible—before the ultimate constitution of matter was known! During the present generation, an entirely new light has been thrown upon this central problem, and the ideas of centuries have been discarded. Let us trace the final steps of research in this direction, and see how the latest findings of modern science have thrown light upon the world-old problem of the ultimate constitution of matter.

RADIO-ACTIVITY

We saw at the very beginning of this little book that, from time immemorial, something corresponding to Atoms were regarded as the ultimate "building stones" of the universe—tiny particles, incapable of diversion, beyond which it was impossible to go. Beginning with Epicurus and Democritus, this idea took scientific form; it was held by many philosophers throughout the ages; it formed the basis of Dalton's atomic theory, and was assumed by the Periodic Law. It was not until the last years of the preceding century that this idea was called into question. The discovery of *radium*, by the Curies, caused a sensation in the scientific world. How account for the phenomena observed? Radium seemed to give off energy continuously, without losing any; heat was constantly being radiated without lessening the original amount. Had the secret of perpetual motion been discovered? What was happening? The discovery of other radio-active elements only tended to increase the problem, instead of solving it. Here was some new property of matter, hitherto unsuspected, going on before the eyes of chemists, which they could not understand or explain.

INTRA-ATOMIC ENERGY

Professor E. Rutherford, of M'Gill University, Canada, was among the first to propose a new and startling theory. He said: Suppose that the atoms are *not* indivisible? Suppose that they are capable of being split-up into something still smaller and finer? If the atoms themselves are being disintegrated, immense quantities of energy would probably be available—"intra-atomic energy"—which would account for the results obtained. It is true that we should no longer have our stable atoms; they would vanish and be represented by something else. And that "something" would no longer be matter, in the sense that we now understand it; but we could account for the observed facts (radio-activity, etc.), and we can then endeavor to discover what atoms are resolved into later on. This theory was soon proved to be true; atoms were shown to be divisible, and capable of being split-up into something still smaller, which were no longer "matter" in the old sense. Matter, in short, had technically disappeared, and had been resolved into its component parts. This being so, the question at once arose: Of what is matter (the atom) composed?

THE THEORY OF MATTER

Without going into great detail, or attempting to trace the history of the various discoveries which led up to it, it may now be stated definitely that matter is built-up of *electricity*. For the proof of this, the scientific world has to thank Sir J. J. Thomson, who first popularized this view in his book "Electricity and Matter." He was closely seconded by Sir Oliver Lodge, Sir William Crookes, and many other eminent scientists. On this view, matter totally disappears, as such; it becomes super-sensible;

it is resolved into energy. Electricity and the ether somehow are responsible for matter, but just *how* was not at the time understood.

It took many years of patient research to arrive at definite conclusions; in fact, it may be said that definite conclusions have not even yet been reached,—though more or less unanimity of opinion exists as to the structure of atoms. The new theory of matter is that each atom is built up of negative "electrons," and positive "protons"—the former revolving round the latter in orbits analogous to those of our solar system. The protons, positively charged, remain in the center of the atom; the electrons, negatively charged, circle about them, just as our planets circle about the sun. The number of these protons and electrons varies according to the nature of the element. Hydrogen representing unity, has but one electron revolving around a single proton; helium comes next, with two; and so on, up the scale, until we reach uranium, which has ninety-two. The positive and the negative charges balance one another in all stable atoms; and when this is not the case, the atom tends to go to pieces or disintegrate; electrons are shot off, which join some other atom, and radio-activity results. The nature of the element itself is accordingly changed, and may even be so fundamentally changed by this process that it turns into something else; *i. e.*, the transmutation of one element into another has taken place, as dreamed of by the alchemists! Hence we often hear of the "new alchemy." This, in rough outline, is the modern conception of the atom, and of the constitution of matter generally.

WITHIN THE ATOM

Let us now endeavor to analyze the atom more closely, in the light of these newer researches. We have seen that the electrons revolve round the central protons. These protons are probably composed of electrons and hydrogen nuclei. The total central "sun"—to use the astronomical analogy—is known as the nucleus. The relative sizes of these bodies may be appreciated when it is stated that they have been compared to the sizes of the planets, relative to the distances separating them from the sun. Vast spaces exist, therefore, within the atom, in which the electrons revolve. Yet the atoms themselves are inconceivably small! The following quotation from Bertrand Russell's "A. B. C. of Atoms" will perhaps make this clear. He says:

"It will help us to picture the world of atoms if we have, to begin with, some idea of the size of these units. Let us begin with a gramme of hydrogen (1-453 of a pound), which is not a very large quantity. How many atoms will it contain? If the atoms were made up into bundles of a million-million, and then into a million-million of these bundles, we should have about a gramme and a half of hydrogen. That is to say, the weight of one atom of hydrogen is about a million-millionth of a million-millionth of a gramme and a half. Other atoms weigh more than the atom of hydrogen, but not enormously more; an atom of oxygen weighs sixteen times as much, an atom of lead rather more than 200 times as much. *Per contra*, an electron weighs very much less than a hydrogen atom; it takes about 1,850 electrons to weigh as much as one hydrogen atom.

ELECTRONS

The inner rings of electrons give rise to X-rays when they are disturbed, and it is chiefly by means of X-rays that their constitution is studied. The nucleus itself is the source of radio-activity. . . . The most complex atom known is that of uranium, which has, in its normal state, 92 electrons revolving round the nucleus, while the nucleus itself probably consists of 238 hydrogen nuclei and 146 electrons. . . .

Under normal conditions, when the hydrogen atom is unelectrified, the electron simply continues to go round and round the nucleus, just as the earth continues to go round and round the sun. The electron may move in any one of a certain set of orbits, some larger, some smaller, some circular, some elliptical. But when the atom is undisturbed, it has a preference for the smallest of the circular orbits, in which the distance between the nucleus and the electron is about half a hundred-millionth of a centimetre. It goes round in this tiny orbit with very great rapidity; in fact its velocity is about a hundred-and-thirty-fourth of the velocity of light, which is 186,000 miles a second. Thus the electron manages to cover about 1,400 miles in every second. To do this, it has to go round its tiny orbit about seven thousand million times in a millionth of a second; that is to say, in a millionth of a second it has to live through about seven thousand million of its "years"!

Such figures, such facts, stagger the imagination. The mind of man cannot really conceive them. And yet we know that they are not fanciful; calculations and indirect measurements have been made with the utmost exactitude. And, after all, the infinitely little is no more staggering than the infinitely great. For in astronomy we know that stars billions of miles distant from us in space have been seen, measured, photographed and analyzed. Tens of thousands of "light-years" separate us from them (*i. e.*, space which would be travelled by light, speeding at 186,000 miles a second). And yet the structure of the atom closely resembles the planetary system! Is the whole Universe, great and small, built according to the same plan, according to the same model? It would appear so!

It will be seen from the above that the modern science of chemistry overlaps other sciences in many directions—physics, biology, astronomy, etc. These sciences are to a certain extent now inter-woven and inter-blended. Where the one ends and the other begins it is hard to say. Again we see the importance of co-operation in these various fields of inquiry!

THE NATURE OF MATTER

These newer researches in chemistry have finally enabled us to realize the ultimate constitution of matter; we have seen that it is composed of atoms, but these atoms themselves are complex things; they in turn are composed of electrons, and in the last analysis matter may be said to be non-existent! It has been resolved into electricity. But this conception of matter has also enabled us to explain many things before inexplicable—chemical combination, radio-activity, and what not. The world-old problem as to the nature of matter has at last been solved. It now devolves upon the physicist to explain the ultimate nature of electricity!

Matter, then, in a sense, can dissociate, disintegrate, dematerialize. It can also integrate, materialize, come into existence. Matter can be made to vanish and reappear. The old law of the "indestructibility of matter" is not valid, as generally understood. Matter can be resolved into energy. And this energy is radiated into space, or converted into other modes of energy, and finally into heat, which is in turn radiated into the surrounding medium. The whole universe seems to resemble a clock, which has been wound-up, and is slowly running down. Even the law of the "conservation of energy" has been called into question (See LeBon, "The Evolution of Matter," and "The Evolution of Forces"). Is the whole Universe in some mysterious manner also being wound-up? Or does it move in vast cycles, of alternate action and inaction, as the Hindu philosophers have always contended? These are ultimate questions which only the science of the future can solve!

PART II

We have now made a rapid survey of the history of chemistry, and traced the evolution of thought which has rendered possible the newer conceptions of the constitution of matter. We must now say a few words as to the nature of the various elements themselves, and give a brief account of some modern researches. A few practical hints as to experiments may also be of interest to the reader.

We have seen that when two chemical elements combine, some third substance is formed, quite different in properties from the original two. Thus, water seems to us entirely different from the two invisible gases which compose it —oxygen and hydrogen. Yet a simple experiment will prove that such is the case. We can decompose water by means of an electric current, when the original gases are given off, in the proportion of two to one—hydrogen collecting at the negative pole, and oxygen at the positive. This process can be kept up until all the water has been decomposed, and only hydrogen and oxygen gases remain. This process of electrical decomposition is known as *electrolysis.*

THE ELEMENTS

Hydrogen is the lightest of all gases, and, as we have seen, the simplest of the elements, in its constitution. Like all gases, it can be liquefied, and even frozen solid into a hard lump, like ice. On the other hand, even the densest of substances can be liquefied, and even turned into gas or vapor at a sufficiently high temperature. (Gases are rendered liquid or solid at a very low temperature.) Liquid air, for example, is so cold that when a can of it is set upon a block of ice the liquid air boils and gives off "steam"!

Oxygen gas constitutes about one-fifth of our atmospheric air (the other four parts being nitrogen) and is the most essential element in supporting life. Without it, life would at once become extinct. All forms of combustion take place very rapidly in oxygen, and the combustion going on within the human body is no exception to this rule. The atmospheric nitrogen acts as a sort of dilutant, being an inert gas. If a mouse be placed under a jar of pure oxygen gas, it will often run round and round until it drops dead with exhaustion. In an atmosphere of pure oxygen, we should soon burn up, and live our lives too rapidly.

Oxygen has a great tendency to combine with various other elements, particularly metals. Thus, iron rust is due to the combination of oxygen with iron; the blackening and tarnishing of cooking pots is due to the slow oxidation of copper, etc.

In breathing, we take in oxygen from the air, which combines with the gases in the lungs, forming carbon dioxide. Curiously enough, plants thrive upon this gas, which is so poisonous to human beings, and in turn give off oxygen. Hence the value of plants and flowers in the room, or in any densely inhabited area.

Nitrogen is a very important element, entering into many chemical combinations. It forms the basis of explosives, used in war. Until relatively recently, this element had to be obtained from substances dug out of the ground, but during the late war, methods were devised for obtaining it from the air. "Nitrogen fixation" became possible. If it had not been for this discovery, Germany would have had to give up the war in 1916, at the latest.

Nitrogen combines with hydrogen, to form ammonia; with oxygen and water, to form nitric acid; with nitric acid and potash to form gunpowder, etc.

Certain oxides combine with water, to form what are known as *bases*. Bases can combine with acids, giving rise to *salts*.

Carbon is an essential element for all living matter; it combines with oxygen, to yield carbonic acid; with hydrogen, giving rise to a great number of compounds, such as benzene, turpentine, etc. Marsh gas, illuminating gas, acetylene, etc., are compounds of carbon.

Chlorine is a very important element, combining with sodium to form common salt. As we have seen, the saltness of the sea is due to this substance. Owing to its great affinity for hydrogen, chlorine decomposes water, setting free oxygen. The result of this is that a mixture of chlorine and water has strong bleaching qualities.

Chlorine also combines with hydrogen to form hydrochloric acid. On the other hand, it shows little sympathy for oxygen, forming but few stable compounds. Chloroform, so long useful in surgical anaesthesia, is a compound of chlorine, carbon and hydrogen.

Sulphur can assume a variety of appearances (allotrophic variation) as we have seen. Sulphuric acid, etc., are its compounds. The latter substance is used for bleaching violets, but the flowers become violet again when put into an ammonia solution.

Sodium is a metal, which burns when thrown into water. It is the other constituent of common salt, and enters into a great variety of combinations. Carbonate of soda is one of these.

Many of the elements—iron, nickel, gold, platinum, silver, etc.,—are too well known to necessitate more than a brief note. It is interesting to notice, however, that there are certain "family relations" among a number of the elements. Thus, sodium and potassium are "related"; and so are barium, strontium and calcium. Again, oxygen and sulphur have a number of points in common,—although one is a solid and the other a gas! Gold stands rather apart from the rest.

Two very interesting groups should be mentioned in this place. The first is the group of *rare gases*—argon, neon, etc.,—most of which have been discovered only recently. They are inert, and partly on account of this, and partly on account of their rarity, their discovery was so long delayed.

RADIO-ACTIVITY

The second list is the *radio-active* group of elements,—uranium, radium, thorium, actinium, etc. These all possess their characteristic properties in varying degrees,—giving off alpha, beta and gamma rays. A certain mysterious "emanation" is also emitted by radio-active elements, but the study of these rays and their influence would take us into the realm of "physics," and would more properly belong to a book on physics than in the present, dealing with chemistry.

One very interesting fact should, however, be mentioned in this connection, and that is the evolution of matter which has been observed, as the result of spectrum analysis. We have heard much of organic evolution, meaning the evolution of life upon our planet. It is equally true that there is an inorganic evolution, in which the gradual development of chemical elements may similarly be traced. Thus, it has been noticed that, in the hottest stars, (gaseous) the fewest chemical elements exist; in those of medium temperature (metallic), more elements are found, while in those having the lowest temperature (carbon stars) the greatest number of chemical elements are to be distinguished. This seems to prove that the higher the temperature, the fewer the elements, which in turn leads to the conclusion that all elements are perhaps ultimately ONE — as Sir William Crookes suggested many years ago. As these stars cool, more and more elements seem to be "crystallized out," so to say,—the many being formed from the fewer. The newer researches on the constitution of matter render this idea all the more plausible.

THE ORIGIN OF LIFE

Just here, it might be well to point out the late place occupied by life, in this process of inorganic evolution. The Absolute Zero of inter-stellar space is about —273°C. On the other hand, the temperature of the hottest stars is more than 30,000°! (Argo, Alnitam etc.) The temperature must fall from this to a few degrees above Zero (the boiling point of water), before life can become manifest at all. Life as we know it can only exist between the boiling and the freezing points of water. This point is only reached towards the very end of the scale. It has therefore been said that, cosmically speaking, life is only a "flash in the pan" between two eternities"—but for us that flash in the pan is everything!

The question of the origin of life upon our planet has been discussed at some length in my little book on "Life: Its Origin and Nature," in the present series. It may be of interest to mention here, however, a few of the experiments which have been made upon the artificial creation of life, by means of inorganic chemicals, since these properly fall into place in a book devoted to chemistry.

Dr. H. Charlton Bastian, of England, conducted many years ago a series of experiments of this character, in which he claimed to have made living matter from sterilized chemicals. He placed these in a glass bottle which had been sterilized, heated the contents until steam issued from the mouth of the flask, and then instantly sealed up the bottle, preventing the entrance of air. The flasks were then put away for several days, and at the end of that time were found, upon examination, to contain living organisms.

"CREATION" OF LIFE

The reader will probably be interested in knowing the precise chemical formulæ employed for obtaining these astonishing results. Several such formulæ are given in Dr. Bastian's book, "The Evolution of Life," of which the following are samples:

Sodium silicate, two, or three, drops.
Ammonium phosphate, four, or six, grains.
Dilute phosphoric acid, four, or six, drops.
Distilled water, one fluid ounce.

Another formula is the following:

Sodium silicate, three drops.
Liquor ferri pernitratis, eight drops.
Distilled water, one fluid ounce.

The reader can try the experiment for himself. It should be said, however, that although Dr. Bastian's results were undoubted, they failed to carry conviction to the scientific world as a whole, since they contended that some experimental error must have crept in, to render these results possible; and it is significant, in this connection, that the same experiments repeated by other men failed to yield the same striking results.

Chemistry, then, enters into practically every field of inquiry—the constitution of human beings, no less than that of metals, earths or distant nebulæ. Everything material in the Universe is composed of elements, of atoms, and these atoms are built-up, as we have seen, of electrons, which are not matter at all, but bundles of energy. No two particles of matter in the world actually touch, or come near to touching one another. It is an interesting thought, when one stops to think of it that, for instance, the steel pillar supporting a "sky-scraper," upon which rests an enormous weight (the whole of the superstructure) is not really dense and solid, as it appears, but is actually tenuous and shadowy, and that no two of its atoms ever touch one another; they are separated by relatively vast spaces, filled only with the hypothetical "ether." The whole weight of the building may be said to rest upon nothing,—or at most upon ether, which thus bears its strain!

THE ETHER

And what is this ether? Is it matter in some subtle form, or is it something else? We do not know; certainly it is no form of matter known to us, and its reality has even been called into question of late. Hæckel, as we know, contended ("The Riddle of the Universe") that the ether must be like some extremely attenuated jelly, and that a sphere of it the size of the earth would probably weigh about 250 pounds! Such crude conceptions have long since been given up. It is far more subtle than this. Is it analogous to the finest gas? Some have thought so; and yet Sir Oliver Lodge, one of the greatest authorities upon the ether, has contended that it is more dense and solid than platinum or gold, and that matter represents mere "bubbles" within this dense medium, capable of moving freely through it. In support of this view, he has cited (in his "Ether of Space" the enormous gravitational pull of the earth upon the moon, *e. g.*, or of the sun upon the earth. The mass of the earth is approximately 6,000 trillion tons; that of the moon one-eightieth of this. From these data, the gravitational pull of the earth upon the moon can be calculated; and, regarding this, Sir Oliver says:

"A pillar of steel which could transmit this force, provided it could sustain a tension of 40 tons to the square inch, would have a diameter of about 400 miles. . . . If this force were to be transmitted by a forest of weightless pillars, each a square foot in cross section, with a tension of 30 tons to the square inch throughout, there would have to be 5 million million of them."

Calculating the gravitational pull of the sun on the earth, in a similar manner, it was calculated that the strain in this case would have to be borne by "a million million round rods or pillars each thirty feet in diameter."

It may readily be seen, then, from these figures, that something enormously dense, apparently, must exist in order to bear this strain, and this must be the ether. And yet no physical experiments have proved to us the existence of the ether; we only infer its presence, and say that it *must* exist, in order to account for certain phenomena observed in physics. It was, I think, Lord Kelvin who remarked that no man could believe in the ether without at the same time believing it to possess opposite and contradictory properties! Indeed, it would seem so!

CHEMISTRY AND META-PHYSICS

Such speculations as these lead us far afield, into the realm of mathematics, metaphysics and ultimate realities. Even the most material of all the sciences—chemistry—leads thither when pushed to its final analysis. The visible, sensible universe vanishes, and is replaced by the invisible, the super-sensible. Yet science has been our guide throughout. William James once remarked that metaphysics is merely "persistently clear thinking." It endeavors to find the ultimate causes of things, the *noumena* behind phenomena, the reality behind appearances. The physical world in which we live is a world of phenomena only; real in a sense, and for all practical purposes, and yet the greatest of all unrealities in another sense. It is a mere world of appearances; a phantasmagoria of fleeting shapes and shadows. We feel that reality must exist somehow, somewhere; yet we can never find it. We can no more find it by chemical analysis than we can discover the mind and soul of man by dissecting the brains of corpses, —or even by vivisection! Something always escapes us—the Soul of Things, the Ultimate Reality, the Great Unknown.

Such thoughts and speculations as these, however, need not occupy the mind of the practical chemist. For him, atoms exist, so do elements, so does "matter." For practical, daily life, we certainly have to live *as if* matter existed, and the chemist has to proceed with his work upon the assumption that matter actually does exist—it is "real." Certain it is that the practical furtherance and application of this science can come about in no other way. Chemistry has revolutionized our lives; it has penetrated all fields of commerce and industry, and its practical application has rendered possible and pleasant the lives of countless thousands of persons now living upon our planet. We owe more to chemistry than we can ever repay —or rather to those brilliant and unselfish men who have built up the modern science of chemistry. It is my hope that the present little book may in some degree have helped to emphasize this fact.