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THE STORY OF ALCHEMY AND THE BEGINNINGS OF CHEMISTRY

by

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Fellow and Formerly Prælector in Chemistry of Gonville and Caius College,

Cambridge

With Eighteen Illustrations

New and Enlarged Edition

Hodder and Stoughton

London, New York, Toronto

[Illustration: AN ALCHEMICAL LABORATORY]

"It is neither religious nor wise to judge that

of which you know nothing."

\_A Brief Guide to the Celestial Ruby\_, by PHILALETHES (17th century)

\* \* \* \* \*

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PREFACE.

The Story of Alchemy and the Beginnings of Chemistry is very

interesting in itself. It is also a pregnant example of the contrast

between the scientific and the emotional methods of regarding nature;

and it admirably illustrates the differences between well-grounded,

suggestive, hypotheses, and baseless speculations.

I have tried to tell the story so that it may be intelligible to the

ordinary reader.

M.M. PATTISON MUIR.

CAMBRIDGE, November 1902.

\* \* \* \* \*

NOTE TO NEW EDITION.

A few small changes have been made. The last chapter has been

re-written and considerably enlarged.

M.M.P.M.

FARNHAM, September 1913.

\* \* \* \* \*

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CHAPTER I

THE EXPLANATION OF MATERIAL CHANGES GIVEN BY THE GREEK THINKERS.

For thousands of years before men had any accurate and exact knowledge

of the changes of material things, they had thought about these

changes, regarded them as revelations of spiritual truths, built on

them theories of things in heaven and earth (and a good many things in

neither), and used them in manufactures, arts, and handicrafts,

especially in one very curious manufacture wherein not the thousandth

fragment of a grain of the finished article was ever produced.

The accurate and systematic study of the changes which material things

undergo is called chemistry; we may, perhaps, describe alchemy as the

superficial, and what may be called subjective, examination of these

changes, and the speculative systems, and imaginary arts and

manufactures, founded on that examination.

We are assured by many old writers that Adam was the first alchemist,

and we are told by one of the initiated that Adam was created on the

sixth day, being the 15th of March, of the first year of the world;

certainly alchemy had a long life, for chemistry did not begin until

about the middle of the 18th century.

No branch of science has had so long a period of incubation as

chemistry. There must be some extraordinary difficulty in the way of

disentangling the steps of those changes wherein substances of one

kind are produced from substances totally unlike them. To inquire how

those of acute intellects and much learning regarded such occurrences

in the times when man's outlook on the world was very different from

what it is now, ought to be interesting, and the results of that

inquiry must surely be instructive.

If the reader turns to a modern book on chemistry (for instance, \_The

Story of the Chemical Elements\_, in this series), he will find, at

first, superficial descriptions of special instances of those

occurrences which are the subject of the chemist's study; he will

learn that only certain parts of such events are dealt with in

chemistry; more accurate descriptions will then be given of changes

which occur in nature, or can be produced by altering the ordinary

conditions, and the reader will be taught to see certain points of

likeness between these changes; he will be shown how to disentangle

chemical occurrences, to find their similarities and differences; and,

gradually, he will feel his way to general statements, which are more

or less rigorous and accurate expressions of what holds good in a

large number of chemical processes; finally, he will discover that

some generalisations have been made which are exact and completely

accurate descriptions applicable to every case of chemical change.

But if we turn to the writings of the alchemists, we are in a

different world. There is nothing even remotely resembling what one

finds in a modern book on chemistry.

Here are a few quotations from alchemical writings [1]:

[1] Most of the quotations from alchemical writings, in this

book, are taken from a series of translations, published in

1893-94, under the supervision of Mr A.E. Waite.

"It is necessary to deprive matter of its qualities in order to

draw out its soul.... Copper is like a man; it has a soul and a

body ... the soul is the most subtile part ... that is to say, the

tinctorial spirit. The body is the ponderable, material,

terrestrial thing, endowed with a shadow.... After a series of

suitable treatments copper becomes without shadow and better than

gold.... The elements grow and are transmuted, because it is their

qualities, not their substances which are contrary." (Stephanus of

Alexandria, about 620 A.D.)

"If we would elicit our Medecine from the precious metals, we must

destroy the particular metalic form, without impairing its

specific properties. The specific properties of the metal have

their abode in its spiritual part, which resides in homogeneous

water. Thus we must destroy the particular form of gold, and

change it into its generic homogeneous water, in which the spirit

of gold is preserved; this spirit afterwards restores the

consistency of its water, and brings forth a new form (after the

necessary putrefaction) a thousand times more perfect than the

form of gold which it lost by being reincrudated." (Philalethes,

17th century.)

"The bodily nature of things is a concealing outward vesture."

(Michael Sendivogius, 17th century.)

"Nothing of true value is located in the body of a substance, but

in the virtue ... the less there is of body, the more in

proportion is the virtue." (Paracelsus, 16th century.)

"There are four elements, and each has at its centre another

element which makes it what it is. These are the four pillars of

the world.... It is their contrary action which keeps up the

harmony and equilibrium of the mundane machinery." (Michael

Sendivogius.)

"Nature cannot work till it has been supplied with a material: the

first matter is furnished by God, the second matter by the sage."

(Michael Sendivogius.)

"When corruptible elements are united in a certain substance,

their strife must sooner or later bring about its decomposition,

which is, of course, followed by putrefaction; in putrefaction,

the impure is separated from the pure; and if the pure elements

are then once more joined together by the action of natural heat,

a much nobler and higher form of life is produced.... If the

hidden central fire, which during life was in a state of

passivity, obtain the mastery, it attracts to itself all the pure

elements, which are thus separated from the impure, and form the

nucleus of a far purer form of life." (Michael Sendivogius.)

"Cause that which is above to be below; that which is visible to

be invisible; that which is palpable to become impalpable. Again

let that which is below become that which is above; let the

invisible become visible, and the impalpable become palpable. Here

you see the perfection of our Art, without any defect or

diminution." (Basil Valentine, 15th century.)

"Think most diligently about this; often bear in mind, observe and

comprehend, that all minerals and metals together, in the same

time, and after the same fashion, and of one and the same

principal matter, are produced and generated. That matter is no

other than a mere vapour, which is extracted from the elementary

earth by the superior stars, or by a sidereal distillation of the

macrocosm; which sidereal hot infusion, with an airy sulphurous

property, descending upon inferiors, so acts and operates as that

there is implanted, spiritually and invisibly, a certain power and

virtue in those metals and minerals; which fume, moreover,

resolves in the earth into a certain water, wherefrom all metals

are thenceforth generated and ripened to their perfection, and

thence proceeds this or that metal or mineral, according as one of

the three principles acquires dominion, and they have much or

little of sulphur and salt, or an unequal mixture of these; whence

some metals are fixed--that is, constant or stable; and some are

volatile and easily changeable, as is seen in gold, silver,

copper, iron, tin, and lead." (Basil Valentine.)

"To grasp the invisible elements, to attract them by their

material correspondences, to control, purify, and transform them

by the living power of the Spirit--this is true Alchemy."

(Paracelsus.)

"Destruction perfects that which is good; for the good cannot

appear on account of that which conceals it.... Each one of the

visible metals is a concealment of the other six metals."

(Paracelsus.)

These sayings read like sentences in a forgotten tongue.

Humboldt tells of a parrot which had lived with a tribe of American

Indians, and learnt scraps of their language; the tribe totally

disappeared; the parrot alone remained, and babbled words in the

language which no living human being could understand.

Are the words I have quoted unintelligible, like the parrot's prating?

Perhaps the language may be reconstructed; perhaps it may be found to

embody something worth a hearing. Success is most likely to come by

considering the growth of alchemy; by trying to find the ideas which

were expressed in the strange tongue; by endeavouring to look at our

surroundings as the alchemists looked at theirs.

Do what we will, we always, more or less, construct our own universe.

The history of science may be described as the history of the

attempts, and the failures, of men "to see things as they are."

"Nothing is harder," said the Latin poet Lucretius, "than to separate

manifest facts from doubtful, what straightway the mind adds on of

itself."

Observations of the changes which are constantly happening in the sky,

and on the earth, must have prompted men long ago to ask whether there

are any limits to the changes of things around them. And this question

must have become more urgent as working in metals, making colours and

dyes, preparing new kinds of food and drink, producing substances with

smells and tastes unlike those of familiar objects, and other pursuits

like these, made men acquainted with transformations which seemed to

penetrate to the very foundations of things.

Can one thing be changed into any other thing; or, are there classes

of things within each of which change is possible, while the passage

from one class to another is not possible? Are all the varied

substances seen, tasted, handled, smelt, composed of a limited number

of essentially different things; or, is each fundamentally different

from every other substance? Such questions as these must have pressed

for answers long ago.

Some of the Greek philosophers who lived four or five hundred years

before Christ formed a theory of the transformations of matter, which

is essentially the theory held by naturalists to-day.

These philosophers taught that to understand nature we must get

beneath the superficial qualities of things. "According to

convention," said Democritus (born 460 B.C.), "there are a sweet and a

bitter, a hot and a cold, and according to convention there is

colour. In truth there are atoms and a void." Those investigators

attempted to connect all the differences which are observed between

the qualities of things with differences of size, shape, position, and

movement of atoms. They said that all things are formed by the

coalescence of certain unchangeable, indestructible, and impenetrable

particles which they named atoms; the total number of atoms is

constant; not one of them can be destroyed, nor can one be created;

when a substance ceases to exist and another is formed, the process is

not a destruction of matter, it is a re-arrangement of atoms.

Only fragments of the writings of the founders of the atomic theory

have come to us. The views of these philosophers are preserved, and

doubtless amplified and modified, in a Latin poem, \_Concerning the

Nature of Things\_, written by Lucretius, who was born a century before

the beginning of our era. Let us consider the picture given in that

poem of the material universe, and the method whereby the picture was

produced.[2]

[2] The quotations from Lucretius are taken from Munro's

translation (4th Edition, 1886).

All knowledge, said Lucretius, is based on "the aspect and the law of

nature." True knowledge can be obtained only by the use of the senses;

there is no other method. "From the senses first has proceeded the

knowledge of the true, and the senses cannot be refuted. Shall reason,

founded on false sense, be able to contradict [the senses], wholly

founded as it is on the senses? And if they are not true, then all

reason as well is rendered false." The first principle in nature is

asserted by Lucretius to be that "Nothing is ever gotten out of

nothing." "A thing never returns to nothing, but all things after

disruption go back to the first bodies of matter." If there were not

imperishable seeds of things, atoms, "first-beginnings of solid

singleness," then, Lucretius urges, "infinite time gone by and lapse

of days must have eaten up all things that are of mortal body."

The first-beginnings, or atoms, of things were thought of by Lucretius

as always moving; "there is no lowest point in the sum of the

universe" where they can rest; they meet, clash, rebound, or sometimes

join together into groups of atoms which move about as wholes. Change,

growth, decay, formation, disruption--these are the marks of all

things. "The war of first-beginnings waged from eternity is carried on

with dubious issue: now here, now there, the life-bringing elements of

things get the mastery, and are o'ermastered in turn; with the funeral

wail blends the cry which babies raise when they enter the borders of

light; and no night ever followed day, nor morning night, that heard

not, mingling with the sickly infant's cries, the attendants' wailings

on death and black funeral."

Lucretius pictured the atoms of things as like the things perceived by

the senses; he said that atoms of different kinds have different

shapes, but the number of shapes is finite, because there is a limit

to the number of different things we see, smell, taste, and handle; he

implies, although I do not think he definitely asserts, that all atoms

of one kind are identical in every respect.

We now know that many compounds exist which are formed by the union of

the same quantities by weight of the same elements, and, nevertheless,

differ in properties; modern chemistry explains this fact by saying

that the properties of a substance depend, not only on the kind of

atoms which compose the minute particles of a compound, and the number

of atoms of each kind, but also on the mode of arrangement of the

atoms.[3] The same doctrine was taught by Lucretius, two thousand

years ago. "It often makes a great difference," he said, "with what

things, and in what positions the same first-beginnings are held in

union, and what motions they mutually impart and receive." For

instance, certain atoms may be so arranged at one time as to produce

fire, and, at another time, the arrangement of the same atoms may be

such that the result is a fir-tree. The differences between the

colours of things are said by Lucretius to be due to differences in

the arrangements and motions of atoms. As the colour of the sea when

wind lashes it into foam is different from the colour when the waters

are at rest, so do the colours of things change when the atoms whereof

the things are composed change from one arrangement to another, or

from sluggish movements to rapid and tumultuous motions.

[3] See the chapter \_Molecular Architecture\_ in the \_Story of

the Chemical Elements\_.

Lucretius pictured a solid substance as a vast number of atoms

squeezed closely together, a liquid as composed of not so many atoms

less tightly packed, and a gas as a comparatively small number of

atoms with considerable freedom of motion. Essentially the same

picture is presented by the molecular theory of to-day.

To meet the objection that atoms are invisible, and therefore cannot

exist, Lucretius enumerates many things we cannot see although we know

they exist. No one doubts the existence of winds, heat, cold and

smells; yet no one has seen the wind, or heat, or cold, or a smell.

Clothes become moist when hung near the sea, and dry when spread in

the sunshine; but no one has seen the moisture entering or leaving the

clothes. A pavement trodden by many feet is worn away; but the minute

particles are removed without our eyes being able to see them.

Another objector urges--"You say the atoms are always moving, yet the

things we look at, which you assert to be vast numbers of moving

atoms, are often motionless." Him Lucretius answers by an analogy.

"And herein you need not wonder at this, that though the

first-beginnings of things are all in motion, yet the sum is seen to

rest in supreme repose, unless when a thing exhibits motions with its

individual body. For all the nature of first things lies far away from

our senses, beneath their ken; and, therefore, since they are

themselves beyond what you can see, they must withdraw from sight

their motion as well; and the more so, that the things which we can

see do yet often conceal their motions when a great distance off.

Thus, often, the woolly flocks as they crop the glad pastures on a

hill, creep on whither the grass, jewelled with fresh dew, summons or

invites each, and the lambs, fed to the full, gambol and playfully

butt; all which objects appear to us from a distance to be blended

together, and to rest like a white spot on a green hill. Again, when

mighty legions fill with their movements all parts of the plains,

waging the mimicry of war, the glitter lifts itself up to the sky, and

the whole earth round gleams with brass, and beneath a noise is raised

by the mighty tramplings of men, and the mountains, stricken by the

shouting, echo the voices to the stars of heaven, and horsemen fly

about, and suddenly wheeling, scour across the middle of the plains,

shaking them with the vehemence of their charge. And yet there is some

spot on the high hills, seen from which they appear to stand still and

to rest on the plains as a bright spot."

The atomic theory of the Greek thinkers was constructed by reasoning

on natural phenomena. Lucretius constantly appeals to observed facts

for confirmation of his theoretical teachings, or refutation of

opinions he thought erroneous. Besides giving a general mental

presentation of the material universe, the theory was applied to many

specific transmutations; but minute descriptions of what are now

called chemical changes could not be given in terms of the theory,

because no searching examination of so much as one such change had

been made, nor, I think, one may say, could be made under the

conditions of Greek life. More than two thousand years passed before

investigators began to make accurate measurements of the quantities of

the substances which take part in those changes wherein certain

things seem to be destroyed and other totally different things to be

produced; until accurate knowledge had been obtained of the quantities

of the definite substances which interact in the transformations of

matter, the atomic theory could not do more than draw the outlines of

a picture of material changes.

A scientific theory has been described as "the likening of our

imaginings to what we actually observe." So long as we observe only in

the rough, only in a broad and general way, our imaginings must also

be rough, broad, and general. It was the great glory of the Greek

thinkers about natural events that their observations were accurate,

on the whole, and as far as they went, and the theory they formed was

based on no trivial or accidental features of the facts, but on what

has proved to be the very essence of the phenomena they sought to

bring into one point of view; for all the advances made in our own

times in clear knowledge of the transformations of matter have been

made by using, as a guide to experimental inquiries, the conception

that the differences between the qualities of substances are connected

with differences in the weights and movements of minute particles; and

this was the central idea of the atomic theory of the Greek

philosophers.

The atomic theory was used by the great physicists of the later

Renaissance, by Galileo, Gassendi, Newton and others. Our own

countryman, John Dalton, while trying (in the early years of the 19th

century) to form a mental presentation of the atmosphere in terms of

the theory of atoms, rediscovered the possibility of differences

between the sizes of atoms, applied this idea to the facts concerning

the quantitative compositions of compounds which had been established

by others, developed a method for determining the relative weights of

atoms of different kinds, and started chemistry on the course which it

has followed so successfully.

Instead of blaming the Greek philosophers for lack of quantitatively

accurate experimental inquiry, we should rather be full of admiring

wonder at the extraordinary acuteness of their mental vision, and the

soundness of their scientific spirit.

The ancient atomists distinguished the essential properties of things

from their accidental features. The former cannot be removed,

Lucretius said, without "utter destruction accompanying the

severance"; the latter may be altered "while the nature of the thing

remains unharmed." As examples of essential properties, Lucretius

mentions "the weight of a stone, the heat of fire, the fluidity of

water." Such things as liberty, war, slavery, riches, poverty, and the

like, were accounted accidents. Time also was said to be an accident:

it "exists not by itself; but simply from the things which happen, the

sense apprehends what has been done in time past, as well as what is

present, and what is to follow after."

As our story proceeds, we shall see that the chemists of the middle

ages, the alchemists, founded their theory of material changes on the

difference between a supposed essential substratum of things, and

their qualities which could be taken off, they said, and put on, as

clothes are removed and replaced.

How different from the clear, harmonious, orderly, Greek scheme, is

any picture we can form, from such quotations as I have given from

their writings, of the alchemists' conception of the world. The Greeks

likened their imaginings of nature to the natural facts they observed;

the alchemists created an imaginary world after their own likeness.

While Christianity was superseding the old religions, and the

theological system of the Christian Church was replacing the

cosmogonies of the heathen, the contrast between the power of evil and

the power of good was more fully realised than in the days of the

Greeks; a sharper division was drawn between this world and another

world, and that other world was divided into two irreconcilable and

absolutely opposite parts. Man came to be regarded as the centre of a

tremendous and never-ceasing battle, urged between the powers of good

and the powers of evil. The sights and sounds of nature were regarded

as the vestments, or the voices, of the unseen combatants. Life was at

once very real and the mere shadow of a dream. The conditions were

favourable to the growth of magic; for man was regarded as the measure

of the universe, the central figure in an awful tragedy.

Magic is an attempt, by thinking and speculating about what we

consider must be the order of nature, to discover some means of

penetrating into the secret life of natural things, of realising the

hidden powers and virtues of things, grasping the concealed thread of

unity which is supposed to run through all phenomena however seemingly

diverse, entering into sympathy with the supposed inner oneness of

life, death, the present, past, and future. Magic grows, and gathers

strength, when men are sure their theory of the universe must be the

one true theory, and they see only through the glasses which their

theory supplies. "He who knows himself thoroughly knows God and all

the mysteries of His nature," says a modern writer on magic. That

saying expresses the fundamental hypothesis, and the method, of all

systems of magic and mysticism. Of such systems, alchemy was one.

CHAPTER II.

A SKETCH OF ALCHEMICAL THEORY.

The system which began to be called \_alchemy\_ in the 6th and 7th

centuries of our era had no special name before that time, but was

known as \_the sacred art, the divine science, the occult science, the

art of Hermes\_.

A commentator on Aristotle, writing in the 4th century A.D., calls

certain instruments used for fusion and calcination "\_chuika organa\_,"

that is, instruments for melting and pouring. Hence, probably, came

the adjective \_chyic\_ or \_chymic\_, and, at a somewhat later time, the

word \_chemia\_ as the name of that art which deals with calcinations,

fusions, meltings, and the like. The writer of a treatise on

astrology, in the 5th century, speaking of the influences of the stars

on the dispositions of man, says: "If a man is born under Mercury he

will give himself to astronomy; if Mars, he will follow the profession

of arms; if Saturn, he will devote himself to the science of alchemy

(\_Scientia alchemiae\_)." The word \_alchemia\_ which appears in this

treatise, was formed by prefixing the Arabic \_al\_ (meaning \_the\_) to

\_chemia\_, a word, as we have seen, of Greek origin.

It is the growth, development, and transformation into chemistry, of

this \_alchemia\_ which we have to consider.

Alchemy, that is, \_the\_ art of melting, pouring, and transforming,

must necessarily pay much attention to working with crucibles,

furnaces, alembics, and other vessels wherein things are fused,

distilled, calcined, and dissolved. The old drawings of alchemical

operations show us men busy calcining, cohobating, distilling,

dissolving, digesting, and performing other processes of like

character to these.

The alchemists could not be accused of laziness or aversion to work in

their laboratories. Paracelsus (16th century) says of them: "They are

not given to idleness, nor go in a proud habit, or plush and velvet

garments, often showing their rings on their fingers, or wearing

swords with silver hilts by their sides, or fine and gay gloves on

their hands; but diligently follow their labours, sweating whole days

and nights by their furnaces. They do not spend their time abroad for

recreation, but take delight in their laboratories. They put their

fingers among coals, into clay and filth, not into gold rings. They

are sooty and black, like smiths and miners, and do not pride

themselves upon clean and beautiful faces."

In these respects the chemist of to-day faithfully follows the

practice of the alchemists who were his predecessors. You can nose a

chemist in a crowd by the smell of the laboratory which hangs about

him; you can pick him out by the stains on his hands and clothes. He

also "takes delight in his laboratory"; he does not always "pride

himself on a clean and beautiful face"; he "sweats whole days and

nights by his furnace."

Why does the chemist toil so eagerly? Why did the alchemists so

untiringly pursue their quest? I think it is not unfair to say: the

chemist experiments in order that he "may liken his imaginings to the

facts which he observes"; the alchemist toiled that he might liken the

facts which he observed to his imaginings. The difference may be put

in another way by saying: the chemist's object is to discover "how

changes happen in combinations of the unchanging"; the alchemist's

endeavour was to prove the truth of his fundamental assertion, "that

every substance contains undeveloped resources and potentialities, and

can be brought outward and forward into perfection."

Looking around him, and observing the changes of things, the alchemist

was deeply impressed by the growth and modification of plants and

animals; he argued that minerals and metals also grow, change,

develop. He said in effect: "Nature is one, there must be unity in all

the diversity I see. When a grain of corn falls into the earth it

dies, but this dying is the first step towards a new life; the dead

seed is changed into the living plant. So it must be with all other

things in nature: the mineral, or the metal, seems dead when it is

buried in the earth, but, in reality, it is growing, changing, and

becoming more perfect." The perfection of the seed is the plant. What

is the perfection of the common metals? "Evidently," the alchemist

replied, "the perfect metal is gold; the common metals are trying to

become gold." "Gold is the intention of Nature in regard to all

metals," said an alchemical writer. Plants are preserved by the

preservation of their seed. "In like manner," the alchemist's argument

proceeded, "there must be a seed in metals which is their essence; if

I can separate the seed and bring it under the proper conditions, I

can cause it to grow into the perfect metal." "Animal life, and human

life also," we may suppose the alchemist saying, "are continued by the

same method as that whereby the life of plants is continued; all life

springs from seed; the seed is fructified by the union of the male and

the female; in metals also there must be the two characters; the union

of these is needed for the production of new metals; the conjoining of

metals must go before the birth of the perfect metal."

"Now," we may suppose the argument to proceed, "now, the passage from

the imperfect to the more perfect is not easy. It is harder to

practise virtue than to acquiesce in vice; virtue comes not naturally

to man; that he may gain the higher life, he must be helped by grace.

Therefore, the task of exalting the purer metals into the perfect

gold, of developing the lower order into the higher, is not easy. If

Nature does this, she does it slowly and painfully; if the exaltation

of the common metals to a higher plane is to be effected rapidly, it

can be done only by the help of man."

So far as I can judge from their writings, the argument of the

alchemists may be rendered by some such form as the foregoing. A

careful examination of the alchemical argument shows that it rests on

a (supposed) intimate knowledge of nature's plan of working, and the

certainty that simplicity is the essential mark of that plan.

That the alchemists were satisfied of the great simplicity of nature,

and their own knowledge of the ways of nature's work, is apparent from

their writings.

The author of \_The New Chemical Light\_ (17th century) says:

"Simplicity is the seal of truth.... Nature is wonderfully simple, and

the characteristic mark of a childlike simplicity is stamped upon all

that is true and noble in Nature." In another place the same author

says: "Nature is one, true, simple, self-contained, created of God,

and informed with a certain universal spirit." The same author,

Michael Sendivogius, remarks: "It may be asked how I come to have this

knowledge about heavenly things which are far removed beyond human

ken. My answer is that the sages have been taught by God that this

natural world is only an image and material copy of a heavenly and

spiritual pattern; that the very existence of this world is based upon

the reality of its heavenly archetype.... Thus the sage sees heaven

reflected in Nature as in a mirror, and he pursues this Art, not for

the sake of gold or silver, but for the love of the knowledge which it

reveals."

The \_Only True Way\_ advises all who wish to become true alchemists to

leave the circuitous paths of pretended philosophers, and to follow

nature, which is simple; the complicated processes described in books

are said to be the traps laid by the "cunning sophists" to catch the

unwary.

In \_A Catechism of Alchemy\_, Paracelsus asks: "What road should the

philosopher follow?" He answers, "That exactly which was followed by

the Great Architect of the Universe in the creation of the world."

One might suppose it would be easier, and perhaps more profitable, to

examine, observe, and experiment, than to turn one's eyes inwards with

the hope of discovering exactly "the road followed by the Great

Architect of the Universe in the creation of the world." But the

alchemical method found it easier to begin by introspection. The

alchemist spun his universe from his own ideas of order, symmetry, and

simplicity, as the spider spins her web from her own substance.

A favourite saying of the alchemists was, "What is above is as what is

below." In one of its aspects this saying meant, "processes happen

within the earth like those which occur on the earth; minerals and

metals live, as animals and plants live; all pass through corruption

towards perfection." In another aspect the saying meant "the human

being is the world in miniature; as is the microcosm, so is the

macrocosm; to know oneself is to know all the world."

Every man knows he ought to try to rise to better things, and many men

endeavour to do what they know they ought to do; therefore, he who

feels sure that all nature is fashioned after the image of man,

projects his own ideas of progress, development, virtue, matter and

spirit, on to nature outside himself; and, as a matter of course, this

kind of naturalist uses the same language when he is speaking of the

changes of material things as he employs to express the changes of his

mental states, his hopes, fears, aspirations, and struggles.

The language of the alchemists was, therefore, rich in such

expressions as these; "the elements are to be so conjoined that the

nobler and fuller life may be produced"; "our arcanum is gold exalted

to the highest degree of perfection to which the combined action of

nature and art can develop it."

Such commingling of ethical and physical ideas, such application of

moral conceptions to material phenomena, was characteristic of the

alchemical method of regarding nature. The necessary results were;

great confusion of thought, much mystification of ideas, and a

superabundance of \_views\_ about natural events.

When the author of \_The Metamorphosis of Metals\_ was seeking for an

argument in favour of his view, that water is the source and primal

element of all things, he found what he sought in the Biblical text:

"In the beginning the spirit of God moved upon the face of the

waters." Similarly, the author of \_The Sodic Hydrolith\_ clenches his

argument in favour of the existence of the Philosopher's Stone, by the

quotation: "Therefore, thus saith the Lord; behold I lay in Zion for a

foundation a Stone, a tried Stone, a precious corner Stone, a sure

foundation. He that has it shall not be confounded." This author works

out in detail an analogy between the functions and virtues of the

\_Stone\_, and the story of man's fall and redemption, as set forth in

the Old and New Testaments. The same author speaks of "Satan, that

grim pseudo-alchemist."

That the attribution, by the alchemists, of moral virtues and vices to

natural things was in keeping with some deep-seated tendency of human

nature, is shown by the persistence of some of their methods of

stating the properties of substances: we still speak of "perfect and

imperfect gases," "noble and base metals," "good and bad conductors of

electricity," and "laws governing natural phenomena."

Convinced of the simplicity of nature, certain that all natural events

follow one course, sure that this course was known to them and was

represented by the growth of plants and animals, the alchemists set

themselves the task, firstly, of proving by observations and

experiments that their view of natural occurrences was correct; and,

secondly, of discovering and gaining possession of the instrument

whereby nature effects her transmutations and perfects her operations.

The mastery of this instrument would give them power to change any

metal into gold, the cure of all diseases, and the happiness which

must come from the practical knowledge of the supreme secret of

nature.

The central quest of alchemy was the quest of an undefined and

undefinable something wherein was supposed to be contained all the

powers and potencies of life, and whatever makes life worth living.

The names given to this mystical something were as many as the

properties which were assigned to it. It was called \_the one thing,

the essence, the philosopher's stone, the stone of wisdom, the

heavenly balm, the divine water, the virgin water, the carbuncle of

the sun, the old dragon, the lion, the basilisk, the phoenix\_; and

many other names were given to it.

We may come near to expressing the alchemist's view of the essential

character of the object of their search by naming it \_the soul of all

things\_. "Alchemy," a modern writer says, "is the science of the soul

of all things."

The essence was supposed to have a material form, an ethereal or

middle nature, and an immaterial or spiritual life.

No one might hope to make this essence from any one substance,

because, as one of the alchemists says, "It is the attribute of God

alone to make one out of one; you must produce one thing out of two

by natural generation." The alchemists did not pretend to create gold,

but only to produce it from other things.

The author of \_A Brief Guide to the Celestial Ruby\_ says: "We do not,

as is sometimes said, profess to create gold and silver, but only to

find an agent which ... is capable of entering into an intimate and

maturing union with the Mercury of the base metals." And again: "Our

Art ... only arrogates to itself the power of developing, through the

removal of all defects and superfluities, the golden nature which the

baser metals possess." Bonus, in his tract on \_The New Pearl of Great

Price\_ (16th century), says: "The Art of Alchemy ... does not create

metals, or even develop them out of the metallic first-substance; it

only takes up the unfinished handicraft of Nature and completes it....

Nature has only left a comparatively small thing for the artist to

do--the completion of that which she has already begun."

If the essence were ever attained, it would be by following the course

which nature follows in producing the perfect plant from the imperfect

seed, by discovering and separating the seed of metals, and bringing

that seed under the conditions which alone are suitable for its

growth. Metals must have seed, the alchemists said, for it would be

absurd to suppose they have none. "What prerogative have vegetables

above metals," exclaims one of them, "that God should give seed to the

one and withhold it from the other? Are not metals as much in His

sight as trees?"

As metals, then, possess seed, it is evident how this seed is to be

made active; the seed of a plant is quickened by descending into the

earth, therefore the seed of metals must be destroyed before it

becomes life-producing. "The processes of our art must begin with

dissolution of gold; they must terminate in a restoration of the

essential quality of gold." "Gold does not easily give up its nature,

and will fight for its life; but our agent is strong enough to

overcome and kill it, and then it also has power to restore it to

life, and to change the lifeless remains into a new and pure body."

The application of the doctrine of the existence of seed in metals led

to the performance of many experiments, and, hence, to the

accumulation of a considerable body of facts established by

experimental inquiries. The belief of the alchemists that all natural

events are connected by a hidden thread, that everything has an

influence on other things, that "what is above is as what is below,"

constrained them to place stress on the supposed connexion between the

planets and the metals, and to further their metallic transformations

by performing them at times when certain planets were in conjunction.

The seven principal planets and the seven principal metals were called

by the same names: \_Sol\_ (gold), \_Luna\_ (silver), \_Saturn\_ (lead),

\_Jupiter\_ (tin), \_Mars\_ (iron), \_Venus\_ (copper), and \_Mercury\_

(mercury). The author of \_The New Chemical Light\_ taught that one

metal could be propagated from another only in the order of

superiority of the planets. He placed the seven planets in the

following descending order: Saturn, Jupiter, Mars, Sol, Venus,

Mercury, Luna. "The virtues of the planets descend," he said, "but do

not ascend"; it is easy to change Mars (iron) into Venus (copper), for

instance, but Venus cannot be transformed into Mars.

Although the alchemists regarded everything as influencing, and

influenced by, other things, they were persuaded that the greatest

effects are produced on a substance by substances of like nature with

itself. Hence, most of them taught that the seed of metals will be

obtained by operations with metals, not by the action on metals of

things of animal or vegetable origin. Each class of substances, they

said, has a life, or spirit (an essential character, we might say) of

its own. "The life of sulphur," Paracelsus said, "is a combustible,

ill-smelling, fatness.... The life of gems and corals is mere

colour.... The life of water is its flowing.... The life of fire is

air." Grant an attraction of like to like, and the reason becomes

apparent for such directions as these: "Nothing heterogeneous must be

introduced into our magistery"; "Everything should be made to act on

that which is like it, and then Nature will perform her duty."

Although each class of substances was said by the alchemists to have

its own particular character, or life, nevertheless they taught that

there is a deep-seated likeness between all things, inasmuch as the

power of \_the essence\_, or \_the one thing\_, is so great that under its

influence different things are produced from the same origin, and

different things are caused to pass into and become the same thing.

In \_The New Chemical Light\_ it is said: "While the seed of all things

is one, it is made to generate a great variety of things."

It is not easy now--it could not have been easy at any time--to give

clear and exact meanings to the doctrines of the alchemists, or the

directions they gave for performing the operations necessary for the

production of the object of their search. And the difficulty is much

increased when we are told that "The Sage jealously conceals [his

knowledge] from the sinner and the scornful, lest the mysteries of

heaven should be laid bare to the vulgar gaze." We almost despair when

an alchemical writer assures us that the Sages "Set pen to paper for

the express purpose of concealing their meaning. The sense of a whole

passage is often hopelessly obscured by the addition or omission of

one little word, for instance the addition of the word \_not\_ in the

wrong place." Another writer says: "The Sages are in the habit of

using words which may convey either a true or a false impression; the

former to their own disciples and children, the latter to the

ignorant, the foolish, and the unworthy." Sometimes, after

descriptions of processes couched in strange and mystical language,

the writer will add, "If you cannot perceive what you ought to

understand herein, you should not devote yourself to the study of

philosophy." Philalethes, in his \_Brief Guide to the Celestial Ruby\_,

seems to feel some pity for his readers; after describing what he

calls "the generic homogeneous water of gold," he says: "If you wish

for a more particular description of our water, I am impelled by

motives of charity to tell you that it is living, flexible, clear,

nitid, white as snow, hot, humid, airy, vaporous, and digestive."

Alchemy began by asserting that nature must be simple; it assumed that

a knowledge of the plan and method of natural occurrences is to be

obtained by thinking; and it used analogy as the guide in applying

this knowledge of nature's design to particular events, especially the

analogy, assumed by alchemy to exist, between material phenomena and

human emotions.

CHAPTER III.

THE ALCHEMICAL CONCEPTION OF THE UNITY AND SIMPLICITY OF NATURE.

In the preceding chapter I have referred to the frequent use made by

the alchemists of their supposition that nature follows the same plan,

or at any rate a very similar plan, in all her processes. If this

supposition is accepted, the primary business of an investigator of

nature is to trace likenesses and analogies between what seem on the

surface to be dissimilar and unconnected events. As this idea, and

this practice, were the foundations whereon the superstructure of

alchemy was raised, I think it is important to amplify them more fully

than I have done already.

Mention is made in many alchemical writings of a mythical personage

named \_Hermes Trismegistus\_, who is said to have lived a little later

than the time of Moses. Representations of Hermes Trismegistus are

found on ancient Egyptian monuments. We are told that Alexander the

Great found his tomb near Hebron; and that the tomb contained a slab

of emerald whereon thirteen sentences were written. The eighth

sentence is rendered in many alchemical books as follows:

"Ascend with the greatest sagacity from the earth to heaven, and then

again descend to the earth, and unite together the powers of things

superior and things inferior. Thus you will obtain the glory of the

whole world, and obscurity will fly away from you."

This sentence evidently teaches the unity of things in heaven and

things on earth, and asserts the possibility of gaining, not merely a

theoretical, but also a practical, knowledge of the essential

characters of all things. Moreover, the sentence implies that this

fruitful knowledge is to be obtained by examining nature, using as

guide the fundamental similarity supposed to exist between things

above and things beneath.

The alchemical writers constantly harp on this theme: follow nature;

provided you never lose the clue, which is simplicity and similarity.

The author of \_The Only Way\_ (1677) beseeches his readers "to enlist

under the standard of that method which proceeds in strict obedience

to the teaching of nature ... in short, the method which nature

herself pursues in the bowels of the earth."

The alchemists tell us not to expect much help from books and written

directions. When one of them has said all he can say, he adds--"The

question is whether even this book will convey any information to one

before whom the writings of the Sages and the open book of Nature are

exhibited in vain." Another tells his readers the only thing for them

is "to beseech God to give you the real philosophical temper, and to

open your eyes to the facts of nature; thus alone will you reach the

coveted goal."

"Follow nature" is sound advice. But, nature was to be followed with

eyes closed save to one vision, and the vision was to be seen before

the following began.

The alchemists' general conception of nature led them to assign to

every substance a condition or state natural to it, and wherein alone

it could be said to be as it was designed to be. Each substance, they

taught, could be caused to leave its natural state only by violent, or

non-natural, means, and any substance which had been driven from its

natural condition by violence was ready, and even eager, to return to

the condition consonant with its nature.

Thus Norton, in his \_Ordinal of Alchemy\_, says: "Metals are generated

in the earth, for above ground they are subject to rust; hence above

ground is the place of corruption of metals, and of their gradual

destruction. The cause which we assign to this fact is that above

ground they are not in their proper element, and an unnatural position

is destructive to natural objects, as we see, for instance, that

fishes die when they are taken out of the water; and as it is natural

for men, beasts, and birds to live in the air, so stones and metals

are naturally generated under the earth."

In his \_New Pearl of Great Price\_ (16th century), Bonus says:--"The

object of Nature in all things is to introduce into each substance the

form which properly belongs to it; and this is also the design of our

Art."

This view assumed the knowledge of the natural conditions of the

substances wherewith experiments were performed. It supposed that man

could act as a guide, to bring back to its natural condition a

substance which had been removed from that condition, either by

violent processes of nature, or by man's device. The alchemist

regarded himself as an arbiter in questions concerning the natural

condition of each substance he dealt with. He thought he could say,

"this substance ought to be thus, or thus," "that substance is

constrained, thwarted, hindered from becoming what nature meant it to

be."

In Ben Jonson's play called \_The Alchemist\_, Subtle (who is the

alchemist of the play) says, " ... metals would be gold if they had

time."

The alchemist not only attributed ethical qualities to material

things, he also became the guardian and guide of the moral practices

of these things. He thought himself able to recall the erring metal to

the path of metalline virtue, to lead the extravagant mineral back to

the moral home-life from which it had been seduced, to show the

doubting and vacillating salt what it was ignorantly seeking, and to

help it to find the unrealised object of its search. The alchemist

acted as a sort of conscience to the metals, minerals, salts, and

other substances he submitted to the processes of his laboratory. He

treated them as a wise physician might treat an ignorant and somewhat

refractory patient. "I know what you want better than you do," he

seems often to be saying to the metals he is calcining, separating,

joining and subliming.

But the ignorant alchemist was not always thanked for his treatment.

Sometimes the patient rebelled. For instance, Michael Sendivogius, in

his tract, \_The New Chemical Light drawn from the Fountain of Nature

and of Manual Experience\_ (17th century), recounts \_a dialogue between

Mercury, the Alchemist, and Nature\_.

"On a certain bright morning a number of Alchemists met together in a

meadow, and consulted as to the best way of preparing the

Philosopher's Stone.... Most of them agreed that Mercury was the first

substance. Others said, no, it was sulphur, or something else.... Just

as the dispute began to run high, there arose a violent wind, which

dispersed the Alchemists into all the different countries of the

world; and as they had arrived at no conclusion, each one went on

seeking the Philosopher's Stone in his own old way, this one expecting

to find it in one substance, and that in another, so that the search

has continued without intermission even unto this day. One of them,

however, had at least got the idea into his head that Mercury was the

substance of the Stone, and determined to concentrate all his efforts

on the chemical preparation of Mercury.... He took common Mercury and

began to work with it. He placed it in a glass vessel over the fire,

when it, of course, evaporated. So in his ignorance he struck his

wife, and said: 'No one but you has entered my laboratory; you must

have taken my Mercury out of the vessel.' The woman, with tears,

protested her innocence. The Alchemist put some more Mercury into the

vessel.... The Mercury rose to the top of the vessel in vaporous

steam. Then the Alchemist was full of joy, because he remembered that

the first substance of the Stone is described by the Sages as

volatile; and he thought that now at last he \_must\_ be on the right

track. He now began to subject the Mercury to all sorts of chemical

processes, to sublime it, and to calcine it with all manner of things,

with salts, sulphur, metals, minerals, blood, hair, aqua fortis,

herbs, urine, and vinegar.... Everything he could think of was tried;

but without producing the desired effect." The Alchemist then

despaired; after a dream, wherein an old man came and talked with him

about the "Mercury of the Sages," the Alchemist thought he would charm

the Mercury, and so he used a form of incantation. The Mercury

suddenly began to speak, and asked the Alchemist why he had troubled

him so much, and so on. The Alchemist replied, and questioned the

Mercury. The Mercury makes fun of the philosopher. Then the Alchemist

again torments the Mercury by heating him with all manner of horrible

things. At last Mercury calls in the aid of Nature, who soundly rates

the philosopher, tells him he is grossly ignorant, and ends by saying:

"The best thing you can do is to give yourself up to the king's

officers, who will quickly put an end to you and your philosophy."

As long as men were fully persuaded that they knew the plan whereon

the world was framed, that it was possible for them to follow exactly

"the road which was followed by the Great Architect of the Universe in

the creation of the world," a real knowledge of natural events was

impossible; for every attempt to penetrate nature's secrets

presupposed a knowledge of the essential characteristics of that which

was to be investigated. But genuine knowledge begins when the

investigator admits that he must learn of nature, not nature of him.

It might be truly said of one who held the alchemical conception of

nature that "his foible was omniscience"; and omniscience negatives

the attainment of knowledge.

The alchemical notion of a natural state as proper to each substance

was vigorously combated by the Honourable Robert Boyle (born 1626,

died 1691), a man of singularly clear and penetrative intellect. In \_A

Paradox of the Natural and Supernatural States of Bodies, Especially

of the Air\_, Boyle says:--"I know that not only in living, but even in

inanimate, bodies, of which alone I here discourse, men have

universally admitted the famous distinction between the natural and

preternatural, or violent state of bodies, and do daily, without the

least scruple, found upon it hypotheses and ratiocinations, as if it

were most certain that what they call nature had purposely formed

bodies in such a determinate state, and were always watchful that they

should not by any external violence be put out of it. But

notwithstanding so general a consent of men in this point, I confess,

I cannot yet be satisfied about it in the sense wherein it is wont to

be taken. It is not, that I believe, that there is no sense in which,

or in the account upon which, a body may he said to be in its natural

state; but that I think the common distinction of a natural and

violent state of bodies has not been clearly explained and

considerately settled, and both is not well grounded, and is

oftentimes ill applied. For when I consider that whatever state a body

be put into, or kept in, it obtains or retains that state, assenting

to the catholic laws of nature, I cannot think it fit to deny that in

this sense the body proposed is in a natural state; but then, upon the

same ground, it will he hard to deny but that those bodies which are

said to be in a violent state may also be in a natural one, since the

violence they are presumed to suffer from outward agents is likewise

exercised no otherwise than according to the established laws of

universal nature."

There must be something very fascinating and comforting in the

alchemical view of nature, as a harmony constructed on one simple

plan, which can be grasped as a whole, and also in its details, by the

introspective processes of the human intellect; for that conception

prevails to-day among those who have not investigated natural

occurrences for themselves. The alchemical view of nature still forms

the foundation of systems of ethics, of philosophy, of art. It appeals

to the innate desire of man to make himself the measure of all

things. It is so easy, so authoritative, apparently so satisfactory.

No amount of thinking and reasoning will ever demonstrate its falsity.

It can be conquered only by a patient, unbiassed, searching

examination of some limited portion of natural events.

CHAPTER IV.

THE ALCHEMICAL ELEMENTS AND PRINCIPLES.

The alchemists were sure that the intention of nature regarding metals

was that they should become gold, for gold was considered to be the

most perfect metal, and nature, they said, evidently strains after

perfection. The alchemist found that metals were worn away, eaten

through, broken, and finally caused to disappear, by many acid and

acrid liquids which he prepared from mineral substances. But gold

resisted the attacks of these liquids; it was not changed by heat, nor

was it affected by sulphur, a substance which changed limpid, running

mercury into an inert, black solid. Hence, gold was more perfect in

the alchemical scale than any other metal.

Since gold was considered to be the most perfect metal, it was

self-evident to the alchemical mind that nature must form gold slowly

in the earth, must transmute gradually the inferior metals into gold.

"The only thing that distinguishes one metal from another," writes an

alchemist who went under the name of Philalethes, "is its degree of

maturity, which is, of course, greatest in the most precious metals;

the difference between gold and lead is not one of substance, but of

digestion; in the baser metal the coction has not been such as to

purge out its metallic impurities. If by any means this superfluous

impure matter could be organically removed from the baser metals, they

would become gold and silver. So miners tell us that lead has in many

cases developed into silver in the bowels of the earth, and we contend

that the same effect is produced in a much shorter time by means of

our Art."

Stories were told about the finding of gold in deserted mines which

had been worked out long before; these stories were supposed to prove

that gold was bred in the earth. The facts that pieces of silver were

found in tin and lead mines, and gold was found in silver mines, were

adduced as proofs that, as the author of \_The New Pearl of Great

Price\_ says, "Nature is continually at work changing other metals into

gold, because, though in a certain sense they are complete in

themselves, they have not yet reached the highest perfection of which

they are capable, and to which nature has destined them." What nature

did in the earth man could accomplish in the workshop. For is not man

the crown of the world, the masterpiece of nature, the flower of the

universe; was he not given dominion over all things when the world was

created?

In asserting that the baser metals could be transmuted into gold, and

in attempting to effect this transmutation, the alchemist was not

acting on a vague; haphazard surmise; he was pursuing a policy

dictated by his conception of the order of nature; he was following

the method which he conceived to be that used by nature herself. The

transmutation of metals was part and parcel of a system of natural

philosophy. If this transmutation were impossible, the alchemical

scheme of things would be destroyed, the believer in the transmutation

would be left without a sense of order in the material universe. And,

moreover, the alchemist's conception of an orderly material universe

was so intimately connected with his ideas of morality and religion,

that to disprove the possibility of the great transmutation would be

to remove not only the basis of his system of material things, but the

foundations of his system of ethics also. To take away his belief in

the possibility of changing other metals into gold would be to convert

the alchemist into an atheist.

How, then, was the transmutation to be accomplished? Evidently by the

method whereby nature brings to perfection other living things; for

the alchemist's belief in the simplicity and unity of nature compelled

him to regard metals as living things.

Plants are improved by appropriate culture, by digging and enriching

the soil, by judicious selection of seed; animals are improved by

careful breeding. By similar processes metals will be encouraged and

helped towards perfection. The perfect state of gold will not be

reached at a bound; it will be gained gradually. Many partial

purifications will be needed. As \_Subtle\_ says in \_The Alchemist\_--

'twere absurd

To think that nature in the earth bred gold

Perfect in the instant; something went before,

There must be remote matter....

Nature doth first beget the imperfect, then

Proceeds she to the perfect.

At this stage the alchemical argument becomes very ultra-physical. It

may, perhaps, be rendered somewhat as follows:--

Man is the most perfect of animals; in man there is a union of three

parts, these are body, soul, and spirit. Metals also may be said to

have a body, a soul, and a spirit; there is a specific bodily, or

material, form belonging to each metal; there is a metalline soul

characteristic of this or that class of metals; there is a spirit, or

inner immaterial potency, which is the very essence of all metals.

The soul and spirit of man are clogged by his body. If the spiritual

nature is to become the dominating partner, the body must be

mortified: the alchemists, of course, used this kind of imagery, and

it was very real to them. In like manner the spirit of metals will be

laid bare and enabled to exercise its transforming influences, only

when the material form of the individual metal has been destroyed. The

first thing to do, then, is to strip off and cast aside those

properties of metals which appeal to the senses.

"It is necessary to deprive matter of its qualities in order to draw

out its soul," said Stephanus of Alexandria in the 7th century; and in

the 17th century Paracelsus said, "Nothing of true value is located in

the body of a substance, but in the virtue ... the less there is of

body the more in proportion is the virtue."

But the possession of the soul of metals is not the final stage:

mastery of the soul may mean the power of transmuting a metal into

another like itself; it will not suffice for the great transmutation,

for in that process a metal becomes gold, the one and only perfect

metal. Hence the soul also must be removed, in order that the spirit,

the essence, the kernel, may be obtained.

And as it is with metals, so, the alchemists argued, it is with all

things. There are a few \_Principles\_ which may be thought of as

conditioning the specific bodily and material forms of things; beneath

these, there are certain \_Elements\_ which are common to many things

whose principles are not the same; and, hidden by the wrappings of

elements and principles, there is the one \_Essence\_, the spirit, the

mystic uniting bond, the final goal of the philosopher.

I propose in this chapter to try to analyse the alchemical conceptions

of Elements and Principles, and in the next chapter to attempt some

kind of description of the Essence.

In his \_Tract Concerning the Great Stone of the Ancient Sages\_, Basil

Valentine speaks of the "three Principles," salt, sulphur, and

mercury, the source of which is the Elements.

"There are four Elements, and each has at its centre another element

which makes it what it is. These are the four pillars of the earth."

Of the element \_Earth\_, he says:--"In this element the other three,

especially fire, are latent.... It is gross and porous, specifically

heavy, but naturally light.... It receives all that the other three

project into it, conscientiously conceals what it should hide, and

brings to light that which it should manifest.... Outwardly it is

visible and fixed, inwardly it is invisible and volatile."

Of the element \_Water\_, Basil Valentine says:--"Outwardly it is

volatile, inwardly it is fixed, cold, and humid.... It is the solvent

of the world, and exists in three degrees of excellence: the pure, the

purer, and the purest. Of its purest substance the heavens were

created; of that which is less pure the atmospheric air was formed;

that which is simply pure remains in its proper sphere where ... it is

guardian of all subtle substances here below."

Concerning the element \_Air\_, he writes:--"The most noble Element of

Air ... is volatile, but may be fixed, and when fixed renders all

bodies penetrable.... It is nobler than Earth or Water.... It

nourishes, impregnates, conserves the other elements."

Finally, of the element \_Fire\_:--"Fire is the purest and noblest of

all Elements, full of adhesive unctuous corrosiveness, penetrant,

digestive, inwardly fixed, hot and dry, outwardly visible, and

tempered by the earth.... This Element is the most passive of all, and

resembles a chariot; when it is drawn, it moves; when it is not drawn,

it stands still."

Basil Valentine then tells his readers that Adam was compounded of the

four pure Elements, but after his expulsion from Paradise he became

subject to the various impurities of the animal creation. "The pure

Elements of his creation were gradually mingled and infected with the

corruptible elements of the outer world, and thus his body became more

and more gross, and liable, through its grossness, to natural decay

and death." The process of degeneration was slow at first, but "as

time went on, the seed out of which men were generated became more and

more infected with perishable elements. The continued use of

corruptible food rendered their bodies more and more gross; and human

life was soon reduced to a very brief span."

Basil Valentine then deals with the formation of the three

\_Principles\_ of things, by the mutual action of the four Elements.

Fire acting on Air produced \_Sulphur\_; Air acting on Water produced

\_Mercury\_; Water acting on Earth produced \_Salt\_. Earth having nothing

to act on produced nothing, but became the nurse of the three

Principles. "The three Principles," he says, "are necessary because

they are the immediate substance of metals. The remoter substance of

metals is the four elements, but no one can produce anything out of

them but God; and even God makes nothing of them but these three

Principles."

To endeavour to obtain the four pure Elements is a hopeless task. But

the Sage has the three Principles at hand. "The artist should

determine which of the three Principles he is seeking, and should

assist it so that it may overcome its contrary." "The art consists in

an even mingling of the virtues of the Elements; in the natural

equilibrium of the hot, the dry, the cold, and the moist."

The account of the Elements given by Philalethes differs from that of

Basil Valentine.

Philalethes enumerates three Elements only: Air, Water, and Earth.

Things are not formed by the mixture of these Elements, for

"dissimilar things can never really unite." By analysing the

properties of the three Elements, Philalethes reduced them finally to

one, namely, Water. "Water," he says, "is the first principle of all

things." "Earth is the fundamental Element in which all bodies grow

and are preserved. Air is the medium into which they grow, and by

means of which the celestial virtues are communicated to them."

According to Philalethes, \_Mercury\_ is the most important of the three

Principles. Although gold is formed by the aid of Mercury, it is only

when Mercury has been matured, developed, and perfected, that it is

able to transmute inferior metals into gold. The essential thing to do

is, therefore, to find an agent which will bring about the maturing

and perfecting of Mercury. This agent, Philalethes calls "Our divine

Arcanum."

Although it appears to me impossible to translate the sayings of the

alchemists concerning Elements and Principles into expressions which

shall have definite and exact meanings for us to-day, still we may,

perhaps, get an inkling of the meaning of such sentences as those I

have quoted from Basil Valentine and Philalethes.

Take the terms \_Fire\_ and \_Water\_. In former times all liquid

substances were supposed to be liquid because they possessed something

in common; this hypothetical something was called the \_Element,

Water\_. Similarly, the view prevailed until comparatively recent

times, that burning substances burn because of the presence in them of

a hypothetical imponderable fluid, called "\_Caloric\_"; the alchemists

preferred to call this indefinable something an Element, and to name

it \_Fire\_.

We are accustomed to-day to use the words \_fire\_ and \_water\_ with

different meanings, according to the ideas we wish to express. When we

say "do not touch the fire," or "put your hand into the water," we are

regarding fire and water as material things; when we say "the house is

on fire," or speak of "a diamond of the first water," we are thinking

of the condition or state of a burning body, or of a substance as

transparent as water. When we say "put out the fire," or "his heart

became as water," we are referring to the act of burning, or are using

an image which likens the thing spoken of to a substance in the act of

liquefying.

As we do to-day, so the alchemists did before us; they used the words

\_fire\_ and \_water\_ to express different ideas.

Such terms as hardness, softness, coldness, toughness, and the like,

are employed for the purpose of bringing together into one point of

view different things which are alike in, at least, one respect. Hard

things may differ in size, weight, shape, colour, texture, &c. A soft

thing may weigh the same as a hard thing; both may have the same

colour or the same size, or be at the same temperature, and so on. By

classing together various things as hard or soft, or smooth or rough,

we eliminate (for the time) all the properties wherein the things

differ, and regard them only as having one property in common. The

words hardness, softness, &c., are useful class-marks.

Similarly the alchemical Elements and Principles were useful

class-marks.

We must not suppose that when the alchemists spoke of certain things

as formed from, or by the union of, the same Elements or the same

Principles, they meant that these things contained a common substance.

Their Elements and Principles were not thought of as substances, at

least not in the modern meaning of the expression, \_a substance\_; they

were qualities only.

If we think of the alchemical elements earth, air, fire, and water, as

general expressions of what seemed to the alchemists the most

important properties of all substances, we may be able to attach some

kind of meaning to the sayings of Basil Valentine, which I have

quoted. For instance, when that alchemist tells us, "Fire is the most

passive of all elements, and resembles a chariot; when it is drawn, it

moves; when it is not drawn, it stands still"--we may suppose he meant

to express the fact that a vast number of substances can be burnt, and

that combustion does not begin of itself, but requires an external

agency to start it.

Unfortunately, most of the terms which the alchemists used to

designate their Elements and Principles are terms which are now

employed to designate specific substances. The word \_fire\_ is still

employed rather as a quality of many things under special conditions,

than as a specific substance; but \_earth\_, \_water\_, \_air\_, \_salt\_,

\_sulphur\_, and \_mercury\_, are to-day the names applied to certain

groups of properties, each of which is different from all other groups

of properties, and is, therefore, called, in ordinary speech, a

definite kind of matter.

As knowledge became more accurate and more concentrated, the words

\_sulphur\_, \_salt\_, \_mercury\_, &c., began to be applied to distinct

substances, and as these terms were still employed in their alchemical

sense as compendious expressions for certain qualities common to great

classes of substances, much confusion arose. Kunckel, the discoverer

of phosphorus, who lived between 1630 and 1702, complained of the

alchemists' habit of giving different names to the same substance, and

the same name to different substances. "The sulphur of one," he says,

"is not the sulphur of another, to the great injury of science. To

that one replies that everyone is perfectly free to baptise his infant

as he pleases. Granted. You may if you like call an ass an ox, but you

will never make anyone believe that your ox is an ass." Boyle is very

severe on the vague and loose use of words practised by so many

writers of his time. In \_The Sceptical Chymist\_ (published 1678-9) he

says: "If judicious men, skilled in chymical affairs, shall once agree

to write clearly and plainly of them, and thereby keep men from being

stunned, as it were, or imposed upon by dark and empty words; it is to

be hoped that these [other] men finding, that they can no longer write

impertinently and absurdly, without being laughed at for doing so,

will be reduced either to write nothing, or books that may teach us

something, and not rob men, as formerly, of invaluable time; and so

ceasing to trouble the world with riddles or impertinences, we shall

either by their books receive an advantage, or by their silence escape

an inconvenience."

Most of the alchemists taught that the elements produced what they

called \_seed\_, by their mutual reactions, and the principles matured

this seed and brought it to perfection. They supposed that each class,

or kind, of things had its own seed, and that to obtain the seed was

to have the power of producing the things which sprung from that seed.

Some of them, however, asserted that all things come from a common

seed, and that the nature of the products of this seed is conditioned

by the circumstances under which it is caused to develop.

Thus Michael Sendivogius writes as follows in \_The New Chemical Light,

drawn from the fountain of Nature and of Manual Experience\_ (17th

century):--

"Wherever there is seed, Nature will work through it, whether it

be good or bad." "The four Elements, by their continued action,

project a constant supply of seed to the centre of the earth,

where it is digested, and whence it proceeds again in generative

motions. Now the centre of the earth is a certain void place where

nothing is at rest, and upon the margin or circumference of this

centre the four Elements project their qualities.... The magnetic

force of our earth-centre attracts to itself as much as is needed

of the cognate seminal substance, while that which cannot be used

for vital generation is thrust forth in the shape of stones and

other rubbish. This is the fountain-head of all things

terrestrial. Let us illustrate the matter by supposing a glass of

water to be set in the middle of a table, round the margin of

which are placed little heaps of salt, and of powders of different

colours. If the water be poured out, it will run all over the

table in divergent rivulets, and will become salt where it touches

the salt, red where it touches the red powder, and so on. The

water does not change the '\_places\_,' but the several '\_places\_'

differentiate the water.[4] In the same way, the seed which is the

product of the four Elements is projected in all directions from

the earth-centre, and produces different things, according to the

quality of the different places. Thus, while the seed of all

things is one, it is made to generate a great variety of

things.... So long as Nature's seed remains in the centre it can

indifferently produce a tree or a metal, a herb or a stone, and in

like manner, according to the purity of the place, it will produce

what is less or more pure."

[4] The author I am quoting had said--"Nature is divided into

four '\_places\_' in which she brings forth all things that

appear and that are in the shade; and according to the good or

bad quality of the '\_place\_,' she brings forth good or bad

things.... It is most important for us to know her '\_places\_'

... in order that we may join things together according to

Nature."

CHAPTER V.

THE ALCHEMICAL ESSENCE.

In the last chapter I tried to describe the alchemical view of the

interdependence of different substances. Taking for granted the

tripartite nature of man, the co-existence in him of body, soul, and

spirit (no one of which was defined), the alchemists concluded that

all things are formed as man is formed; that in everything there is a

specific bodily form, some portion of soul, and a dash of spirit. I

considered the term \_soul\_ to be the alchemical name for the

properties common to a class of substances, and the term \_spirit\_ to

mean the property which was thought by the alchemists to be common to

all things.

The alchemists considered it possible to arrange all substances in

four general classes, the marks whereof were expressed by the terms

hot, cold, moist, and dry; they thought of these properties as

typified by what they called the four Elements--fire, air, water, and

earth. Everything, they taught, was produced from the four Elements,

not immediately, but through the mediation of the three

Principles--mercury, sulphur, and salt. These Principles were regarded

as the tools put into the hands of him who desired to effect the

transmutation of one substance into another. The Principles were not

thought of as definite substances, nor as properties of this or that

specified substance; they were considered to be the characteristic

properties of large classes of substances.

The chemist of to-day places many compounds in the same class because

all are acids, because all react similarly under similar conditions.

It used to be said that every acid possesses more or less of \_the

principle of acidity\_. Lavoisier changed the language whereby certain

facts concerning acids were expressed. He thought that experiments

proved all acids to be compounds of the element oxygen; and for many

years after Lavoisier, the alchemical expression \_the principle of

acidity\_ was superseded by the word \_oxygen\_. Although Lavoisier

recognised that not every compound of oxygen is an acid, he taught

that every acid is a compound of oxygen. We know now that many acids

are not compounds of oxygen, but we have not yet sufficient knowledge

to frame a complete definition of the term \_acid\_. Nevertheless it is

convenient, indeed it is necessary, to place together many compounds

which react similarly under certain defined conditions, and to give a

common name to them all. The alchemists also classified substances,

but their classification was necessarily more vague than ours; and

they necessarily expressed their reasons for putting different

substances in the same class in a language which arose out of the

general conceptions of natural phenomena which prevailed in their

time.

The primary classification of substances made by the alchemists was

expressed by saying; these substances are rich in the principle

\_sulphur\_, those contain much of the principle \_mercury\_, and this

class is marked by the preponderance of the principle \_salt\_. The

secondary classification of the alchemists was expressed by saying;

this class is characterised by dryness, that by moisture, another by

coldness, and a fourth by hotness; the dry substances contain much of

the element \_Earth\_, the moist substances are rich in the element

\_Water\_, in the cold substances the element \_Air\_ preponderates, and

the hot substances contain more of the element \_Fire\_ than of the

other elements.

The alchemists went a step further in their classification of things.

They asserted that there is One Thing present in all things; that

everything is a vehicle for the more or less perfect exhibition of the

properties of the One Thing; that there is a Primal Element common to

all substances. The final aim of alchemy was to obtain the One Thing,

the Primal Element, the Soul of all Things, so purified, not only from

all specific substances, but also from all admixture of the four

Elements and the three Principles, as to make possible the

accomplishment of any transmutation by the use of it.

If a person ignorant of its powers were to obtain the Essence, he

might work vast havoc and cause enormous confusion; it was necessary,

therefore, to know the conditions under which the potencies of the

Essence became active. Hence there was need of prolonged study of the

mutual actions of the most seemingly diverse substances, and of minute

and patient examination of the conditions under which nature performs

her marvellous transmutations. The quest of the One Thing was fraught

with peril, and was to be attempted only by those who had served a

long and laborious apprenticeship.

In \_The Chemical Treatise of Thomas Norton, the Englishman, called

Believe-me, or the Ordinal of Alchemy\_ (15th century), the adept is

warned not to disclose his secrets to ordinary people.

"You should carefully test and examine the life, character, and mental

aptitudes of any person who would be initiated in this Art, and then

you should bind him, by a sacred oath, not to let our Magistery be

commonly or vulgarly known. Only when he begins to grow old and

feeble, he may reveal it to one person, but not to more, and that one

man must be virtuous.... If any wicked man should learn to practise

the Art, the event would be fraught with great danger to Christendom.

For such a man would overstep all bounds of moderation, and would

remove from their hereditary thrones those legitimate princes who rule

over the peoples of Christendom."

The results of the experimental examination of the compositions and

properties of substances, made since the time of the alchemists, have

led to the modern conception of the chemical element, and the

isolation of about seventy or eighty different elements. No substance

now called an element has been produced in the laboratory by uniting

two, or more, distinct substances, nor has any been separated into

two, or more, unlike portions. The only decided change which a

chemical element has been caused to undergo is the combination of it

with some other element or elements, or with a compound or compounds.

But it is possible that all the chemical elements may be combinations

of different quantities of one primal element. Certain facts make this

supposition tenable; and some chemists expect that the supposition

will be proved to be correct. If the hypothetical primal element

should be isolated, we should have fulfilled the aim of alchemy, and

gained the One Thing; but the fulfilment would not be that whereof the

alchemists dreamed.

Inasmuch as the alchemical Essence was thought of as the Universal

Spirit to whose presence is due whatever degree of perfection any

specific substance exhibits, it followed that the more perfect a

substance the greater is the quantity of the Essence in it. But even

in the most perfect substance found in nature--which substance, the

alchemists said, is gold--the Essence is hidden by wrappings of

specific properties which prevent the ordinary man from recognising

it. Remove these wrappings from some special substance, and you have

the perfect form of that thing; you have some portion of the Universal

Spirit joined to the one general property of the class of things

whereof the particular substance is a member. Then remove the

class-property, often spoken of by the alchemists as \_the life\_, of

the substance, and you have the Essence itself.

The alchemists thought that to every thing, or at any rate to every

class of things, there corresponds a more perfect form than that which

we see and handle; they spoke of gold, and the \_gold of the Sages\_;

mercury, and the \_mercury of the Philosophers\_; sulphur, and the

\_heavenly sulphur of him whose eyes are opened\_.

To remove the outer wrappings of ordinary properties which present

themselves to the untrained senses, was regarded by the alchemists to

be a difficult task; to tear away the soul (the class-property) of a

substance, and yet retain the Essence which made that substance its

dwelling place, was possible only after vast labour, and by the use of

the proper agent working under the proper conditions. An exceedingly

powerful, delicate, and refined agent was needed; and the mastery of

the agent was to be acquired by bitter experience, and, probably,

after many disappointments.

"Gold," an alchemist tells us, "does not easily give up its nature,

and will fight for its life; but our agent is strong enough to

overcome and kill it, and then it also has the power to restore it to

life, and to change the lifeless remains into a new and pure body."

Thomas Norton, the author of \_The Ordinal of Alchemy\_, writing in the

15th century, says the worker in transmutations is often tempted to be

in a hurry, or to despair, and he is often deceived. His servants will

be either stupid and faithful, or quick-witted and false. He may be

robbed of everything when his work is almost finished. The only

remedies are infinite patience, a sense of virtue, and sound reason.

"In the pursuit of our Art," he says, "you should take care, from time

to time, to unbend your mind from its sterner employments with some

convenient recreation."

The choice of workmen to aid in the mechanical parts of the quest was

a great trouble to the alchemists. On this subject Norton says--"If

you would be free from all fear over the gross work, follow my

counsel, and never engage married men; for they soon give in and

pretend they are tired out.... Hire your workmen for certain

stipulated wages, and not for longer periods than twenty-four hours at

a time. Give them higher wages than they would receive elsewhere, and

be prompt and ready in your payments."

Many accounts are given by alchemical writers of the agent, and many

names are bestowed on it. The author of \_A Brief Guide to the

Celestial Ruby\_ speaks thus of the agent--"It is our doorkeeper, our

balm, our honey, oil, urine, maydew, mother, egg, secret furnace,

oven, true fire, venomous dragon, Theriac, ardent wine, Green Lion,

Bird of Hermes, Goose of Hermogenes, two-edged sword in the hand of

the Cherub that guards the Tree of Life.... It is our true secret

vessel, and the Garden of the Sages in which our sun rises and sets.

It is our Royal Mineral, our triumphant vegetable Saturnia, and the

magic rod of Hermes, by means of which he assumes any shape he likes."

Sometimes we are told that the agent is mercury, sometimes that it is

gold, but not common mercury or common gold. "Supplement your common

mercury with the inward fire which it needs, and you will soon get rid

of all superfluous dross." "The agent is gold, as highly matured as

natural and artificial digestion can make it, and a thousand times

more perfect than the common metal of that name. Gold, thus exalted,

radically penetrates, tinges, and fixes metals."

The alchemists generally likened the work to be performed by their

agent to the killing of a living thing. They constantly use the

allegory of death, followed by resurrection, in describing the steps

whereby the Essence was to be obtained, and the processes whereby the

baser metals were to be partially purified. They speak of the

mortification of metals, the dissolution and putrefaction of

substances, as preliminaries to the appearance of the true life of the

things whose outward properties have been destroyed. For instance,

Paracelsus says: "Destruction perfects that which is good; for the

good cannot appear on account of that which conceals it." The same

alchemist speaks of rusting as the mortification of metals; he says:

"The mortification of metals is the removal of their bodily

structure.... The mortification of woods is their being turned into

charcoal or ashes."

Paracelsus distinguishes natural from artificial mortification,

"Whatever nature consumes," he says, "man cannot restore. But whatever

man destroys man can restore, and break again when restored." Things

which had been mortified by man's device were considered by Paracelsus

not to be really dead. He gives this extraordinary illustration of his

meaning: "You see this is the case with lions, which are all born

dead, and are first vitalised by the horrible noise of their parents,

just as a sleeping person is awakened by a shout."

The mortification of metals is represented in alchemical books by

various images and allegories. Fig. I. is reduced from a cut in a 16th

century work, \_The Book of Lambspring, a noble ancient Philosopher,

concerning the Philosophical Stone\_.

[Illustration: Here the father devours the son;

The soul and spirit flow forth from the body.

FIG. I.]

The image used to set forth the mortification of metals is a king

swallowing his son. Figs. II. and III. are reduced from Basil

Valentine's \_Twelve Keys\_. Both of these figures represent the process

of mortification by images connected with death and burial.

[Illustration: FIG. II.]

In his explanation (?) of these figures, Basil Valentine says:--

"Neither human nor animal bodies can be multiplied or propagated

without decomposition; the grain and all vegetable seed, when cast

into the ground, must decay before it can spring up again;

moreover, putrefaction imparts life to many worms and other

animalculæ.... If bread is placed in honey, and suffered to decay,

ants are generated ... maggots are also developed by the decay of

nuts, apples, and pears. The same thing may be observed in regard

to vegetable life. Nettles and other weeds spring up where no such

seed has ever been sown. This occurs only by putrefaction. The

reason is that the soil in such places is so disposed, and, as it

were, impregnated, that it produces these fruits; which is a

result of the properties of sidereal influences; consequently the

seed is spiritually produced in the earth, and putrefies in the

earth, and by the operation of the elements generates corporeal

matter according to the species of nature. Thus the stars and the

elements may generate new spiritual, and ultimately, new vegetable

seed, by means of putrefaction.... Know that, in like manner, no

metallic seed can develop, or multiply, unless the said seed, by

itself alone, and without the introduction of any foreign

substance, be reduced to a perfect putrefaction."

[Illustration: FIG. III.]

The action of the mineral agent in perfecting substances is often

likened by the alchemists to the conjoining of the male and the

female, followed by the production of offspring. They insist on the

need of a union of two things, in order to produce something more

perfect than either. The agent, they say, must work upon something;

alone it is nothing.

The methods whereby the agent is itself perfected, and the processes

wherein the agent effects the perfecting of the less perfect things,

were divided into stages by the alchemists. They generally spoke of

these stages as \_Gates\_, and enumerated ten or sometimes twelve of

them. As examples of the alchemical description of these gates, I give

some extracts from \_A Brief Guide to the Celestial Ruby\_.

The first gate is \_Calcination\_, which is "the drying up of the

humours"; by this process the substance "is concocted into a black

powder which is yet unctuous, and retains its radical humour." When

gold passes through this gate, "We observe in it two natures, the

fixed and the volatile, which we liken to two serpents." The fixed

nature is likened to a serpent without wings; the volatile, to a

serpent with wings: calcination unites these two into one. The second

gate, \_Dissolution\_, is likened to death and burial; but the true

Essence will appear glorious and beautiful when this gate is passed.

The worker is told not to be discouraged by this apparent death. \_The

mercury of the sages\_ is spoken of by this author as the queen, and

gold as the king. The king dies for love of the queen, but he is

revived by his spouse, who is made fruitful by him and brings forth "a

most royal son."

Figs. IV. and V. are reduced from \_The Book of Lambspring\_; they

express the need of the conjunction of two to produce one.

[Illustration: Here you behold a great marvel--

Two Lions are joined into one.

The spirit and soul must be united in their body.

FIG. IV.]

After dissolution came \_Conjunction\_, wherein the separated elements

were combined. Then followed \_Putrefaction\_, necessary for the

germination of the seed which had been produced by calcination,

dissolution, and conjunction. Putrefaction was followed by

\_Congelation\_ and \_Citation\_. The passage through the next gate,

called \_Sublimation\_, caused the body to become spiritual, and the

spiritual to be made corporal. \_Fermentation\_ followed, whereby the

substance became soft and flowed like wax. Finally, by \_Exaltation\_,

the Stone was perfected.

[Illustration: Here are two birds, great and strong--the body and

spirit; one devours the other.

Let the body be placed in horse-dung, or a warm bath,

the spirit having been extracted from it. The body has

become white by the process, the spirit red by our art.

All that exists tends towards perfection, and thus is

the Philosopher's Stone prepared.

FIG. V.]

The author of \_The Open Entrance\_ speaks of the various stages in the

perfecting of the agent as \_regimens\_. The beginning of the heating

of gold with mercury is likened to the king stripping off his golden

garments and descending into the fountain; this is the \_regimen of

Mercury\_. As the heating is continued, all becomes black; this is the

\_regimen of Saturn\_. Then is noticed a play of many colours; this is

the \_regimen of Jupiter\_: if the heat is not regulated properly, "the

young ones of the crow will go back to the nest." About the end of the

fourth month you will see "the sign of the waxing moon," and all

becomes white; this is the \_regimen of the Moon\_. The white colour

gives place to purple and green; you are now in the \_regimen of

Venus\_. After that, appear all the colours of the rainbow, or of a

peacock's tail; this is the \_regimen of Mars\_. Finally the colour

becomes orange and golden; this is the \_regimen of the Sun\_.

The reader may wish to have some description of the Essence. The

alchemists could describe it only in contraries. It had a bodily form,

but its method of working was spiritual. In \_The Sodic Hydrolith, or

Water Stone of the Wise\_ we are told:--

"The stone is conceived below the earth, born in the earth,

quickened in heaven, dies in time, and obtains eternal glory....

It is bluish-grey and green.... It flows like water, yet it makes

no wet; it is of great weight, and is small."

Philalethes says, in \_A Brief Guide to the Celestial Ruby\_: "The

Philosopher's Stone is a certain heavenly, spiritual, penetrative, and

fixed substance, which brings all metals to the perfection of gold or

silver (according to the quality of the Medicine), and that by natural

methods, which yet in their effects transcend Nature.... Know then

that it is called a stone, not because it is like a stone, but only

because, by virtue of its fixed nature, it resists the action of fire

as successfully as any stone. In species it is gold, more pure than

the purest; it is fixed and incombustible like a stone, but its

appearance is that of very fine powder, impalpable to the touch, sweet

to the taste, fragrant to the smell, in potency a most penetrative

spirit, apparently dry and yet unctuous, and easily capable of tinging

a plate of metal.... If we say that its nature is spiritual, it would

be no more than the truth; if we described it as corporeal, the

expression would be equally correct."

The same author says: "There is a substance of a metalline species

which looks so cloudy that the universe will have nothing to do with

it. Its visible form is vile; it defiles metalline bodies, and no one

can readily imagine that the pearly drink of bright Phoebus should

spring from thence. Its components are a most pure and tender mercury,

a dry incarcerate sulphur, which binds it and restrains fluxation....

Know this subject, it is the sure basis of all our secrets.... To deal

plainly, it is the child of Saturn, of mean price and great venom....

It is not malleable, though metalline. Its colour is sable, with

intermixed argent which mark the sable fields with veins of glittering

argent."

In trying to attach definite meanings to the alchemical accounts of

Principles, Elements, and the One Thing, and the directions which the

alchemists give for changing one substance into others, we are very

apt to be misled by the use of such an expression as \_the

transmutation of the elements\_. To a chemist that phrase means the

change of an element into another element, an element being a definite

substance, which no one has been able to produce by the combination of

two or more substances unlike itself, or to separate into two or more

substances unlike itself. But whatever may have been the alchemical

meaning of the word \_element\_, it was certainly not that given to the

same word to-day. Nor did the word \_transmutation\_ mean to the

alchemist what it means to the chemist.

The facts which are known at present concerning the elements make

unthinkable such a change as that of lead into silver; but new facts

\_may\_ be discovered which will make possible the separation of lead

into things unlike itself, and the production of silver by the

combination of some of these constituents of lead. The alchemist

supposed he knew such facts as enabled him not only to form a mental

picture of the change of lead into silver, or tin into gold, but also

to assert that such changes must necessarily happen, and to accomplish

them. Although we are quite sure that the alchemist's facts were only

imaginings, we ought not to blame him for his reasoning on what he

took to be facts.

Every metal is now said to be an element, in the modern meaning of

that word: the alchemist regarded the metals as composite substances;

but he also thought of them as more simple than many other things.

Hence, if he was able to transmute one metal into another, he would

have strong evidence in support of his general conception of the

unity of all things. And, as transmutation meant, to the alchemist,

the bringing of a substance to the condition of greatest perfection

possible for that substance, his view of the unity of nature might be

said to be proved if he succeeded in changing one of the metals, one

of these comparatively simple substances, into the most perfect of all

metals, that is, into gold.

The transmutation of the baser metals into gold thus came to be the

practical test of the justness of the alchemical scheme of things.

Some alchemists assert they had themselves performed the great

transmutation; others tell of people who had accomplished the work.

The following story is an example of the accounts given of the making

of gold. It is taken from \_John Frederick Helvetius' Golden Calf,

which the world worships and adores\_ (17th century):--

"On the 27th December 1666, in the forenoon, there came to my

house a certain man, who was a complete stranger to me, but of an

honest grave countenance, and an authoritative mien, clothed in a

simple garb.... He was of middle height, his face was long and

slightly pock-marked, his hair was black and straight, his chin

close-shaven, his age about forty-three or forty-four, and his

native province, as far as I could make out, North Holland. After

we had exchanged salutations, he asked me whether he might have

some conversation with me. He wished to say something to me about

the Pyrotechnic Art, as he had read one of my tracts (directed

against the Sympathetic Powder of Dr Digby), in which I hinted a

suspicion whether the Grand Arcanum of the Sages was not after all

a gigantic hoax. He, therefore, took that opportunity of asking me

whether I could not believe that such a grand mystery might exist

in the nature of things, by means of which a physician could

restore any patient whose vitals were not irreparably destroyed. I

answered, 'Such a medicine would be a most desirable acquisition

for any physician; nor can any man tell how many secrets there may

be hidden in Nature; yet, though I have read much about the truth

of this art, it has never been my good fortune to meet with a real

master of the alchemical science.' ... After some further

conversation, the Artist Elias (for it was he) thus addressed me:

'Since you have read so much in the works of the alchemists about

this stone, its substance, its colour and its wonderful effects,

may I be allowed the question, whether you have not prepared it

yourself?' On my answering his question in the negative, he took

out of his bag a cunningly-worked ivory box, in which were three

large pieces of substance resembling glass, or pale sulphur, and

informed me that here was enough of the tincture for the

production of twenty tons of gold. When I had held the precious

treasure in my hand for a quarter of an hour (during which time I

listened to a recital of its wonderful curative properties), I was

compelled to restore it to its owner, which I could not help doing

with a certain degree of reluctance.... My request that he would

give me a piece of his stone (though it were no larger than a

coriander seed), he somewhat brusquely refused, adding, in a

milder tone, that he could not give it me for all the wealth I

possessed, and that not on account of its great preciousness, but

for some other reason which it was not lawful for him to

divulge.... Then he inquired whether I could not show him into a

room at the back of the house, where we should be less liable to

the observation of passers-by. On my conducting him into the state

parlour (which he entered without wiping his dirty boots), he

demanded of me a gold coin, and while I was looking for it, he

produced from his breast pocket a green silk handkerchief, in

which were folded up five medals, the gold of which was infinitely

superior to that of my gold piece." Here follows the inscriptions

on the medals. "I was filled with admiration, and asked my visitor

whence he had obtained that wonderful knowledge of the whole

world. He replied that it was a gift freely bestowed on him by a

friend who had stayed a few days at his house." Here follows the

stranger's account of this friend's experiments. "When my strange

visitor had concluded his narrative, I besought him to give me a

proof of his assertion, by performing the transmutatory operation

on some metals in my presence. He answered evasively, that he

could not do so then, but that he would return in three weeks, and

that, if he was then at liberty to do so, he would show me

something that would make me open my eyes. He appeared punctually

to the promised day, and invited me to take a walk with him, in

the course of which we discoursed profoundly on the secrets of

Nature in fire, though I noticed that my companion was very chary

in imparting information about the Grand Arcanum.... At last I

asked him point blank to show me the transmutation of metals. I

besought him to come and dine with me, and to spend the night at

my house; I entreated; I expostulated; but in vain. He remained

firm. I reminded him of his promise. He retorted that his promise

had been conditional upon his being permitted to reveal the secret

to me. At last, however, I prevailed upon him to give me a piece

of his precious stone--a piece no larger than a grain of rape

seed.... He bid me take half an ounce of lead ... and melt it in

the crucible; for the Medicine would certainly not tinge more of

the base metal than it was sufficient for.... He promised to

return at nine o'clock the next morning.... But at the stated hour

on the following day he did not make his appearance; in his stead,

however, there came, a few hours later, a stranger, who told me

that his friend the artist was unavoidably detained, but that he

would call at three o'clock in the afternoon. The afternoon came;

I waited for him till half-past seven o'clock. He did not appear.

Thereupon my wife came and tempted me to try the transmutation

myself. I determined however to wait till the morrow. On the

morrow ... I asked my wife to put the tincture in wax, and I

myself ... prepared six drachms of lead; I then cast the tincture,

enveloped as it was in wax, on the lead; as soon as it was melted,

there was a hissing sound and a slight effervescence, and after a

quarter of an hour I found that the whole mass of lead had been

turned into the finest gold.... We immediately took it to the

goldsmith, who at once declared it the finest gold he had ever

seen, and offered to pay fifty florins an ounce for it." He then

describes various tests which were made to prove the purity of the

gold. "Thus I have unfolded to you the whole story from beginning

to end. The gold I still retain in my possession, but I cannot

tell you what has become of the Artist Elias."

CHAPTER VI.

ALCHEMY AS AN EXPERIMENTAL ART.

A modern writer, Mr A.E. Waite, in his \_Lives of the Alchemystical

Philosophers\_, says: "The physical theory of transmutation is based on

the composite character of the metals, on their generation in the

bowels of the earth, and on the existence in nature of a pure and

penetrating matter which applied to any substance exalts and perfects

it after its own kind." It must he admitted that the alchemists could

cite many instances of transmutations which seemed to lead to the

conclusion, that there is no difference of kind between the metals and

other substances such as water, acids, oils, resins, and wood. We are

able to-day to effect a vast number of transformations wherein one

substance is exchanged for another, or made to take the place of

another. We can give fairly satisfactory descriptions of these

changes; and, by comparing them one with another, we are able to

express their essential features in general terms which can be applied

to each particular instance. The alchemists had no searching knowledge

of what may be called the mechanism of such changes; they gave an

explanation of them which we must call incorrect, in the present state

of our knowledge. But, as Hoefer says in his \_Histoire de la Chimie\_,

"to jeer at [the alchemical] theory is to commit at once an

anachronism and an injustice.... Unless the world should finish

to-morrow, no one can have the pretension to suppose that our

contemporaries have said the last word of science, and nothing will

remain for our descendants to discover, no errors for them to correct,

no theories for them to set straight."

[Illustration: FIG. VI. \_See p. 90.\_]

[Illustration: FIG. VII. \_See p. 90.\_]

[Illustration: FIG. VIII. \_See p. 91.\_]

What kind of experimental evidence could an alchemist furnish in

support of his theory of transmutation? In answering this question, I

cannot do better than give a condensed rendering of certain pages in

Hoefer's \_Histoire de la Chimie\_.

The reader is supposed to be present at experiments conducted in the

laboratory of a Grand Master of the Sacred Art in the 5th or 6th

century.

\_Experiment\_.--Ordinary water is boiled in an open vessel; the water

is changed to a vapour which disappears, and a white powdery earth

remains in the vessel.

\_Conclusion\_.--Water is changed into air and earth.

Did we not know that ordinary water holds certain substances in

solution, and that boiling water acts on the vessel wherein it is

boiled, we should have no objection to urge against this conclusion.

It only remained to transmute fire that the transmutation of the four

elements might be completed.

\_Experiment.\_--A piece of red-hot iron is placed in a bell-jar, filled

with water, held over a basin containing water; the volume of the

water decreases, and the air in the bell-jar takes fire when a lighted

taper is brought into it.

\_Conclusion.\_--Water is changed into fire.

That interpretation was perfectly reasonable at a time when the fact

was unknown that water is composed of two gaseous substances; that one

of these (oxygen) is absorbed by the iron, and the other (hydrogen)

collects in the bell-jar, and ignites when brought into contact with a

flame.

\_Experiment\_.--Lead, or any other metal except gold or silver, is

calcined in the air; the metal loses its characteristic properties,

and is changed into a powdery substance, a kind of cinder or calx.

When this cinder, which was said to be the result of the \_death of the

metal\_, is heated in a crucible with some grains of wheat, one sees

the metal revive, and resume its original form and properties.

\_Conclusion.\_--The metal which had been destroyed is revivified by the

grains of wheat and the action of fire.

Is this not to perform the miracle of the resurrection?

No objection can he raised to this interpretation, as long as we are

ignorant of the phenomena of oxidation, and the reduction of oxides by

means of carbon, or organic substances rich in carbon, such as sugar,

flour, seeds, etc. Grains of wheat were the symbol of life, and, by

extension, of the resurrection and eternal life.

[Illustration: FIG. IX. \_See p. 91.\_]

\_Experiment\_.--Ordinary lead is calcined in a cupel made of cinders or

powdered bones; the lead is changed to a cinder which disappears into

the cupel, and a button of silver remains.

\_Conclusion\_.--The lead has vanished; what more natural than the

conclusion that it has been transformed into silver? It was not known

then that all specimens of lead contain more or less silver.

[Illustration: FIG. X. \_See p. 92.\_]

\_Experiment.\_-The vapour of arsenic bleaches copper. This fact gave

rise to many allegories and enigmas concerning the means of

transforming copper into silver.

Sulphur, which acts on metals and changes many of them into black

substances, was looked on as a very mysterious thing. It was with

sulphur that the coagulation (solidification) of mercury was effected.

\_Experiment\_.--Mercury is allowed to fall, in a fine rain, on to

melted sulphur; a black substance is produced; this black substance is

heated in a closed vessel, it is volatilised and transformed into a

beautiful red solid.

One could scarcely suppose that the black and the red substances are

identical, if one did not know that they are composed of the same

quantities of the same elements, sulphur and mercury.

How greatly must this phenomenon have affected the imagination of the

chemists of ancient times, always so ready to be affected by

everything that seemed supernatural!

Black and red were the symbols of darkness and light, of the evil and

the good principle; and the union of these two principles represented

the moral order. At a later time the idea helped to establish the

alchemical doctrine that sulphur and mercury are the Principles of all

things.

\_Experiment.\_--Various organic substances are analysed by heating in a

distillation-apparatus; the products are, in each case, a solid

residue, liquids which distil off, and certain spirits which are

disengaged.

The results supported the ancient theory which asserted that \_earth\_,

\_water\_, \_air\_, and \_fire\_ are the four Elements of the world. The

solid residue represented \_earth\_; the liquid products of the

distillation, \_water\_; and the spirituous substances, \_air\_. \_Fire\_

was regarded sometimes as the means of purification, sometimes as the

soul, or invisible part, of all substances.

\_Experiment\_.-A strong acid is poured on to copper. The metal is

attacked, and at last disappears, giving place to a green liquid, as

transparent as water. A thin sheet of iron is plunged into the liquid;

the copper re-appears, and the iron vanishes.

What more simple than to conclude that the iron has been transformed

into copper?

Had lead, silver, or gold been used in place of copper, one would have

said that the iron was transformed into lead, silver, or gold.

In their search for "the pure and penetrating matter which applied to

any substance exalts and perfects it after its own kind," the

alchemists necessarily made many inventions, laid the foundation of

many arts and manufactures, and discovered many facts of importance in

the science of chemistry.

The practitioners of the \_Sacred Art\_ of Egypt must have been

acquainted with many operations which we now class as belonging to

applied chemistry; witness, their jewellery, pottery, dyes and

pigments, bleaching, glass-making, working in metals and alloys, and

their use of spices, essential oils, and soda in embalming, and for

other purposes.

During the centuries when alchemy flourished, gunpowder was invented,

the art of printing was established, the compass was brought into use,

the art of painting and staining glass was begun and carried to

perfection, paper was made from rags, practical metallurgy advanced by

leaps and bounds, many new alloys of metals came into use, glass

mirrors were manufactured, and considerable advances were made in

practical medicine and sanitation.

[Illustration: FIG. XI. \_See p. 92.\_]

Basil Valentine, who was one of the greatest alchemists of the 16th

century, discovered many of the properties of the metal antimony, and

prepared and examined many compounds of that metal; he made green

vitriol from pyrites, brandy from fermented grape-juice, fulminating

gold, sulphide of potash, and spirits of salt; he made and used baths

of artificial mineral waters, and he prepared various metals by what

are now called \_wet methods\_, for instance, copper, by immersing

plates of iron in solutions of bluestone. He examined the air of

mines, and suggested practical methods for determining whether the

air in a mine was respirable. Hoefer draws attention to a remarkable

observation recorded by this alchemist. Speaking of the "spirit of

mercury," Basil Valentine says it is "the origin of all the metals;

that spirit is nothing else than an air flying here and there without

wings; it is a moving wind, which, after it has been chased from its

home of Vulcan (that is, fire), returns to the chaos; then it expands

and passes into the region of the air from whence it had come." As

Hoefer remarks, this is perhaps one of the earliest accounts of the

gas discovered by Priestley and studied by Lavoisier, the gas we now

call oxygen, and recognise as of paramount importance in chemical

reactions.

[Illustration: FIG. XII. \_See p. 92.\_]

Besides discovering and recording many facts which have become part

and parcel of the science of chemistry, the alchemists invented and

used various pieces of apparatus, and conducted many operations, which

are still employed in chemical laboratories. I shall reproduce

illustrations of some of these processes and pieces of apparatus, and

quote a few of the directions, given in a book, published in 1664,

called \_The Art of Distillation\_, by John French, Dr. in Physick.

The method recommended by French for hermetically sealing the neck of

a glass vessel is shown in Fig. VI. p. 80. The neck of the vessel is

surrounded by a tray containing burning coals; when the glass melts it

is cut off by shears, and then closed by tongs, which are made hot

before use.

Fig. VII. p. 81, represents a method for covering an open vessel,

air-tight, with a receptacle into which a substance may be sublimed

from the lower vessel. The lettering explains the method of using the

apparatus.

French gives very practical directions and much sound advice for

conducting distillations of various kinds. The following are specimens

of his directions and advice:--

"When you put water into a seething Balneum wherein there are

glasses let it be hot, or else thou wilt endanger the breaking of

the glasses.

"When thou takest any earthen, or glass vessel from the fire,

expose it not to the cold aire too suddenly for fear it should

break.

"In all your operations diligently observe the processes which you

read, and vary not a little from them, for sometimes a small

mistake or neglect spoils the whole operation, and frustrates your

expectations.

"Try not at first experiments of great cost, or great difficulty;

for it will be a great discouragement to thee, and thou wilt be

very apt to mistake.

"If any one would enter upon the practices of Chymistry, let him

apply himself to some expert artist for to be instructed in the

manual operation of things; for by this means he will learn more

in two months, than he can by his practice and study in seven

years, as also avoid much pains and cost, and redeem much time

which else of necessity he will lose."

Fig. VIII. p. 82, represents a common cold still, and Fig. IX. p. 84,

is a sketch of an apparatus for distilling by the aid of boiling

water. The bath wherein the vessels are placed in Fig. IX. was called

by the alchemists \_balneum Mariae\_, from Mary the Jewess, who is

mentioned in the older alchemical writings, and is supposed to have

invented an apparatus of this character. Nothing definite is known of

Mary the Jewess. A writer of the 7th century says she was initiated in

the sacred art in the temple of Memphis; a legend prevailed among some

of the alchemists that she was the sister of Moses.

Fig. X. p. 85, represents methods of distilling with an apparatus for

cooling the volatile products; the lower vessel is an \_alembic\_, with

a long neck, the upper part of which passes through a vessel

containing cold water.

[Illustration: Fig XIII. \_See p. 94.\_]

Fig. XI. p. 88, shows a \_pelican\_, that is a vessel wherein a liquid

might be heated for a long time, and the volatile products be

constantly returned to the original vessel.

Fig. XII. p. 89, represents a retort with a receiver.

Some of the pieces of apparatus for distilling, which are described

by French, are shown in the following figures. Besides describing

apparatus for distilling, subliming, and other processes in the

laboratory, French gives directions for making tinctures, essences,

essential oils, spirits of salt, and pure saltpetre, oil of vitriol,

butter of antimony, calces (or as we now say, oxides) of metals, and

many other substances. He describes processes for making fresh water

from salt, artificial mineral water, medicated hot baths for invalids

(one of the figures represents an apparatus very like those advertised

to-day as "Turkish baths at home"), and artificial precious stones; he

tells how to test minerals, and make alloys, and describes the

preparation of many substances made from gold and silver. He also

gives many curious receipts; for instance, "To make Firre-trees appear

in Turpentine," "To make a Plant grow in two or three hours," "To make

the representation of the whole world in a Glass," "To extract a white

Milkie substance from the raies of the Moon."

[Illustration: FIG. XIV. \_See p. 94.\_]

The process of making oil of vitriol, by burning sulphur under a hood

fitted with a side tube for the outflow of the oil of vitriol, is

represented in Fig. XIII. p. 92.

Fig. XIV. p. 93, is interesting; it is an apparatus for rectifying

spirits, by distilling, and liquefying only the most volatile portions

of the distillate. The spirituous liquor was heated, and the vapours

caused to traverse a long zigzag tube, wherein the less volatile

portions condensed to liquid, which flowed back into the vessel; the

vapour then passed into another vessel, and then through a second

zigzag tube, and was finally cooled by water, and the condensed liquid

collected. This apparatus was the forerunner of that used to-day, for

effecting the separation of liquids which boil at different

temperatures, by the process called \_fractional distillation\_.

We should never forget that the alchemists were patient and laborious

workers, their theories were vitally connected with their practice,

and there was a constant action and reaction between their general

scheme of things and many branches of what we now call chemical

manufactures. We may laugh at many of their theories, and regret that

much useless material was accumulated by them; we may agree with Boyle

(end of 17th century) when he likens the "hermetick philosophers," in

their search for truth, to "the navigators of Solomon's Tarshish

fleet, who brought home from their long and tedious voyages, not only

gold, and silver, and ivory, but apes and peacocks too; for so the

writings of several of your hermetick philosophers present us,

together with divers substantial and noble experiments, theories,

which either like peacocks' feathers make a great show but are neither

solid nor useful; or else like apes, if they have some appearance of

being rational, are blemished with some absurdity or other, that, when

they are attentively considered make them appear ridiculous." But

however we may condemn their method, because it rested on their own

conception of what the order of nature must be, we cannot but praise

their assiduity in conducting experiments and gathering facts.

As Bacon says, in \_De Augmentis Scientiarum\_:

"Alchemy may be compared to the man who told his sons that he had

left them gold buried somewhere in his vineyard; where they by

digging found no gold, but by turning up the mould about the roots

of the vines, procured a plentiful vintage. So the search and

endeavours to make gold have brought many useful inventions and

instructive experiments to light."

CHAPTER VII.

THE LANGUAGE OF ALCHEMY

The vagueness of the general conceptions of alchemy, and the

attribution of ethical qualities to material things by the alchemists,

necessarily led to the employment of a language which is inexact,

undescriptive, and unsuggestive to modern ears. The same name was

given to different things, and the same thing went under many names.

In Chapter IV. I endeavoured to analyse two terms which were

constantly used by the alchemists to convey ideas of great importance,

the terms \_Element\_ and \_Principle\_. That attempt sufficed, at any

rate, to show the vagueness of the ideas which these terms were

intended to express, and to make evident the inconsistencies between

the meanings given to the words by different alchemical writers. The

story quoted in Chapter III., from Michael Sendivogius, illustrates

the difficulty which the alchemists themselves had in understanding

what they meant by the term \_Mercury\_; yet there is perhaps no word

more often used by them than that. Some of them evidently took it to

mean the substance then, and now, called mercury; the results of this

literal interpretation were disastrous; others thought of mercury as a

substance which could be obtained, or, at any rate, might be obtained,

by repeatedly distilling ordinary mercury, both alone and when mixed

with other substances; others used the word to mean a hypothetical

something which was liquid but did not wet things, limpid yet capable

of becoming solid, volatile yet able to prevent the volatilisation of

other things, and white, yet ready to cause other white things to

change their colour; they thought of this something, this soul of

mercury, as having properties without itself being tangible, as at

once a substance and not a substance, at once a bodily spirit and a

spiritual body.

It was impossible to express the alchemical ideas in any language save

that of far-fetched allegory. The alchemical writings abound in such

allegories. Here are two of them.

The first allegory is taken from \_The Twelve Keys\_, of Basilius

Valentinus, the Benedictine:--

"The eleventh key to the knowledge of the augmentation of our

Stone I will put before you in the form of a parable.

"There lived in the East a gilded knight, named Orpheus, who was

possessed of immense wealth, and had everything that heart can

wish. He had taken to wife his own sister, Euridice, who did not,

however, bear him any children. This he regarded as the punishment

of his sin in having wedded his own sister, and was instant in

prayer to God both by day and by night, that the curse might be

taken from him. One night when he was buried in a deep sleep,

there came to him a certain winged messenger, named Phoebus, who

touched his feet, which were very hot, and said: 'Thou noble

knight, since thou hast wandered through many cities and kingdoms

and suffered many things at sea, in battle, and in the lists, the

heavenly Father has bidden me make known to thee the following

means of obtaining thy prayer: Take blood from thy right side, and

from the left side of thy spouse. For this blood is the heart's

blood of your parents, and though it may seem to be of two kinds,

yet, in reality, it is only one. Mix the two kinds of blood, and

keep the mixture tightly enclosed in the globe of the seven wise

Masters. Then that which is generated will be nourished with its

own flesh and blood, and will complete its course of development

when the Moon has changed for the eighth time. If thou repeat this

process again and again, thou shalt see children's children, and

the offspring of thy body shall fill the world.' When Phoebus

had thus spoken, he winged his flight heavenward. In the morning

the knight arose and did the bidding of the celestial messenger,

and God gave to him and to his wife many children, who inherited

their father's glory, wealth, and knightly honours from generation

to generation."

In the "Dedicatory Epistle" to his \_Triumphal Chariot of Antimony\_,

Basil Valentine addresses his brother alchemists as follows:--

"Mercury appeared to me in a dream, and brought me back from my

devious courses to the one way. 'Behold me clad not in the garb of

the vulgar, but in the philosopher's mantle.' So he said, and

straightway began to leap along the road in headlong bounds. Then,

when he was tired, he sat down, and, turning to me, who had

followed him in the spirit, bade me mark that he no longer

possessed that youthful vigour with which he would at the first

have overcome every obstacle, if he had not been allowed a free

course. Encouraged by his friendly salutation, I addressed him in

the following terms: 'Mercury, eloquent scion of Atlas, and father

of all Alchemists, since thou hast guided me hitherto, shew me, I

pray thee, the way to those Blessed Isles, which thou hast

promised to reveal to all thine elect children. 'Dost thou

remember,' he replied, that when I quitted thy laboratory, I left

behind me a garment so thoroughly saturated with my own blood,

that neither the wind could efface it, nor all-devouring time

destroy its indelible essence? Fetch it hither to me, that I may

not catch a chill from the state of perspiration in which I now

am; but let me clothe myself warmly in it, and be closely incited

thereto, so that I may safely reach my bride, who is sick with

love. She has meekly borne many wrongs, being driven through water

and fire, and compelled to ascend and descend times without

number--yet has she been carried through it all by the hope of

entering with me the bridal chamber, wherein we expect to beget a

son adorned from his birth with the royal crown which he may not

share with others. Yet may he bring his friends to the palace,

where sits enthroned the King of Kings, who communicates his

dignity readily and liberally to all that approach him.'

"I brought him the garment, and it fitted him so closely, that it

looked like an iron skin securing him against all the assaults of

Vulcan. 'Let us proceed,' he then said, and straightway sped

across the open field, while I boldly strove to keep up with my

guide.

"Thus we reached his bride, whose virtue and constancy were equal

to his own. There I beheld their marvellous conjugal union and

nuptial consummation, whence was born the son crowned with the

royal diadem. When I was about to salute him as King of Kings and

Lord of Lords, my Genius stood by me and warned me not to be

deceived, since this was only the King's forerunner, but not the

King himself whom I sought.

"When I heard the admonition, I did not know whether to be sad or

joyful. 'Depart,' then said Mercury, 'with this bridal gift, and

when you come to those disciples who have seen the Lord himself,

show them this sign.' And therewith he gave me a gold ring from

his son's finger. 'They know the golden branch which must be

consecrated to Proserpina before you can enter the palace of

Pluto. When he sees this ring, perhaps one will open to you with a

word the door of that chamber, where sits enthroned in his

magnificence the Desire of all Nations, who is known only to the

Sages.'

"When he had thus spoken, the vision vanished, but the bridal gift

which I still held in my hand shewed me that it had not been a

mere dream. It was of gold, but to me more precious than the most

prized of all metals. Unto you I will shew it when I am permitted

to see your faces, and to converse with you freely. Till that

earnestly wished-for time, I bid you farewell."

One result of the alchemical modes of expression was, that he who

tried to follow the directions given in alchemical books got into

dire confusion. He did not know what substances to use in his

operations; for when he was told to employ "the homogeneous water of

gold," for example, the expression might mean anything, and in despair

he distilled, and calcined, and cohobated, and tried to decompose

everything he could lay hands on. Those who pretended to know abused

and vilified those who differed from them.

In \_A Demonstration of Nature\_, by John A. Mehung (17th century),

Nature addresses the alchemical worker in the following words:--

"You break vials, and consume coals, only to soften your brains

still more with the vapours. You also digest alum, salt, orpiment,

and altrament; you melt metals, build small and large furnaces,

and use many vessels; nevertheless I am sick of your folly, and

you suffocate me with your sulphurous smoke.... You would do

better to mind your own business, than to dissolve and distil so

many absurd substances, and then to pass them through alembics,

cucurbits, stills, and pelicans."

Henry Madathanas, writing in 1622, says:--

"Then I understood that their purgations, sublimations,

cementations, distillations, rectifications, circulations,

putrefactions, conjunctions, calcinations, incinerations,

mortifications, revivifications, as also their tripods, athanors,

reverberatory alembics, excrements of horses, ashes, sand, stills,

pelican-viols, retorts, fixations, etc., are mere plausible

impostures and frauds."

The author of \_The Only Way\_ (1677) says:

"Surely every true Artist must look on this elaborate tissue of

baseless operations as the merest folly, and can only wonder that

the eyes of those silly dupes are not at last opened, that they

may see something besides such absurd sophisms, and read something

besides those stupid and deceitful books.... I can speak from

bitter experience, for I, too, toiled for many years ... and

endeavoured to reach the coveted goal by sublimation,

distillation, calcination, circulation, and so forth, and to

fashion the Stone out of substances such as urine, salt, atrament,

alum, etc. I have tried hard to evolve it out of hairs, wine,

eggs, bones, and all manner of herbs; out of arsenic, mercury, and

sulphur, and all the minerals and metals.... I have spent nights

and days in dissolving, coagulating, amalgamating, and

precipitating. Yet from all these things I derived neither profit

nor joy."

Another writer speaks of many would-be alchemists as "floundering

about in a sea of specious book-learning."

If alchemists could speak of their own processes and materials as

those authors spoke whom I have quoted, we must expect that the

alchemical language would appear mere jargon to the uninitiated. In

Ben Jonson's play \_The Alchemist\_, \_Surley\_, who is the sceptic of the

piece, says to Subtle, who is the alchemist--

... Alchemy is a pretty kind of game,

Somewhat like tricks o' the cards, to cheat a man

With charming ...

What else are all your terms,

Whereon no one of your writers 'grees with other?

Of your elixir, your \_lac virginis\_,

Your stone, your med'cine, and your chrysosperme,

Your sal, your sulphur, and your mercury,

Your oil of height, your tree of life, your blood,

Your marchesite, your tutie, your magnesia,

Your toad, your crow, your dragon, and your panther;

Your sun, your moon, your firmament, your adrop,

Your lato, azoch, zernich, chibrit, heutarit,

And then your red man, and your white woman,

With all your broths, your menstrues, and materials,

Of lye and egg-shells, women's terms, man's blood,

Hair o' the head, burnt clout, chalk, merds, and clay,

Powder of bones, scalings of iron, glass,

And moulds of other strange ingredients,

Would burst a man to name?

To which \_Subtle\_ answers,

And all these named

Intending but one thing; which art our writers

Used to obscure their art.

Was not all the knowledge

Of the Egyptians writ in mystic symbols?

Speak not the Scriptures oft in parables?

Are not the choicest fables of the poets,

That were the fountains and first springs of wisdom,

Wrapp'd in perplexed allegories?

The alchemists were very fond of using the names of animals as symbols

of certain mineral substances, and of representing operations in the

laboratory by what may be called animal allegories. The \_yellow lion\_

was the alchemical symbol of yellow sulphides, the \_red lion\_ was

synonymous with cinnabar, and the \_green lion\_ meant salts of iron and

of copper. Black sulphides were called \_eagles\_, and sometimes

\_crows\_. When black sulphide of mercury is strongly heated, a red

sublimate is obtained, which has the same composition as the black

compound; if the temperature is not kept very high, but little of the

red sulphide is produced; the alchemists directed to urge the fire,

"else the black crows will go back to the nest."

[Illustration: A salamander lives in the fire, which imparts to it a

most glorious hue.

This is the reiteration, gradation, and amelioration

of the Tincture, or Philosopher's Stone; and the whole

is called its Augmentation.

FIG. XV.]

The salamander was called the king of animals, because it was supposed

that he lived and delighted in fire; keeping a strong fire alight

under a salamander was sometimes compared to the purification of gold

by heating it.

Fig. XV., reduced from \_The Book of Lambspring\_ represents this

process.

The alchemists employed many signs, or shorthand expressions, in place

of writing the names of substances. The following are a few of the

signs which were used frequently.

[Symbol: Saturn] Saturn, also lead; [Symbol: Jupiter] Jupiter, also

tin; [Symbol: Mars-1] and [Symbol: Mars-2] Mars, also iron; [Symbol:

Sun] Sol, also gold; [Symbol: Venus] Venus, also copper; [Symbol:

Mercury-1], [Symbol: Mercury-2] and [Symbol: Mercury-3] Mercury;

[Symbol: Moon] Luna, also silver; [Symbol: Sulphur] Sulphur; [Symbol:

Vitriol] Vitriol; [Symbol: Fire] fire; [Symbol: Air] air; [Symbol:

Water] and [Symbol: Aquarius] water; [Symbol: Earth] earth; [Symbol:

Aqua Fortis] aqua fortis; [Symbol: Aqua Regis] aqua regis; [Symbol:

Aqua Vitæ] aqua vitæ; [Symbol: Day] day; [Symbol: Night] night;

[Symbol: Amalgam] Amalgam; [Symbol: Alembic] Alembic.

CHAPTER VIII.

THE DEGENERACY OF ALCHEMY.

I have tried to show that alchemy aimed at giving experimental proof

of a certain theory of the whole system of nature, including humanity.

The practical culmination of the alchemical quest presented a

threefold aspect; the alchemists sought the stone of wisdom, for by

gaining that they gained the control of wealth; they sought the

universal panacea, for that would give them the power of enjoying

wealth and life; they sought the soul of the world, for thereby they

could hold communion with spiritual existences, and enjoy the fruition

of spiritual life.

The object of their search was to satisfy their material needs, their

intellectual capacities, and their spiritual yearnings. The alchemists

of the nobler sort always made the first of these objects subsidiary

to the other two; they gave as their reason for desiring to make gold,

the hope that gold might become so common that it would cease to be

sought after by mankind. The author of \_An Open Substance\_ says:

"Would to God ... all men might become adepts in our art, for then

gold, the common idol of mankind, would lose its value, and we should

prize it only for its scientific teaching."

But the desire to make gold must always have been a very powerful

incentive in determining men to attempt the laborious discipline of

alchemy; and with them, as with all men, the love of money was the

root of much evil. When a man became a student of alchemy merely for

the purpose of making gold, and failed to make it--as he always

did--it was very easy for him to pretend he had succeeded in order

that he might really make gold by cheating other people. Such a man

rapidly degenerated into a charlatan; he used the language of alchemy

to cover his frauds, and with the hope of deluding his dupes by

high-sounding phrases. And, it must be admitted, alchemy lent itself

admirably to imposture. It promised unlimited wealth; it encouraged

the wildest dreams of the seeker after pleasure; and over these dreams

it cast the glamour of great ideas, the idea of the unity of nature,

and the idea of communion with other spheres of life, of calling in

the help of 'inheritors of unfulfilled renown,' and so it seemed to

touch to fine issues the sordidness of unblushing avarice.

Moreover, the working with strange ingredients and odd-fashioned

instruments, and the employment of mouth-filling phrases, and scraps

of occult learning which seemed to imply unutterable things, gave just

that pleasing dash of would-be wickedness to the process of consulting

the alchemist which acts as a fascination to many people. The earnest

person felt that by using the skill and knowledge of the alchemists,

for what he deemed a good purpose, he was compelling the powers of

evil to work for him and his objects.

It was impossible that such a system as alchemy should appear to the

plain man of the middle ages, when the whole scheme of life and the

universe rested on a magical basis, to be more than a kind of magic

which hovered between the black magic of the Sorcerer and the white

magic of the Church. Nor is it to be wondered at that a system which

lends itself to imposture so easily as alchemy did, should be thought

of by the plain man of modern times as having been nothing but a

machinery of fraud.

It is evident from the \_Canon's Yeoman's Tale\_ in Chaucer, that many

of those who professed to turn the base metals into gold were held in

bad repute as early as the 14th century. The "false chanoun" persuaded

the priest, who was his dupe, to send his servant for quicksilver,

which he promised to make into "as good silver and as fyn, As ther is

any in youre purse or myn"; he then gave the priest a "crosselet," and

bid him put it on the fire, and blow the coals. While the priest was

busy with the fire,

This false chanoun--the foulè feend hym fecche!--

Out of his bosom took a bechen cole,

In which ful subtilly was maad an hole,

And therinne put was of silver lemaille

An ounce, and stoppéd was withouten faille

The hole with wex, to kepe the lemaille in.

The "false chanoun" pretended to be sorry for the priest, who was so

busily blowing the fire:--

Ye been right hoot, I se wel how ye swete;

Have heer a clooth, and wipe awey the we't.

And whylès that the preest wipèd his face,

This chanoun took his cole with hardè grace,

And leyde it above, upon the middèward

Of the crosselet, and blew wel afterward.

Til that the colès gonnè fastè brenne.

As the coal burned the silver fell into the "crosselet." Then the

canon said they would both go together and fetch chalk, and a pail of

water, for he would pour out the silver he had made in the form of an

ingot. They locked the door, and took the key with them. On returning,

the canon formed the chalk into a mould, and poured the contents of

the crucible into it. Then he bade the priest,

Look what ther is, put in thin hand and grope,

Thow fyndè shalt ther silver, as I hope.

What, devel of hellè! Sholde it ellis be?

Shavyng of silver silver is, \_parde!\_

He putte his hand in, and took up a teyne

Of silver fyn, and glad in every veyne

Was this preest, when he saugh that it was so.

The conclusion of the \_Canon's Yeoman's Tale\_ shows that, in the 14th

century, there was a general belief in the possibility of finding the

philosopher's stone, and effecting the transmutation, although the

common practitioners of the art were regarded as deceivers. A disciple

of Plato is supposed to ask his master to tell him the "namè of the

privee stoon." Plato gives him certain directions, and tells him he

must use \_magnasia\_; the disciple asks--

'What is Magnasia, good sire, I yow preye?'

'It is a water that is maad, I seye,

Of elementés fourè,' quod Plato.

'Telle me the rootè, good sire,' quod he tho,

Of that water, if it be yourè wille.'

'Nay, nay,' quod Plato, 'certein that I nylle;

The philosophres sworn were everychoon

That they sholden discovers it unto noon,

Ne in no book it write in no manere,

For unto Crist it is so lief and deere,

That he wol nat that it discovered bee,

But where it liketh to his deitee

Man for tenspire, and eek for to deffende

Whom that hym liketh; lo, this is the ende.'

The belief in the possibility of alchemy seems to have been general

sometime before Chaucer wrote; but that belief was accompanied by the

conviction that alchemy was an impious pursuit, because the

transmutation of baser metals into gold was regarded as trenching on

the prerogative of the Creator, to whom alone this power rightfully

belonged. In his \_Inferno\_ (which was probably written about the year

1300), Dante places the alchemists in the eighth circle of hell, not

apparently because they were fraudulent impostors, but because, as one

of them says, "I aped creative nature by my subtle art."

In later times, some of those who pretended to have the secret and to

perform great wonders by the use of it, became rich and celebrated,

and were much sought after. The most distinguished of these

pseudo-alchemists was he who passed under the name of Cagliostro. His

life bears witness to the eagerness of human beings to be deceived.

Joseph Balsamo was born in 1743 at Palermo, where his parents were

tradespeople in a good way of business.[5] In the memoir of himself,

which he wrote in prison, Balsamo seeks to surround his birth and

parentage with mystery; he says, "I am ignorant, not only of my

birthplace, but even of the parents who bore me.... My earliest

infancy was passed in the town of Medina, in Arabia, where I was

brought up under the name of Acharat."

[5] The account of the life of Cagliostro is much condensed

from Mr A.E. Waite's \_Lives of the Alchemystical Philosophers\_.

When he was thirteen years of age, Balsamo's parents determined he

should be trained for the priesthood, but he ran away from his school.

He was then confined in a Benedictine monastery. He showed a

remarkable taste for natural history, and acquired considerable

knowledge of the use of drugs; but he soon tired of the discipline and

escaped. For some years he wandered about in different parts of Italy,

living by his wits and by cheating. A goldsmith consulted him about a

hidden treasure; he pretended to invoke the aid of spirits, frightened

the goldsmith, got sixty ounces of gold from him to carry on his

incantations, left him in the lurch, and fled to Messina. In that

town he discovered an aged aunt who was sick; the aunt died, and left

her money to the Church. Balsamo assumed her family name, added a

title of nobility, and was known henceforward as the Count Alessandro

Cagliostro.

In Messina he met a mysterious person whom he calls Altotas, and from

whom, he says in his Memoir, he learnt much. The following account of

the meeting of Balsamo and the stranger is taken from Waite's book:

"As he was promenading one day near the jetty at the extremity of the

port he encountered an individual singularly habited and possessed of

a most remarkable countenance. This person, aged apparently about

fifty years, seemed to be an Armenian, though, according to other

accounts, he was a Spaniard or Greek. He wore a species of caftan, a

silk bonnet, and the extremities of his breeches were concealed in a

pair of wide boots. In his left hand he held a parasol, and in his

right the end of a cord, to which was attached a graceful Albanian

greyhound.... Cagliostro saluted this grotesque being, who bowed

slightly, but with satisfied dignity. 'You do not reside in Messina,

signor?' he said in Sicilian, but with a marked foreign accent.

Cagliostro replied that he was tarrying for a few days, and they began

to converse on the beauty of the town and on its advantageous

situation, a kind of Oriental imagery individualising the eloquence of

the stranger, whose remarks were, moreover, adroitly adorned with a

few appropriate compliments."

Although the stranger said he received no one at his house he allowed

Cagliostro to visit him. After various mysterious doings the two went

off to Egypt, and afterwards to Malta, where they performed many

wonderful deeds before the Grand Master, who was much impressed. At

Malta Altotas died, or, at anyrate, vanished. Cagliostro then

travelled for some time, and was well received by noblemen,

ambassadors, and others in high position. At Rome he fell in love with

a young and beautiful lady, Lorenza Feliciani, and married her.

Cagliostro used his young wife as a decoy to attract rich and foolish

men. He and his wife thrived for a time, and accumulated money and

jewels; but a confederate betrayed them, and they fled to Venice, and

then wandered for several years in Italy, France, and England. They

seem to have made a living by the sale of lotions for the skin, and by

practising skilful deceptions.

About the year 1770 Cagliostro began to pose as an alchemist. After

another period of wandering he paid a second visit to London and

founded a secret society, based on (supposed) Egyptian rites, mingled

with those of freemasonry. The suggestion of this society is said to

have come from a curious book he picked up on a second-hand stall in

London. The society attracted people by the strangeness of its

initiatory rites, and the promises of happiness and wellbeing made by

its founder to those who joined it. Lodges were established in many

countries, many disciples were obtained, great riches were amassed,

and Cagliostro flourished exceedingly.

In his \_Histoire du Merveilleux dans les Temps modernes\_, Figuier,

speaking of Cagliostro about this period of his career, says:

"He proclaimed himself the bearer of the mysteries of Isis and Anubis

from the far East.... He obtained numerous and distinguished

followers, who on one occasion assembled in great force to hear Joseph

Balsamo expound to them the doctrines of Egyptian freemasonry. At this

solemn convention he is said to have spoken with overpowering

eloquence;... his audience departed in amazement and completely

converted to the regenerated and purified masonry. None doubted that

he was an initiate of the arcana of nature, as preserved in the temple

of Apis at the era when Cambyses belaboured that capricious divinity.

From this moment the initiations into the new masonry were numerous,

albeit they were limited to the aristocracy of society. There are

reasons to believe that the grandees who were deemed worthy of

admission paid exceedingly extravagantly for the honour."

Cagliostro posed as a physician, and claimed the power of curing

diseases simply by the laying on of hands. He went so far as to assert

he had restored to life the dead child of a nobleman in Paris; the

discovery that the miracle was effected by substituting a living child

for the dead one caused him to flee, laden with spoil, to Warsaw, and

then to Strassburg.

Cagliostro entered Strassburg in state, amid an admiring crowd, who

regarded him as more than human. Rumour said he had amassed vast

riches by the transmutation of base metals into gold. Some people in

the crowd said he was the wandering Jew, others that he had been

present at the marriage feast of Cana, some asserted he was born

before the deluge, and one supposed he might be the devil. The

goldsmith whom he had cheated of sixty ounces of gold many years

before was in the crowd, and, recognising him, tried to stop the

carriage, shouting: "Joseph Balsamo! It is Joseph! Rogue, where are my

sixty ounces of gold?" "Cagliostro scarcely deigned to glance at the

furious goldsmith; but in the middle of the profound silence which the

incident occasioned among the crowd, a voice, apparently in the

clouds, uttered with great distinctness the following words: 'Remove

this lunatic, who is possessed by infernal spirits.' Some of the

spectators fell on their knees, others seized the unfortunate

goldsmith, and the brilliant cortege passed on" (Waite).

From Strassburg Cagliostro\* went to Paris, where he lived in great

splendour, curing diseases, making gold and diamonds, mystifying and

duping people of all ranks by the splendid ritual and gorgeous

feasting of his secret society, and amassing riches. He got entangled

in the affair of the Diamond Necklace, and left Paris. Trying to

advance his society in Italy he was arrested by the agents of the

Inquisition, and imprisoned, then tried, and condemned to death. The

sentence was commuted to perpetual imprisonment. After two years in

the prison of San Angelo he died at the age of fifty.

\*Transcriber's Note: Original "Cagliosto".

CHAPTER IX.

PARACELSUS AND SOME OTHER ALCHEMISTS.

The accounts which have come to us of the men who followed the pursuit

of the \_One Thing\_ are vague, scrappy, and confusing.

Alchemical books abound in quotations from the writings of \_Geber\_.

Five hundred treatises were attributed to this man during the middle

ages, yet we have no certain knowledge of his name, or of the time or

place of his birth. Hoefer says he probably lived in the middle of the

8th century, was a native of Mesopotamia, and was named \_Djabar

Al-Konfi\_. Waite calls him \_Abou Moussah Djafar al-Sofi\_. Some of the

mediæval adepts spoke of him as the King of India, others called him a

Prince of Persia. Most of the Arabian writers on alchemy and medicine,

after the 9th century, refer to Geber as their master.

All the MSS. of writings attributed to Geber which have been examined

are in Latin, but the library of Leyden is said to possess some works

by him written in Arabic. These MSS. contain directions for preparing

many metals, salts, acids, oils, etc., and for performing such

operations as distillation, cupellation, dissolution, calcination, and

the like.

Of the other Arabian alchemists, the most celebrated in the middle

ages were \_Rhasis\_, \_Alfarabi\_, and \_Avicenna\_, who are supposed to

have lived in the 9th and 10th centuries.

The following story of Alfarabi's powers is taken from Waite's \_Lives

of the Alchemystical Philosophers\_:--

"Alfarabi was returning from a pilgrimage to Mecca, when, passing

through Syria, he stopped at the Court of the Sultan, and entered

his presence, while he was surrounded by numerous sage persons,

who were discoursing with the monarch on the sciences. Alfarabi

... presented himself in his travelling attire, and when the

Sultan desired he should be seated, with astonishing philosophical

freedom he planted himself at the end of the royal sofa. The

Prince, aghast at his boldness, called one of his officers, and in

a tongue generally unknown commanded him to eject the intruder.

The philosopher, however, promptly made answer in the same tongue:

'Oh, Lord, he who acts hastily is liable to hasty repentance.' The

Prince was equally astounded to find himself understood by the

stranger as by the manner in which the reply was given. Anxious to

know more of his guest he began to question him, and soon

discovered that he was acquainted with seventy languages. Problems

for discussion were then propounded to the philosophers, who had

witnessed the discourteous intrusion with considerable indignation

and disgust, but Alfarabi disputed with so much eloquence and

vivacity that he reduced all the doctors to silence, and they

began writing down his discourse. The Sultan then ordered his

musicians to perform for the diversion of the company. When they

struck up, the philosopher accompanied them on a lute with such

infinite grace and tenderness that he elicited the unmeasured

admiration of the whole distinguished assembly. At the request of

the Sultan he produced a piece of his own composing, sang it, and

accompanied it with great force and spirit to the delight of all

his hearers. The air was so sprightly that even the gravest

philosopher could not resist dancing, but by another tune he as

easily melted them to tears, and then by a soft unobtrusive melody

he lulled the whole company to sleep."

The most remarkable of the alchemists was he who is generally known as

\_Paracelsus\_. He was born about 1493, and died about 1540. It is

probable that the place of his birth was Einsiedeln, near Zurich. He

claimed relationship with the noble family of Bombast von Hohenheim;

but some of his biographers doubt whether he really was connected with

that family. His name, or at any rate the name by which he was known,

was Aureolus Philippus Theophrastus Bombast von Hohenheim. His father

in alchemy, Trimethius, Abbot of Spannheim and then of Wurzburg, who

was a theologian, a poet, an astronomer, and a necromancer, named him

\_Paracelsus\_; this name is taken by some to be a kind of Græco-Latin

paraphrase of von Hohenheim (of high lineage), and to mean "belonging

to a lofty place"; others say it signifies "greater than Celsus," who

was a celebrated Latin writer on medicine of the 1st century.

Paracelsus studied at the University of Basle; but, getting into

trouble with the authorities, he left the university, and for some

years wandered over Europe, supporting himself, according to one

account, by "psalm-singing, astrological productions, chiromantic

soothsaying, and, it has been said, by necromantic practices." He may

have got as far as Constantinople; as a rumour floated about that he

received the Stone of Wisdom from an adept in that city. He returned

to Basle, and in 1527 delivered lectures with the sanction of the

Rector of the university. He made enemies of the physicians by abusing

their custom of seeking knowledge only from ancient writers and not

from nature; he annoyed the apothecaries by calling their tinctures,

decoctions, and extracts, mere \_soup-messes\_; and he roused the ire of

all learned people by delivering his lectures in German. He was

attacked publicly and also anonymously. Of the pamphlets published

against him he said, "These vile ribaldries would raise the ire of a

turtle-dove." And Paracelsus was no turtle-dove. The following extract

from (a translation of) the preface to \_The Book concerning the

Tinctures of the Philosophers written against those Sophists born

since the Deluge\_, shews that his style of writing was abusive, and

his opinion of himself, to say the least, not very humble:--

"From the middle of this age the Monarchy of all the Arts has been

at length derived and conferred on me, Theophrastus Paracelsus,

Prince of Philosophy and Medicine. For this purpose I have been

chosen by God to extinguish and blot out all the phantasies of

elaborate and false works, of delusive and presumptuous words, be

they the words of Aristotle, Galen, Avicenna, Mesva, or the

dogmas of any among their followers. My theory, proceeding as it

does from the light of Nature, can never, through its consistency,

pass away or be changed; but in the fifty-eighth year after its

millennium and a half it will then begin to flourish. The practice

at the same time following upon the theory will be proved by

wonderful and incredible signs, so as to be open to mechanics and

common people, and they will thoroughly understand how firm and

immovable is that Paracelsic Art against the triflings of the

Sophists; though meanwhile that sophistical science has to have

its ineptitude propped up and fortified by papal and imperial

privileges.... So then, you wormy and lousy Sophist, since you

deem the monarch of Arcana a mere ignorant, fatuous, and prodigal

quack, now, in this mid age, I determine in my present treatise to

disclose the honourable course of procedure in these matters, the

virtues and preparation of the celebrated Tincture of the

Philosophers for the use and honour of all who love the truth, and

in order that all who despise the true arts may be reduced to

poverty."

The turbulent and restless spirit of Paracelsus brought him into open

conflict with the authorities of Basle. He fled from that town in

1528, and after many wanderings, he found rest at Salzburg, under the

protection of the archbishop. He died at Salzburg in 1541, in his

forty-eighth year.

The character and abilities of Paracelsus have been vastly praised by

some, and inordinately abused by others. One author says of him: "He

lived like a pig, looked like a drover, found his greatest enjoyment

in the company of the most dissolute and lowest rabble, and throughout

his glorious life he was generally drunk." Another author says:

"Probably no physician has grasped his life's task with a purer

enthusiasm, or devoted himself more faithfully to it, or more fully

maintained the moral worthiness of his calling than did the reformer

of Einsiedeln." He certainly seems to have been loved and respected by

his pupils and followers, for he is referred to by them as "the noble

and beloved monarch," "the German Hemes," and "our dear Preceptor and

King of Arts."

There seems no doubt that Paracelsus discovered many facts which

became of great importance in chemistry: he prepared the inflammable

gas we now call hydrogen, by the reaction between iron filings and oil

of vitriol; he distinguished metals from substances which had been

classed with metals but lacked the essential metalline character of

ductility; he made medicinal preparations of mercury, lead and iron,

and introduced many new and powerful drugs, notably laudanum.

Paracelsus insisted that medicine is a branch of chemistry, and that

the restoration of the body of a patient to a condition of chemical

equilibrium is the restoration to health.

Paracelsus trusted in his method; he was endeavouring to substitute

direct appeal to nature for appeal to the authority of writers about

nature. "After me," he cries, "you Avicenna, Galen, Rhasis, Montagnana

and the others. You after me, not I after you. You of Paris, you of

Montpellier, you of Swabia, of Meissen and Vienna; you who come from

the countries along the Danube and the Rhine; and you, too, from the

Islands of the Ocean. Follow me. It is not for me to follow you, for

mine is the monarchy." But the work was too arduous, the struggle too

unequal. "With few appliances, with no accurate knowledge, with no

help from the work of others, without polished and sharpened weapons,

and without the skill that comes from long handling of instruments of

precision, what could Paracelsus effect in his struggle to wrest her

secrets from nature? Of necessity, he grew weary of the task, and

tried to construct a universe which should be simpler than that most

complex order which refused to yield to his analysis." And so he came

back to the universe which man constructs for himself, and exclaimed--

"Each man has ... all the wisdom and power of the world in

himself; he possesses one kind of knowledge as much as another,

and he who does not find that which is in him cannot truly say

that he does not possess it, but only that he was not capable of

successfully seeking for it."

We leave a great genius, with his own words in our ears: "Have no care

of my misery, reader; let me bear my burden myself. I have two

failings: my poverty and my piety. My poverty was thrown in my face by

a Burgomaster who had perhaps only seen doctors attired in silken

robes, never basking in tattered rags in the sunshine. So it was

decreed I was not a doctor. For my piety I am arraigned by the

parsons, for ... I do not at all love those who teach what they do not

themselves practise."

CHAPTER X.

SUMMARY OF THE ALCHEMICAL DOCTRINE.--THE REPLACEMENT OF THE THREE

PRINCIPLES OF THE ALCHEMISTS BY THE SINGLE PRINCIPLE OF PHLOGISTON.

The \_Sacred Art\_, which had its origin and home in Egypt, was very

definitely associated with the religious rites, and the theological

teaching, recognised by the state. The Egyptian priests were initiated

into the mysteries of the divine art: and as the initiated claimed to

imitate the work of the deity, the priest was regarded by the ordinary

people as something more than a representative, as a mirror, of the

divinity. The sacred art of Egypt was transmuted into alchemy by

contact with European thought and handicrafts, and the tenets and

mysticism of the Catholic Church; and the conception of nature, which

was the result of this blending, prevailed from about the 9th until

towards the end of the 18th century.

Like its predecessor, alchemy postulated an orderly universe; but

alchemy was richer in fantastic details, more picturesquely

embroidered, more prodigal of strange fancies, than the sacred art of

Egypt.

The alchemist constructed his ordered scheme of nature on the basis of

the supposed universality of life. For him, everything lived, and the

life of things was threefold. The alchemist thought he recognised the

manifestation of life in the form, or body, of a thing, in its soul,

and in its spirit. Things might differ much in appearance, in size,

taste, smell, and other outward properties, and yet be intimately

related, because, according to the alchemist, they were produced from

the same principles, they were animated by the same soul. Things might

resemble one another closely in their outward properties and yet

differ widely in essential features, because, according to the

alchemist, they were formed from different elements, in their

spiritual properties they were unlike. The alchemists taught that the

true transformation, in alchemical language the transmutation, of one

thing into another could be effected only by spiritual means acting on

the spirit of the thing, because the transmutation consisted

essentially in raising the substance to the highest perfection whereof

it was capable; the result of this spiritual action might become

apparent in the material form of the substance. In attempting to apply

such vague conceptions as these, alchemy was obliged to use the

language which had been developed for the expression of human emotions

and desires, not only for the explanation of the facts it observed,

but also for the bare recital of these facts.

The outlook of alchemy on the world outside human beings was

essentially anthropomorphic. In the image of man, the alchemist

created his universe.

In the times when alchemy was dominant, the divine scheme of creation,

and the place given to man in that scheme, were supposed to be

thoroughly understood. Everything had its place, designed for it from

the beginning, and in that place it remained unless it were forced

from it by violent means. A great part of the business of experimental

alchemy was to discover the natural position, or condition, of each

substance; and the discovery was to be made by interpreting the facts

brought to light by observation and experiment by the aid of

hypotheses deduced from the general scheme of things which had been

formed independently of observation or experiment. Alchemy was a part

of magic; for magic interprets and corrects the knowledge gained by

the senses by the touchstone of generalisations which have been

supplied, partly by the emotions, and partly by extra-human authority,

and accepted as necessarily true.

The conception of natural order which regulates the life of the savage

is closely related to that which guided the alchemists. The essential

features of both are the notion that everything is alive, and the

persuasion that things can be radically acted on only by using life as

a factor. There is also an intimate connexion between alchemy and

witchcraft. Witches were people who were supposed to make an unlawful

use of the powers of life; alchemists were often thought to pass

beyond what is permitted to the creature, and to encroach on the

prerogative of the Creator.

The long duration of alchemy shows that it appealed to some

deep-seated want of human beings. Was not that want the necessity for

the realisation of order in the universe? Men were unwilling to wait

until patient examination of the facts of their own nature, and the

facts of nature outside themselves, might lead them to the realisation

of the interdependence of all things. They found it easier to evolve a

scheme of things from a superficial glance at themselves and their

surroundings; naturally they adopted the easier plan. Alchemy was a

part of the plan of nature produced by this method. The extraordinary

dominancy of such a scheme is testified to by the continued belief in

alchemy, although the one experiment, which seems to us to be the

crucial experiment of the system, was never accomplished. But it is

also to be remembered that the alchemists were acquainted with, and

practised, many processes which we should now describe as operations

of manufacturing and technical chemistry; and the practical usefulness

of these processes bore testimony, of the kind which convinces the

plain man, to the justness of their theories.

I have always regarded two facts as most interesting and instructive:

that the doctrine of the essential unity of all things, and the

simplicity of natural order, was accepted for centuries by many, I

think one may say, by most men, as undoubtedly a true presentation of

the divine scheme of things; and, secondly, that in more recent times

people were quite as certain of the necessary truth of the doctrine,

the exact opposite of the alchemical, that the Creator had divided his

creation into portions each of which was independent of all the

others. Both of these schemes were formed by the same method, by

introspection preceding observation; both were overthrown by the same

method, by observation and experiment proceeding hand in hand with

reasoning. In each case, the humility of science vanquished the

conceit of ignorance.

The change from alchemy to chemistry is an admirable example of the

change from a theory formed by looking inwards, and then projected on

to external facts, to a theory formed by studying facts, and then

thinking about them. This change proceeded slowly; it is not possible

to name a time when it may be said, here alchemy finishes and

chemistry begins. To adapt a saying of one of the alchemists, quoted

in a former chapter; alchemy would not easily give up its nature, and

fought for its life; but an agent was found strong enough to overcome

and kill it, and then that agent also had the power to change the

lifeless remains into a new and pure body. The agent was the accurate

and imaginative investigation of facts.

The first great step taken in the path which led from alchemy to

chemistry was the substitution of one Principle, the Principle of

Phlogiston, for the three Principles of salt, sulphur, and mercury.

This step was taken by concentrating attention and investigation, by

replacing the superficial examination of many diverse phenomena by the

more searching study of one class of occurrences. That the field of

study should be widened, it was necessary that it should first be

narrowed.

Lead, tin, iron, or copper is calcined. The prominent and striking

feature of these events is the disappearance of the metal, and the

formation of something very unlike it. But the original metal is

restored by a second process, which is like the first because it also

is a calcination, but seems to differ from the first operation in that

the burnt metal is calcined with another substance, with grains of

wheat or powdered charcoal. Led thereto by their theory that

destruction must precede re-vivification, death must come before

resurrection, the alchemists confined their attention to one feature

common to all calcinations of metals, and gave a superficial

description of these occurrences by classing them together as

processes of mortification. Sulphur, wood, wax, oil, and many other

things are easily burned: the alchemists said, these things also

undergo mortification, they too are killed; but, as "man can restore

that which man has destroyed," it must be possible to restore to life

the thing which has been mortified. The burnt sulphur, wood, wax, or

oil, is not really dead, the alchemists argued; to use the allegory of

Paracelsus, they are like young lions which are born dead, and are

brought to life by the roaring of their parents: if we make a

sufficiently loud noise, if we use the proper means, we shall bring

life into what seems to be dead material. As it is the roaring of the

parents of the young lions which alone can cause the still-born cubs

to live, so it is only by the spiritual agency of life, proceeded the

alchemical argument, that life can be brought into the mortified

sulphur, wood, wax, and oil.

The alchemical explanation was superficial, theoretical, in the wrong

meaning of that word, and unworkable. It was superficial because it

overlooked the fact that the primary calcination, the mortification,

of the metals, and the other substances, was effected in the air, that

is to say, in contact with something different from the thing which

was calcined; the explanation was of the kind which people call

theoretical, when they wish to condemn an explanation and put it out

of court, because it was merely a re-statement of the facts in the

language of a theory which had not been deduced from the facts

themselves, or from facts like those to be explained, but from what

were supposed to be facts without proper investigation, and, if facts,

were of a totally different kind from those to which the explanation

applied; and lastly, the explanation was unworkable, because it

suggested no method whereby its accuracy could be tested, no definite

line of investigation which might be pursued.

That great naturalist, the Honourable Robert Boyle (born in 1626, died

in 1691), very perseveringly besought those who examined processes of

calcination to pay heed to the action of everything which might take

part in the processes. He was especially desirous they should consider

what part the air might play in calcinations; he spoke of the air as a

"menstruum or additament," and said that, in such operations as

calcination, "We may well take the freedom to examine ... whether

there intervene not a coalition of the parts of the body wrought upon

with those of the menstruum, whereby the produced concrete may be

judged to result from the union of both."

It was by examining the part played by the air in processes of

calcination and burning that men at last became able to give

approximately complete descriptions of these processes.

Boyle recognised that the air is not a simple or elementary substance;

he spoke of it as "a confused aggregate of effluviums from such

differing bodies, that, though they all agree in constituting by their

minuteness and various motions one great mass of fluid matter, yet

perhaps there is scarce a more heterogeneous body in the world."

Clement of Alexandria who lived in the end of the 2nd, and the early

part of the 3rd, century A.D., seems to have regarded the air as

playing a very important part in combustions; he said--"Airs are

divided into two categories; an air for the divine flame, which is the

soul; and a material air which is the nourisher of sensible fire, and

the basis of combustible matter." Sentences like that I have just

quoted are found here and there in the writings of the earlier and

later alchemists; now and again we also find statements which may be

interpreted, in the light of the fuller knowledge we now have, as

indicating at least suspicions that the atmosphere is a mixture of

different kinds of air, and that only some of these take part in

calcining and burning operations. Those suspicions were confirmed by

experiments on the calcination of metals and other substances,

conducted in the 17th century by Jean Rey a French physician, and by

John Mayow of Oxford. But these observations and the conclusions

founded on them, did not bear much fruit until the time of Lavoisier,

that is, towards the close of the 18th century. They were overshadowed

and put aside by the work of Stahl (1660-1724). Some of the alchemists

of the 14th, 15th and 16th centuries taught that combustion and

calcination are processes wherein \_the igneous principle\_ is

destroyed, using the word "destroyed" in its alchemical meaning. This

description of processes of burning was much more in keeping with the

ideas of the time than that given by Boyle, Rey and Mayow. It was

adopted by Stahl, and made the basis of a general theory of those

changes wherein one substance disappears and another, or others, very

unlike it, are produced.

That he might bring into one point of view, and compare the various

changes effected by the agency of fire, Stahl invented a new

Principle, which he named \_Phlogiston\_, and constructed an hypothesis

which is generally known as the phlogistic theory. He explained, and

applied, this hypothesis in various books, especially in one published

at Halle in 1717.

Stahl observed that many substances which differed much from one

another in various respects were alike in one respect; they were all

combustible. All the combustible substances, he argued, must contain a

common principle; he named this supposed principle, \_phlogiston\_ (from

the Greek word \_phlogistos\_ = burnt, or set on fire). Stahl said that

the phlogiston of a combustible thing escapes as the substance burns,

and, becoming apparent to the senses, is named fire or flame. The

phlogiston in a combustible substance was supposed to be so

intimately associated with something else that our senses cannot

perceive it; nevertheless, the theory said, it is there; we can see

only the escaping phlogiston, we can perceive only the phlogiston

which is set free from its combination with other things. The theory

thought of phlogiston as imprisoned in the thing which can be burnt,

and as itself forming part of the prison; that the prisoner should be

set free, the walls of the prison had to be removed; the freeing of

the prisoner destroyed the prison. As escaping, or free, phlogiston

was called fire, or flame, so the phlogiston in a combustible

substance was sometimes called combined fire, or flame in the state of

combination. A peculiarity of the strange thing called phlogiston was

that it preferred to be concealed in something, hidden, imprisoned,

combined; free phlogiston\* was supposed to be always ready to become

combined phlogiston.

\*Transcriber's Note: Original "phlogstion".

The phlogistic theory said that what remains when a substance has been

burnt is the original substance deprived of phlogiston; and,

therefore, to restore the phlogiston to the product of burning is to

re-form the combustible substance. But how is such a restoration of

phlogiston to be accomplished? Evidently by heating the burnt thing

with something which is very ready to burn. Because, according to the

theory, everything which can be burnt contains phlogiston, the more

ready a substance is to burn the richer it is in phlogiston; burning

is the outrush of phlogiston, phlogiston prefers to be combined with

something; therefore, if you mix what remains after burning, with

something which is very combustible, and heat the mixture, you are

bringing the burnt matter under conditions which are very favourable

for the reception of phlogiston by it, for you are bringing it into

intimate contact with something from which freedom-hating phlogiston

is being forced to escape.

Charcoal, sulphur, phosphorus, oils and fats are easily burnt; these

substances were, therefore, chosen for the purpose of changing things

which had been burnt into things which could again be burnt; these,

and a few other substances like these, were classed together, and

called \_phlogisticating agents\_.

Very many of the substances which were dealt with by the experimenters

of the last quarter of the 17th, and the first half of the 18th,

century, were either substances which could be burned, or those which

had been produced by burning; hence the phlogistic theory brought into

one point of view, compared, and emphasised the similarities between,

a great many things which had not been thought of as connected before

that theory was promulgated. Moreover, the theory asserted that all

combustible, or incinerable, things are composed of phlogiston, and

another principle, or, as was often said, another element, which is

different in different kinds of combustible substances. The metals,

for instance, were said to be composed of phlogiston and an earthy

principle or element, which was somewhat different in different

metals. The phlogisteans taught that the earthy principle of a metal

remains in the form of ash, cinders, or calx, when the metal is

calcined, or, as they expressed it, when the metal is deprived of its

phlogiston.

The phlogistic theory savoured of alchemy; it postulated an undefined,

undefinable, intangible Principle; it said that all combustible

substances are formed by the union of this Principle with another,

which is sometimes of an earthy character, sometimes of a fatty

nature, sometimes highly volatile in habit. Nevertheless, the theory

of Stahl was a step away from purely alchemical conceptions towards

the accurate description of a very important class of changes. The

principle of phlogiston could be recognised by the senses as it was in

the act of escaping from a substance; and the other principle of

combustible things was scarcely a Principle in the alchemical sense,

for, in the case of metals at any rate, it remained when the things

which had contained it were burnt, and could be seen, handled, and

weighed. To say that metals are composed of phlogiston and an earthy

substance, was to express facts in such a language that the expression

might be made the basis of experimental inquiry; it was very different

from the assertion that metals are produced by the spiritual actions

of the three Principles, salt, mercury and sulphur, the first of which

is not salt, the second is not mercury, and the third is not sulphur.

The followers of Stahl often spoke of metals as composed of phlogiston

and an \_element\_ of an earthy character; this expression also was an

advance, from the hazy notion of \_Element\_ in purely alchemical

writings, towards accuracy and fulness of description. An element was

now something which could he seen and experimented with; it was no

longer a semi-spiritual existence which could not be grasped by the

senses.

The phlogistic theory regarded the calcination of a metal as the

separation of it into two things, unlike the metal, and unlike each

other; one of these things was phlogiston, the other was an earth-like

residue. The theory thought of the re-formation of a metal from its

calx, that is, the earthy substance which remains after combustion, as

the combination of two things to produce one, apparently homogeneous,

substance. Metals appeared to the phlogisteans, as they appeared to

the alchemists, to be composite substances. Processes of burning were

regarded by alchemists and phlogisteans alike, as processes of

simplification.

The fact had been noticed and recorded, during the middle ages, that

the earth-like matter which remains when a metal is calcined is

heavier than the metal itself. From this fact, modern investigators of

natural phenomena would draw the conclusion, that calcination of a

metal is an addition of something to the metal, not a separation of

the metal into different things. It seems impossible to us that a

substance should be separated into portions, and one of these parts

should weigh as much as, or more than, the whole.

The exact investigation of material changes called chemistry rests on

the statement that \_mass\_, and mass is practically measured by

\_weight\_, is the one property of what we call matter, the

determination whereof enables us to decide whether a change is a

combination, or coalescence, of different things, or a separation of

one thing into parts. That any part of a material system can be

removed without the weight of the portion which remains being less

than the original weight of the whole system, is unthinkable, in the

present state of our knowledge of material changes.

But in the 17th century, and throughout most of the 18th, only a few

of those who examined changes in the properties of substances paid

heed to changes of weight; they had not realised the importance of the

property of mass, as measured by weight. The convinced upholder of the

phlogistic theory had two answers to the argument, that, because the

earth-like product of the calcination of a metal weighs more than the

metal itself, therefore the metal cannot have lost something in the

process; for, if one portion of what is taken away weighs more than

the metal from which it has been separated, it is evident that the

weight of the two portions into which the metal is said to have been

divided must be considerably greater than the weight of the undivided

metal. The upholders of the theory sometimes met the argument by

saying, "Of course the calx weighs more than the metal, because

phlogiston tends to lighten a body which contains it; and therefore

the body weighs more after it has lost phlogiston than it did when the

phlogiston formed part of it;" sometimes, and more often, their answer

was--"loss or gain of weight is an accident, the essential thing is

change of qualities."

If the argument against the separation of a metal into two

constituents, by calcination, were answered to-day as it was answered

by the upholders of the phlogistic theory, in the middle of the 18th

century, the answers would justly be considered inconsequent and

ridiculous. But it does not follow that the statements were either

far-fetched or absurd at the time they were made. They were expressed

in the phraseology of the time; a phraseology, it is true, sadly

lacking in consistency, clearness, and appropriateness, but the only

language then available for the description of such changes as those

which happen when metals are calcined. One might suppose that it must

always have sounded ridiculous to say that the weight of a thing can

be decreased by adding something to it, that part of a thing weighs

more than the whole of it. But the absurdity disappears if it can be

admitted that mass, which is measured by weight, may be a property

like colour, or taste, or smell; for the colour, taste, or smell of a

thing may certainly be made less by adding something else, and the

colour, taste, or smell of a thing may also be increased by adding

something else. If we did not know that what we call \_quantity of

substance\_ is measured by the property named \_mass\_, we might very

well accept the proposition that the entrance of phlogiston into a

substance decreases the quantity, hence the mass, and, therefore, the

weight, of the substance.

Although Stahl and his followers were emerging from the trammels of

alchemy, they were still bound by many of the conceptions of that

scheme of nature. We have learned, in previous chapters, that the

central idea of alchemy was expressed in the saying: "Matter must be

deprived of its properties in order to draw out its soul." The

properties of substances are everything to the modern chemist--indeed,

such words as iron, copper, water, and gold are to him merely

convenient expressions for certain definable groups of properties--but

the phlogisteans regarded the properties of things, including mass, as

of secondary importance; they were still trying to get beneath the

properties of a thing, to its hypothetical essence, or substance.

Looking back, we cannot think of phlogiston as a substance, or as a

thing, in the modern meanings of these terms as they are used in

natural science. Nowadays we think, we are obliged to think, of the

sum of the quantities of all the things in the universe as unchanging,

and unchangeable by any agency whereof we have definite knowledge. The

meaning we give to the word \_thing\_ rests upon the acceptance of this

hypothesis. But the terms \_substance\_, \_thing\_, \_properties\_ were used

very vaguely a couple of centuries ago; and it would be truly absurd

to carry back to that time the meanings which we give to these terms

to-day, and then to brand as ridiculous the attempts of the men who

studied, then, the same problems which we study now, to express the

results of their study in generalisations which employed the terms in

question, in what seems to us a loose, vague, and inexact manner.

By asserting, and to some extent experimentally proving, the existence

of one principle in many apparently very different substances (or, as

would be said to-day, one property common to many substances), the

phlogistic theory acted as a very useful means for collecting, and

placing in a favourable position for closer inspection, many

substances which would probably have remained scattered and detached

from one another had this theory not been constructed. A single

assumption was made, that all combustible substances are alike in one

respect, namely, in containing combined fire, or phlogiston; by the

help of this assumption, the theory of phlogiston emphasised the

fundamental similarity between all processes of combustion. The theory

of phlogiston was extraordinarily simple, compared with the alchemical

vagaries which preceded it. Hoefer says, in his \_Histoire de la

Chimie\_, "If it is true that simplicity is the distinctive character

of verity, never was a theory so true as that of Stahl."

The phlogistic theory did more than serve as a means for bringing

together many apparently disconnected facts. By concentrating the

attention of the students of material changes on one class of events,

and giving descriptions of these events without using either of the

four alchemical Elements, or the three Principles, Stahl, and those

who followed him, did an immense service to the advancement of clear

thinking about natural occurrences. The principle of phlogiston was

more tangible, and more readily used, than the Salt, Sulphur, and

Mercury of the alchemists; and to accustom people to speak of the

material substance which remained when a metal, or other combustible

substance, was calcined or burnt, as one of the \_elements\_ of the

thing which had been changed, prepared the way for the chemical

conception of an element as a definite substance with certain definite

properties.

In addition to these advantages, the phlogistic theory was based on

experiments, and led to experiments, the results of which proved that

the capacity to undergo combustion might be conveyed to an

incombustible substance, by causing it to react with some other

substance, itself combustible, under definite conditions. The theory

thus prepared the way for the representation of a chemical change as

an interaction between definite kinds of substances, marked by precise

alterations both of properties and composition.

The great fault of the theory of phlogiston, considered as a general

conception which brings many facts into one point of view, and leads

the way to new and exact knowledge, was its looseness, its

flexibility. It was very easy to make use of the theory in a broad and

general way; by stretching it here, and modifying it there, it seemed

to cover all the facts concerning combustion and calcination which

were discovered during two generations after the publication of

Stahl's books. But many of the subsidiary hypotheses which were

required to make the theory cover the new facts were contradictory, or

at any rate seemed to be contradictory, of the primary assumptions of

the theory. The addition of this ancillary machinery burdened the

mechanism of the theory, threw it out of order, and finally made it

unworkable. The phlogistic theory was destroyed by its own

cumbersomeness.

A scientific theory never lasts long if its fundamental assumptions

are stated so loosely that they may be easily modified, expanded,

contracted, and adjusted to meet the requirements of newly discovered

facts. It is true that the theories which have been of the greatest

service in science, as summaries of the relations between established

facts, and suggestions of lines of investigation, have been stated in

terms whose full meaning has gradually unfolded itself. But the

foundations of these theories have been at once so rigidly defined and

clearly stated as to be incapable of essential modification, and so

full of meaning and widely applicable as to cover large classes of

facts which were unknown when the theories were constructed. Of the

founders of the lasting and expansible theories of natural science, it

may be said, that "thoughts beyond their thoughts to those high bards

were given."

CHAPTER XI.

THE EXAMINATION OF THE PHENOMENA OF COMBUSTION.

The alchemists thought that the most effectual method of separating a

complex substance into more simple substances was to subject it to the

action of heat. They were constantly distilling, incinerating,

subliming, heating, in order that the spirit, or inner kernel of

things, might be obtained. They took for granted that the action of

fire was to simplify, and that simplification proceeded whatever might

be the nature of the substance which was subjected to this action.

Boyle insisted that the effect of heating one substance may be, and

often is, essentially different from the effect of heating another

substance; and that the behaviour of the same substance when heated,

sometimes varies when the conditions are changed. He takes the example

of heating sulphur or brimstone: "Exposed to a moderate fire in

subliming pots, it rises all into dry, and almost tasteless, flowers;

whereas being exposed to a naked fire, it affords store of a saline

and fretting liquor." Boyle thought that the action of fire was not

necessarily to separate a thing into its principles or elements, but,

in most cases, was either to rearrange the parts of the thing, so that

new, and it might be, more complex things, were produced, or to form

less simple things by the union of the substance with what he called,

"the matter of fire." When the product of heating a substance, for

example, tin or lead, weighed more than the substance itself, Boyle

supposed that the gain in weight was often caused by the "matter of

fire" adding itself to the substance which was heated. He commended to

the investigation of philosophers this "subtil fluid," which is "able

to pierce into the compact and solid bodies of metals, and add

something to them that has no despicable weight upon the balance, and

is able for a considerable time to continue fixed in the fire." Boyle

also drew attention to the possibility of action taking place between

a substance which is heated and some other substance, wherewith the

original thing may have been mixed. In a word, Boyle showed that the

alchemical assumption--fire simplifies--was too simple; and he taught,

by precept and example, that the only way of discovering what the

action of fire is, on this substance or on that, is to make accurate

experiments. "I consider," he says, "that, generally speaking, to

render a reason of an effect or phenomenon, is to deduce it from

something else in nature more known than itself; and that consequently

there may be divers kinds of degrees of explication of the same

thing."

Boyle published his experiments and opinions concerning the action of

fire on different substances in the seventies of the 17th century;

Stahl's books, which laid the foundation of the phlogistic theory, and

confirmed the alchemical opinion that the action of fire is

essentially a simplifying action, were published about forty years

later. But fifty years before Boyle, a French physician, named Jean

Rey, had noticed that the calcination of a metal is the production of

a more complex, from a less complex substance; and had assigned the

increase in weight which accompanies that operation to the attachment

of particles of the air to the metal. A few years before the

publication of Boyle's work, from which I have quoted, John Mayow,

student of Oxford, recounted experiments which led to the conclusion

that the air contains two substances, one of which supports combustion

and the breathing of animals, while the other extinguishes fire. Mayow

called the active component of the atmosphere \_fiery air\_; but he was

unable to say definitely what becomes of this fiery air when a

substance is burnt, although he thought that, in some cases, it

probably attaches itself to the burning substances, by which,

therefore, it may be said to be fixed. Mayow proved that the air

wherein a substance is burnt, or an animal breathes, diminishes in

volume during the burning, or the breathing. He tried, without much

success, to restore to air that part of it which disappears when

combustion, or respiration, proceeds in it.

What happens when a substance is burnt in the air? The alchemists

answered this question by asserting that the substance is separated or

analysed into things simpler than itself. Boyle said: the process is

not necessarily a simplification; it may be, and certainly sometimes

is, the formation of something more complicated than the original

substance, and when this happens, the process often consists in the

fixation of "the matter of fire" by the burning substance. Rey said:

calcination, of a metal at anyrate, probably consists in the fixation

of particles of air by the substance which is calcined. Mayow answered

the question by asserting, on the ground of the results of his

experiments, that the substance which is being calcined lays hold of a

particular constituent of the air, not the air as a whole.

Now, it is evident that if Mayow's answer was a true description of

the process of calcination, or combustion, it should be possible to

separate the calcined substance into two different things, one of

which would be the thing which was calcined, and the other would be

that constituent of the air which had united with the burning, or

calcining, substance. It seems clear to us that the one method of

proving the accuracy of Mayow's supposition must be, to weigh a

definite, combustible, substance--say, a metal; to calcine this in a

measured quantity of air; to weigh the product, and to measure the

quantity of air which remains; to separate the product of calcination

into the original metal, and a kind of air or gas; to prove that the

metal thus obtained is the same, and has the same weight, as the metal

which was calcined; and to prove that the air or gas obtained from the

calcined metal is the same, both in quality and quantity, as the air

which disappeared in the process of calcination.

This proof was not forthcoming until about a century after the

publication of Mayow's work. The experiments which furnished the proof

were rendered possible by a notable discovery made on the 1st of

August 1774, by the celebrated Joseph Priestley.

Priestley prepared many "airs" of different kinds: by the actions of

acids on metals, by allowing vegetables to decay, by heating beef,

mutton, and other animal substances, and by other methods. He says:

"Having procured a lens of twelve inches diameter and twenty inches

focal distance, I proceeded with great alacrity to examine, by the

help of it, what kind of air a great variety of substances, natural

and factitious, would yield.... With this apparatus, after a variety

of other experiments.... on the 1st of August, 1774, I endeavoured to

extract air from \_mercurius calcinatus per se\_; and I presently found

that, by means of this lens, air was expelled from it very readily.

Having got about three or four times as much as the bulk of my

materials, I admitted water to it, and found that it was not imbibed

by it. But what surprised me more than I can well express was, that a

candle burned in this air with a remarkably vigorous flame.... I was

utterly at a loss how to account for it."

[Illustration: FIG. XVI.]

The apparatus used by Priestley, in his experiments on different kinds

of air, is represented in Fig. XVI., which is reduced from an

illustration in Priestley's book on \_Airs\_.

Priestley had made a discovery which was destined to change Alchemy

into Chemistry. But he did not know what his discovery meant. It was

reserved for the greatest of all chemists, Antoine Lavoisier, to use

the fact stumbled on by Priestley.

After some months Priestley began to think it possible that the new

"air" he had obtained from calcined mercury might be fit for

respiration. To his surprise he found that a mouse lived in this air

much longer than in common air; the new air was evidently better, or

purer, than ordinary air. Priestley measured what he called the

"goodness" of the new air, by a process of his own devising, and

concluded that it was "between four and five times as good as common

air."

Priestley was a thorough-going phlogistean. He seems to have been able

to describe the results of his experiments only in the language of the

phlogistic theory; just as the results of most of the experiments made

to-day on the changes of compounds of the element carbon cannot be

described by chemists except by making use of the conceptions and the

language of the atomic and molecular theory.[6]

[6] I have given numerous illustrations of the truth of this

statement in the book, in this series, entitled \_The Story of

the Wanderings of Atoms\_.

The upholder of the phlogistic theory could not think of burning as

possible unless there was a suitable receptacle for the phlogiston of

the burning substance: when burning occurred in the air, the part

played by the air, according to the phlogistic chemist, was to receive

the expelled phlogiston; in this sense the air acted as the \_pabulum\_,

or nourishment, of the burning substance. Inasmuch as substances

burned more vigorously and brilliantly in the new air than in common

air, Priestley argued that the new air was more ready, more eager,

than ordinary air, to receive phlogiston; and, therefore, that the new

air contained less phlogiston than ordinary air, or, perhaps, no

phlogiston. Arguing thus, Priestley, of course, named the new aeriform

substance \_dephlogisticated air\_, and thought of it as ordinary air

deprived of some, or it might be all, of its phlogiston.

The breathing of animals and the burning of substances were supposed

to load the atmosphere with phlogiston. Priestley spoke of the

atmosphere as being constantly "vitiated," "rendered noxious,"

"depraved," or "corrupted" by processes of respiration and combustion;

he called those processes whereby the atmosphere is restored to its

original condition (or "depurated," as he said), "dephlogisticating

processes." As he had obtained his \_dephlogisticated air\_ by heating

the calx of mercury, that is the powder produced by calcining mercury

in the air, Priestley was forced to suppose that the calcination of

mercury in the air must be a more complex occurrence than merely the

expulsion of phlogiston from the mercury: for, if the process

consisted only in the expulsion of phlogiston, how could heating what

remained produce exceedingly pure ordinary air? It seemed necessary

to suppose that not only was phlogiston expelled from mercury during

calcination, but that the mercury also imbibed some portion, and that

the purest portion, of the surrounding air. Priestley did not,

however, go so far as this; he was content to suppose that in some

way, which he did not explain, the process of calcination resulted in

the loss of phlogiston by the mercury, and the gain, by the

dephlogisticated mercury, of the property of yielding exceedingly pure

or dephlogisticated air when it was heated very strongly.

Priestley thought of properties in much the same way as the alchemists

thought of them, as wrappings, or coverings of an essential something,

from which they can be removed and around which they can again be

placed. The protean principle of phlogiston was always at hand, and,

by skilful management, was ready to adapt itself to any facts. Before

the phenomena of combustion could be described accurately, it was

necessary to do two things; to ignore the theory of phlogiston, and to

weigh and measure all the substances which take part in some selected

processes of burning.

Looking back at the attempts made in the past to describe natural

events, we are often inclined to exclaim, "Why did investigators bind

themselves with the cords of absurd theories; why did they always wear

blinkers; why did they look at nature through the distorting mists

rising from their own imaginations?" We are too ready to forget the

tremendous difficulties which beset the path of him who is seeking

accurate knowledge.

"To climb steep hills requires slow pace at first."

Forgetting that the statements wherein the men of science of our own

time describe the relations between natural events are, and must be,

expressed in terms of some general conception, some theory, of these

relations; forgetting that the simplest natural occurrence is so

complicated that our powers of description are incapable of expressing

it completely and accurately; forgetting the uselessness of

disconnected facts; we are inclined to overestimate the importance of

our own views of nature's ways, and to underestimate the usefulness of

the views of our predecessors. Moreover, as naturalists have not been

obliged, in recent times, to make a complete renunciation of any

comprehensive theory wherein they had lived and moved for many years,

we forget the difficulties of breaking loose from a way of looking at

natural events which has become almost as real as the events

themselves, of abandoning a language which has expressed the most

vividly realised conceptions of generations of investigators, of

forming a completely new mental picture of natural occurrences, and

developing a completely new language for the expression of those

conceptions and these occurrences.

The younger students of natural science of to-day are beginning to

forget what their fathers told them of the fierce battle which had to

be fought, before the upholders of the Darwinian theory of the origin

of species were able to convince those for whom the older view, that

species are, and always have been, absolutely distinct, had become a

matter of supreme scientific, and even ethical, importance.

A theory which has prevailed for generations in natural science, and

has been accepted and used by everyone, can be replaced by a more

accurate description of the relations between natural facts, only by

the determination, labour, and genius of a man of supreme power. Such

a service to science, and humanity, was rendered by Darwin; a like

service was done, more than three-quarters of a century before Darwin,

by Lavoisier.

Antoine Laurent Lavoisier was born in Paris in 1743. His father, who

was a merchant in a good position, gave his son the best education

which was then possible, in physical, astronomical, botanical, and

chemical science. At the age of twenty-one, Lavoisier gained the prize

offered by the Government for devising an effective and economical

method of lighting the public streets. From that time until, on the

8th of May 1794, the Government of the Revolution declared, "The

Republic has no need of men of science," and the guillotine ended his

life, Lavoisier continued his researches in chemistry, geology,

physics, and other branches of natural science, and his investigations

into the most suitable methods of using the knowledge gained by

naturalists for advancing the welfare of the community.

In Chapter VI., I said that when an alchemist boiled water in an open

vessel, and obtained a white earthy solid, in place of the water which

disappeared, he was producing some sort of experimental proof of the

justness of his assertion that water can be changed into earth.

Lavoisier began his work on the transformations of matter by

demonstrating that this alleged transmutation does not happen; and he

did this by weighing the water, the vessel, and the earthy solid.

Lavoisier had constructed for him a pelican of white glass (see Fig.

XI., p. 88), with a stopper of glass. He cleaned, dried, and weighed

this vessel; then he put into it rain-water which he had distilled

eight times; he heated the vessel, removing the stopper from time to

time to allow the expanding air to escape, then put in the stopper,

allowed the vessel to cool, and weighed very carefully. The difference

between the second and the first weighing was the weight of water in

the vessel. He then fastened the stopper securely with cement, and

kept the apparatus at a temperature about 30° or 40° below that of

boiling water, for a hundred and one days. At the end of that time a

fine white solid had collected on the bottom of the vessel. Lavoisier

removed the cement from the stopper, and weighed the apparatus; the

weight was the same as it had been before the heating began. He

removed the stopper; air rushed in, with a hissing noise. Lavoisier

concluded that air had not penetrated through the apparatus during the

process of heating. He then poured out the water, and the solid which

had formed in the vessel, set them aside, dried, and weighed the

pelican; it had lost 17-4/10 grains. Lavoisier concluded that the

solid which had formed in the water was produced by the solvent action

of the water on the glass vessel. He argued that if this conclusion

was correct, the weight of the solid must be equal to the loss of

weight suffered by the vessel; he therefore separated the solid from

the water in which it was suspended, dried, and weighed it. The solid

weighed 4-9/10 grains. Lavoisier's conclusion seemed to be incorrect;

the weight of the solid, which was supposed to be produced by the

action of the water on the vessel, was 12-1/2 grains less than the weight

of the material removed from the vessel. But some of the material

which was removed from the vessel might have remained dissolved in the

water: Lavoisier distilled the water, which he had separated from the

solid, in a glass vessel, until only a very little remained in the

distilling apparatus; he poured this small quantity into a glass

basin, and boiled until the whole of the water had disappeared as

steam. There remained a white, earthy solid, the weight of which was

15-1/2 grains. Lavoisier had obtained 4-9/10 + 15-1/2 = 20-2/5 grains

of solid; the pelican had lost 17-2/5 grains. The difference between

these weights, namely, 3 grains, was accounted for by Lavoisier as due

to the solvent action of the water on the glass apparatus wherein it

had been distilled, and on the glass basin wherein it had been

evaporated to dryness.

Lavoisier's experiments proved that when distilled water is heated in

a glass vessel, it dissolves some of the material of the vessel, and

the white, earthy solid which is obtained by boiling down the water is

merely the material which has been removed from the glass vessel. His

experiments also proved that the water does not undergo any change

during the process; that at the end of the operation it is what it was

at the beginning--water, and nothing but water.

By this investigation Lavoisier destroyed part of the experimental

basis of alchemy, and established the one and only method by which

chemical changes can be investigated; the method wherein constant use

is made of the balance.

Lavoisier now turned his attention to the calcination of metals, and

particularly the calcination of tin. Boyle supposed that the increase

in weight which accompanies the calcination of a metal is due to the

fixation of "matter of fire" by the calcining metal; Rey regarded the

increase in weight as the result of the combination of the air with

the metal; Mayow thought that the atmosphere contains two different

kinds of "airs," and one of these unites with the heated metal.

Lavoisier proposed to test these suppositions by calcining a weighed

quantity of tin in a closed glass vessel, which had been weighed

before, and should be weighed after, the calcination. If Boyle's view

was correct, the weight of the vessel and the tin would be greater at

the end than it was at the beginning of the operation; for "matter of

fire" would pass through the vessel and unite with the metal. If there

was no change in the total weight of the apparatus and its contents,

and if air rushed in when the vessel was opened after the calcination,

and the total weight was then greater than at the beginning of the

process, it would be necessary to adopt either the supposition of Rey

or that of Mayow.

Lavoisier made a series of experiments. The results were these: there

was no change in the total weight of the apparatus and its contents;

when the vessel was opened after the calcination was finished, air

rushed in, and the whole apparatus now weighed more than it did before

the vessel was opened; the weight of the air which rushed in was

exactly equal to the increase in the weight of the tin produced by the

calcination, in other words, the weight of the inrushing air was

exactly equal to the difference between the weights of the tin and the

calx formed by calcining the tin. Lavoisier concluded that to calcine

tin is to cause it to combine with a portion of the air wherein it is

calcined. The weighings he made showed that about one-fifth of the

whole weight of air in the closed flask wherein he calcined tin had

disappeared during the operation.

Other experiments led Lavoisier to suspect that the portion of the air

which had united with the tin was different from the portion which had

not combined with that metal. He, therefore, set himself to discover

whether there are different kinds of "airs" in the atmosphere, and, if

there is more than one kind of "air," what is the nature of that "air"

which combines with a metal in the process of calcination. He proposed

to cause a metallic calx (that is, the substance formed by calcining

a metal in the air) to give up the "air" which had been absorbed in

its formation, and to compare this "air" with atmospheric air.

About this time Priestley visited Paris, saw Lavoisier, and told him

of the new "air" he had obtained by heating calcined mercury.

Lavoisier saw the great importance of Priestley's discovery; he

repeated Priestley's experiment, and concluded that the air, or gas,

which he refers to in his Laboratory Journal as "l'air dephlogistique

de M. Priestley" was nothing else than the purest portion of the air

we breathe. He prepared this "air" and burned various substances in

it. Finding that very many of the products of these combustions had

the properties of acids, he gave to the new "air" the name \_oxygen\_,

which means \_the acid-producer\_.

At a later time, Lavoisier devised and conducted an experiment which

laid bare the change of composition that happens when mercury is

calcined in the air. He calcined a weighed quantity of mercury for

many days in a measured volume of air, in an apparatus arranged so

that he was able to determine how much of the air disappeared during

the process; he collected and weighed the red solid which formed on

the surface of the heated mercury; finally he heated this red solid to

a high temperature, collected and measured the gas which was given

off, and weighed the mercury which was produced. The sum of the

weights of the mercury and the gas which were produced by heating the

calcined mercury was equal to the weight of the calcined mercury; and

the weight of the gas produced by heating the calcined mercury was

equal to the weight of the portion of the air which had disappeared

during the formation of the calcined mercury. This experiment proved

that the calcination of mercury in the air consists in the combination

of a constituent of the air with the mercury. Fig. XVII. (reduced from

an illustration in Lavoisier's Memoir) represents the apparatus used

by Lavoisier. Mayow's supposition was confirmed.

[Illustration: FIG. XVII.]

Lavoisier made many more experiments on combustion, and proved that in

every case the component of the atmosphere which he had named oxygen

combined with the substance, or with some part of the substance, which

was burned. By these experiments the theory of Phlogiston was

destroyed; and with its destruction, the whole alchemical apparatus of

Principles and Elements, Essences and Qualities, Souls and Spirits,

disappeared.

CHAPTER XII.

THE RECOGNITION OF CHEMICAL CHANGES AS THE INTERACTIONS OF DEFINITE

SUBSTANCES.

The experimental study of combustion made by Lavoisier proved the

correctness of that part of Stahl's phlogistic theory which asserted

that all processes of combustion are very similar, but also proved

that this likeness consists in the combination of a distinct gaseous

substance with the material undergoing combustion, and not in the

escape therefrom of the \_Principle of fire\_, as asserted by the theory

of Stahl. After about the year 1790, it was necessary to think of

combustions in the air as combinations of a particular gas, or \_air\_,

with the burning substances, or some portions of them.

This description of processes of burning necessarily led to a

comparison of the gaseous constituent of the atmosphere which played

so important a part in these processes, with the substances which were

burned; it led to the examination of the compositions of many

substances, and made it necessary to devise a language whereby these

compositions could be stated clearly and consistently.

We have seen, in former chapters, the extreme haziness of the

alchemical views of composition, and the connexions between

composition and properties. Although Boyle[7] had stated very lucidly

what he meant by the composition of a definite substance, about a

century before Lavoisier's work on combustion, nevertheless the views

of chemists concerning composition remained very vague and incapable

of definite expression, until the experimental investigations of

Lavoisier enabled him to form a clear mental picture of chemical

changes as interactions between definite quantities of distinct

substances.

[7] Boyle said, in 1689, "I mean by elements ... certain

primitive and simple, or perfectly unmixed bodies; which not

being made of any other bodies, or of one another, are the

ingredients of which all those called perfectly mixt bodies are

immediately compounded, and into which they are ultimately

resolved."

Let us consider some of the work of Lavoisier in this direction. I

select his experimental examination of the interactions of metals and

acids.

Many experimenters had noticed that gases (or airs, as they were

called up till near the end of the 18th century) are generally

produced when metals are dissolving in acids. Most of those who

noticed this said that the gases came from the dissolving metals;

Lavoisier said they were produced by the decomposition of the acids.

In order to study the interaction of nitric acid and mercury,

Lavoisier caused a weighed quantity of the metal to react with a

weighed quantity of the acid, and collected the gas which was

produced; when all the metal had dissolved, he evaporated the liquid

until a white solid was obtained; he heated this solid until it was

changed to the red substance called, at that time, \_red precipitate\_,

and collected the gas produced. Finally, Lavoisier strongly heated the

red precipitate; it changed to a gas, which he collected, and mercury,

which he weighed.

The weight of the mercury obtained by Lavoisier at the end of this

series of changes was the same, less a few grains, as the weight of

the mercury which he had caused to react with the nitric acid. The gas

obtained during the solution of the metal in the acid, and during the

decomposition of the white solid by heat, was the same as a gas which

had been prepared by Priestley and called by him \_nitrous air\_; and

the gas obtained by heating the red precipitate was found to be

oxygen. Lavoisier then mixed measured volumes of oxygen and "nitrous

air," standing over water; a red gas was formed, and dissolved in the

water, and Lavoisier proved that the water now contained nitric acid.

The conclusions regarding the composition of nitric acid drawn by

Lavoisier from these experiments was, that "nitric acid is nothing

else than \_nitrous air\_, combined with almost its own volume of the

purest part of atmospheric air, and a considerable quantity of water."

Lavoisier supposed that the stages in the complete reaction between

mercury and nitric acid were these: the withdrawal of oxygen from the

acid by the mercury, and the union of the compound of mercury and

oxygen thus formed with the constituents of the acid which remained

when part of its oxygen was taken away. The removal of oxygen from

nitric acid by the mercury produced \_nitrous air\_; when the product of

the union of the oxide of mercury and the nitric acid deprived of part

of its oxygen was heated, more nitrous air was given off, and oxide of

mercury remained, and was decomposed, at a higher temperature, into

mercury and oxygen.

Lavoisier thought of these reactions as the tearing asunder, by

mercury, of nitric acid into definite quantities of its three

components, themselves distinct substances, nitrous air, water, and

oxygen; and the combination of the mercury with a certain measurable

quantity of one of these components, namely, oxygen, followed by the

union of this compound of mercury and oxygen with what remained of the

components of nitric acid.

Lavoisier had formed a clear, consistent, and suggestive mental

picture of chemical changes. He thought of a chemical reaction as

always the same under the same conditions, as an action between a

fixed and measurable quantity of one substance, having definite and

definable properties, with fixed and measurable quantities of other

substances, the properties of each of which were definite and

definable.

Lavoisier also recognised that certain definite substances could be

divided into things simpler than themselves, but that other substances

refused to undergo simplification by division into two or more unlike

portions. He spoke of the object of chemistry as follows:--[8] "In

submitting to experiments the different substances found in nature,

chemistry seeks to decompose these substances, and to get them into

such conditions that their various components may be examined

separately. Chemistry advances to its end by dividing, sub-dividing,

and again sub-dividing, and we do not know what will be the limits of

such operations. We cannot be certain that what we regard as simple

to-day is indeed simple; all we can say is, that such a substance is

the actual term whereat chemical analysis has arrived, and that with

our present knowledge we cannot sub-divide it."

[8] I have given a free rendering of Lavoisier's words.

In these words Lavoisier defines the chemical conception of

\_elements\_; since his time an element is "the actual term whereat

chemical analysis has arrived," it is that which "with our present

knowledge we cannot sub-divide"; and, as a working hypothesis, the

notion of \_element\_ has no wider meaning than this. I have already

quoted Boyle's statement that by \_elements\_ he meant "certain

primitive and simple bodies ... not made of any other bodies, or of

one another." Boyle was still slightly restrained by the alchemical

atmosphere around him; he was still inclined to say, "this \_must\_ be

the way nature works, she \_must\_ begin with certain substances which

are absolutely simple." Lavoisier had thrown off all the trammels

which hindered the alchemists from making rigorous experimental

investigations. If one may judge from his writings, he had not

struggled to free himself from these trammels, he had not slowly

emerged from the quagmires of alchemy, and painfully gained firmer

ground; the extraordinary clearness and directness of his mental

vision had led him straight to the very heart of the problems of

chemistry, and enabled him not only calmly to ignore all the machinery

of Elements, Principles, Essences, and the like, which the alchemists

had constructed so laboriously, but also to construct, in place of

that mechanism which hindered inquiry, genuine scientific hypotheses

which directed inquiry, and were themselves altered by the results of

the experiments they had suggested.

Lavoisier made these great advances by applying himself to the minute

and exhaustive examination of a few cases of chemical change, and

endeavouring to account for everything which took part in the

processes he studied, by weighing or measuring each distinct substance

which was present when the change began, and each which was present

when the change was finished. He did not make haphazard experiments;

he had a method, a system; he used hypotheses, and he used them

rightly. "Systems in physics," Lavoisier writes, "are but the proper

instruments for helping the feebleness of our senses. Properly

speaking, they are methods of approximation which put us on the track

of solving problems; they are the hypotheses which, successively

modified, corrected, and changed, by experience, ought to conduct us,

some day, by the method of exclusions and eliminations, to the

knowledge of the true laws of nature."

In a memoir wherein he is considering the production of carbonic acid

and alcohol by the fermentation of fruit-juice, Lavoisier says, "It is

evident that we must know the nature and composition of the

substances which can be fermented and the products of fermentation;

for nothing is created, either in the operations of art or in those of

nature; and it may be laid down that the quantity of material present

at the beginning of every operation is the same as the quantity

present at the end, that the quality and quantity of the principles[9]

are the same, and that nothing happens save certain changes, certain

modifications. On this principle is based the whole art of

experimenting in chemistry; in all chemical experiments we must

suppose that there is a true equality between the principles[10] of

the substances which are examined and those which are obtained from

them by analysis."

[9, 10] Lavoisier uses the word \_principle\_, here and

elsewhere, to mean a definite homogeneous substance; he uses it

as synonymous with the more modern terms element and compound.

If Lavoisier's memoirs are examined closely, it is seen that at the

very beginning of his chemical inquiries he assumed the accuracy, and

the universal application, of the generalisation "nothing is created,

either in the operations of art or in those of nature." Naturalists

had been feeling their way for centuries towards such a generalisation

as this; it had been in the air for many generations; sometimes it was

almost realised by this or that investigator, then it escaped for long

periods. Lavoisier seems to have realised, by what we call intuition,

that however great and astonishing may be the changes in the

properties of the substances which mutually react, there is no change

in the total quantity of material.

Not only did Lavoisier realise and act on this principle, he also

measured quantities of substances by the one practical method, namely,

by weighing; and by doing this he showed chemists the only road along

which they could advance towards a genuine knowledge of material

changes.

The generalisation expressed by Lavoisier in the words I have quoted

is now known as the \_law of the conservation of mass\_; it is generally

stated in some such form as this:--the sum of the masses of all the

homogeneous substances which take part in a chemical (or physical)

change does not itself change. The science of chemistry rests on this

law; every quantitative analysis assumes the accuracy, and is a proof

of the validity, of it.[11]

[11] I have considered the law of the conservation of mass in some

detail in Chapter IV. of \_The Story of the Chemical Elements\_.

By accepting the accuracy of this generalisation, and using it in

every experiment, Lavoisier was able to form a clear mental picture of

a chemical change as the separation and combination of homogeneous

substances; for, by using the balance, he was able to follow each

substance through the maze of changes, to determine when it united

with other substances, and when it separated into substances simpler

than itself.

CHAPTER XIII.

THE CHEMICAL ELEMENTS CONTRASTED WITH THE ALCHEMICAL PRINCIPLES.

It was known to many observers in the later years of the 17th century

that the product of the calcination of a metal weighs more than the

metal; but it was still possible, at that time, to assert that this

fact is of no importance to one who is seeking to give an accurate

description of the process of calcination. Weight, which measures mass

or quantity of substance, was thought of, in these days, as a property

like colour, taste, or smell, a property which was sometimes

decreased, and sometimes increased, by adding one substance to

another. Students of natural occurrences were, however, feeling their

way towards the recognition of some property of substances which did

not change in the haphazard way wherein most properties seemed to

alter. Lavoisier reached this property at one bound. By his

experimental investigations, he taught that, however greatly the

properties of one substance may be masked, or altered, by adding

another substance to it, yet the property we call mass, and measure by

weight, is not affected by these changes; for Lavoisier showed, that

the mass of the product of the union of two substances is always

exactly the sum of the masses of these two substances, and the sum of

the masses of the substances whereinto one substance is divided is

always exactly equal to that mass of the substance which is divided.

For the undefined, ever-changing, protean essence, or soul, of a thing

which the alchemists thought of as hidden by wrappings of properties,

the exact investigations of Lavoisier, and those of others who worked

on the same lines as he, substituted this definite, fixed,

unmodifiable property of mass. Lavoisier, and those who followed in

his footsteps, also did away with the alchemical notion of the

existence of an essential substratum, independent of changes in those

properties of a substance which can be observed by the senses. For the

experimental researches of these men obliged naturalists to recognise,

that a change in the properties of a definite, homogeneous substance,

such as pure water, pure chalk, or pure sulphur, is accompanied (or,

as we generally say, is caused) by the formation of a new substance or

substances; and this formation, this apparent creation, of new

material, is effected, either by the addition of something to the

original substance, or by the separation of it into portions which are

unlike it, and unlike one another. If the change is a combination, or

coalescence, of two things into one, then the mass, and hence the

weight, of the product is equal to the sum of those masses, and hence

those weights, of the things which have united to form it; if the

change is a separation of one distinct substance into several

substances, then the sum of the masses, and hence the weights, of the

products is equal to that mass, and hence that weight, of the

substance which has been separated.

Consider the word \_water\_, and the substance represented by this word.

In Chapter IV., I gave illustrations of the different meanings which

have been given to this word; it is sometimes used to represent a

material substance, sometimes a quality more or less characteristic of

that substance, and sometimes a process to which that substance, and

many others like it, may be subjected. But when the word \_water\_ is

used with a definite and exact meaning, it is a succinct expression

for a certain group, or collocation, of measurable properties which

are always found together, and is, therefore, thought of as a distinct

substance. This substance can be separated into two other substances

very unlike it, and can be formed by causing these to unite. One

hundred parts, by weight, of pure water are always formed by the union

of 11.11 parts of hydrogen, and 88.89 parts of oxygen, and can be

separated into these quantities of those substances. When water is

formed by the union of hydrogen and oxygen, in the ratio of 11.11

parts by weight of the former to 88.89 of the latter, the properties

of the two substances which coalesce to form it disappear, except

their masses. It is customary to say that water \_contains\_ hydrogen

and oxygen; but this expression is scarcely an accurate description of

the facts. What we call \_substances\_ are known to us only by their

properties, that is, the ways wherein they act on our senses. Hydrogen

has certain definite properties, oxygen has other definite properties,

and the properties of water are perfectly distinct from those of

either of the substances which it is said to contain. It is,

therefore, somewhat misleading to say that water \_contains\_

substances the properties whereof, except their masses, disappeared at

the moment when they united and water was produced. Nevertheless we

are forced to think of water as, in a sense, containing hydrogen and

oxygen. For, one of the properties of hydrogen is its power to

coalesce, or combine, with oxygen to form water, and one of the

properties of oxygen is its ability to unite with hydrogen to form

water; and these properties of those substances cannot be recognised,

or even suspected, unless certain definite quantities of the two

substances are brought together under certain definite conditions. The

properties which characterise hydrogen, and those which characterise

oxygen, when these things are separated from all other substances, can

be determined and measured in terms of the similar properties of some

other substance taken as a standard. These two distinct substances

disappear when they are brought into contact, under the proper

conditions, and something (water) is obtained whose properties are

very unlike those of hydrogen or oxygen; this new thing can be caused

to disappear, and hydrogen and oxygen are again produced. This cycle

of changes can be repeated as often as we please; the quantities of

hydrogen and oxygen which are obtained when we choose to stop the

process are exactly the same as the quantities of those substances

which disappeared in the first operation whereby water was produced.

Hence, water is an intimate union of hydrogen and oxygen; and, in this

sense, water may be said to contain hydrogen and oxygen.

The alchemist would have said, the properties of hydrogen and oxygen

are destroyed when these things unite to form water, but the essence,

or substratum, of each remains. The chemist says, you cannot discover

all the properties of hydrogen and oxygen by examining these

substances apart from one another, for one of the most important

properties of either is manifested only when the two mutually react:

the formation of water is not the destruction of the properties of

hydrogen and oxygen and the revelation of their essential substrata,

it is rather the manifestation of a property of each which cannot be

discovered except by causing the union of both.

There was, then, a certain degree of accuracy in the alchemical

description of the processes we now call chemical changes, as being

the removal of the outer properties of the things which react, and the

manifestation of their essential substance. But there is a vast

difference between this description and the chemical presentment of

these processes as reactions between definite and measurable

quantities of elements, or compounds, or both, resulting in the

re-distribution, of the elements, or the separation of the compounds

into their elements, and the formation of new compounds by the

re-combination of these elements.

Let us contrast the two descriptions somewhat more fully.

The alchemist wished to effect the transmutation of one substance into

another; he despaired of the possibility of separating the Elements

whereof the substance might be formed, but he thought he could

manipulate what he called the \_virtues\_ of the Elements by a judicious

use of some or all of the three Principles, which he named Sulphur,

Salt, and Mercury. He could not state in definite language what he

meant by these Principles; they were states, conditions, or qualities,

of classes of substances, which could not be defined. The directions

the alchemist was able to give to those who sought to effect the

change of one thing into another were these. Firstly, to remove those

properties which characterised the thing to be changed, and leave only

the properties which it shared with other things like it; secondly, to

destroy the properties which the thing to be changed possessed in

common with certain other things; thirdly, to commingle the Essence of

the thing with the Essence of something else, in due proportion and

under proper conditions; and, finally, to hope for the best, keep a

clear head, and maintain a sense of virtue.

If he who was about to attempt the transmutation inquired how he was

to destroy the specific properties, and the class properties, of the

thing he proposed to change, and by what methods he was to obtain its

Essence, and cause that Essence to produce the new thing, he would be

told to travel along "the road which was followed by the Great

Architect of the Universe in the creation of the world." And if he

demanded more detailed directions, he would be informed that the

substance wherewith his experiments began must first be mortified,

then dissolved, then conjoined, then putrefied, then congealed, then

cibated, then sublimed, and fermented, and, finally, exalted. He

would, moreover, be warned that in all these operations he must use,

not things which he could touch, handle, and weigh, but the \_virtues\_,

the \_lives\_, the \_souls\_, of such things.

When the student of chemistry desires to effect the transformation of

one definite substance into another, he is told to determine, by

quantitative experiments, what are the elements, and what the

quantities of these elements, which compose the compound which he

proposes to change, and the compound into which he proposes to change

it; and he is given working definitions of the words \_element\_ and

\_compound\_. If the compound he desires to produce is found to be

composed of elements different from those which form the compound

wherewith his operations begin, he is directed to bring about a

reaction, or a series of reactions, between the compound which is to

be changed, and some other collocation of elements the composition of

which is known to be such that it can supply the new elements which

are needed for the production of the new compound.

Since Lavoisier realised, for himself, and those who were to come

after him, the meaning of the terms \_element\_ and \_compound\_, we may

say that chemists have been able to form a mental picture of the

change from one definite substance to another, which is clear,

suggestive, and consistent, because it is an approximately accurate

description of the facts discovered by careful and penetrative

investigations. This presentment of the change has been substituted

for the alchemical conception, which was an attempt to express what

introspection and reasoning on the results of superficial

investigations, guided by specious analogies, suggested ought to be

the facts.

Lavoisier was the man who made possible the more accurate, and more

far-reaching, description of the changes which result in the

production of substances very unlike those which are changed; and he

did this by experimentally analysing the conceptions of the element

and the compound, giving definite and workable meanings to these

conceptions, and establishing, on an experimental foundation, the

generalisation that the sum of the quantities of the substances which

take part in any change is itself unchanged.

A chemical element was thought of by Lavoisier as "the actual term

whereat analysis has arrived," a definite substance "which we cannot

subdivide with our present knowledge," but not necessarily a substance

which will never be divided. A compound was thought of by him as a

definite substance which is always produced by the union of the same

quantities of the same elements, and can be separated into the same

quantities of the same elements.

These conceptions were amplified and made more full of meaning by the

work of many who came after Lavoisier, notably by John Dalton, who was

born in 1766 and died in 1844.

In Chapter I., I gave a sketch of the atomic theory of the Greek

thinkers. The founder of that theory, who flourished about 500 B.C.,

said that every substance is a collocation of a vast number of minute

particles, which are unchangeable, indestructible, and impenetrable,

and are therefore properly called \_atoms\_; that the differences which

are observed between the qualities of things are due to differences in

the numbers, sizes, shapes, positions, and movements of atoms, and

that the process which occurs when one substance is apparently

destroyed and another is produced in its place, is nothing more than a

rearrangement of atoms.

The supposition that changes in the properties of substances are

connected with changes in the numbers, movements, and arrangements of

different kinds of minute particles, was used in a general way by many

naturalists of the 17th and 18th centuries; but Dalton was the first

to show that the data obtained by the analyses of compounds make it

possible to determine the relative weights of the atoms of the

elements.

Dalton used the word \_atom\_ to denote the smallest particle of an

element, or a compound, which exhibits the properties characteristic

of that element or compound. He supposed that the atoms of an element

are never divided in any of the reactions of that element, but the

atoms of a compound are often separated into the atoms of the elements

whereof the compound is composed. Apparently without knowing that the

supposition had been made more than two thousand years before his

time, Dalton was led by his study of the composition and properties of

the atmosphere to assume that the atoms of different substances,

whether elements or compounds, are of different sizes and have

different weights. He assumed that when two elements unite to form

only one compound, the atom of that compound has the simplest

possible composition, is formed by the union of a single atom of each

element. Dalton knew only one compound of hydrogen and nitrogen,

namely, ammonia. Analyses of this compound show that it is composed of

one part by weight of hydrogen and 4.66 parts by weight of nitrogen.

Dalton said one atom of hydrogen combines with one atom of nitrogen to

form an atom of ammonia; hence an atom of nitrogen is 4.66 times

heavier than an atom of hydrogen; in other words, if the \_atomic

weight\_ of hydrogen is taken as unity, the \_atomic weight\_ of nitrogen

is expressed by the number 4.66. Dalton referred the atomic weights of

the elements to the atomic weight of hydrogen as unity, because

hydrogen is lighter than any other substance; hence the numbers which

tell how much heavier the atoms of the elements are than an atom of

hydrogen are always greater than one, are always positive numbers.

When two elements unite in different proportions, by weight, to form

more than one compound, Dalton supposed that (in most cases at any

rate) one of the compounds is formed by the union of a single atom of

each element; the next compound is formed by the union of one atom of

the element which is present in smaller quantity with two, three, or

more, atoms of the other element, and the next compound is formed by

the union of one atom of the first element with a larger number

(always, necessarily, a whole number) of atoms of the other element

than is contained in the second compound; and so on. From this

assumption, and the Daltonian conception of the atom, it follows that

the quantities by weight of one element which are found to unite with

one and the same weight of another element must always be expressible

as whole multiples of one number. For if two elements, A and B, form a

compound, that compound is formed, by supposition, of one atom of A

and one atom of B; if more of B is added, at least one atom of B must

be added; however much of B is added the quantity must be a whole

number of atoms; and as every atom of B is the same in all respects as

every other atom of B, the weights of B added to a constant weight of

A must be whole multiples of the atomic weight of B.

The facts which were available in Dalton's time confirmed this

deduction from the atomic theory within the limits of experimental

errors; and the facts which have been established since Dalton's time

are completely in keeping with the deduction. Take, for instance,

three compounds of the elements nitrogen and oxygen. That one of the

three which contains least oxygen is composed of 63.64 \_per cent.\_ of

nitrogen, and 36.36 \_per cent.\_ of oxygen; if the atomic weight of

nitrogen is taken to be 4.66, which is the weight of nitrogen that

combines with one part by weight of hydrogen, then the weight of

oxygen combined with 4.66 of nitrogen is 2.66 (63.64:36.36 =

4.66:2.66). The weights of oxygen which combine with 4.66 parts by

weight of nitrogen to form the second and third compounds,

respectively, must be whole multiples of 2.66; these weights are 5.32

and 10.64. Now 5.32 = 2.66 x 2, and 10.64 = 2.66 x 4. Hence, the

quantities by weight of oxygen which combine with one and the same

weight of nitrogen are such that two of these quantities are whole

multiples of the third quantity.

Dalton's application of the Greek atomic theory to the facts

established by the analyses of compounds enabled him to attach to each

element a number which he called the atomic weight of the element, and

to summarise all the facts concerning the compositions of compounds in

the statement, that the elements combine in the ratios of their atomic

weights, or in the ratios of whole multiples of their atomic weights.

All the investigations which have been made into the compositions of

compounds, since Dalton's time, have confirmed the generalisation

which followed from Dalton's application of the atomic theory.

Even if the theory of atoms were abandoned, the generalisation would

remain, as an accurate and exact statement of facts which hold good in

every chemical change, that a number can be attached to each element,

and the weights of the elements which combine are in the ratios of

these numbers, or whole multiples of these numbers.

Since chemists realised the meaning of Dalton's book, published in

1808, and entitled, \_A New System of Chemical Philosophy\_, elements

have been regarded as distinct and definite substances, which have not

been divided into parts different from themselves, and unite with each

other in definite quantities by weight which can be accurately

expressed as whole multiples of certain fixed quantities; and

compounds have been regarded as distinct and definite substances

which are formed by the union of, and can be separated into,

quantities of various elements which are expressible by certain fixed

numbers or whole multiples thereof. These descriptions of elements and

compounds are expressions of actual facts. They enable chemists to

state the compositions of all the compounds which are, or can be,

formed by the union of any elements. For example, let A, B, C, and D

represent four elements, and also certain definite weights of these

elements, then the compositions of all the compounds which can be

formed by the union of these elements are expressed by the scheme

A\_{\_n\_} B\_{\_m\_} C\_{\_p\_} D\_{\_q\_}, where \_m\_ \_n\_ \_p\_ and \_q\_ are whole

numbers.

These descriptions of elements and compounds also enable chemists to

form a clear picture to themselves of any chemical change. They think

of a chemical change as being; (1) a union of those weights of two, or

more, elements which are expressed by the numbers attached to these

elements, or by whole multiples of these numbers; or (2) a union of

such weights of two, or more, compounds as can be expressed by certain

numbers or by whole multiples of these numbers; or (3) a reaction

between elements and compounds, or between compounds and compounds,

resulting in the redistribution of the elements concerned, in such a

way that the complete change of composition can be expressed by using

the numbers, or whole multiples of the numbers, attached to the

elements.

How different is this conception of a change wherein substances are

formed, entirely unlike those things which react to form them, from

the alchemical presentment of such a process! The alchemist spoke of

stripping off the outer properties of the thing to be changed, and, by

operating spiritually on the soul which was thus laid bare, inducing

the essential virtue of the substance to exhibit its powers of

transmutation. But he was unable to give definite meanings to the

expressions which he used, he was unable to think clearly about the

transformations which he tried to accomplish. The chemist discards the

machinery of virtues, souls, and powers. It is true that he

substitutes a machinery of minute particles; but this machinery is

merely a means of thinking clearly and consistently about the changes

which he studies. The alchemist thought, vaguely, of substance as

something underlying, and independent of, properties; the chemist uses

the expression, this or that substance, as a convenient way of

presenting and reasoning about certain groups of properties. It seems

to me that if we think of \_matter\_ as something more than properties

recognised by the senses, we are going back on the road which leads to

the confusion of the alchemical times.

The alchemists expressed their conceptions in what seems to us a

crude, inconsistent, and very undescriptive language. Chemists use a

language which is certainly symbolical, but also intelligible, and on

the whole fairly descriptive of the facts.

A name is given to each elementary substance, that is, each substance

which has not been decomposed; the name generally expresses some

characteristic property of the substance, or tells something about

its origin or the place of its discovery. The names of compounds are

formed by putting together the names of the elements which combine to

produce them; and the relative quantities of these elements are

indicated either by the use of Latin or Greek prefixes, or by

variations in the terminal syllables of the names of the elements.

CHAPTER XIV.

THE MODERN FORM OF THE ALCHEMICAL QUEST OF THE ONE THING.

The study of the properties of the elements shows that these

substances fall into groups, the members of each of which are like one

another, and form compounds which are similar. The examination of the

properties and compositions of compounds has shown that similarity of

properties is always accompanied by similarity of composition. Hence,

the fact that certain elements are very closely allied in their

properties suggests that these elements may also be allied in their

composition. Now, to speak of the composition of an element is to

think of the element as formed by the union of at least two different

substances; it implies the supposition that some elements at any rate

are really compounds.

The fact that there is a very definite connexion between the values of

the atomic weights, and the properties, of the elements, lends some

support to the hypothesis that the substances we call, and are obliged

at present to call, elements, may have been formed from one, or a few,

distinct substances, by some process of progressive change. If the

elements are considered in the order of increasing atomic weights,

from hydrogen, whose atomic weight is taken as unity because it is the

lightest substance known, to uranium, an atom of which is 240 times

heavier than an atom of hydrogen, it is found that the elements fall

into periods, and the properties of those in one period vary from

element to element, in a way which is, broadly and on the whole, like

the variation of the properties of those in other periods. This fact

suggests the supposition--it might be more accurate to say the

speculation--that the elements mark the stable points in a process of

change, which has not proceeded continuously from a very simple

substance to a very complex one, but has repeated itself, with certain

variations, again and again. If such a process has occurred, we might

reasonably expect to find substances exhibiting only minute

differences in their properties, differences so slight as to make it

impossible to assign the substances, definitely and certainly, either

to the class of elements or to that of compounds. We find exactly such

substances among what are called the \_rare earths\_. There are

earth-like substances which exhibit no differences of chemical

properties, and yet show minute differences in the characters of the

light which they emit when they are raised to a very high

temperature.

The results of analysis by the spectroscope of the light emitted by

certain elements at different temperatures may be reasonably

interpreted by supposing that these elements are separated into

simpler substances by the action on them of very large quantities of

thermal energy. The spectrum of the light emitted by glowing iron

heated by a Bunsen flame (say, at 1200° C. = about 2200° F.) shows a

few lines and flutings; when iron is heated in an electric arc (say,

to 3500° C. = about 6300° F.) the spectrum shows some two thousand

lines; at the higher temperature produced by the electric

spark-discharge, the spectrum shows only a few lines. As a guide to

further investigation, we may provisionally infer from these facts

that iron is changed at very high temperatures into substances simpler

than itself.

Sir Norman Lockyer's study of the spectra of the light from stars has

shown that the light from those stars which are presumably the

hottest, judging by the general character of their spectra, reveals

the presence of a very small number of chemical elements; and that the

number of spectral lines, and, therefore, the number of elements,

increases as we pass from the hottest to cooler stars. At each stage

of the change from the hottest to cooler stars certain substances

disappear and certain other substances take their places. It may be

supposed, as a suggestive hypothesis, that the lowering of stellar

temperature is accompanied by the formation, from simpler forms of

matter, of such elements as iron, calcium, manganese, and other

metals.

In the year 1896, the French chemist Becquerel discovered the fact

that salts of the metal uranium, the atomic weight of which is 240,

and is greater than that of any other element, emit rays which cause

electrified bodies to lose their electric charges, and act on

photographic plates that are wrapped in sheets of black paper, or in

thin sheets of other substances which stop rays of light. The

\_radio-activity\_ of salts of uranium was proved not to be increased or

diminished when these salts had been shielded for five years from the

action of light by keeping them in leaden boxes. Shortly after

Becquerel's discovery, experiments proved that salts of the rare metal

thorium are radio-active. This discovery was followed by Madame

Curie's demonstration of the fact that certain specimens of

\_pitchblende\_, a mineral which contains compounds of uranium and of

many other metals, are extremely radio-active, and by the separation

from pitchblende, by Monsieur and Madame Curie, of new substances much

more radio-active than compounds of uranium or of thorium. The new

substances were proved to be compounds chemically very similar to

salts of barium. Their compositions were determined on the supposition

that they were salts of an unknown metal closely allied to barium.

Because of the great radio-activity of the compounds, the hypothetical

metal of them was named \_Radium\_. At a later time, radium was isolated

by Madame Curie. It is described by her as a white, hard, metal-like

solid, which reacts with water at the ordinary temperature, as barium

does.

Since the discovery of radium compounds, many radio-active substances

have been isolated. Only exceedingly minute quantities of any of them

have been obtained. The quantities of substances used in experiments

on radio-activity are so small that they escape the ordinary methods

of measurement, and are scarcely amenable to the ordinary processes of

the chemical laboratory. Fortunately, radio-activity can be detected

and measured by electrical methods of extraordinary fineness, methods

the delicacy of which very much more exceeds that of spectroscopic

methods than the sensitiveness of these surpasses that of ordinary

chemical analysis.

At the time of the discovery of radio-activity, about seventy-five

substances were called elements; in other words, about seventy-five

different substances were known to chemists, none of which had been

separated into unlike parts, none of which had been made by the

coalescence of unlike substances. Compounds of only two of these

substances, uranium and thorium, are radio-active. Radio-activity is a

very remarkable phenomenon. So far as we know at present,

radio-activity is not a property of the substances which form almost

the whole of the rocks, the waters, and the atmosphere of the earth;

it is not a property of the materials which constitute living

organisms. It is a property of some thirty substances--of course, the

number may be increased--a few of which are found widely distributed

in rocks and waters, but none of which is found anywhere except in

extraordinarily minute quantity. Radium is the most abundant of these

substances; but only a very few grains of radium chloride can be

obtained from a couple of tons of pitchblende.

In Chapter X. of \_The Story of the Chemical Elements\_ I have given a

short account of the outstanding phenomena of radio-activity; for the

present purpose it will suffice to state a few facts of fundamental

importance.

Radio-active substances are stores of energy, some of which is

constantly escaping from them; they are constantly changing without

external compulsion, and are constantly radiating energy: all

explosives are storehouses of energy which, or part of which, can be

obtained from them; but the liberation of their energy must be started

by some kind of external shock. When an explosive substance has

exploded, its existence as an explosive is finished; the products of

the explosion are substances from which energy cannot be obtained:

when a radio-active substance has exploded, it explodes again, and

again, and again; a time comes, sooner or later, when it has changed

into substances that are useless as sources of energy. The

disintegration of an explosive, started by an external force, is

generally completed in a fraction of a second; change of condition

changes the rate of explosion: the "half-life period" of each

radio-active substance is a constant characteristic of it; if a gram

of radium were kept for about 1800 years, half of it would have

changed into radio-inactive substances. Conditions may be arranged so

that an explosive remains unchanged--wet gun-cotton is not exploded by

a shock which would start the explosion of dry gun-cotton--in other

words, the explosion of an explosive can be regulated: the explosive

changes of a radio-active substance, which are accompanied by the

radiation of energy, cannot be regulated; they proceed spontaneously

in a regular and definable manner which is not influenced by any

external conditions--such as great change of temperature, presence or

absence of other substances--so far as these conditions have been made

the subject of experiment: the amount of activity of a radio-active

substance has not been increased or diminished by any process to which

the substance has been subjected. Explosives are manufactured

articles; explosiveness is a property of certain arrangements of

certain quantities of certain elements: so far as experiments have

gone, it has not been found possible to add the property of

radio-activity to an inactive substance, or to remove the property of

radio-activity from an active substance; the cessation of the

radio-activity of an active substance is accompanied by the

disappearance of the substance, and the production of inactive bodies

altogether unlike the original active body.

Radio-active substances are constantly giving off energy in the form

of heat, sending forth \_rays\_ which have definite and remarkable

properties, and producing gaseous \_emanations\_ which are very

unstable, and change, some very rapidly, some less rapidly, into other

substances, and emit \_rays\_ which are generally the same as the rays

emitted by the parent substance. In briefly considering these three

phenomena, I shall choose radium compounds as representative of the

class of radio-active substances.

Radium compounds spontaneously give off energy in the form of heat. A

quantity of radium chloride which contains 1 gram of radium

continuously gives out, per hour, a quantity of heat sufficient to

raise the temperature of 1 gram of water through 100° C., or 100 grams

of water through 1° C. The heat given out by 1 gram of radium during

twenty-four hours would raise the temperature of 2400 grams of water

through 1° C.; in one year the temperature of 876,000 grams of water

would be raised through 1° C.; and in 1800 years, which is

approximately the half-life period of radium, the temperature of

1,576,800 \_kilograms\_ of water would be raised through 1° C. These

results may be expressed by saying that if 1 gram (about 15 grains) of

radium were kept until half of it had changed into inactive

substances, and if the heat spontaneously produced during the changes

which occurred were caused to act on water, that quantity of heat

would raise the temperature of about 15½ tons of water from its

freezing- to its boiling-point.

Radium compounds send forth three kinds of rays, distinguished as

\_alpha\_, \_beta\_, and \_gamma\_ rays. Experiments have made it extremely

probable that the [alpha]-rays are streams of very minute particles,

somewhat heavier than atoms of hydrogen, moving at the rate of about

18,000 miles per second; and that the [beta]-rays are streams of much

more minute particles, the mass of each of which is about one

one-thousandth of the mass of an atom of hydrogen, moving about ten

times more rapidly than the [alpha]-particles, that is, moving at the

rate of about 180,000 miles per second. The [gamma]-rays are probably

pulsations of the ether, the medium supposed to fill space. The

emission of [alpha]-rays by radium is accompanied by the production of

the inert elementary gas, helium; therefore, the [alpha]-rays are, or

quickly change into, rapidly moving particles of helium. The particles

which constitute the [beta]-rays carry electric charges; these

electrified particles, each approximately a thousand times lighter

than an atom of hydrogen, moving nearly as rapidly as the pulsations

of the ether which we call light, are named \_electrons\_. The rays from

radium compounds discharge electrified bodies, ionise gases, that is,

cause them to conduct electricity, act on photographic plates, and

produce profound changes in living organisms.

The radium emanation is a gas about 111 times heavier than hydrogen;

to this gas Sir William Ramsay has given the name \_niton\_. The gas has

been condensed to a colourless liquid, and frozen to an opaque solid

which glows like a minute arc-light. Radium emanation gives off

[alpha]-particles, that is, very rapidly moving atoms of helium, and

deposits exceedingly minute quantities of a solid, radio-active

substance known as radium A. The change of the emanation into helium

and radium A proceeds fairly rapidly: the half-life period of the

emanation is a little less than four days. This change is attended by

the liberation of much energy.

The only satisfactory mental picture which the facts allow us to form,

at present, of the emission of [beta]-rays from radium compounds is

that which represents these rays as streams of electrons, that is,

particles, each about a thousand times lighter than an atom of

hydrogen, each carrying an electric charge, and moving at the rate of

about 180,000 miles per second, that is, nearly as rapidly as light.

When an electric discharge is passed from a plate of metal, arranged

as the kathode, to a metallic wire arranged as the anode, both sealed

through the walls of a glass tube or bulb from which almost the whole

of the air has been extracted, rays proceed from the kathode, in a

direction at right angles thereto, and, striking the glass in the

neighbourhood of the anode, produce a green phosphorescence. Facts

have been gradually accumulated which force us to think of these

\_kathode rays\_ as streams of very rapidly moving electrons, that is,

as streams of extraordinarily minute electrically charged particles

identical with the particles which form the [beta]-rays emitted by

compounds of radium.

The phenomena of radio-activity, and also the phenomena of the kathode

rays, have obliged us to refine our machinery of minute particles by

including therein particles at least a thousand times lighter than

atoms of hydrogen. The term \_electron\_ was suggested, a good many

years ago, by Dr Johnstone Stoney, for the unit charge of electricity

which is carried by an atom of hydrogen when hydrogen atoms move in a

liquid or gas under the directing influence of the electric current.

Some chemists speak of the electrons, which are the [beta]-rays from

radium, and the kathode rays produced in almost vacuous tubes, as

non-material particles of electricity. Non-material means devoid of

mass. The method by which approximate determinations have been made of

the charges on electrons consists in measuring the ratio between the

charges and the masses of these particles. If the results of the

determinations are accepted, electrons are not devoid of mass.

Electrons must be thought of as material particles differing from

other minute material particles in the extraordinary smallness of

their masses, in the identity of their properties, including their

mass, in their always carrying electric charges, and in the vast

velocity of their motion. We must think of an electron either as a

unit charge of electricity one property of which is its minute mass,

or as a material particle having an extremely small mass and carrying

a unit charge of electricity: the two mental pictures are almost, if

not quite, identical.

Electrons are produced by sending an electric discharge through a

glass bulb containing a minute quantity of air or other gas, using

metallic plates or wires as kathode and anode. Experiments have shown

that the electrons are identical in all their properties, whatever

metal is used to form the kathode and anode, and of whatever gas there

is a minute quantity in the bulb. The conclusion must be drawn that

identical electrons are constituents of, or are produced from, very

different kinds of chemical elements. As the facts about kathode rays,

and the facts of radio-activity are (at present) inexplicable except

on the supposition that these phenomena are exhibited by particles of

extraordinary minuteness, and as the smallest particles with which

chemists are concerned in their everyday work are the atoms of the

elements, we seem obliged to think of many kinds of atoms as

structures, not as homogeneous bodies. We seem obliged to think of

atoms as very minute material particles, which either normally are, or

under definite conditions may be, associated with electrically charged

particles very much lighter than themselves, all of which are

identical, whatever be the atoms with which they are associated or

from which they are produced.

In their study of different kinds of matter, chemists have found it

very helpful to place in one class those substances which they have

not been able to separate into unlike parts. They have distinguished

this class of substances from other substances, and have named them

\_elements\_. The expression \_chemical elements\_ is merely a summary of

certain observed facts. For many centuries chemists have worked with a

conceptual machinery based on the notion that matter has a grained

structure. For more than a hundred years they have been accustomed to

think of atoms as the ultimate particles with which they have had to

deal. Working with this order-producing instrument, they have regarded

the properties of elements as properties of the atoms, or of groups of

a few of the atoms, of these substances. That they might think clearly

and suggestively about the properties of elements, and connect these

with other chemical facts, they have translated the language of

sense-perceptions into the language of thought, and, for \_properties

of those substances which have not been decomposed\_, have used the

more fertile expression \_atomic properties\_. When a chemist thinks of

an atom, he thinks of the minutest particle of one of the substances

which have the class-mark \_have-not-been-decomposed\_, and the

class-name \_element\_. The chemist does not call these substances

elements because he has been forced to regard the minute particles of

them as undivided, much less because he thinks of these particles as

indivisible; his mental picture of their structure as an atomic

structure formed itself from the fact that they had not been

decomposed. The formation of the class \_element\_ followed necessarily

from observed facts, and has been justified by the usefulness of it as

an instrument for forwarding accurate knowledge. The conception of the

elementary atom as a particle which had not been decomposed followed

from many observed facts besides those concerning elements, and has

been justified by the usefulness of it as an instrument for forwarding

accurate knowledge. Investigations proved radio-activity to be a

property of the very minute particles of certain substances, and each

radio-active substance to have characteristic properties, among which

were certain of those that belong to elements, and to some extent are

characteristic of elements. Evidently, the simplest way for a chemist

to think about radio-activity was to think of it as an atomic

property; hence, as atomic properties had always been regarded, in the

last analysis, as properties of elements, it was natural to place the

radio-active substances in the class \_elements\_, provided that one

forgot for the time that these substances have not the class-mark

\_have-not-been-decomposed\_.

As the facts of radio-activity led to the conclusion that some of the

minute particles of radio-active substances are constantly

disintegrating, and as these substances had been labelled \_elements\_,

it seemed probable, or at least possible, that the other bodies which

chemists have long called elements are not true elements, but are

merely more stable collocations of particles than the substances which

are classed as compounds. As compounds can be changed into certain

other compounds, although not into any other compounds, a way seemed

to be opening which might lead to the transformation of some elements

into some other elements.

The probability that one element might be changed into another was

increased by the demonstration of the connexions between uranium and

radium. The metal uranium has been classed with the elements since it

was isolated in 1840. In 1896, Becquerel found that compounds of

uranium, and also the metal itself, are radio-active. In the light of

what is now known about radio-activity, it is necessary to suppose

that some of the minute particles of uranium emit particles lighter

than themselves, and change into some substance, or substances,

different from uranium; in other words, it is necessary to suppose

that some particles of uranium are spontaneously disintegrating.

This supposition is confirmed by the fact, experimentally proved,

that uranium emits [alpha]-rays, that is, atoms of helium, and

produces a substance known as uranium X. Uranium X is itself

radio-active; it emits [beta]-rays, that is, it gives off electrons.

Inasmuch as all minerals which contain compounds of uranium contain

compounds of radium also, it is probable that radium is one of the

disintegration-products of uranium. The rate of decay of radium may be

roughly expressed by saying that, if a quantity of radium were kept

for ten thousand years, only about one per cent. of the original

quantity would then remain unchanged. Even if it were assumed that at

a remote time the earth's crust contained considerable quantities of

radium compounds, it is certain that they would have completely

disappeared long ago, had not compounds of radium been reproduced from

other materials. Again, the most likely hypothesis is that compounds

of radium are being produced from compounds of uranium.

Uranium is a substance which, after being rightly classed with the

elements for more than half a century, because it had not been

separated into unlike parts, must now be classed with the radium-like

substances which disintegrate spontaneously, although it differs from

other radio-active substances in that its rate of change is almost

infinitively slower than that of any of them, except thorium.[12]

Thorium, a very rare metal, is the second of the seventy-five or

eighty elements known when radio-activity was discovered, which has

been found to undergo spontaneous disintegration with the emission of

rays. The rate of change of thorium is considerably slower than that

of uranium.[13] None of the other substances placed in the class of

elements is radio-active.

[12] The life-period of uranium is probably about eight

thousand million years.

[13] The life-period of thorium is possibly about forty

thousand million years.

On p. 192 I said, that when the radio-active substances had been

labelled \_elements\_, the facts of radio-activity led some chemists to

the conclusion that the other bodies which had for long been called by

this class-name, or at any rate some of these bodies, are perhaps not

true elements, but are merely more stable collocations of particles

than the substances called compounds. It seems to me that this

reasoning rests on an unscientific use of the term \_element\_; it rests

on giving to that class-name the meaning, \_substances asserted to be

undecomposable\_. A line of demarcation is drawn between \_elements\_,

meaning thereby forms of matter said to be undecomposable but probably

capable of separation into unlike parts, and \_true elements\_, meaning

thereby groups of identical undecomposable particles. If one names the

radio-active substances \_elements\_, one is placing in this class

substances which are specially characterised by a property the direct

opposite of that the possession of which by other substances was the

reason for the formation of the class. To do this may be ingenious; it

is certainly not scientific.

Since the time of Lavoisier, since the last decade of the eighteenth

century, careful chemists have meant by an element a substance which

has not been separated into unlike parts, and they have not meant

more than that. The term \_element\_ has been used by accurate thinkers

as a useful class-mark which connotes a property--the property of not

having been decomposed--common to all substances placed in the class,

and differentiating them from all other substances. Whenever chemists

have thought of elements as the ultimate kinds of matter with which

the physical world is constructed--and they have occasionally so

thought and written--they have fallen into quagmires of confusion.

Of course, the elements may, some day, be separated into unlike parts.

The facts of radio-activity certainly suggest some kind of inorganic

evolution. Whether the elements are decomposed is to be determined by

experimental inquiry, remembering always that no number of failures to

simplify them will justify the assertion that they cannot be

simplified. Chemistry neither asserts or denies the decomposability of

the elements. At present, we have to recognise the existence of

extremely small quantities, widely distributed in rocks and waters, of

some thirty substances, the minute particles of which are constantly

emitting streams of more minute, identical particles that carry with

them very large quantities of energy, all of which thirty substances

are characterised, and are differentiated from all other classes of

substances wherewith chemistry is concerned, by their spontaneous

mutability, and each is characterised by its special rate of change

and by the nature of the products of its mutations. We have now to

think of the minute particles of two of the seventy-five or eighty

substances which until the other day had not been decomposed, and were

therefore justly called elements, as very slowly emitting streams of

minuter particles and producing characteristic products of their

disintegration. And we have to think of some eighty substances as

particular kinds of matter, at present properly called elements,

because they are characterised, and differentiated from all other

substances, by the fact that none of them has been separated into

unlike parts.

The study of radio-activity has introduced into chemistry and physics

a new order of minute particles. Dalton made the atom a beacon-light

which revealed to chemists paths that led them to wider and more

accurate knowledge. Avogadro illuminated chemical, and also physical,

ways by his conception of the molecule as a stable, although

separable, group of atoms with particular properties different from

those of the atoms which constituted it. The work of many

investigators has made the old paths clearer, and has shown to

chemists and physicists ways they had not seen before, by forcing them

to think of, and to make use of, a third kind of material particles

that are endowed with the extraordinary property of radio-activity.

Dalton often said: "Thou knowest thou canst not cut an atom"; but the

fact that he applied the term \_atom\_ to the small particles of

compounds proves that he had escaped the danger of logically defining

the atom, the danger of thinking of it as a particle which never can

be cut. The molecule of Avogadro has always been a decomposable

particle. The peculiarity of the new kind of particles, the particles

of radio-active bodies, is, not that they can be separated into unlike

parts by the action of external forces, but that they are constantly

separating of their own accord into unlike parts, and that their

spontaneous disintegration is accompanied by the production of energy,

the quantity of which is enormous in comparison with the minuteness of

the material specks which are the carriers of it.

The continued study of the properties of the minute particles of

radio-active substances--a new name is needed for those most mutable

of material grains--must lead to discoveries of great moment for

chemistry and physics. That study has already thrown much light on the

phenomena of electric conductivity; it has given us the electron, a

particle at least a thousand times lighter than an atom of hydrogen;

it has shown us that identical electrons are given off by, or are

separated from, different kinds of elementary atoms, under definable

conditions; it has revealed unlooked-for sources of energy; it has

opened, and begun the elucidation of, a new department of physical

science; it has suggested a new way of attacking the old problem of

the alchemists, the problem of the transmutation of the elements.

The minute particles of two of the substances for many years classed

as elements give off electrons; uranium and thorium are radio-active.

Electrons are produced by sending an electric discharge through very

small traces of different gases, using electrodes of different metals.

Electrons are also produced by exposing various metals to the action

of ultra-violet light, and by raising the temperature of various

metals to incandescence. Electrons are always identical, whatever be

their source. Three questions suggest themselves. Can the atoms of all

the elements be caused to give off electrons? Are electrons normal

constituents of all elementary atoms? Are elementary atoms

collocations of electrons? These questions are included in the

demand--Is it possible "to imagine a model which has in it the

potentiality of explaining" radio-activity and other allied phenomena,

as well as all other chemical and physical properties of elements and

compounds? These questions are answerable by experimental

investigation, and only by experimental investigation. If experimental

inquiry leads to affirmative answers to the questions, we shall have

to think of atoms as structures of particles much lighter than

themselves; we shall have to think of the atoms of all kinds of

substances, however much the substances differ chemically and

physically, as collocations of identical particles; we shall have to

think of the properties of atoms as conditioned, in our final

analysis, by the number and the arrangement of their constitutive

electrons. Now, if a large probability were established in favour of

the view that different atoms are collocations of different numbers of

identical particles, or of equal numbers of differently arranged

identical particles, we should have a guide which might lead to

methods whereby one collocation of particles could be formed from

another collocation of the same particles, a guide which might lead

to methods whereby one element could be transformed into another

element.

To attempt "to imagine a model which has in it the potentiality of

explaining" radio-activity, the production of kathode rays, and the

other chemical and physical properties of elements and compounds,

might indeed seem to be a hopeless undertaking. A beginning has been

made in the mental construction of such a model by Professor Sir J.J.

Thomson. To attempt a description of his reasoning and his results is

beyond the scope of this book.[14]

[14] The subject is discussed in Sir J.J. Thomson's

\_Electricity and Matter\_.

The facts that the emanation from radium compounds spontaneously gives

off very large quantities of energy, and that the emanation can easily

be brought into contact with substances on which it is desired to do

work, suggested to Sir William Ramsay that the transformation of

compounds of one element into compounds of another element might

possibly be effected by enclosing a solution of a compound along with

radium emanation in a sealed tube, and leaving the arrangement to

itself. Under these conditions, the molecules of the compound would be

constantly bombarded by a vast number of electrons shot forth at

enormous velocities from the emanation. The notion was that the

molecules of the compound would break down under the bombardment, and

that the atoms so produced might be knocked into simpler groups of

particles--in other words, changed into other atoms--by the terrific,

silent shocks of the electrons fired at them incessantly by the

disintegrating emanation. Sir William Ramsay regards his experimental

results as establishing a large probability in favour of the assertion

that compounds of copper were transformed into compounds of lithium

and sodium, and compounds of thorium, of cerium, and of certain other

rare metals, into compounds of carbon. The experimental evidence in

favour of this statement has not been accepted by chemists as

conclusive. A way has, however, been opened which may lead to

discoveries of great moment.

Let us suppose that the transformation of one element into another

element or into other elements has been accomplished. Let us suppose

that the conception of elementary atoms as very stable arrangements of

many identical particles, from about a thousand to about a quarter of

a million times lighter than the atoms, has been justified by crucial

experiments. Let us suppose that the conception of the minute grains

of radio-active substances as particular but constantly changing

arrangements of the same identical particles, stable groups of which

are the atoms of the elements, has been firmly established. One result

of the establishment of the electronic conception of atomic structure

would be an increase of our wonder at the complexity of nature's ways,

and an increase of our wonder that it should be possible to substitute

a simple, almost rigid, mechanical machinery for the ever-changing

flow of experience, and, by the use of that mental mechanism, not

only to explain very many phenomena of vast complexity, but also to

predict occurrences of similar entanglement and to verify these

predictions.

The results which have been obtained in the examination of

radio-activity, of kathode rays, of spectra at different temperatures,

and of phenomena allied to these, bring again into prominence the

ancient problem of the structure of what we call matter. Is matter

fundamentally homogeneous or heterogeneous? Chemistry studies the

relations between the changes of composition and the changes of

properties which happen simultaneously in material systems. The

burning fire of wood, coal, or gas; the preparation of food to excite

and to satisfy the appetite; the change of minerals into the iron,

steel, copper, brass, lead, tin, lighting burning and lubricating

oils, dye-stuffs and drugs of commerce; the change of the skins, wool,

and hair of animals, and of the seeds and fibres of plants, into

clothing for human beings; the manufacture from rags, grass, or wood

of a material fitted to receive and to preserve the symbols of human

hopes, fears, aspirations, love and hate, pity and aversion; the

strange and most delicate processes which, happening without

cessation, in plants and animals and men, maintain that balanced

equilibrium which we call life; and, when the silver cord is being

loosed and the bowl broken at the cistern, the awful changes which

herald the approach of death; not only the growing grass in midsummer

meadows, not only the coming of autumn "in dyed garments, travelling

in the glory of his apparel," but also the opening buds, the pleasant

scents, the tender colours which stir our hearts in "the spring time,

the only pretty ring time, when birds do sing, ding-a--dong-ding":

these, and a thousand other changes have all their aspects which it is

the business of the chemist to investigate. Confronted with so vast a

multitude of never-ceasing changes, and bidden to find order there, if

he can--bidden, rather compelled by that imperious command which

forces the human mind to seek unity in variety, and, if need be, to

create a cosmos from a chaos; no wonder that the early chemists jumped

at the notion that there must be, that there is, some \_One Thing\_,

some \_Universal Essence\_, which binds into an orderly whole the

perplexing phenomena of nature, some \_Water of Paradise\_ which is for

the healing of all disorder, some "Well at the World's End," a draught

whereof shall bring peace and calm security.

The alchemists set forth on the quest. Their quest was barren. They

made the great mistake of fashioning \_The One Thing, The Essence, The

Water of Paradise\_, from their own imaginings of what nature ought to

be. In their own likeness they created their goal, and the road to it.

If we are to understand nature, they cried, her ways must be simple;

therefore, her ways are simple. Chemists are people of a humbler

heart. Their reward has been greater than the alchemists dreamed. By

selecting a few instances of material changes, and studying these with

painful care, they have gradually elaborated a general conception of

all those transformations wherein substances are produced unlike those

by the interaction of which they are formed. That general conception

is now both widening and becoming more definite. To-day, chemists see

a way opening before them which they reasonably hope will lead them to

a finer, a more far-reaching, a more suggestive, at once a more

complex and a simpler conception of material changes than any of those

which have guided them in the past.

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