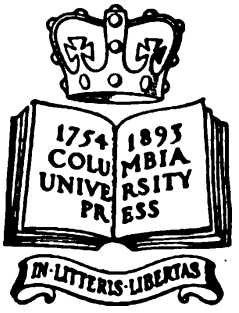
ALCHEMY
CHILD OF GREEK PHILOSOPHY

BY ARTHUR JOHN HOPKINS



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PREFACE

THE collection of data for the writing of our general histories is a preliminary task, generally not difficult—for often the facts have been provided in large part by previous work. In such a case the real task of the historian is that of a correct interpretation, a sifting and weighing the significance of this material to the history as a whole.

But it is unfortunately true that historians of the beginning of chemistry—which is alchemy—have had to begin with the fundamental work of fact-finding and confirmation; and this preliminary labor has been so difficult and time-consuming that no real history of alchemy has yet appeared.

A synthetic history is formed only after some connecting thread has been discovered—a theory binding together events with events, periods with periods; and interpreting also the gradual but necessary changes of attitude on the part of those leading spirits which appear from time to time as the history develops.

Sarton has well said concerning his encyclopedic *Introduction to the History of Science,* that he has merely collected "materials" for a history of science. Likewise, our historians of alchemy may be said to have given us that with which we have had to be content, an enumeration in chronological order of certain important events

in this subject. We have acquired from them materials for a history of alchemy.

In the early nineties of the last century, many young men, of whom the author was one, were reading Ernst von Meyer's popular *History of Chemistry* and growing more and more fascinated by the author's many-sided development of the subject. Still the impression remained of one thing missing—the few pages and inadequate treatment of alchemy left the reader with a questioning and unsatisfied wonder. I distinctly remember, after reading and re-reading this book, my thrill of anticipation when a delayed copy of Berthelot's *Les Origines de l'alchimie* (1885) was secured; which was followed, with dramatic intervals, by the *Collection des alchimistes grecs* (1888) and *La chimie au moyen age* (1893). It is impossible to estimate the influence which the last six folio volumes exerted, as they laid bare the actual writings of the real alchemists of ancient and medieval days. Here was indeed a rich fund of material for the history of alchemy.

But still the questions would not down! They crowded upon one, more and more. The writings were at hand but who was to be the interpreter? Why did the earliest alchemists have to write so obscurely that they are quite incomprehensible to the modern reader? And why, a thousand years later, was their strange collection of terms preserved and continued as if it were an indispensable

sign-manual of the initiated? In fact what was it the ancient alchemists were writing about? What also was the cause of their enthusiasm and their staccato language? What was the central penetrating thought and whence did it come?

A more particular question, but still important, has to do with that period which is even now referred to as the "beginning of alchemy in the 14th and 15th centuries." Knowing now that this is quite wrong, knowing that alchemy at that time was about a thousand years old, how shall we explain this sudden recrudescence of alchemy in a hysterical form—like the tantric rites in India—"The strangest myth that ever troubled the mind of man"?

In 1902 I published in *The Chemical News* a short article which called attention to a parallelism between the ancient recipes for coloring metals and the methods of modern bronzing. This parallelism, I thought, provided a key by which to discover, from known results, what the ancient Egyptian artizans were striving to attain.

This was the basis of that interpretation which the careful reader will discover interlaced with the narrative part of the history here presented, a theory of alchemistic thought which has gradually become sufficiently expanded to provide plausible answers to many of the questions which have troubled us heretofore—one which some

contemporary writers have referred to as the "color theory."

During the past thirty years, I have withheld from publication any complete statement of this conception of alchemy, waiting to see what effect the rapidly accumulating facts would have upon it, whether favorable or unfavorable. Perhaps now somewhat of the test of time will have absolved me from the charge of putting forth an unfinished thought, for I begin to feel with Lavoisier

> "A physicist who would wait before
> publishing his work until he is
> entirely satisfied, would run the
> risk of arriving at the end of his
> career without having fulfilled his
> self-imposed task and without having
> done anything for science or society."

It seems proper therefore at this time to submit to the judgment of the patient reader the question as to whether or not this theory makes clearer the long struggle of the alchemist to explain the secrets of matter—a struggle which began at nearly the opening of the Christian era and ended only with the coming of Lavoisier in the last quarter of the eighteenth century.

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Chapter 1

ALCHEMY

> *To conserve only the facts which are the data of nature and which can not deceive us, to seek the truth only in the natural sequence of experience . . . by reducing reasoning to judgments so common that* [*the readers*] *never lose sight of the evidence which guides them.* Lavoisier, *Traité élémentaire de chimie.*

It is a trite saying that he cannot succeed, in discussing the progress of a country, who does not take into consideration the most highly developed interests of the people. Greece, without its philosophy, would be shorn of its major interest; so Israel, without its religion; and Egypt, without its artisanship and industry.

We have to give attention, therefore, to that pronounced leaning of the Egyptian people toward a refined technique in the mechanical arts. But it sometimes happens, as in this case, that the art develops almost too rapidly and in consequence products unexpected and perhaps undesired are brought out. These products, coming as a surprise, need to be explained, but centuries of development may be required before scientific knowledge in its slow advance can formulate the explanation looked for. This was illustrated in regard to metal work in Egypt. The world actually waited until the eighteenth century, until the

time of Lavoisier and the rise of modern chemistry, before the simple trade-secrets of the Egyptian artisan could be scientifically understood. Generally, such phenomena are termed mysteries until the time of such understanding arrives.

In Egypt, however, in the Alexandrian age, an attempt was made to clear up this mystery and to this end Greek philosophy and popular theories were available and were invoked. The application thus made was alchemy—a form of philosophy applied to technique.

The theories of alchemy consisted of scattered notions inherited from a diluted, syncretic form of the philosophy enunciated in the fourth century B.C. by Plato and Aristotle. These ideas were woven into a working hypothesis which, for a time, really seemed to explain the marvels achieved by the artisans.

Resting upon a material foundation, from which it never deviated, alchemy became firmly established; and by clothing its answer to the practical problems of the artisan in a mystic and idealistic philosophy dear to the oriental mind, it first captured the imagination of the Egyptian people and with it the acquiescence of the great Roman civilization.

Moreover, by bringing its theories to bear upon the world of matter, alchemy broached a subject for investigation never before attempted in a practical way and

thus initiated an entirely new research. In that it applied these theories to new observations, the proper scientific sequence was followed. Although its observations were incorrect or incorrectly stated, and were checked by the light of a theory unacceptable to us, it is still true that we have here the balanced scientific method illustrated, followed by the triumph of an established materialistic philosophy, to guide and trouble the world of thought—and this in Egypt, in the early centuries of our era.

In attempting now to tell the story of alchemy, I am hindered by the fact that the whole subject has been so beclouded by a mass of mysticism and misunderstanding that it has been difficult to make clear the simple tale. We are, therefore, greatly indebted to that illustrious member of the French Academy, Berthelot, who, from 1885 to 1906, aroused a new interest in the history of alchemy by giving to the world a translation and study of numerous alchemistic manuscripts which had lain buried for centuries in the great libraries of Europe. Many of his discoveries are embodied in the pages which follow. Those which are so taken have to do largely with the literature and technique of alchemy. As regards theory, the whole subject, as presented by Berthelot, was so new that it is not surprising that a comprehensive explanation of alchemy was still lacking—such a theory as would coördinate the whole and make clear to the modern mind what

was the purpose and underlying conception of the alchemist.

Our historians of the past have been wont to teach us that the final quite complicated structure which we know as alchemy was an error suddenly appearing. Let us rather think of it as a gradual inheritance—the outgrowth of the best and soberest thought of the ancient mind. Although it depended upon false premisès and definitions, yet it was a consistent whole; and, given those definitions, the result was far from being absurd. So plausible did this philosophy seem that the theory of alchemy and its hopes took a firm hold on the ancient mind and influenced the best-educated scholars for more than a thousand years. Among the common people of Western Europe that hope was still vital up to a hundred and fifty years ago and still survives as an amazingly potent factor among the people of Turkey, Syria and Egypt, where alchemists are even now attempting to carry out a transmutation which constantly eludes their grasp.

Transmutation under these Egyptian conditions must be considered as having been successful; gold, as defined by the alchemist, was produced; and the hope of the alchemist was reasonable, though never realized, that the philosophers' stone, which should be capable of transmuting any metal into gold, would eventually be found.

Chapter II

GENERAL SURVEY OF ALCHEMISTIC HISTORY

The new commentators of Plato and Aristotle. Bib. Nat. de Paris, *MS 2327, Fol. 195.*

We know that the story of earliest alchemy must be placed locally in Egypt—in that country where for forty centuries or more a civilization had grown up on the banks of the Nile—for this location is attested by all the later authors. It is deduced also from internal evidence, in the copies which we have of the ancient writings. In these, we find the ancient Egyptian gods are mentioned and the cities of the Nile delta—many of these no longer existing. The flora and fauna, the calendar terms, the names of those who practiced alchemy, all are Egyptian. The word alchemy, even, is thought to be derived from *chem* or *cham,* the Egyptian for black.[1]

On the other hand, as regards date we are not at all so certain. The generally accepted but rather vague statement for the time of the birth of alchemy is "somewhat after the beginning of the Christian era."

Sometimes it is suggested that, by inheritance, the date of earliest alchemy may be pushed back much further. Its

[1] See Chap. VI for this and other derivations.

philosophy came from the fourth century B.C. in Greece and this was soon joined to astrology from Chaldea and magic from the East. But none of these was alchemy.

Also, on the technical side, alchemistic practice came from the ancient arts of the physician, the painter, the dyer, arts flourishing on the shores of the Mediterranean or indigenous to Egypt. But neither were these arts alchemy.[2]

Certain writers, evidently wishing to give to alchemy the prestige of a very great age, have ascribed to it even a semidivine origin.[3] Others refer to the mystical Ostanes, the Mede, as the first teacher of alchemy.[4]

It is thus seen that we have no surety from the alchemists for any date. We are further handicapped, in judging the date of the birth of alchemy, by our lack of the Egyptian writings in the original. None of these has survived either in papyrus or manuscript.[5] Now a copy is

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[2] The suspicion that the art of alchemy might have been introduced in very ancient times from India is now dispelled. See P. C. Ray, *Hindu Chemistry*, 1902.

[3] These refer to (1) the story told in the Book of Genesis, VI; (2) the Noah fragment in the Book of Enoch, VI, VII, VIII; (3) *The Isis Myth*. These are abstracted in Appendix I.

[4] Ostanes is mentioned by Pliny and by Zosimus. Synesius has this statement: "Democritus . . . was initiated into the mysteries of the great Ostanes in the temple of Memphis—by him and by his disciples, priests of Egypt. Learning his principles from him, Democritus composed four books—on Bronzing, on Gold and Silver, on Stones and on Purple."

[5] Note that the Papyrus of Leyden (the one marked with the letter X) and the Papyrus Holmiensis are no longer considered to have been, in their origin, alchemistic. Although they contain recipes for the imitation of gold and silver, for the imitation of purple and of precious stones, and although the first of

quite inferior to an original in matter of trustworthiness. The original will often supply evidence of its date which is wholly lacking in a copy. Also, one is never sure what interpolations have crept into a copy, indistinguishable from the original text.

The writings upon which our knowledge of alchemy rests are such copies, in manuscript, of the alchemistic literature of the early centuries, being presumably a collection of excerpts from the works of the earliest Egyptian writers—men who lived in Egypt and wrote in Greek, on papyrus, from possibly the first to the seventh centuries. But unfortunately the first of these manuscripts dates from no earlier than the tenth century. These rather modern manuscripts (from the tenth to the seventeenth centuries) are those which have recently been discovered and translated by Berthelot. It is from these, aided by a few Arabic and still more modern authors, that we must build up a history of alchemy.

If, as we maintain, real alchemy did not exist until philosophy had been applied to explain the artistic creations of the worker in metals—until there was a theory of

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these was of special interest to the alchemists—and some of these recipes are found copied into the alchemistic text—yet these industries have been shown to have been common, as a whole, to all the coast cities of the Mediterranean from Gaul to Phœnicia and in point of time probably preceded alchemy in Egypt. See Hammer-Jensen: "Deux papyrus à contenue d'ordre chimique," *Bulletin de l'Academie Royale des sciences et des lettres de Danemark*, 1916, pp. 279-302.

alchemy—we can give a date for this only by using the vague expression, "some time after the beginning of the Christian era." Probably, as in all such developments, the transition from the *primitive art* to the *formal science* may have been gradual and derived from many sources, until finally the scattered ideas were collected, brought into a system, and exploited as alchemy by some prominent writer.

In the manuscripts which we have, the authors who are considered the first authorities on alchemy, with their possible dates, are the following:

The Pseudo-Democritus	First or second century
Synesius	Second or third century
Zosimus	Third to fourth century
Olympiodorus	Fifth or sixth century
Stephanus	Seventh century

They are all to be counted Eygptian. Stephanus, although he was a professor in Constantinople, belonged to the Graeco-Egyptian school.

The actual life of alchemy in Egypt must have been very short, if, as is recorded, by Roman decree the practitioners of this art were expelled from Egypt and their books burned in 292. In this short time there must have arisen and flourished an art which so impressed and frightened the government at Rome that the decree of

the Emperor Diocletian seemed a necessary precaution. (See Appendix II.)[6]

What happened after this expulsion, what was the fate of the alchemist, we have no means of knowing. Probably the practitioners fled before the terror of the Roman decree—some east to the medical center in Jundi-Shapur in Persia, or to join the Syrian academies; or to be present a little later at the founding of Constantinople in 330; some west to Cyrene where their successors later joined the Islamic invasion of Spain (711).

The technique of alchemy continued in spite of the Roman decree, as Berthelot has clearly shown, and there is evidence that the theory of alchemy continued even in Egypt, but in an emasculated form. The writings, too, cannot have been utterly destroyed, for certain copies, sections or abstracts, held in great reverence by the academicians of Persia, Syria and Constantinople, were translated, along with all the great literature of ancient times, some of these alchemistic productions having come down, in copy, even to us.

Beginning with the ninth century, the Mohammedans were especially active in the preservation of this literature. Up to the eleventh or twelfth century—especially in Per-

[6] Concerning the reliability of this story, see von Lippmann, *Entstehung und Ausbreitung der Alchemie*, 1919, pp. 289-293; Berthelot, *Les Origines de l'alchimie*, 1885, pp. 72-73; Ingeborg Hammer-Jensen, *Die älteste Alchymie*, 1921, p. 78.

sia and in Spain—they fostered the ancient writings and introduced the subject of alchemy (mostly through Spain) to their Christian conquerors. During these Dark Ages—dark, because Christian intelligence was at a low ebb—there was little literary contact between the two peoples striving for the possession of the Spanish peninsula. During many centuries, therefore, alchemy remained the possession of the learned academicians, physicians, and philosophers of Islam.

In the twelfth century, Latin translations of Arabic and Spanish works first began to appear in Spain, disclosing a previously unsuspected wealth of literature in the hands of their distinguished Moslem enemy—Arabic forms of Aristotle's works, some books on medicine and on mathematics.

Among others, there came to an astonished Christendom certain books by Arabic authors on the preparation of gold. The fascinating subject of alchemy was discussed as to its existence or possibility by many a well-known author. The knowledge of alchemy became then widespread and popular. Certain adepts appeared who claimed to have made gold. Every large city had its alchemist.

But because the true theory of alchemy, the original Egyptian theory, was no longer understood, the writers of Western Europe were never able to carry out in practice the promises expressed in their books. The actual gold

which was looked for was never produced. This whole period was one of false alchemy, or pseudo-alchemy, gradually falling into disfavor and finally superseded by modern chemistry.

In concluding this rapid survey, it is convenient to point out, in order to guide our steps during a more detailed study, that the history of alchemy falls naturally into three periods, each period followed by a mid-period of transition: (1) Egyptian or true alchemy, transition to Islam; (2) Islamic alchemy, transition to Western Europe; (3) pseudo-alchemy, final transition to modern chemistry.

Chapter III

INFLUENCES

"We must make the attempt to get back to a condition in which we can look at the 'appearances' as they present themselves to an observer not yet biased unconsciously in favour of a 'materialistic' philosophy."
A. E. Taylor, *Commentary on Plato's Timaeus.*

In order to understand the setting of alchemy, let us return to Egypt—to Alexandria, where the art began at the acme of glory in that famous city and at a time when the ruling class was Greek. Alexander had founded his colony in 311 B.C. and almost immediately the little community had established a Ptolemaic school of philosophy in which the fundamental ideas, modified by later influences, were essentially those of Plato and Aristotle.

To gain an idea of the everyday thoughts of the people and thus of the mental attitude underlying alchemy, we need first to examine the teachings of these two great Greek philosophers, since alchemy must have reflected the common thoughts of the people—the philosophy of its period, else it could never have been born, or having been born could not have lived in a country hostile to its ideals.

It is conceded that there were other influences which controlled and determined the mentality of the alchemist and these will be discussed in the following sections of

this chapter; but Greek influences are most important and will be indicated first.

I. GREEK INFLUENCE

We therefore turn first to the well-known *Timaeus* of Plato[1] the only work of the author known to Western Europe before the twelfth century. Its influence (extended by the works of Aristotle and transmitted by the Neoplatonists)[2] is acknowledged by writers on nature in all the early centuries of our era. In the writings of the early alchemists, Plato and Aristotle are referred to as their predecessors and guides and the doctrines of the *Timaeus* —such as the nonexistence of matter—are accepted as true.

Jowett, in his introduction to this book, makes the following terse comment:

> Of all the writings of Plato, the *Timaeus* is the most obscure and repulsive to the modern reader, and has nevertheless had the greatest influence over the ancient and mediaeval world.

And Archer-Hind:

> Not one of Plato's writings exercised so powerful an influence on subsequent Greek thought. . . . In it the great master

[1] In doing so, we are passing over the Ionian school and Empedocles, with the conception of the four "elements"; Socrates also with his insistence upon exact definition—since these philosophers are preliminary to and are included in the work of the two here mentioned.

[2] Especially by the translation of the Stoic, Posidonius, in the first century.

has given us some of his profoundest thoughts and sublimest utterances—the focus to which the rays of Plato's thoughts converge, a complete and coherent scheme of monistic idealism.

The obscurity of which Jowett speaks is explained by the last clause. We are not monistic idealists, dealing with pure reason divorced from all recognition of matter as an entity, and it is very difficult for us, therefore, to put ourselves in the attitude of the ancient searcher for the truth. Yet an effort must be made, however foreign to our manner of thought, in order that we may gain a position sympathetic with the alchemist whose well-founded claim to a position as "expositor of Greek philosophy" has remained unrecognized up to the present time.[8]

Plato

Two pupils followed Socrates—Plato and Antisthenes (Chart, page 23). The latter founded the school of Cynics whose individualistic concepts aroused Plato's strong opposition. Against individualism, Plato sought general laws, universal truths, and, above all these, an ideal unity in the world. His opposition to the Cynics led him to invent the term ideas, carrying the meaning that above the knowledge which the individual gains by sense (by see-

[8] See Chap. XI, note 1.

ing, hearing, etc.), there are realities in knowledge gained by mind alone. These ideas, or ideals of knowledge, belong to the world of thought only, far apart from the world of sensation and far above it.[4]

The highest knowledge must have, for its object, "true being," that is, generalities, as distinct from that lower knowledge brought to us by sense which is not real.

In the world of nature, of many objects differing each from each, these ideas may be likened to mathematical laws or generalizations—only Plato thought of ideas as more personal, as more living and controlling than these; and ideas which never change are truly real. They are, in fact, our only realities—eternally and divinely true.

Material objects in nature which we think we see or hear Plato conceived as merely copies—imperfect copies of which the originals are real or ideal. These objects have no existence except as the pure light of the ideas is feebly reflected upon matter. The imperfection of our sense-knowledge is due to us,[5] to the varying degree in which our senses are capable of apprehending the eternal type—the highest idea, which Plato calls the "idea of the Good." We see through a glass darkly, assigning properties as ap-

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[4] See W. G. de Burgh, *The Legacy of the Ancient World*, 1924, p. 141,—especially this clear sentence: "No sensible lines or circles are perfectly equal; and to call an action good or a picture beautiful implies a single standard of goodness or of beauty to which the particular instances are imperfect approximations."

[5] Archer-Hind, *The Timaeus of Plato*, 1888, Introduction, pp. 22, 31-34.

pearances—which vary with us—to objects which are themselves changing. Therefore of nature and natural phenomena we can have no true knowledge.

After having established his system of philosophy, in which the discussion of ideas or forms, as established world formulas, occupies so much room and in which the changing phenomena of nature can have little part, Plato surprises us by definitely directing his inquiry upon the nature of matter which he calls "a new field, an unknown territory . . . not previously explored or even defined." Thus he tells us in the *Timaeus* [6] that he intends to enter lightly upon the realm of nature, but only, as it were, as a recreation, a sensible amusement—for by apprehending the facts which are necessities of nature "we may grasp the truths which are the objects of our serious study." [7] It is thus evident that Plato looked upon this study of nature as steps by which to mount to the higher realms of a real idealistic philosophy. But the experience in finding *general* ideas in knowledge and ethics served him again in this excursion into the material world. Here also a general substratum is discovered from which are derived all the apparent objects of nature. This substratum is matter—which is undefined and unknowable, just as ideal goodness is undefined and unknowable. Goodness and matter are alike in being known only indirectly. Matter is recog-

[6] *Timaeus*, 59, D.

[7] *Timaeus*, 69, A.

nized in individual objects, as it were, by reflected light. The reaction of ideal matter to the light of our mental concepts, which are ideas also, becomes evident in the appearances which we call objects of sense perception. To Plato, who had entered upon this study as an amusement, this discovery, this possibility of applying his main thesis to the new faith, must have come as a delightful surprise.

Here our author pauses to recall that Empedocles had attempted to explain the composition of all natural objects as made up of four units—earth, water, air, and fire. But Plato shows that these can have no unitary character, that they cannot be considered "elements," for they easily pass into one another, all being different appearances of the substratum matter. "Suppose a man having moulded all kinds of figures out of gold should unceasingly remould them, interchanging them all with one another, it were much the safest thing in view of truth to say that it is gold; but as to the triangles or any other shapes that were impressed on it, never to speak of them as existing, seeing that they change even as we are in the act of defining them." [8] And so, "what we now have named water, by condensation as we suppose, we see turning to stones and earth, and, by rarefying and expanding, this same 'element' becomes wind and air." [9] It is safer to speak of these elements as qualities—not as *this* fire but having

[8] *Timaeus*, 50, B.

[9] *Timaeus*, 49, C.

a nature such as fire[10]—and so with the other three.

On the other hand, matter, having no qualities, serves most suitably as a passive recipient of those general concepts which he calls ideas or forms, without itself contaminating them. "Just as in the making of sweet unguents, men purposely contrive, as the beginning of the work, to make the fluids which are to receive the perfumes perfectly scentless; and those who set about moulding figures in any soft substance do not suffer any shape to show itself therein at the beginning but they first knead it smooth and make it as uniform as they can."[11]

The properties which distinguish individual objects, and the characters we assign them, cannot in a corporeal sense be caused by matter for matter is universal and without properties and even nonexistent. Again we see that these natural objects have no real existence but are products of our unreliable perceptions. Such existence as may be assigned to them is due to the images thrown out by the universal ideas and localized by the substratum, matter.

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[10] *Timaeus*, 49, E. Throughout the whole history of alchemy, this thought of qualities imposed upon general matter is accepted as the sufficient definition of the individual metal. That the metals did not owe their distinctive properties to a material cause (a permanent substance), but to varying attributes, was expressed in the thirteenth century by Jean de Meung, as quoted on p. 24, note 21. Compare also this alchemistic expression: "To transmute, in these authors, means to give a body to the incorporeal" (Berthelot, *Collection des anciens alchimistes grecs*, III, XXVIII, 7).

[11] *Timaeus*, 50, E. For the alchemistic application, see Chapter VI, p. 93.

It is easy to see that Plato in his philosophy did not study nature as an object in itself; and that, since his chief interest was in the universals, he passed lightly over the individual objects of sense.[12] But he *provided the foundations for a philosophy of nature* which was to follow him in the work of his pupil Aristotle—who, we shall see, laid less stress upon the ideal and more upon the objects of everyday life. As de Burgh has already noted:[13] "In Raphael's cartoon of *The School of Athens,* Plato is portrayed as pointing upwards to the heavens, Aristotle as pointing downwards to the earth."

Aristotle

In attempting to compare Aristotle's scheme of philosophy with Plato's, we find a growth in thought founded upon agreement rather than opposition. Aristotle accepts Plato's theory of forms or ideas but at the same time indicates his disapproval of its all-inclusiveness. He thinks Plato's enthusiasm has carried him too far. The master's conception of ideas as the only realities made no appeal to his brilliant pupil. As a biologist and systematist, Aristotle's interest was in those natural objects of everyday life which are changing in time and place. He was interested

[12] Archer-Hind: *The Timaeus of Plato,* Introduction, p. 32.
[13] de Burgh, *The Legacy of the Ancient World,* 1924, p. 169, note 2.

in growth and development and the generation of plants and animals—also in the change by which brass becomes a statue, and how bricks and stones, by preparation, form a house. Such questions entered into his experience as a naturalist—especially the whole subject of change.[14] Plato had looked with suspicion upon susceptibility to change. Aristotle emphatically denied that this introduced unreality.

Aristotle asks first where we may place these interesting natural objects—where are they in the scheme of nature? Certainly not in Plato's everlasting generalizations, for these never change; and therefore we can get nowhere by studying them. Plato was wrong. But also the Cynics were wrong. Natural objects are not the inconstant results of mere sense-perception. Reality lies between. As Plato said, real objects result from the reaction of mind upon matter. Again he asks, "Where then?" And the answer will be found by *classification,* by which means as a biologist he had trained himself to limit and thereby to define. First, then, he posits the most general class, the genus,[15] too general to give us an idea of objects or objectivity. To illustrate we may have the genus animal. Second, there come the subdivisions of the genus into species, such as man, horse, cow, and so on, and the differences between species

[14] de Burgh, *Legacy of the Ancient World,* 1924, pp. 169-171.
[15] Lalo, *Aristote,* p. 103.

(of the same genus) are called specific differences or sometimes qualities.[16] The determination of specific differences or species is the object of all science. But we have not yet objectivity. A single man, besides his characteristic common to man, has added properties which belong to no other man and the single individual is thus defined. It is not necessary, to go further to accidental properties, such as may or may not be properties, which the Cynics made essential and Plato condemned. Reality in nature lies between. The individual is the first subdivision of the species. It is this individual with definite "qualities" and distinctive differences which is of value for study and a reality in the field of knowledge. It is not true that the forms (ideas) are real; or that that undefinable something which we call matter is real;[17] but when matter has been "informed by the ideas," we have the realities of nature—the natural objects. Aristotle illustrates thus: "As forms are to matter, so also is Soul to Body." The soul brings the potential body to active realization of a happy life. It is as if the author had said: "Our bodies, like matter, are negligible until the soul comes to inform and inspire them." Therefore the complete man (of the species, man) has a particular union of ideal and matter which gives him specific

[16] *Metaphysics,* 1020 b.

[17] "I mean by matter what is not yet actually an individual object, but is such potentially." (*Metaphysics,* VII, 1, 1020 b and 1029 a.)

and distinguishing qualities. The latter, however, may change and such changes are constantly taking place, as in generation, or when a man becomes good or bad.[18]

The general trend of nature, Aristotle held, was toward improvement, thus differing from Plato, who stated that all things partook of the universal essence of the good: "Nothing exists which is not good." But to Aristotle, qualities whether good or bad are ever becoming more and more perfect.[19] "Nature does nothing in vain but aims at final causes." "Nature and God are working towards an end, striving for what is perfect." [20]

Aristotle has also some interesting observations on the four "elements" of Empedocles. He agrees with Plato in denying that these are elements but goes further, explaining why they may change into one another, for the four have common properties: fire being hot and dry, while air is hot and moist; water is moist and cold and earth is cold and dry. Their interchangeability may be shown graphically by the chart on p. 24.

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[18] The alchemists, who came later, seized upon this idea, stating that in metals there is a common body, matter, alike and unchangeable, but the differences between metals may change. There is nothing strange in supposing that brass may lose some of its elementary earth and partake more of the higher elements such as fire. By changing to higher qualities, brass may be changed into gold, for "the quality of gold is independent of the metallic substance which is its support." See Hopkins, *Isis*, VII (1925), 59-60.

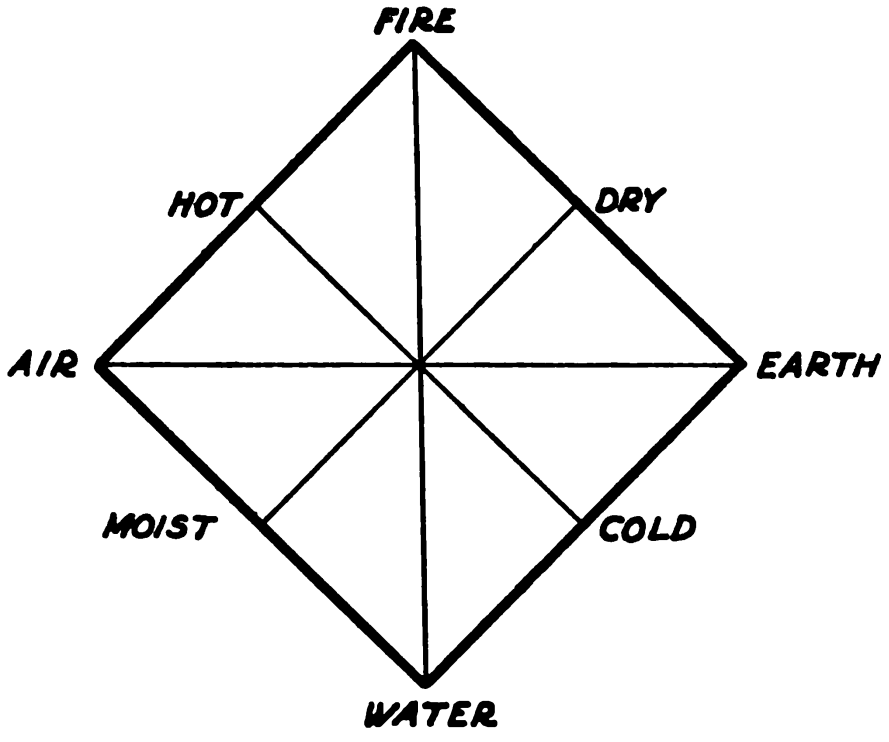
[19] To the alchemists, also, nature (of which one genus is the minerals; and one species in this genus, the metals) is striving toward metallic perfection which is gold.

[20] *De caelo*, I, 4, 271 a, 3; II, 5, 288 a, 2.

Plato's "Reality": Generalizations
Unreal: Sense Perceptions

Aristotle's classification of knowledge gives:

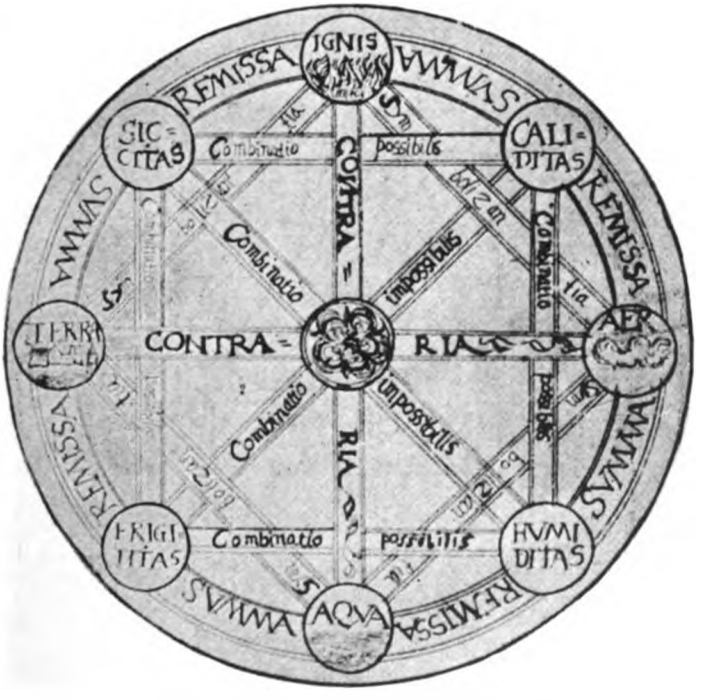
1. The most *general* class:
   Subdivisions of each genus
2. By *specific* qualities:
   Subdivisions of each species
3. By distinctive differences which is REALITY:
4. Under Class 3 may be accidental differences emphasized by the cynics.



But these properties, hot, cold, wet, and dry, are really only two, hot and moist (and their opposites). Now, heat is due to "fire" and moisture to "water." "Fire" and "water" become, therefore, the most important elements —elements which are opposed to each other.[21]

In Aristotle's *Physics* we find matter conceived as a means toward an end, which is form. Thus a house is made of

[21] It is perhaps unnecessary to recall that the later alchemists took these two opposed elements, fire and water, as exactly expressed in the metallic world by sulphur and mercury. These two stood early in alchemistic history as the alchemistic elements and continued thus, even to the birth of chemistry in the eighteenth century. Thus in the *Roman de la Rose* (thirteenth century) of Jean de Meung (line 17,055): "They all come from one matter, however nature may bring them forth. For combined in different proportions within the mines, they are formed from sulphur and quicksilver, as the books say."



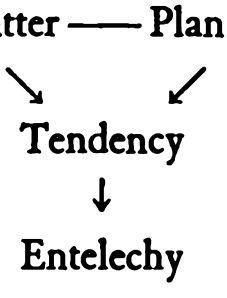
ELEMENTS OF EMPEDOCLES

bricks but it is the particular architecture of the house which is in the builder's mind. In these the bricks are the material upon which the form is built and the form is the important thing, the end, and the guide, the so-called formal cause, while matter is negligible. It was upon this conception, above all, that the alchemists conceived the possibility of transmutation.

And finally Aristotle discusses the process of all change in art and in nature—the change of real substance in place or time. Of all the contributions of this remarkable mind the "Theory of Forms" was perhaps the most famous. Here he analyzes the growth and generation of living nature, yet makes his theory applicable to nature in all its transformations.

Aristotle: Change within the Species

We have: 1. Matter
2. The individualizing tendency
3. The plan
4. Entelechy



The four essentials in growth are (1) a material, (2) an individualizing tendency, (3) a generalization or formula, and (4) an end of the process. In the life cycle of the oak, we find the parent oak producing acorns, containing particular germs which can grow into oaks and only oaks, and finally we have the full-grown oak produced, endowed with power to germinate again, repeating the cycle. In this process, the corporeal matter (1) is quite negligible except in so far as the form, or quality of being an oak (3), has endowed the matter (1) with activity (2); but the most important elements to note are the process or tendency (2) and the final product of the cycle (4), the "entelechy," *with its power of reproduction.*[22] These two, he points out, are important as illustrative of all regular changes in nature.

It is impossible here to go further into this great theory, but its mention is necessary in order to explain how later the alchemists applied these ideas to the metals which were to them as living as the oak, since "*all* nature is living." The metals were striving to finish their peculiar cycle, tending toward perfection as fire seeks its source,[23] toward the entelechy which is gold. And the gold is then

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[22] "*De anima,*" II, 4, 15: "Since the end of the function of the soul is to produce another like itself, the first and rudimentary form of soul would be generative—generative, that is, of another like itself" (translation, Edwin Wallace, *Aristoteles*).

[23] The great cosmic center of fire and air is in the sun and the upper atmosphere. Air and fire are therefore said to be light elements as distinguished

able to produce a portion of lead or copper which again tends to complete the cycle, ending with the final gold.

In reference to the influence of Greek nature philosophy on alchemistic theory, Zeller, in his *Greek Philosophy,* says:

> [Aristotle] also assumes a qualitative change of matter, and more especially of the elements into each other. By this change, the qualities of one are changed under the influence of another. This relation of activity and passivity is only possible when two bodies are opposed to each other which are partly similar and partly dissimilar, that is, when they are opposed within the same genus.

And Lalo in his little book *Aristote,* says:

> But his analysis of the elements is much less happy. The atoms, already profoundly defined by Leucippus and Democritus, he has replaced by unchangeable qualities. He has given pretext to the badly understood transmutations of the alchemists and has retarded the development of classical physics and chemistry.

Whether we agree or not with the sentiment of the last sentence, there seems no doubt that Plato and Aristotle furnished the philosophy upon which alchemy rose and

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from water and earth. But this is explained (since like seeks like) by their escape to their source:

> "Rivers to the ocean run
> Nor stay in all their course,
> Fire ascending seeks the sun,
> Both speed them to their source."
> (Church hymn, 1742.)

which sustained the early alchemists in their hopes of transmutation. Greek philosophy was the source of alchemy and to it the alchemists constantly appealed.

But there were other psychic influences besides philosophy; and, before leaving this subject, we should note that there were prevalent, at the time of Plato and Aristotle, certain beliefs (which arose from the love of analogy), beliefs held sacred by the common people which influenced, not the people only, but philosophy as well, and have continued to influence philosophy, even to the present time. Of these, the following four are the most important:

1. Hylozoism: all nature is like man, alive and sensitive.

2. That the great universe of sun and stars, the "macrocosm" is guided by the same laws which obtain on the earth, the "microcosm."

3. Astrology: the stars influence and foretell the course of events on this earth.

4. Animism: any event apparently spontaneous is really due to some personality—fairy, wood spirit, hobgoblin, etc.

Between Aristotle and the alchemists from three to four centuries intervened, and in this interim, wherever the influence of Greece reached, the philosophy of Plato and

Aristotle gradually filtered down from the upper philosophic and exclusive circles even to the minds of the common people. Unconsciously, all thinking people, as if by inheritance, reasoned just as the great philosophers had thought before them.

In Egypt, the alchemists, who were very much "of the people," believed with Plato in the universality of matter and with Aristotle in the importance of individual qualities, in the trend of these qualities toward perfection and in the possibility of assisting nature in this struggle. Moreover, during the first centuries of our era, the four mystic beliefs just mentioned were prevalent in the Greek colony in Alexandria where alchemy first began; and to those holding these ideas the possibility of assisting the metals to become gold must have seemed not at all remote.

Résumé

To gather together such of the teachings of Greek philosophy as were later applied by the alchemists to their new philosophy, it is necessary at the same time to review and to anticipate. But the alchemistic ideas, stolen from the pages following, must appear only nominally, to be explained and illustrated, as the story proceeds.

The alchemist believed with Plato in the nonexistence of matter and with Aristotle in the reality of individual

objects. Following the latter's classification, the alchemist posited a genus mineral of which one species was the

GREEK PHILOSOPHY IN ITS
DEVELOPMENT OF NATURE PHILOSOPHY

(WITH EARLY MEDICINE)

V	Socrates (Ethics)		Hippocrates
	Plato (Teleology)	Antisthenes	(Medicine)
IV		(Cynics)	
	Aristotle (Biology)		
		Theophrastus	
III		(Botany)	
II			
I			
A.D.			
1			Dioscorides
			(Materia Medica)
2			Galen (Medicine)

metals, having the common element of "water" or fusibility. Individual metals owe their individuality to the "distinctive differences" included in grades of fusibility, volatility and color. The latter tend (and may be aided)

to change, but always toward perfection, *i.e.*, to the entelechy gold (which unites the two Aristotelian elements fire and water) and this is able to reproduce itself, thus transmuting less perfect metals into gold.

2. INFLUENCE OF ALEXANDRIAN RELIGIONS[24]

Since the days of Plato and Aristotle, other influences had arisen by the beginning of our Christian era to determine the mentality of the alchemist. Greek nature philosophy was becoming alchemistic philosophy.

Under the more southern climate, exactly what we would expect was taking place—a softening and adaptation of the stern philosophy of the north to fit the lives of those who dwelt under the fierce glare of the eternal Egyptian sun as it beat down upon the desert sands. In Alexandria, three great divisions of men met as mental antagonists: first the Greeks (to whom were joined the Jews), second the native Egyptians, and lastly the Christians. But the sapping effect of the southern climate upon these "men of many minds" brought about an unconscious yielding, tending to modify inherited oppositions.

Alexandria from her founding had been the heir and protector of a stern philosophy; but had gradually become rich and commercial, very worldly and very attrac-

[24] See chart, Religions in Egypt, p. 33.

tive. She was a cosmopolitan city with many racial divisions and many and diverse interests. The large native population of this wonderful city crowded the Rhacotis district in the southwest, still holding to the worship of the ancient Egyptian gods. In the northeast, a section was set off as the Jewish quarter; while from the date of the martyrdom of St. Mark, the Christian infiltration was making gradually increasing progress. Greeks, Jews, Egyptians and Christians, differing from one another in many ways, all agreed in one particular. They all believed in a god, not doubting his existence, as had been the case in earlier times. But, though they all believed, yet also were they all troubled by one common mystery, one ever-recurring question: How could God be far away and all-powerful and yet near to man and sympathetic? Historically, the first solution to this question was offered by the Alexandrian Jews in imagining a mediator acting as agent of God and yet close to man. These Jews had lived so long in the philosophic atmosphere of the Greek colony that they had become dissatisfied with the simple worship of Jehovah and (before the alchemistic period) had begun to think with the Greeks philosophically. Their imagined intermediary they called "Sophia" or Wisdom who bridges the chasm between God and man. One well-known result of this idealization of Sophia or Logos was the Wisdom of Solomon, about 100 B.C., a

book now forming a portion of our Apocrypha (see following chart).

RELIGIONS IN EGYPT

Jews Septuagint "Sophia"	Greeks τὸ πᾶν νοῦς	Christians	Gnostics
A.D.		(St. Mark)	"Gnosis"
	Neoplatonism		Cerinthus
100			Valentinus
	(Ammonius)		
200	Plotinus	Clement	
	Porphyry	Origen	
300		Coptic Church	
		Arius	
400		Athanasius	
500			

Religious Persecutions in Alexandria

284 "Era of Martyrs" Decius vs. Christians
303 Diocletian vs. Christians
391 Christians (Theophilus) vs. Neoplatonists
451 Christians (Cyril) vs. Neoplatonists (Hypatia)
631 Christians (Athanasius) vs. Christians (Arian Copts)

Christianity entering Egypt was confronted by the philosophers with this same question: What of the mediator? The answer was prompt and acceptable. The mediator was personal, Jesus, whom the Jews call the Christ.

Though the new faith had crept into Egypt as a lowly religion, preached to the common people with methods like those of our Salvation Army, this prompt reply brought the sect, for the first time, into prominence. Clement of Alexandria, who elaborated the answer, further claimed no less than that Jesus was the Logos, the Word, through whom God could be known, explaining that the Hebrew religion and all others had been not antagonistic to Christianity but of definite value as a preparation for the supreme event, the coming of Jesus. It was this elaboration which raised the faith to a philosophy or world religion.

Had the teaching of these fathers fallen on virgin soil, the result might have been more fortunate; but from the fact that old ideas are not easily removed there resulted two modified religious forms or syncretic religions: a Christianized Gnosticism and a Neoplatonic form of Christianity.

Gnosticism, although derived from oriental dualism, penetrated Egypt from Syria about the first century B.C., but it was not until the second century that a definite sect was formed in Alexandria. To the intellectual Egyptian and the Egyptian Jew, discouraged[25] by the search for a faith to which to cling, since the old Egyptian gods had been degraded (perhaps by the contempt of the Roman

[25] Dietrich, *Abraxas*.

army), Gnosticism brought a union of all knowledge with the One of Plato; and to the people, appreciation of the value of ecstatic spiritual visitations, and the attainment of perfect health. It brought also the mysticism, dear to all oriental countries, and a study of "holy words" and number combinations and the number values of certain letters. But above all, it brought again that emphasis of evil, in the opposition of good and bad, which being later accepted by Christianity has been a frequent breeder of controversy. Gnostics held that all creation had been, in its origin, a mistake—not of God—but of a demiurge who had condemned us all to be slaves of a lower life. From this disaster, our only salvation was through Gnosis, a secret knowledge or liturgy which had been revealed to Gnostics alone.

Confronted by the persuasive arguments of Clement of Alexandria, many of this sect accepted the dictum that all tokens, Gnosis, Logos, Sophia, were brought to us from God by Jesus, coming for that purpose.

So far Gnosticism accepted the central doctrine of Christianity; but because it could not part with its many apocryphal tales and beliefs it was not accepted by the early Christian church and Valentinus, the foremost exponent, was listed as a heretic.[26]

Manichaeism (still more insistent on the awfulness of

[26] St. Irenaeus: *Contra omnes haereses* (c. 180).

evil and the necessity of salvation) replaced Gnosticism in the third and fourth centuries.

Neoplatonism, originally Alexandrian and Greek, united a modified Platonism with oriental elements and some of those of the Jew, Philo. Originally it stood in opposition to Gnosticism and Christianity but by 415 had ceased to exist in Egypt.

The Christian Neoplatonists accepted evil, although its existence was denied by Plato (for "all things exist in proportion as they are good"). But they did not recognize evil as necessarily eternal since it was they who taught that the means of salvation exists in all things, in that each has the desire to become as perfect as possible.[27]

Reality in Morals

Plato: Goodness alone.

Aristotle: Nature striving after the perfect.

Gnostics: Evil existent and eternal.

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[27] Note that two factors of Plato's system had been discarded: (1) that in formulae, forms, generalizations, was the *only* reality. Aristotle had found reality in natural objects. (2) Nothing exists which is not good. The Egyptians were very sure that evil exists. These changes illustrate the tendency toward a modification more and more suited to the practical everyday man.

The Christian ecclesiastics, opposed to the "things of this world," did not at first accept alchemy. But later when Christianity became itself modified by absorbing some of the beautiful imagery of the native Egyptian religion, and (much later) by fusion with Aristotelian philosophy, alchemy was accepted as true and alchemistic ideas were gradually absorbed into the Christian religion.

The Mediator

The Jews: Sophia (Logos).
Christians: Personal (Jesus).

Syncretic Religions

(Christian-Egyptian) Gnostics: The Logos by the personal mediator.

(Christian-Greek) Neoplatonists: Evil overcome by the tendency toward perfection.

Review

Philosophy and religious ideas are found closely connected in the minds of a people who could believe that the metals are living—"like man, are alive and sensitive." Accepting Aristotle's tendency toward perfection, the alchemists visualized the metals as striving to become as perfect as possible, to become white as silver or even yellow as gold—so perfect that goodness and light should abound more and more and the "sun metal" should illustrate the triumph of perfection over the primitive evil of the common "earth metals."

3. INFLUENCE OF EGYPTIAN CIVILIZATION

In the beginning, alchemy was far from being philosophical. It was just an ordinary art like that of the carpenter or blacksmith. It was on this primitive side of its character that it derived from ancient Egypt.

We have to go back very far to discover why it was that Egypt was peculiarly an artisan's country. Forty centuries are not enough to explain the wonderful religion, the beautiful Osiris cult, which fathered these industries. Originally, the Egyptians worshiped the Sun, the god of warmth and rich crops, for the sun in Egypt seems much closer to man than with us. Also they worshiped the Nile, the god of fertility, which by the mysterious periodic overflowing of its banks deposits a wealth of soil to sustain the cultivated lands. The Sun and the Nile were, then, the two gods "from whom all blessings flow," but of these the sun was the more personal. At the evening of life worthy Egyptians expected to join the sun, as it descends below the horizon and becomes Osiris, taking the wonderful journey of many stages through the underworld. Yet all Egyptians, however worthy, feared the ordeal of death; and the religion which had been beautiful in inception became dour in practice. The wealthy spent all their earthly days in preparation for the life which was

to be eternal. In order that they might be comfortable after death, they built great tombs, filled with furniture and food, lavishly, without question of expense. The walls of these crypts were often covered with pictures illustrating the journey of the sun or the pleasanter activities of the prince during his life on earth. These mortuary monuments, pyramids, and underground cave crypts, as well as the palatial temples to the gods, show how the priestly class ruled the wealthy with fear of death.[28]

Medicine flourished in ancient Egypt, as we see in the Papyrus Ebers and the Papyrus Smith, and here again we see the horror of disease and death as real evils. Plato might shut his eyes to evil, but, to the Egyptian, evil was an ever-present entity. We have seen how this conception was passed on to the Gnostics and to the Christians.[29] The Egyptian never doubted the existence of evil, evil to be feared, of which death was the culmination, something dark and oppressive, like an evil personality to be propitiated if possible. The great Egyptian tombs were, for the nobility, the supposed means of escape from this lurking terror.

A multitude of workmen was employed in construct-

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[28] On the walls of a crypt, in the tomb of Sethos I, in Thebes, is a rude, colored drawing representing the flight of the worthy upward toward heaven, while the wicked are being cast by means of pitchforks into eternal fire.

[29] Even today the prevalence of disease in Egypt is all too evident. The death rate among the natives is high. The infant mortality in the native Boulak district in Cairo is quoted as 85 percent.

ing, furnishing, and decorating these great buildings. Thus a great portion of the population must have been set apart as skilled artisans. Some of the recent findings in the "tombs of the kings" bear witness to a knowledge of craftsmanship rivaling that of our modern artists. The draperies dyed with "royal purple" and intermeshed with gold and silver threads, or studded with gold buttons or colored jewels; the bracelets and necklaces and rings of interwoven silver and gold, or of that alloy of silver and gold known as electrum, often formed into intricate designs and chased to enhance the effect; the wonderful bronze and woodwork, sometimes covered with gold leaf; the paintings, also, on the walls of the tombs and temples—a thousand things attest the excellence of the ancient Egyptian in the manual arts.

This proficiency has never died out in Egypt. As one wanders through the native districts surrounding the Mouski in Cairo, one cannot refrain from amazement at the skill displayed even by boys of tender years as carpenters or turners of wood, producing the delicate *mashrabijeh* work; as workers in metals also, in copper and brass, silver and gold.

The ancient fear of death, which thus indirectly promoted artisanship, established Egypt as the land where the people gloried in their life work, were proud of their skill and not afraid to soil their hands in honest labor.

Much later, as in the early years of the Christian era, Egypt became distinctly the one country in which such an art as alchemy could have hoped to survive, even could it have begun elsewhere.

For the remarkable activity of the Egyptians in the arts, other causes are frequently quoted. Of course, boating and fishing on the Nile were early cultivated; and the ever-changing river was responsible for the need of surveys to keep track of boundaries, as well as astronomical observations giving a calendar by which the flood season could be foretold. Such interests exercise a people in both bodily and mental activity and generate the seeds of invention and excellence born of competition.

While Greece leaned toward philosophy and Judea toward religion, Egypt became the nursery of the arts. Plato, speculating on the material world, called this exercise "a sober and sensible amusement," for he was seeking only illustrations for his ideas of the mind; but the Egyptian made of the world as he found it a laboratory in which, as far as his simple knowledge permitted, he developed the practical arts through both brawn and brain.

Very old and very early was this distinguishing quality of the native Egyptian. The region now known as the desolate "Tombs of the Kings" was noted for its magnificence, even to Homer, who sings of "Thebes with its hundred gates." Farther down the Nile, Memphis and Sak-

khara, now in ruins, were the wonder of travelers only a few centuries ago. Wonder is due not so much to the buildings and decorations as to the artisan who in those early days could plan and carry to completion such ambitious designs.

The attempts to produce color effects in all this work is still evident even after the corroding action of centuries. In a land of neutral hues, where the gray desert sands come close to the dark browns of the cultivated areas, color appealed to the people as a delicious joy. Exterior architecture exposed to sand storms of the desert could be relieved only by variously colored stones. Marble was laid with red sandstone; and granite and flint brought variety. But it was especially in the protected interiors of temples and palaces that colors were massed. Tapestries of different shades, combinations of gold and of silver, great vases of copper and of bronze, helped to satisfy that yearning for color which is present in every primitive people.

Thus, where art was honorable and skill was rewarded, it was but natural that alchemy, the art of "improving" the metals, should have had its humble beginning.

4. THE IMITATIVE ARTS

After an experience of one or two hundred years of intensive practice in the constructive arts, a nation may be

considered proficient and ready to take rank with other nations whose civilization rests upon artisanship. In Egypt, at the time which we are now considering, at least four thousand years' experience had brought the people to the highest excellence possible in those ancient times. It is to be noted also that this perfection of artisanship was not unguided. Egypt could boast also of a corresponding advance in mental achievements, having the greatest share of the world's philosophers, astronomers, architects, surveyors, and mathematicians, advances along many of these lines dating back to very ancient times.

Among the industries shared with neighboring civilizations may be counted the so-called imitative arts which seem to have arisen simultaneously in all parts of the known world.[80] To place before the common people those costly articles which they desired most, at a price within their reach, was the common purpose. Garments dyed with the royal purple, so expensive that only kings and priests could afford to wear them, were imitated. Articles of gold and silver, ornaments of pearls and other precious stones were sold frankly as imitations—the price being within reach of many who could not afford the real things. A little later the government at Rome drew up laws regulating this traffic, to protect the people against

[80] Hammer-Jensen, "Deux papyrus à contenue d'ordre chimique," *Bulletin de l'Academie Royale des sciences et des lettres de Danemark*, 1916, p. 279.

fraud. This industry of substitutes is known to have flourished from Gaul on the west, to India on the east; but all varieties of this common practice were gathered together in Egypt and became one industry. In Gaul the imitation of silver by alloying copper with tin was quite common, this region having the advantage of being near the copper mines of Spain and also on the route from the tin mines of the "Islands of the Cassiterides." Recipes for such alloys form an important portion of the Leyden Papyrus X in which we find also recipes for false royal purple.

The manufacture of artificial pearls started in India, where certain siliceous concretions or nodules are found in the stalks of the bamboo. Recipes for such artificial pearls are found in the Papyrus Holmiensis.

Metals, dyes, and precious stones satisfied the color hunger of the people by their hues and sheen, and it was this hunger for color which made the imitative industry possible. Of this industry the recipes of the two papyri must be considered a part. Although these recipes need not be considered alchemistic, it was upon such recipes that the later alchemistic literature was founded—the alchemistic recipes being copies, either exact or mutilated, of the recipes in the famous papyri. It is probable that the artisans for whom these recipes were written became real alchemists later. Just as the magician became the astrologer and later the astronomer, in the same way the maker

of imitations—the counterfeiter if you will—became the alchemist and later the chemist.

It has been said that the whole object of alchemy was deception. In this connection our attention is drawn to one of the recipes of the Leyden Papyrus, a recipe for the preparation of an alloy so perfect that "it will deceive even the expert."[81] But this characterization of the alchemist should be accepted, even if granted, not as a disgrace; for the artisans were supplying the people with metals which were frankly baubles like our cheap jewelry. Their only fault was that they succeeded too well. The real alchemists accomplished so much more that this early history, this bar sinister, may well be forgotten. These early artisans, although the progenitors of the alchemists, were not alchemists at all. Unconsciously, they were on the brink of a great discovery due to the fact that they were joining two industries—two color industries—in their workshops. They were, first, dyers of fabrics and, second, bronzers or colorers of metals to which all the technical methods of alchemy may be referred.

We think of them as dyers first because we find that some of the methods of dyeing, as well as the vocabulary and technical terms of the dyer, were carried over to the work on the metals. It is quite possible, also, that dyeing

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[81] In this connection, see Leyden papyrus X, and recipes 38 and 57.

came first in the estimation of the heads of the industry because it paid better.

Imitation in metal work was at first very crude, consisting of such processes as the fixing of some substance on the surface of the metal, paints or bronzes, "improving" the color; or fusing together two metals to produce a white alloy. Such recipes are found in the Leyden Papyrus. The red metal, copper, is fused with tin, the product being hard like copper but silver white in appearance. Arsenic, antimony, and mercury were in common use and they all give surprisingly brilliant silvery surface effects on copper. Arsenic gives an appearance like a silver mirror, fleeting to be sure, but the brilliance may be preserved by a thin layer of wax or varnish, as actually called for in the ancient recipes.

Let us see now if we can trace the connection between the dye process and the winning of these metal colors. In nearly all respects the art of dyeing fabrics remains the same in technique today as it was in ancient days, so that we do not have to interpret the method. After preparing the dye bath and making the fabric as white as possible so as not to introduce any interfering color, the dyer may dip the cloth directly into the color; but nearly always it is the practice to dip first into a so-called mordant bath which fixes the color, making it cling to the material, and making the dye "fast." By choosing the mordant, various

modifications of shade, differing from the original dye, can be produced. The mordants were, in Egypt, simple salt solutions, such as common sea salt, or soda from the "bitter lakes," or copperas (iron sulphate), or blue vitriol from the copper mines near Mt. Sinai, or, quite commonly, alum.[82]

It was in this dye shop that the metal work began, where the mordant salts must have been close at hand. We know that in fusing, metals are apt to corrode as the temperature rises. It is therefore customary, in order to lessen this undesirable corrosion, to sprinkle the hot metals with powdered salts. Nowadays salts used in this way are called fluxes because at the temperature of molten metals the salts fuse or flux and spreading over the surface keep away the oxygen of the air which causes the trouble.

The Greek word for dipping is $\beta\alpha\pi\tau\acute{\iota}\zeta\omega$, which is our word baptize—a word frequently used in the dye process. It is remarkable that this same word appears also in the metal coloring. This is interpreted to mean that, probably early in the work, it was found advantageous in cleaning

[82] Pliny, in his *Historia naturalis*, XXV, 42, states: "In Egypt, too, they employ a very remarkable process for the coloring of tissues. After pressing the material which is white at first, they saturate it not with colors but with mordants that are calculated to absorb color. This done, the tissues, still unchanged in appearance, are plunged into a cauldron of boiling dye and are removed the next moment fully colored. It is a singular fact, too, that although the dye in the pan is of one uniform color, the material when taken out is of various colors, according to the nature of the mordants which have been respectively applied to it."

the metal to dip it into the mordant bath—the same bath used as a preliminary to dyeing; and just as a modification of shade of the dye had thus been produced on fabrics, so the valuable fact became known that metals also could be made to assume quite a variety of unusual shades by this dipping process, followed by gentle heating. The first appearance of these colored metals on the market must have come as a novelty and created a demand very encouraging to the manufacturer.

The process of coloring metals, or "bronzing," is now a well-known and established industry; but in Egypt this application of dye methods was surprising in its unexpectedness and was carefully guarded as a trade secret, since the product was a remunerative novelty.

Two of the very numerous colors produced are important: a yellow like gold and a deep black. The latter may be said to have been the national color of Egypt, sacred to their god Anubis.[33] Both bronzes must have made a deep impression upon the artistic sense of the color-hungry people and also have returned a considerable revenue.

An allied discovery should also be mentioned here—that of "sulphur water." This preparation was made by heating raw sulphur with lime and is what we now call calcium sulphide. With water, it gives off by hydrolysis

[33] See Chap. VI, note 28.

the gas hydrogen sulphide.[34] Every student of elementary chemistry is acquainted with the variety of sulphide colors produced by this evil-smelling gas when passed into solutions of the metals. It is also true that, similarly, on the surfaces of the solid metals a varied color effect is produced.[35] Considering the great attention paid later by the alchemists to sulphur and all its compounds, it is easy to see the importance of this early discovery.

And finally, reference should be made to the jeweler's process called "royal cement." To a large quantity of fused base metal a little gold was added and the whole cooled to form one "metal," and this solid solution was then shaped into some form such as a ring. This was then etched on the surface by alum or other mordant salt. The surface of the base metal, such as lead, by this process would be dissolved away, leaving granules of pure gold in relief, thus making the ring appear to be made wholly of gold. This process had been known from very early times. It is even now in use by our modern jewelers.

In review, we have four processes for imitation of the precious metals: alloying, baptizing, the use of "sulphur

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[34] Zosimus adds: "On opening the cover, do not put your nose too close to the mouth of the jar." (Berthelot, *Collection des anciens alchimistes grecs,* III, VIII, 2.)

[35] Perhaps the disagreeable odor increased the mystery. At any rate the name *ὑδωρ θεῖον* may be translated either sulphur water or holy water. This confusion may have been the reason for ascribing to the Egyptian priests and temples the origin of the alchemistic art.

water," and of "royal cement." How these discoveries led up to alchemy proper will be the subject for discussion in a later chapter.

It is to be noted that in no other place in the world had there been such a preparation, as in Egypt, for the growth of alchemy as a theory of the metals, since when the coloring arts arose, they needed only the application of a plausible generalization to be transformed into real alchemistic practice. The theory which was to weld together all these color processes was living in the minds of all Alexandrians—of all who prided themselves on a Greek inheritance—for Greek philosophy working among this practical people was ready and waiting to be applied as an explanation of Egyptian art. Since this explanation proved acceptable, we have here our first illustration of a scientific triumph, the joining of theory with practice.

Chapter IV

THE SETTING OF ALCHEMY

All nature is striving toward improvement.

As has been said, we may be quite certain that alchemy began in Egypt in the early centuries of the Christian era; yet we are not justified in pointing to any particular city as a center of alchemy, at least so far as the records guide us. It is, however, assumed with great probability that this center was Alexandria since all the intellectual life of Egypt was gathered there. Nearly coincident with the beginning of alchemy came the culmination of that material prosperity and academic advancement which made Alexandria the most noted of all the cities of her day in the civilized world.

A study of the conditions and attainments of her people with a description of the ancient city, unfortunately so little known at the present time,[1] will make clear to us why alchemy should have sprung from this Egyptian soil—why Alexandria was the only city in which could have taken place such an intellectual advancement as alchemy represented.

Founded by Alexander in 331 B.C., the city was placed

[1] The greatness of Athens and the might of Rome have been amply recognized but the greatness of this second Athens—the Queen City of the Mediterranean—is hardly referred to and has not been elaborated in our histories.

by his orders upon a peculiarly solid limestone dike, so guarded by another projecting dike that two large harbors, the only two in all the southeastern Mediterranean, made possible the extensive maritime commerce which later developed between Egypt and the cities of Athens and Rome. The advantage of this situation was still further enhanced by a shallow lake on the south which was soon connected with the Nile by a system of canals, so that all the produce of upper Egypt found an outlet through Alexandria. Other canals connected the Nile with the Red Sea. Because of this wisely chosen situation and the canal systems, the city became the one port through which flowed the riches of the Mediterranean cities, of India, and of the fertile granary of the Nile Valley—each consignment contributing its toll in commissions and duties to her merchant princes and to the city government. In consequence, wealth had so accumulated that, within one or two hundred years, there had arisen already such famous buildings as the library, the museum, and the Pharos—that lighthouse reckoned among the seven wonders of the world and from which all the subsequent Mediterranean lighthouses were named.

The plan of the ancient city remains uncertain, since the ruins of its palaces and temples are now buried eight to ten meters below the present level by desert sand or by the encroaching harbor waters. But there are indications

that it was laid out in regular form with streets crossing at right angles. The center of the city was Alexander Place, a large open square crossed by two avenues, the one running north and south called the Soma, from the tomb of Alexander; the other, parallel with the harbor, running west to east and continuing east as Canopic Street far into the country. The western end beginning with the Gate of the Moon was called Rhacotis Street and the eastern portion within the walls ending with the Gate of the Sun was known as Brucheion. Both avenues were completely lined with colonnades.

In the year 400 A.D., a writer (Achilles Tatius) describes Alexandria thus:

> The first thing one noticed in entering Alexandria by the Gate of the Sun was the beauty of the city. A range of columns went from one end of it to the other. Advancing down them, I came in time to the place which bears the name of Alexander and there could see the other half of the town which was equally beautiful. For just as the colonnades stretched ahead of me, so did other colonnades now appear at right angles to them.

The original citadel, called the Rhacotis, was situated in the southwestern portion of the city, south of Rhacotis Street. Upon it was located the magnificent Serapeum, the temple of Osiris-Serapis, with which was connected a portion of the old library, the main portion of which had

been in the Museum, probably in Alexander Place, so close to the harbor that the books were accidentally burned during Cæsar's bombardment of the city. In the center, near the Soma of Alexander, were the tombs also of his successors, the Ptolemies; and from this point extended, toward the harbor and out into the country as far as the present Promontory of Siseleh, the great system of palaces. Near the harbor also was the Cæsareum, with its "Cleopatra needles," begun by Cleopatra as a temple dedicated to the deified Antony; and at the south, on Soma Street, was the Gymnasium.

Alexandria was known as the "Queen City of the Mediterranean." But beyond the beauty of the city, with its Pharos, its famous library, its museum and its Temple of Serapis, its many tombs, statues, and palaces, beyond and above all this, stands today as its greatest claim to eminence its intellectual product—the output of its library and its museum. The material glory has all disappeared. Above the ruins has been built a new commercial city forgetful of the glory of the past. The intellectual city alone remains imperishable and it is this which commands our attention.

Of the many branches of knowledge covered by Alexandrian authors, it will be sufficient to note works in pure literature, in mathematics, in geography and astronomy, and in religious and philosophical speculation. In litera-

ture we have some well-known names: Callimachus the poet, whose pupil was Apollonius of Rhodes; the poet Theocritus; and the scholar Zenodotus, the latter the first librarian, he who brought out the first edition of Homer and divided Homer's poems into books. In mathematics, we find first the great Euclid who, among other books, composed his famous *Elements.* Apollonius of Perga wrote also on conic sections. Hyspeses added two books to Euclid. Theon, father of the martyr Hypatia, gave to the *Elements* its present form and finally Diophantus of Alexandria, about 250 A.D. "divorced algebra from the methods of geometry." In geography and astronomy there are three outstanding names. Erastosthenes early measured the diameter of the earth, obtaining 7,850 miles![2] His coworker, Aristarchus of Samos, first proposed the theory, discarded until the time of Copernicus, that the earth revolves about the sun. The more ancient theory that the universe revolves about the earth was later perfected by Claudius Ptolemy, also an Alexandrian, and is now known as the Ptolemaic theory. The Alexandrian calendar was worked out as early as the third century B.C., but, as in the case of the heliocentric theory, opposition of the priests prevented its use until the reform was made mandatory by Julius Cæsar. It is this calendar, the basis of that now in use, which is known as the Julian.

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[2] Sarton, *Introduction to the History of Science,* I, p. 172.

The Jews were first in the field of religious speculation (see chart, p. 33). These Alexandrian Jews, far from their native Judea, had acquired the language of Greek Alexandria and were in danger of losing their ancient faith. It was for them that the Septuagint translation of the Old Testament was made. The Wisdom of Solomon was probably Alexandrian. Here also Philo, the Jew, developed his great doctrine of the "Logos." The religious controversies of the early centuries reveal some well-known names: Among the Gnostics, Cerinthus, Basilides, and Valentinus; among the Neoplatonists, Plotinus, Porphyry, and Hypatia; among the Christians, after St. Mark, who was martyred close by the city, Clement of Alexandria and Origen as well as the great controversialists Arius, the founder of Arianism and Unitarianism, and Athanasius, whose creed now controls orthodoxy.[8]

It was in Alexandria that Christianity became for the first time a world power. On the other hand, owing to the Athanasius-Arius dispute, it was in Alexandria that the Christian Church became divided into two opposing camps, an opposition which, unfortunately, has lasted even to our day.

In spite of world-rending controversies, the ideas of Greek philosophy, accepted by all sects and by all religions, still controlled the speculations of ecclesiastics and

[8] See chart, p. 33.

scholars. The dominant system of thought was what we now designate as Neoplatonism. While Christianity was inveighing against the "things of this world," the voice of Plato was audible and influential: "All things exist only in proportion as they are good"; and that of Aristotle: "Everything is striving to gain perfection—that ultimate union of the All in the One."

Promulgated in Greece at a time when the purely mental life was considered superior to all others, especially to that of the working classes, this Platonic theory found itself at last in Egypt, among an alien people, proud of their arts and crafts. No doubt this popular philosophy was acceptable to the Egyptians; but no doubt, also, if it had no practical application, it was to them unimportant. In this case, they probably would have nothing to do with it. In Egypt, the idealism of Greece thus found itself confronted with the question, Will it work?

Then came the triumph of philosophy. In the realm of the metals, philosophy found its first successful practical application. We behold philosophy united with art; and this union was alchemy, which is Aristotelian philosophy put to practice.

Alchemy succeeded so far that the metal work of the artisans stands historically as perhaps the first practical illustration to be quoted in support of the Platonic theory.

Hereafter, matter would indeed seem "negligible," but

the metals were endowed with a new life,[4] having common bodies but individual spirits, all striving to become gold. The fire spirit of gold was its pure color and it was toward this pure color that all metals were tending.[5] The task of the alchemist was to assist nature in this upward course. By demonstrating that this assistance could be successfully brought to bear upon the course of nature,[6] alchemy first acquired the prestige of being identified with philosophy; and by supplying practical proofs of its applicability to the things of everyday life, alchemy aided in raising Greek philosophy to a world philosophy, acceptable not only to a small and provincial Greek community in the great Egyptian city, but to all sects and nationalities.

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[4] So Geber, in *The Book of Pity:* "If one of weak intelligence, of low understanding and little experience maintains that these spirits, these bodies and these stones produce no action, that they do not live, that they do not at all recognize each other or refuse to recognize, that they neither agree or disagree, that they do not receive or shun one another, he has only to try this on the fire and he will see with his own eyes all which has just been said" (Berthelot, *La Chimie au moyen âge,* Vol. III, p. 189).

[5] Plato (*Timaeus,* LXVII, C): "Colors, which consist of a flame streaming off from every object." . . . "Everything exists exactly in proportion as it fulfills the end of being as perfect as possible, for just in that degree it participates in the idea of the Good, which is the ultimate source of all existence."

And the alchemists: "All nature is striving toward improvement"; and the Pseudo Roger Bacon in the *Mirror of Alchemy* (thirteenth century): "Nature has always had for an end and tries ceaselessly to reach perfection, that is gold."

[6] "Nature has left only a comparatively small thing for the artist to do—the completion of that which she has already begun." Quoted by Pattison Muir, *Story of Alchemy,* p. 33.

Chapter v

THE LITERATURE

"When they discourse on colors, the mind of the uninitiated falls into confusion." Berthelot, *Collection des anciens alchimistes grecs.*

From the beginning of alchemy, on through the thousand years of the Dark Ages, Europe and the Near East were so racked with wars, invasions, and counter-invasions that not one of the political units has survived. During this never-ending riot, monasteries where the ancient literature was conserved were destroyed and many most valuable writings, records of former attainments, were forever lost to the world.

Under these conditions, the survival of an obscure literature, such as that of alchemy, must be considered remarkable. We are fortunate, therefore, in having inherited the little which we have. Since alchemy dealt with one of the least of the mechanical arts, there would seem to be no reason why the writings on alchemy should have been protected or have seemed of value to the monks. It was also the wish of the alchemist to preserve a masonic secrecy in regard to his methods and technique and for this purpose he adopted a blind and misleading language which appears now so repellent to the reader that he is tempted to declare the whole subject a deceit and the lit-

erature of no account. It is surprising therefore that the pious monks of the old days, with their minds filled with the importance of things of the spirit, should have retained in their collections books seemingly so foreign to their interests.

Yet they not only retained them, but studied them, as we know from the frequent annotations, interpolations, and glosses which have crept into the literature. This interest may perhaps be accounted for by the theoretical side of alchemy which involved a philosophy common to both alchemy and religion, with frequent references to the body and the spirit of the metals.

In quite modern times, there have been discovered, still preserved in the libraries of Europe, a few alchemistic manuscripts, agreeing closely in subject matter and arrangement, thus giving evidence that they are copies of a common source, an original collection of abstracts from the best-known authors of Egypt.

The oldest of these manuscripts—that of St. Marc of Venice—dates from the tenth or eleventh century. The other manuscripts are still further removed from the date of the early writings, some dating from as late as the sixteenth or seventeenth century.

The authors whose writings are given in all these manuscripts, those whose works are the most extensive, have already been named in their probable order on the chart

in Chapter II. There are also in these manuscripts quotations of short abstracts from other authors, less known, such as Mary the Jewess, Pelagus, and the mythical Gnostic, Hermes.

I. THE LEYDEN PAPYRUS X

But keeping this list in reserve for the moment, let us consider another work, dating from about the time of the Pseudo-Democritus, but probably preceding him, the Leyden Papyrus X,[1] the only work dealing with metal coloring which has come to us directly from Egypt; and also the only contemporary writing of this nature which we may compare with that of our first author, "Democritus."[2]

The Papyrus X presents us with a collection of 101 recipes, followed by 10 paragraphs taken from Dioscorides on such metals as are mentioned in the preceding recipes. The recipes are numbered by Berthelot for convenient

[1] With which may be joined the Papyrus Holmiensis, "in part at least written by the same hand."

[2] This papyrus consists of separate books, one for each letter of the alphabet, mostly concerned with law cases, contracts, magic, and dreams. The books designated as V, W, and X seem to have some analogy; but that designated X is the only one especially concerned with the metal industry of the nature already described. The collection was sold by the Swedish vice consul at Alexandria to the government of Holland in 1828. The portion marked X appeared, with Latin translation by Leemans, in 1885. A French translation, edited by Berthelot in 1889, is contained in his *Collection des anciens alchimistes grecs* (1888); and the Greek text and translation in Berthelot's *Archéologie et histoire des sciences* (1906).

reference in his translation. They follow one another, tandem, with no notes or comments, forming thus just a body of practical recipes such as an artisan might use, roughly worded, some incomplete, some carrying merely suggestions of the work to be done. They belong to the widespread art of imitation already referred to. Originally, they were probably in no way connected with alchemy. Included in the 101 recipes, at the end, are 11 recipes for the preparation of a false "royal purple." The remaining 90 recipes deal with the preparation of alloys of the color of silver or gold, the bronzing of metals, and so forth. Berthelot calls attention to the fact that there is in these recipes no reference to metal work in the large, such as blacksmithing or the making of arms. The object is wholly artistic—the production of metals colored like silver and gold, to be used in making ornaments, rings, images, or vases. But through the whole there are two prominent objectives: (a) to increase the body of the precious metals without changing their appearance or color; (b) to change the color of the cheaper metals or alloys so that they will seem to be silver or gold, either by some bronzing surface treatment or by preparing alloys which should be colored both inside and out.

It is hard to decide whether these recipes (purely technical as they are and probably preceding real alchemy, containing nowhere any expression of a theoretical con-

ception of the metals) do not in places, thus early, reflect some of the ideas which so strongly influenced the later alchemist. One of these (89) is a very clear description of the preparation of calcium sulphide which substance was in constant use by the real alchemists.[8]

As illustrating the dilution or "Increase of gold," we have in recipes 16 and 17, which were originally one recipe, a method of producing from a little gold an increased amount of an alloy of golden color:

To augment gold. Take Thracian Cadmia [alloy of copper, zinc, and lead] in thick crusts, or the white kind, and mix it with misy [green vitriol] and Sinope Red [red iron oxide] equal parts with the gold. Let the gold be thrown into the cupel and become bright. Scatter ὸn some of each; allow to cool; and the gold will be doubled.

2. THE PSEUDO-DEMOCRITUS

In contrast with this recipe book for metallic imitations, the book of Democritus called *Physics and Mystics* (although the portions which we have are exasperatingly

[8] Recipe 89: "Discovery of Water of Sulphur. Having mixed a handful of lime and as much sulphur, in fine powder, place them in a vase containing strong vinegar or the urine of a young child. Heat from below until the supernatant liquid appears like blood; decant this carefully to separate it from the dregs and use."

The use is illustrated in another recipe: Recipe 49: "To gild without leaves [of gold] a silver or copper vase. Dissolve some yellow soda and some salt in water; rub with this and it will be [gilded]" (see Appendix III).

meager) stands out as a distinctly literary production. The pen is that of a philosopher, not that of an artisan. Here we have for the first time a discussion of alchemistic ideas, controversy even, giving almost a polemical character to certain portions of the text. And yet there are many recipes, some of them strikingly similar to those of the Leyden Papyrus. The treatise, as we have received it, starts out with recipes for the false purple dye, analogous to those at the end of the papyrus. Then, immediately following comes an account of the supernatural revelation (by the opening of a temple pillar) of the favorite saying of the alchemists, "Nature pleases nature; nature conquers nature; nature produces nature." This finished, the real treatise of Democritus seems to begin. The author announces that the work is divided into two parts, "Chrysopy," or gold-making, and "Argyropy," or silver-making.

At the beginning of the chapter on gold-making, there is revealed to us, at once, the meaning of the title in all its primitive significance! An early recipe reads as follows:

> Copper is made clear and brilliant, free from tarnish and of silvery sheen, by use of arsenic, antimony or mercury. . . . But by adding electrum [a gold-silver alloy] there is produced a gold color; by adding gold, "Gold-coral" is the result.

A second recipe directs that a silver alloy be heated and "dipped" [4] into some yellow material.

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[4] This is the same word used in dyeing cloth which is dipped into the color

[Again:] Cast a sulphur preparation upon silver to get gold; or upon gold to get "Shell gold."

[Again:] First whiten, then yellow Cyprian cadmia;[5] make yellow with . . . any substance which can yellow, for gold is formed from gold and the gold bath.[6]

[Again:] Having obtained the metal [copper] of clear tint, yellow it with anything until a yellow [gold] color is obtained. Cast this upon any kind of metal, for copper of clear tint on becoming yellow tinctures every kind of metal [into gold].[7]

[Again:] Heat green vitriol until it turns yellow, over a moderate fire for three days, and cast it upon copper (or upon silver of our manufacture) and it will be gold.[8]

There follow recipes for coloring the surface of silver with colors derived from plants (in layers of the thickness of the finger nail and of the consistency of wax) to get a gold color; or with arsenic preparations; or to give a gold color to lead by sulphur.

At the end is this statement: "This method of gold-making, accomplished by natural means, is that of Pammenes who taught it to the Egyptian priests."

In the second chapter, on silver-making, recipes with discussion fill the body of the discourse. First comes a

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bath. The word may be freely translated "colored" or "tinctured" (see pp. 47, 48).

[5] Impure zinc oxide obtained as sublimate in roasting copper pyrites.

[6] Note that yellowness and goldness are considered identical so that "anything which can yellow" is the same as anything which can produce gold or the color of gold.

[7] This was the "inexhaustible tincture" of the Leyden Papyrus.

[8] See Berthelot, *Collection des anciens alchimistes grecs*, II, III, 7. Synesius: "In both catalogues, mercury has been classed before all things both *in the yellow which means gold* and *in the white which means silver*."

recipe for whitening copper by arsenic (arsenic called mercury) or by sulphur; or for whitening lead by "white sulphur" (white arsenic); or for whitening metals by varnishes; and recipes for whitening by amalgamation.

Toward the end of this section, an important passage reads as follows:

> Taking the vapor[9] previously described, rub it with alum and misy and having sprinkled the metal with vinegar, cast on it also white cadmia or magnesia or chalk *in order that one metal* may be made from another (*ἵνα γένηται σῶμα ἀπὸ σώματος*).

This is, in substance, all that we have of the famous "Chrysopy" and "Argyropy" of the Pseudo-Democritus. The book is, however, supplemented by a letter purporting to be from Democritus to the physician Leucippus, commenting upon the previous book.

> The work includes Whitening and Yellowing as well as the softening and heating of the copper alloys. I omit tincturing. . . . You can make gold (*ἔχεις ποιῆσαι χρυσόν*) both from cadmia and from other kinds (*εἰδῶν*) both by heating repeatedly and by alloying, so that marvellous things result.

In Democritus, we seem to have, naïvely expressed, the objective of alchemy when the subject was so young that precautions were not yet deemed necessary.

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[9] The original is *νεφέλην*, *i.e.*, mercury or arsenic. The word "cloud" refers to any sublimate or substance capable of volatilization.

3. SYNESIUS

We have from this author a short commentary on the *Physics and Mystics* of Democritus, looked upon as the author of or at least the great authority on the art. Synesius states that Democritus was a very wise man who having arrived in Egypt

composed four books on tincturing (*βίβλους τέσσαρας βαφικάς*): on gold, on silver, on stones, and on purple. He has made two catalogues, one of white and one of yellow. At first he has catalogued the solids, then the liquids or aqueous materials, although none of the latter is employed in the art. In fact, he himself, in speaking of the great Ostanes, testifies that this man did not use the projections or heatings of the Egyptians but that he operates on substances by surfacing from without; and, with heat, effects his preparation. . . . Now what he says signifies that if you do not reduce bodies to their last degree of division, if you do not dissolve, and if you do not remove their liquidity, you do nothing.

The use of surface materials or bronzes is illustrated by this note by Synesius on sulphur water:

Take the water which escapes from the end of the eduction tube and keep it for the decomposition. It is what is called Sulphur Water [or Holy Water *ὕδωρ θεῖον*]. This produces "transformation," *i.e.*, the operation which brings out the hidden nature, which operation is called "solution of the metals."

This quotation is also valuable:

Mercury robs all metals of their appearances. Just as wax takes the color which it has received, so mercury whitens all metals and attracts their souls. It refines them and is diffused. Being thus properly disposed and having in itself the principle of all liquidity, when it has undergone decomposition, it changes colors everywhere.

Mercury was considered a spirit.[10] A spirit was said to be "accidental," because it does not exhibit its properties until it is associated with metals. To associate spirits with metals, it is necessary to make the metals as pure as possible by subliming mercury upon them. The apparatus for this purpose was the aludel or kerotakis.[11] An *unalterable* tincture is obtained only by joining the volatile spirit with a nonvolatile body or metal. If one uses a tincture already joined to a metal, that is to say a permanent tincture, the general rule is that each such substance is to be treated with a "higher" substance, containing a higher degree of spirit, color, or volatility. Thus lead or tin is tinctured by molybdocalc [the lead-copper alloy]; copper by gold; silver by gold; gold by the "coral of gold." The degree of excellence seems almost always to be one of color,[12] acting

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[10] Later writers, such as Geber and Albertus Magnus, list as spirits mercury, sulphur, arsenic, and sal armoniac.

[11] See pp. 72, 73.

[12] Berthelot: *Collection des anciens alchimistes grecs*, III, XII, 4: "All sublimed vapor is a Spirit and *such are the tinctorial qualities*"; and "Arsenic is the soul of gilded matter. . . . Take from it, then, the portion which can color." Also, III, XVII, 1: "In order that the color be fixed without the aid of fire." Also, III, LVI, 2: "We are not obliged to effect Iosis by means of fire.

as a ferment to improve or increase the natural color of the metal as if it were struggling upward toward the perfect color of gold, gold being the highest metal, its color corresponding to fire, the highest of the four elements.

All this "Democritan literature" teaches us that in the early days of alchemy the primitive authors understood, and naïvely tried to make us comprehend, that "gold-making" and "silver-making" are the processes through which the earthy metals are raised to the dignity of gold and silver, by impressing upon their common "bodies" some volatile ennobling "spirit"; the effect of which process was manifested in color, which color was the determining characteristic of the higher metal—just as men are distinguished, not by their common bodies, but by their higher spiritual qualities.

4. ZOSIMUS

The two writers whose works we have considered present us with a picture of alchemy in its early stages. They speak of it as an art (τέχνη), sometimes as the sacred art, as if it were a temple industry. It is evident that the art was successful; the product, imitations of silver and gold, was marketable so that the people accepted it in its various

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One works to get colored metals, or in treating [dye] liquids to produce purple, by the method in the cold, just as well [as by fire]."

forms as a good substitute for the more expensive metals. Democritus and Synesius write as if the technique of the art were familiar to them.

All this is very interesting. It seems that we have here the early industry which was not alchemy but close to it and was fundamental to that form of applied philosophy which was later called alchemy.

A very different outlook appears in our next author, Zosimus. It may be merely a matter of time or it may be that the art had in the meanwhile been discredited by the expulsion of the alchemists from Egypt. However that may be, to Zosimus the technique, the actual handling of details, seems unfamiliar and perhaps somewhat foreign to his thought. Moreover, in all matters of practice the "fathers" of the art are invoked—the men "of long ago."

Zosimus appeals to us as a philosopher. He is, to be sure, not so far from the early days that he does not know the technical methods, but he knows them as one who has received them as an inheritance. Zosimus is the first subtle interpreter of the meaning of alchemistic practice. He speaks in allegory, through dreams, expressing the belief, with Plato, that the material body of gold is nothing; that the quality of gold is independent of the metallic substance which is the support of the spiritual quality and that this spirit—this higher spirit—is gold; that when one possesses a material in which the gold quality resides, just

as one might possess the essential coloring principle of a dye, he thereby has in hand what was later called the philosophers' stone and one can then "tint into gold"; and it is in this way that one can make true gold.

Here are the words of our author:

> But our gold which possesses the desired quality can make gold and tint [transmute] into gold. Here is the great mystery—that the quality becomes gold and it then makes gold.

We have here a very clear statement of one of the fundamental theories of alchemy, a theory which illuminates many otherwise dark passages.

Zosimus is also convinced that silver-making, the argyropy, is but a first though necessary step toward gold-making, or the chrysopy. When the alloy is first whitened, it is indeed whitened on the outside but at the same time it is yellowed on the inside.

> Do not neglect the moment favorable for whitening for in this stage two things are produced at once, the whitening and the yellowing.[18]

Color and the proper sequence of colors are all-important. In this connection he quotes Democritus:

> If the flame is too strong, a yellow color is produced but this will not serve, for at this moment you wish to whiten the metals.

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[18] Berthelot, *Collection des anciens alchimistes grecs*, III, VI, 20: "Nothing is whitened first and yellowed later but one whitens and yellows in one continuous operation."

In the coloring of gold, silk, or skins, one colors yellow *after* having colored white. One must whiten first before tinting purple.

A low fire is necessary, therefore, in order to obtain the white color: "Expose it to the fire as to the action of a strong sunlight."

Now this precaution could have been introduced only for fear some surface bronze might be lost. It is noteworthy that the same precaution occurs in the recipes of our modern bronzers, lest the color produced may be dissipated.

Zosimus registers his belief that Democritus accomplished the whitening of copper by use of arsenic or mercury and not by sulphur. This is the occasion for his introduction of the description of the aludel and kerotakis, instruments used for volatilizing sulphur or arsenic or mercury in a closed vessel so that the elements could be sublimed and purified; and, in case of the kerotakis, act upon a leaf of copper suspended in the closed space.[14] They are familiar tools to Zosimus. These reflux condensers have always been considered alchemistic inventions, destined to play a part in confirming alchemistic theory in the minds of the ancient world.[15]

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[14] The first actual drawings of these pieces of apparatus are found centuries later on the margins of the manuscripts, such as the MS. St. Marc (eleventh century).

[15] Hammer-Jensen claims that this instrument made possible the great al-

One of the descriptions runs as follows:

Taking some arsenic [he means the sulphide], whiten it in the following manner. Make a soft clay disc of the thickness of a little mirror and pierce it with little holes, like a sieve. Place above, adjusting it, a recipient into which put one part sulphur; and into the sieve as much of the arsenic as you wish; and having covered with another recipient and luted the joints, after two days and nights you will find white lead ["white arsenic"]. Cast on a quarter mina of this and heat a whole day, adding a little bitumen and you will have [the result]; and such is the construction of the apparatus.

Berthelot has reproduced the drawing of this apparatus (from the MS St. Marc, eleventh century) in his *Collection* (Introduction, pp. 143 and 146), and he has shown very clearly the derivation of this "sieve" from the painter's palette, on which in the old days colors were mixed in wax, softened by gentle heating. The Greek word for wax (*κηρός*) gave the name kerotakis to the derived form. The four colors at the command of the ancient artist were black, white, yellow, and red, as with the alchemist. When the mercury, like wax, made the metals into a soft alloy or amalgam, the technical term was "softening of the metals." Tin which preceded mercury as the most fusible metal figures largely for this purpose in the recipes of the Leyden Papyrus. At the moment of softening, the

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chemistic discovery: that of a substance (sulphur) which as an "earth," solid, inactive, could be changed into a "spirit," volatile, active; and then changed to a "water." *Die älteste Alchymie*, 1921, pp. 40-41.

amalgam, like the wax on the painter's palette, assumed a new color.

With the alembic (ἄμβιξ) for simple distillations, and the reflux fitted with the kerotakis for treatment of the metals, all the processes of the alchemist could be successfully carried out. These two pieces of apparatus were popularly ascribed to two women frequently cited—the alembic or still to Cleopatra and the kerotakis to Mary, to whom also is ascribed the invention of the water-bath, which the French even now call the *bainmarie*.[16]

By the use of these important inventions, there was firmly established the fundamental thesis of alchemistic philosophy:

> All sublimed vapor is a spirit and such are the *tinctorial* qualities. . . . The vapor is a Spirit—the spirit which penetrates into the Bodies [of the metals]. . . . Above, the things celestial and below the things terrestrial. . . . Such is the useful thing: the tinctorial element. [This is to be understood as the kinetic coloring principle, not the color but the ability to impart color, in analogy to the dye.] . . . The spirit . . . has not been destroyed but it has penetrated into the depths of the metal when the operator has accomplished his work. . . . And when the preparation is colored then it, itself, colors in its turn.

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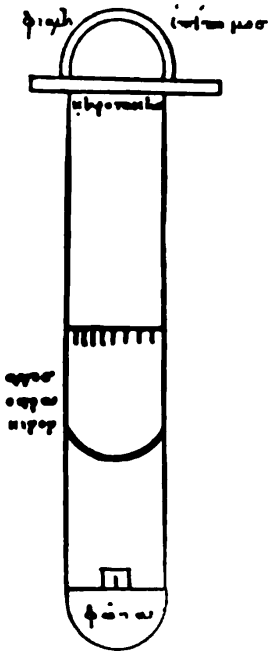
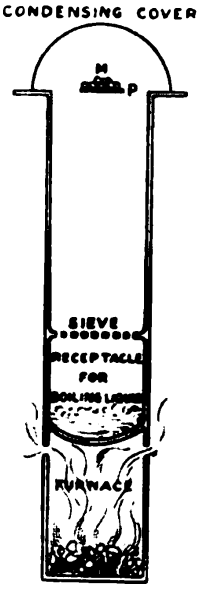
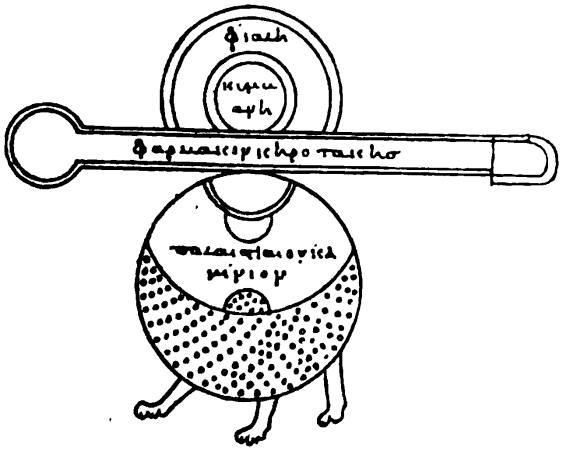
[16] In a recent article by F. Sherwood Taylor (*Journal of Hellenic Studies*, 1930, p. 109), there are given two drawings of the aludel with Kerotakis as given in outline in the ancient manuscripts, faced by two drawings of the same, as they would appear in modern perspective. They give a very clear idea of the possible use of this ancient piece of apparatus, and are reproduced here by kind permission of the author and of the Council of the Hellenic Society.







ALEMBIC AND KEROTAKIS

Agathodemon says: "In order that you may understand the effect which you produce (on getting the copper-tarnish, χάλχανθος, which you know), it is the tinctorial principle which causes the vapor to develop the gold."

After the whitening, with its supposed internal yellowing, the following process, yellowing, was carried out "in order that the gold may exist not only potentially but actually." "Project upon it [white copper] the color of gold, and you will have gold."

The author explains in regard to this whole theory:

> Thus, to convert and transmute, in these [old] authors, is to give a metallic body to the spiritual [volatile] substances . . . but when the spiritual substances have taken on a bodily [metallic] form, the transmutation has taken place . . . by the tincture into white or into yellow. In fact, this conversion is called transmutation.

There is one other conception upon which Zosimus places his seal of approval—the doctrine of the ferment. Stated practically, it is that if one wishes to transmute a metal into silver, one adds first a little portion of silver; if into gold, a portion of gold. Theoretically, the statement would be somewhat as follows: Every metal is striving to become gold but in order to hasten the process, the alchemist adds a catalyst. Gold itself is a matter of color simply, but alchemistic gold is richer in yellowness for it is not only yellow but it can impart yellow [*i.e.*, gold].

"Common gold has only sufficient yellowness for itself." The tincture, like a dye, is rich in color and attracts to itself all the yellow supposed to be hidden in each metal, neglecting the other colors; and one tincture is sufficient for both transmutations, since yellow-red is progressively only a step higher than white.

If you wish to tint into silver, add leaves of silver; if into gold, leaves of gold. For Democritus says:[17] Project Water of Sulphur on common gold and you can give it a perfect tint of gold. A single liquid is recognized as acting on both metals. It is necessary, therefore, that the Sulphur Water play the part of a yeast, producing the like, whether silver or gold. In fact, just as yeast, although in small quantity, raises a great quantity of doùgh, so also a little quantity of gold or silver acts by aid of this reagent.[18]

The few writings of Zosimus which we have received are merely abstracts from much larger works. They contain many quotations from older authors; and, in our manuscript collection, are also intermingled many quotations from later writers, much more modern, in which often the major citations are from the works of Zosimus. It is sometimes very difficult, therefore, to disentangle the authentic from the extraneous and to decide whether Zosimus, the editor, was also an original contributor to

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[17] Berthelot, *Collection des anciens alchimistes grecs*, III, LII, 4.

[18] *Op. cit.*, III, XXI, 3: "Likewise also the little leaf of gold or of silver produces all the powder of projection and makes everything ferment."

the theory of alchemy. He was evidently held in great reverence by his successors who speak of him as "Zosimus, the Crown of Philosophers." It would be safe to say that even if nothing original may be ascribed to Zosimus, he is the first known writer to collect and connect all the alchemistic theories of his predecessors in one consistent whole. Many of these theories he ascribes to the Pseudo-Democritus ("The Philosopher"), to Ostanes, to Mary, and so on. His interest seems to be that of a Gnostic philosopher or theologian. However, his interest in alchemy, as such, is very real and without his emphatic and reiterated statements, very little of the writings of the early alchemists would be intelligible. His explanations, meager though they are, serve as our clearest interpretation of ancient alchemy.

5. OLYMPIODORUS

There is doubt as to the identity of this author whose commentary on the work of Zosimus we have. There were two men of this name: Olympiodorus of Thebes, a Neoplatonist of the fifth century, who wrote a history of his own time, dedicated to Theodosius II, covering the period 407-425; again, Olympiodorus of the sixth century, also a Neoplatonist, who wrote a life of Plato at the time of Justinian. Our writer on alchemy is considered by

Berthelot to be identical with the fifth-century historian; but by Hammer-Jensen to be the sixth century biographer.[19]

It makes little difference. The writing which we have received is, as Hammer-Jensen points out, a letter addressed to a prince—she supposes it to have been the Emperor Justinian—in explanation of the "ancient art," and a very poor explanation it is.

"According to my ability I have written; and I ask that by your prayers you request that divine justice be not irritated against me for having had the audacity to write this work."

We find a wealth of quotations, but disconnected, evidently not understood by the author, who thereby proves that he was living at a date too far removed from real alchemy to enable him to be of assistance to one who wished to understand the practical details of transmutation. If, for instance, Justinian had conceived that he could improvè his exchequer by the artificial production of gold, he must have been deeply disappointed by this reply from one who was reputed to be *au courant* with the subject. A review of the opinions advanced by the ancient Greek philosophers on the nature of matter or a discourse on why the alchemists were justified in clothing their language with obscure statements, hard to understand, might

[19] Hammer-Jensen, *Die älteste Alchymie*, 1921, pp. 125-134.

have been in part satisfying to a Neoplatonic philosopher, but this certainly could not have answered the demand of an emperor asking for practical details of an art. We know that Justinian, shortly after, ordered the dispersion of all the Neoplatonic schools in the Roman Empire!

6. STEPHANUS

The last writer to show an immediate inheritance from the Egyptian alchemists is Stephanus of Alexandria, who is known to have taught philosophy at Constantinople in the seventh century. He lectured to his pupils on the moral bearing of alchemy. As might be expected, his writings are filled with expressions figurative and full of enthusiasm for the subject of which he could have had little true knowledge. Of interest to us is the fact that, as a philosopher, he connects the methods and recipes of the alchemists with the philosophy found in the *Timaeus*.

"The elements are transmuted because the qualities are opposed, not the substances."

He also reflects the ideas expressed best perhaps by Zosimus:

> Mercury takes all forms, as wax attracts every color. So mercury whitens all, attracts the soul of everything. . . . It remains, while they do not; even if it does not appear to remain, it persists, held in the metal.

One sees that mercury, thus considered, was the "principle of liquidity" or "mercury of the philosophers," and at the same time the whitening quality. It corresponded to the "water" of the Greeks while sulphur stood for the "fire." Later, with Geber, mercury and sulphur became more nearly substantive. In mediæval alchemy, as the principles of liquidity and combustibility, they, mercury and sulphur, were either qualities or substantives, as was most convenient to the writer. C. A. Browne states that the poem upon the *Sacred Art* by the Byzantine philosopher Theophrastus[20] was regarded by Reinesius (1634) as a versification of portions of the work of Stephanus. Transmutation is everywhere designated as a process of coloring or tingeing. Here is a significant quotation:

> The white augmented thrice within a fire
> In three days' time is altogether changed
> To lasting yellow and this yellow then
> Will give its hue to every whitened form.
> This power to tinge and shape produces gold
> And thus a wondrous marvel is revealed.

It is easy to see that with the Egyptian school the color quality was strongly stressed. Pelagus[21] says:

> The tinctorial art has been invented in order to make a certain tincture and to produce a certain quality. Also, this is the end of the art.

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[20] *Scientific Monthly*, XI (1920), 193.

[21] Berthelot: *Collection des anciens alchimistes grecs*, IV, I, 1. Pelagus: an unknown authority, but always associated with the color process.

This is reflected by the Pseudo-Geber:[22]

Surely, dear friend, the true substance is a thing which colors. [And again][23] [Unless the operation be according to rule] metals could indeed be colored but with a tincture which pious and modest men would not accept for it could not tint.

W. G. de Burgh, in his *Legacy of the Ancient World,* says that the "essence of scientific . . . thinking lies, not in the object thought about, but in thinking about it on a rational method." And he adds, "Here, too, as elsewhere, 'God cares a great deal more for adverbs than he does for verbs.' " If the scientist stresses adverbs such as answer the questions *How?* and *Why?,* and the practical man stresses nouns and verbs, with the ancient alchemist it was adjectives which were fundamental: moist and hot, liquid and volatile, fusible and combustible. Here lies our great difficulty in understanding ancient philosophy. But we have only to think of qualities, as we now think of combining copper with sulphur in the laboratory, to make the following passage from Roger Bacon seem quite practical:

He who knows the formulas and necessary procedures for producing the yellow color, the great specific gravity, ductility, and so on—he who can command the means of producing these qualities in different degrees, will know the methods and be able to take the steps necessary to join these qualities in such or such metal, whence will result his transmutation into gold.

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[22] Berthelot: *La Chimie au moyen âge,* III, 132.
[23] Berthelot: *op. cit.,* III, 187.

7. REVIEW OF EGYPTIAN ALCHEMY

Alchemy, as developed in the Egyptian school, was a complete unit. Indeed, it is very difficult to find, during the succeeding centuries, any important additions to alchemistic theory, either from Mohammedan or Christian sources, which materially modified any of its Egyptian teachings.

It is time for us to look back over the history of the Egyptian school and summarize what was accomplished. Much, we have found, was inherited. This is as we would expect. Yet there were important innovations, additions, and developments, purely alchemistic. From the uncertain date of the Leyden Papyrus and Democritus' discussion of recipes to the philosophy of Zosimus, surely not more than four or five hundred years, the whole structure of alchemy was completed. Let us see of what this consisted.

The crude early methods of the artisans constituted the point of departure. The first act philosophic was an attempt to explain the results according to the theories of the Greek fathers of philosophy. Then the methods were systematized to bring them into accord with the ideas of "matter" and "spirit." Here the alchemistic invention of the kerotakis was a great aid for by this apparatus the body and spirit of the metals seemed demonstrated. Thus, as

also by the natural development which comes with years, alchemy and Greek philosophy drew closer together so that the vaguely expressed opinion, in the minds of the thoughtful, grew to be a conviction that the essentials of nature were spiritual, that the divine attributes of Aristotle were to be looked upon as the only objects worthy of man's study.

Although, in the centuries which followed, the technique of alchemy, being neglected and forgotten by philosophers, was transmitted as the trade secrets of successive artisans, the theory of alchemy, being in accord with the inherited thought of past ages, was amalgamated with the popular philosophy, and thus appealed, through its spiritual teaching, alike to Mohammedan and to Christian theologians.

The following historical steps may be listed, in résumé, as the sequence of events which marked the progress of the earliest alchemists:

1. There came first the body of recipes (1) for imitation of purple dyes; and (2) by similar methods, for imitation of silver and gold.

2. The appeal to philosophy, to explain the color changes of dyes, especially those due to the use of mordants; and of metal colors—bronzing effects—due to the use of the same salts.

3. The theory of the ferment, due to the use of small

quantities of gold in the "royal cement"; and confirmed by the effect of small quantities of gold in varying the bronzing colors.

4. The theory of improvement toward the more spiritual, toward "fire" or gold; toward the "spirit" or higher color.

5. The invention of the kerotakis, which gave impetus to the theory of improvement, in which the metal "bodies" were transformed by "spirits" into new substances, sometimes to higher colors such as yellow-red and purple.[24]

6. The theory of the "permanent ferment" which explained the bronzing effects produced by compounds. Thus the volatile spirit was considered "accidental," but the permanent ferment, resulting from the union of the spirit with a metal body (in the form of an oxide or salt) was of like value but fixed and lasting.[25]

7. The theory of the "two qualities," mercury and sulphur, standing for "water" and "fire" in the Greek "elements." There were recognized seven bodies (metals) and four spirits. Of the latter, mercury was the spirit of liquidity[26] and sulphur was the spirit of combustibility. This theory of the two qualities remained unmodified[27]

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[24] See ultra, ios, pp. 97 and 110.

[25] The red cuprous oxide spread in a film over a metal, and heated gently, was frequently used to produce a gold color.

[26] And later, volatility also.

[27] Except as noted on pp. 121-122.

until the time of Paracelsus, in the sixteenth century.

8. The theory of the superferment (like the gold ferment which drew all yellows unto itself and by its purity overcame the baseness of metals). There was conceived a higher ferment, permanent because fixed on gold, a color higher than the yellow of gold, a "spirit of metallicity" which could change all things into gold. This "ios" or "coral of gold" was identical with that which was later sought as the philosophers' stone.

To all of which must be added, in anticipation, the following two theories, possibly of oriental origin, but often quoted by the fourteenth-century alchemists:[28]

9. The theory of reflection, that each color conceals an opposite color ("ut ponas occultum manifestum").[29]

10. The theory of the like, that one metal or color attracts the same, rejecting all others. (See pp. 75-76, ante.)

The theories of Plato and Aristotle, appearing in Alexandria as Neoplatonism, were rescued, by their application to the metals, from a tenuous form of pure philosophy and made for the first time concrete. This adaptation was entirely new and made the old theories comprehensible so that they appealed to the practical man, to the artisan, and to the man of affairs.

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[28] See ultra, pp. 103, 119-121, 95, 177 note 7; and (for the fourteenth century) Berthelot, *La Chimie au moyen âge*, I, 283, 313.

[29] Berthelot, *Collection des anciens alchimistes grecs*, p. 191, note 1.

All of this came gradually and from many sources. As the theories were inherited from ancient Greece, so the applications of the art grew from similar arts, with no disturbing incidents. The coloring of the metals grew out of the dyeing of fabrics. The list of colors and their sequence followed that of the painter, who contributed also his palette in the form of the kerotakis. The latter brought out very forcibly the contrast of "body" and "spirit"—the metal and the permeating tinctorial element.

Thus the practice of alchemy grew more and more into strict accord with the theories of Neoplatonism, which had already been to some extent absorbed, unconsciously, into all Alexandrian philosophies and religions.[80] Now with the added groundwork of a practical application, this Neoplatonic-alchemistic philosophy stood as one framework upon which Christianity, and later Islam, confronted the world of objectors, as these two new faiths were building themselves into world religions.[81]

As long as the foundation principles of Greek philos-

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[80] See de Burgh, *The Legacy of the Ancient World*, pp. 292-293. "The distinctive teaching of Christianity fitted naturally into the . . . mold; and early Christian speculation, nursed at Alexandria in the atmosphere of early platonism, developed on lines parallel to Neoplatonism." "The school he [Plotinus] founded flourished for more than two centuries and was still in being when Justinian closed the pagan academies in 529. From that time onwards, the history of Neoplatonism falls almost wholly within the pale of Christian thought. It was, in fact, the gate through which Hellenic philosophy went forth to permeate Christian theology and the mediaeval schools."

[81] In church symbolism today we are taught that the interlaced triangles stand for the two fundamental elements, fire and water.

ophy continued to hold men, as long as "quality principles" were insisted upon as the essence of man (and nature, as the reflection of man) so long also was alchemy acceptable. So strongly did this theory of quality principles hold that, far beyond the time when the modern idea of the fixed properties of gold had been attained by every practical metal worker, philosophy, together with Mohammedanism and Christianity, jealously guarded such conceptions as the temporal character of base matter, the eternal and spiritual and kinetic character of the divine "fire," whether mental, moral, or physical; and in consequence alchemy continued to rule the thoughts of men until after the Renascence, when, under the influence of such men as Boyle and the slow pressure of modern investigation, the actuality of material things impressed itself upon human consciousness and the four elements of the Greeks and the two elements of the alchemists gave way before the convincing experimental work of a Black and a Lavoisier.

Greek philosophy permeated the thoughts and activities of the practical Egyptian people and helped to explain the reactions of the metals, with which they were working, the metals whose surfaces are so sensitive to change. All the theories, which have just been indicated, and which were invented to help the alchemists to understand these mysterious changes of color, derive directly from

Greek philosophy. It would be difficult to account for one of them as from any other source. And this application of Greek philosophy to metallic chemistry was alchemy.

Moreover, these theories which arose in the first school of alchemy (which was the Egyptian)—the school closest to Greek philosophy—continued nearly unmodified to the end of alchemistic history. We find them accepted in the alchemistic language even as late as the fourteenth, fifteenth, and sixteenth centuries. In the schools succeeding the Egyptian, practically no new theories arose—only modifications of those originally derived from Greek philosophy.

In all of this, the fundamental thesis so different from our own is the conception that the essential and technically important thing in metals is not material but spiritual. Spiritual qualities constitute the difference between one metal and another and, as Roger Bacon said in the fourteenth century, "He who knows the formulas . . . for producing [these qualities] will be able to take the steps . . . whence will result his transmutation." Given the conviction that the teachings of Plato and Aristotle were correct, how simple, how natural these applications of the alchemists appear to be!

Chapter VI

METHODS OF TRANSMUTATION

"Let Art learn so much Alchemy that it stains all metals in color." Jean de Meung, *Roman de la rose.*

THE efforts of the alchemists to conceal their methods were not entirely successful. The obstacles which they were able to cast in the path of imitators were real but safeguards were sometimes forgotten, especially in times of controversy.

A much more serious difficulty confronts the modern reader than any which the alchemist attempted to create—the changed viewpoint. We have attempted to understand alchemistic thought by our modern way of thinking, and utterly failed.[1] Thus a recent writer states: "But in none of these treatises . . . can any scientific basis for alchemy be deduced." The alchemists were idealists—not scientists. The viewpoint has changed. Before we could overcome this great difficulty and reach a sympathetic understanding, it has been necessary for us, temporarily, to wrench ourselves free from the scientific mode of thought. It was

[1] How little help would we get (from our modern outlook) if we attempted to understand the alchemists' notion of *tincture*, or *tempering* of bronze, or Zosimus' simple statement "It is the tinctorial property which causes the vapour to develop the gold"!

necessary for us to realize that Plato's ideas of "qualities as entities" and of "matter, a universal" were not merely philosophical. They entered into the everyday life of the people, into the work of the artisan in his shop. It is only thus and recently that we have been able to gain an interpretation or theory of alchemistic methods. And now we find that these old *methods* and this new-old *theory* are in accord and go hand in hand, giving us a great advantage in interpretation—*i.e.*, that the one may be checked by the other.

The viewpoint changes rapidly, also, in details of the arts. A technical term, whose meaning is so obvious that the artisan sees no need to define it, appears and disappears. Time erases its meaning or gives it a new significance. Trade names, so familiar to the artisan, are ephemeral when viewed from the standpoint of history.[2]

The translation of some of the commonest terms of the alchemists is still uncertain. Such, for instance, are sal ammoniac, chrysolith, and alum. "Nitron" may mean soda, common salt, or in general any white salt. "Asem" is silver or any silver-white alloy. Chalcos may be brass or bronze or any copper alloy.[3]

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[2] Our word alcohol formerly signified kohl, the native black sulphide of antimony, used as a cosmetic. Later it came to mean any impalpable powder or sublimate; later, any volatile substance or spirit. It was only in the sixteenth century that it came to refer exclusively to the spirit of wine.

[3] Chalcos generally means brass. Because some of the ancient Greek utensils

Even if the viewpoint had remained the same and the technical terms had held constant, one might still be uncertain of technical meanings, as our present-day experience tells us, for one has to be closely associated with an art or trade to get its proper vocabulary. How incomprehensible to laymen are the words used in our simplest occupations! [4]

Such difficulties abound in alchemistic literature, but it has been found possible to remove or to avoid the stumblingblocks, intentionally or unintentionally placed in our path. From the outstanding facts we have evidence of the existence of a standard process, founded upon or at least in accord with alchemistic theory and thus differing from the early crude methods of the artisans of the Leyden Papyrus. This is a very useful discovery, for we are enabled from what we know of the theory to fix the method, sometimes to supply the step suppressed by the writer; and again from the method to link together the threads

showed the presence of tin, our Greek classicists have been led to insist rather too strongly on "bronze" as the proper translation.

[4] The following illustration is clipped from a recent magazine. It embodies directions to a seamstress. Each expression is, of course, well understood, but a foreigner would find the terms hard to translate, especially if contemporary literature had disappeared, say one thousand years hence:

"Cross-cut bands are the medium turned in even to face and tacked at the edges. Holes are used instead of eyes, made with a stiletto and fan-stitch is used to fix the bones."

In the same article occur the following expressions: Herring-boning, fagotting, shirring, easing, piping, bastings, overcasting, coarse-running, and tacking out.

of alchemistic theory. Very useful again does this fact become, when in later centuries, the theory having been forgotten, the pseudo-alchemists still blindly followed each prescribed color step and voiced their hopes in language actually taken from the ancient Egyptian sequence.

I. THE STANDARD METHOD

According to the doctrine of Plato, the universals, such as matter, came first and upon them were impressed particular and individualizing qualities. It was, therefore, deemed obligatory upon the alchemist, in his practical process of transmutation, as he wished for success, to begin with a material which was unidentifiable by particular qualities; and upon it to impress pure qualities which one after another should gradually rise in the scale of metallic virtue toward perfection. It was therefore necessary to start with a material theoretically correct. The individual metals were impossible. Each was too far removed from the perfect gold. The alchemist must begin simply, with "earth"—some unidentifiable solid—and gradually impose upon this substance more and more of pure liquidity, "water," and more and more the elements of "air" and "fire," thus overlaying and concealing the properties usually associated with "earthy" (*i.e.*, corruption, or the tendency to oxidize). The properties desired,

or the goal of the process, were the properties of gold: water, or fusibility; air, or brilliancy, the color of fire and resistance to fire.

The first step.—Of the seven metals recognized by the Egyptians, each dedicated to a particular planet, two, gold and silver, dedicated respectively to the sun and the moon, were considered high above the others in metallic perfection. One, mercury, at times considered the embodiment of pure liquidity and at times of pure air or volatility, was a transition metal. The four remaining common metals were lead, tin, copper and iron. In order to comply with the demands of theory, the alchemist started with all four, fusing them together into one mass or alloy by which the individuality of each was lost or submerged in the "all" (τὸ πᾶν). This alloy of four metals was known as the "tetrasomy," or because it was a mixed metal, the "metal of magnesia."[5] Such an alloy was considered nearly the ideal "matter" of Plato, having no individual properties. The one property excepted was fusibility and the possession of this property was considered the first advance step, as it classified the alloy as water, thus removing it one stage from earth. Moreover the color was important. The alloy as produced was black from oxidation and this negative color was idealized since from this point *the*

[5] Sometimes a simpler alloy of copper and lead, known as molybdocalc, was used. Berthelot, *Collection des anciens alchimistes grecs,* III, XXVIII, 2.

whole sequence was one of color in which it was important that no interfering color should be introduced, and black was the "absence of all color." [6]

The production of this color black (μελάνωσις) grew to be the criterion of the first step. So widely known was the production of this color in Egypt that it may be the cause of the alchemistic process being known as the Black Art and also as alchemy, from *chem,* meaning black, to which later was affixed the Arabic article *al.*[7] So important was this black as a fundamental material that Mary the Jewess, in a controversial statement, forgetting all precautions in regard to secrecy, protests that her black material, formed by fusing copper with sulphur (black

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[6] It is to be noted also that according to Pliny (see p. 105) black was popular in Egypt, being sacred to the god Anubis. It may be thought of as the national color. See also Plato's "passive recipient" (p. 18, ante).

[7] The following derivations have been given for the word *chem* or *cham:*

1. Black refers to the black soil of the rich cultivated land and thus became a name for Egypt.

2. Black refers to the "oxidized silver" of which Pliny speaks with amazement (see p. 105) and for which the Egyptian artisans were famous.

3. The word *chem* is derived from the Greek χέω, to pour or mix, referring to the "mixing of Fire and Water" in the preparation of the scarlet mercury sulphide (Hammer-Jensen).

4. The word *chem* comes from the Greek word meaning *cunning* (Murad Barodi, *Muktatef,* Cairo, 1882).

5. *Chem* is derived from the Hebrew "from God": *kem* and *yah* (takes its origin from God) (Safedi, in *Carna Hamiyet el Ayen*).

6. *Chem* was also applied to the black powder produced by quicksilver (Budge, *Egyptian Magic,* pp. 19-20).

7. Lastly Lagercrantz: Alchymia may be a changed form of ἀλτεμία meaning perfection (of the metals)—*al-temām,* Arabic like the Greek τέλειος, *i.e.,* perfect (cf. *Summa perfectionis* and *Compositione alchemiæ;* see p. 161, note 4).

copper sulphide) is superior to the "metal of magnesia" since hers was not only superficially black but black throughout all its substance.

The black alloy then, free from individualizing properties, from color especially, raised from the condition of earth to that of water, since its single identifiable property was fusibility, was now theoretically correct, the "first material" of Plato, ready to be gradually improved until it emerges perfect in color.

The second step.—After blackening came whitening, (λεύκωσις) identical with the argyropy or silver-making of Democritus. The tendency of the metals to grow more and more toward the perfect metals may be catalysed by the alchemist by fusing the alloy with a seed or ferment (or yeast) of silver.[8] There was here a possibility rife with deception—or self-deception—for the amount of silver introduced might be considerable. Supposing, however, that the alchemist carefully followed directions and added only a small portion of silver as ferment, this was supposed to gather to itself any silver already developed, so that when the black alloy was flooded with mercury[9] or tin, the surface became glistening white and gave forth the appearance of silver.

[8] The gold and silver tinctures, or ferments, differ only in color; "each of them tints according to its own nature. Gold tints to gold; silver to silver" (Berthelot, *Collection des anciens alchimistes grecs*, IV, I, 8).

[9] Arsenic and antimony were considered identical with or varieties of mercury and are included in the general term "mercury."

As the recipes in the *Physics and Mystics* of Democritus have already indicated, the argyropy consisted in the production of a silvery surface color on the alloy, considered an actual transformation or transmutation into silver. If the metal were in the form of a thin leaf, such as was used in the apparatus with kerotakis, this surface effect became relatively more pronounced.

This product of the alchemistic process was acknowledged to be different from silver, but this was not a matter of importance to the alchemist. His silver was to him superior to common silver! It was not only silvery on the outside, but was yellow on the inside.[10] Already it had passed the intended goal and had been arrested only after starting on its further upward tendency, its struggle, toward reddish-yellow gold. "At the same time you whiten on the outside, you yellow on the inside."

The third step.—As a necessary but preliminary process, the leukosis preceded the xanthosis (ξάνθωσις) or yellowing, identical with the chrysopy of Democritus—the making of gold. Alchemistic silver, as we have found, was nearly gold and ready to make gold. The third step was carried out in a manner similar to the last. Again the alloy was fused—this time with the addition of a little gold as ferment—and the surface was "yellowed with any yellowing material," usually the sulphur of "sulphur

[10] As it probably was, being a copper alloy.

water."[11] The inside had already become yellow and the surface now matched it and the whole was yellow. As like attracts like, the yellowness of the sulphur had brought out all the hidden yellow of the metal and changed it all into a kind of gold in which yellow was abundant and overflowing. The product was superior to common gold (which had "just enough yellow for its own material") for it had yellow to spare so that it could transmute other metals into gold.

The fourth step.—One would suppose that the alchemist, having prepared gold, would be satisfied, but a fourth step is indicated: Melanosis, leukosis, xanthosis, iosis. In this last step (ἴωσις) we have to take refuge in all our ideas of alchemistic theory and step lightly in the maze of vague and unintelligible words. Generally whenever this stage is reached, the alchemist author announces that he will conceal nothing and then breaks forth into an ecstasy of exclamatory sentences: "Oh, natures superior to all Nature!" etc., etc. After the black, white, yellow comes "iosis" which means production of violet or purple.[12] It has not been clear why the production of violet

[11] See Berthelot, *Collection des anciens alchimistes grecs*, II, I, 10, and III, VIII, 1.

[12] Ios is used loosely to mean any brilliant surface tarnish. Thus, ios of copper may be the red sub-oxide or green basic carbonate; ios of iron is the red iron oxide, "Venetian red." It was the *ios of gold* which was the ios or violet. Our word (v)iolet is derived from the old Greek (f)ios (Latin, *viola*). The word ios also meant poison. This similarity of the two words sometimes was the cause of confusion in thought and in translation. (See p. 113, under Pliny.)

or purple should have been considered the last and highest and best step in the transmutation process. Was this final stage so honorable because metal coloring and dyeing began in the same shop, so that the royal purple and the ios of gold made purple the highest attainment of each in brilliancy of color? The analogy is attractive but does not seem sufficient.

Another question arises: Can it be done? Also, was the production of this highest color, higher even than the yellow of gold, only the result of a lively alchemistic imagination, or is there experimental basis for this color? Again, if this violet is possible, is gold a prerequisite for the production of the violet color, just as the alchemist believed that silver must precede gold?

Alchemistic literature certainly gives an affirmative answer to this last question.

> It is the tincture forming in the interior [of the gold] which is the true tincture in violet, which has also been called the Ios of gold.[13]
>
> . . .
>
> By operating on gold you will have the Coral of gold.[14]
>
> . . .
>
> You will find a powerful body having the color of cinnabar, of coral or minium. This great marvel, this indescribable marvel, has been named Coral of gold.[15]
>
> . . .

[13] Berthelot, *Collection des anciens alchimistes grecs,* III, XXIX, 3.
[14] Berthelot, *op. cit.,* II, 1, 7.
[15] Berthelot, *op. cit.,* II, II, 5.

Treat by projection gold with Coral of gold, silver with gold, lead or tin with molybdocalc. Behold how he has made us rise by degrees.[16]

Mary the Jewess in a famous passage says:

If the two do not become one, *i.e.*, if the volatile does not combine with the fixed, nothing will take place which is expected. If one does not whiten and the two become three, with white sulphur which whitens [nothing expected will take place]. But when one yellows, three become four, for one yellows with yellow sulphur. At the end [the climax] when one tints into violet, all things combine into Violet[!] [17]

This passage indicates the superstitious reverence accorded to this highest color; and the preceding quotations show that the color was forming below the yellow gold color, as yellow was below white. The sequence is the same in both steps.

So much for the ancient records. Now let us question modern practice in metal coloring. Improvement over the old methods of bronzing was introduced about twenty-five years ago by utilizing electric deposition, of course unknown to the ancients. But up to that time, the art of metal-coloring, like the art of dyeing, had shown no modification of the old standard methods. Berthelot has shown that the transmission of alchemistic methods of coloring metals may be traced by their recipes through

[16] Berthelot, *op. cit.*, II, III, 17.
[17] Berthelot, *op. cit.*, III, XXVIII, 9.

Syria and Constantinople and the Italian commercial cities into Western Europe; and down through century after century of manuscripts of technical recipes even to the date of the invention of printing. It was then that these recipes became common property and some of them still survive in our bronzing shops today. This gives us a means of comparing the results of modern practice with those of the alchemist.

It has been shown recently[18] that upon alloys containing a very small fraction of gold, it is possible to produce a very beautiful violet bronze, sometimes iridescent;[19] and that the presence of gold is advantageous for the production of this color. Upon copper dipped ("baptized") in a sulphide water, a dark bronze may be produced, followed by a violet (or iridescent violet) which fleeting color may be preserved by covering with a thin layer of wax or varnish, just as the alchemists suggest.[20]

In place of sulphur water, some mordant salt may be used, either scattered over the surface of the warm metal, or in solution. In the latter case, the metal is dipped into

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[18] Hopkins, *Chemical News*, LXXXV (1902), 49.

[19] The iridescence is noted by the alchemist in such expressions as "with all the colors of the peacock's tail" and "with all the colors of the rainbow."

[20] I have at present on my desk specimens made for me by the kindness of Mr. Hagerboom, head of the metal-coloring department of the Corbin Lock Company, of New Britain, Conn. One of these is an iron escutcheon, first copper plated and then dipped in a sulphide bath. It is a very beautiful violet, suggesting iridescence.

the salt solution and then heated; dipped again and then heated, and this repeated many times "until the color is good."

There seems, therefore, no reason to doubt that the alchemist, following the directions which he has given us, must have obtained this brilliant color and associated it with gold.

The following quotations will serve to show that the alchemists, in their process of coloring metals, were acquainted with the methods of dyeing:

Gold and silver, simply spread as surface paints, do not dominate [combine with] iron or copper. The metals must be treated with mordants.[21]

. . .

Don't you see that if the dyer puts the alum [mordant] and the color in the dry state on the cloth, then the color does not permeate the parts of the fabric, unless he uses water. And so it is with you.[22]

On the direct use of the mordant salt on the metal:

How to give an object the gold color. Taking the earth called ochre [iron oxide] put it on the fire until it reddens. Then take it and wash it in water and sal armoniac. Paste this on the object to be gilded; put in the fire; and repeat until there comes smoke and the appearance of color. Then put it into water.[23]

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[21] Berthelot, *Collection des anciens alchimistes grecs*, IV, I, 9.
[22] Anon., *Collection of Essays*, Cairo Royal Library (Collec. 60).
[23] Berthelot, *Collection des anciens alchimistes grecs*, V, I, 13.

This ancient recipe may be compared in every step with the following, published in 1907:[24]

> Red iron oxide is made into a paste with water to the consistency of cream and this is pasted on the article. . . . It is then heated over a fire . . . at a moderate temperature until the paste is thoroughly dry. . . . By means of smoke a deposit forms on the article and when the soot begins to be dissipated by the heat, the metal is considered to be sufficiently heated. . . . Cast work was . . . colored a deep gold color.

Roberts Austen tells us that the Japanese intentionally produce a violet bronze by first preparing an alloy containing about 4 percent of gold. The presence of the gold seems necessary for the success of the process, and the resulting bronze is very beautiful.

The alchemistic thought may perhaps be expressed as follows: Just as the silver ferment added to the alloy gathered to itself all the hidden silver and made the mass ready, on treatment, to take a silvery bronze, while the inside had progressed further (toward gold), and just as the gold ferment gathered to itself and perfected all the gold so that, on treatment, the surface showed a gold color, so the next color which shows itself—the violet—must be as far above yellow as yellow is above silver. The violet bronze must also follow a tendency on the interior of the gold toward violet; and the violet ferment, if obtainable

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[24] A. H. Hiorns, *Metal Colouring and Bronzing*, p. 103.

in sufficient quantity to use, would act like the silver ferment and the gold ferment, to hasten the process through silver and gold to violet—a violet associated with some high spiritual appearance or metal, just as white and yellow were identified with metals.[25]

Besides the standard method, there was also a primitive method out of which the standard grew. There is indication, also, of a third method, in competition with the standard, the method associated with the name of Mary the Jewess.

2. THE PRIMITIVE METHOD

Omitting crude treatment of metals with paints and vegetable dyes, the methods used by the early artisan seem to have consisted of the production of silver alloys and silver surface colors including the use of "sulphur water."

The word *asem* or electrum was applied at first to an alloy of silver and gold, considered an individual metal. The existence of this alloy may have been the original cause of the suggestion of transmutation since by adding silver to it, one would get a metal nearly identical with

[25] It is significant that the Greek word *εἶδος* (meaning appearance), so much used by the alchemists, is commonly translated metal. To the alchemist, the color of the metal *was* the metal.

"All is gold that glitters
For the glitter is the gold" (G. K. Chesterton).

the crude silver from the mine; and by adding gold, something indistinguishable from gold.[26] As gold was frequently alloyed with silver in uncertain quantities, it became more and more difficult to distinguish between asem and silver. At this stage we find (as in the Leyden Papyrus) asem used to mean silver or any alloy of silvery appearance. Alloys of tin and lead, copper and lead, or copper and tin were all called asem. Mercury, which was beginning to displace tin as the most fusible of the metals, was at times used in the place of tin.

An impressive change took place when the red metal copper was alloyed with tin, for the copper was changed into a white metal like silver and having the hardness and color of silver. If a little gold were added (though generally this is not mentioned) the metal might be called potentially gold. This seems to be the meaning in recipes 14 and 15 of the Leyden Papyrus. Recipe 14 is proper for the production of a silver-colored alloy of copper and tin, ending "and worked thus"; and recipe 15 reads:

To tincture gold to make it useful: Pyrite and salts and vinegar derived from the purification of gold; mix all these together and cast into a vessel. Also cast into the chemicals the "gold" previously noted, and leave it some time. And taking it from the vessel, heat it on charcoal and cast it again into the

[26] The paucity of the Egyptian language may perhaps have been responsible for a confusion. Gold was the "yellow metal," and the alloy produced was also a "yellow metal."

vessel where are the aforesaid drugs; and do this many times until it becomes useful.

In this connection, Hiorns states [27] that if tinned copper is dipped three or four times into a solution of copper acetate with ammonium chloride, heating each time, it changes to a splendid yellow. Except for the ammonium chloride, the modern recipe and the ancient agree so closely that the expression "gold previously noted" would seem to be explained.

"Invention of Sulphur Water" is the title of recipe 89 of the Papyrus (see p. 63, note 3). How early this invention was made we do not know. But Pliny, in the first century, cites [28] the curious fact that the Egyptians stained their silver utensils black. We know now [29] that silver utensils dipped in cold alkaline sulphide solutions may be tinted any shade from pale gold to deep gold, according to the time of immersion, and that in a hot solution "oxidized silver" (silver stained black with silver sulphide) is the result. Such methods formed the groundwork upon which the theoretical standard method was built.

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[27] A. H. Hiorns, *Metal Colouring and Bronzing*, p. 107.

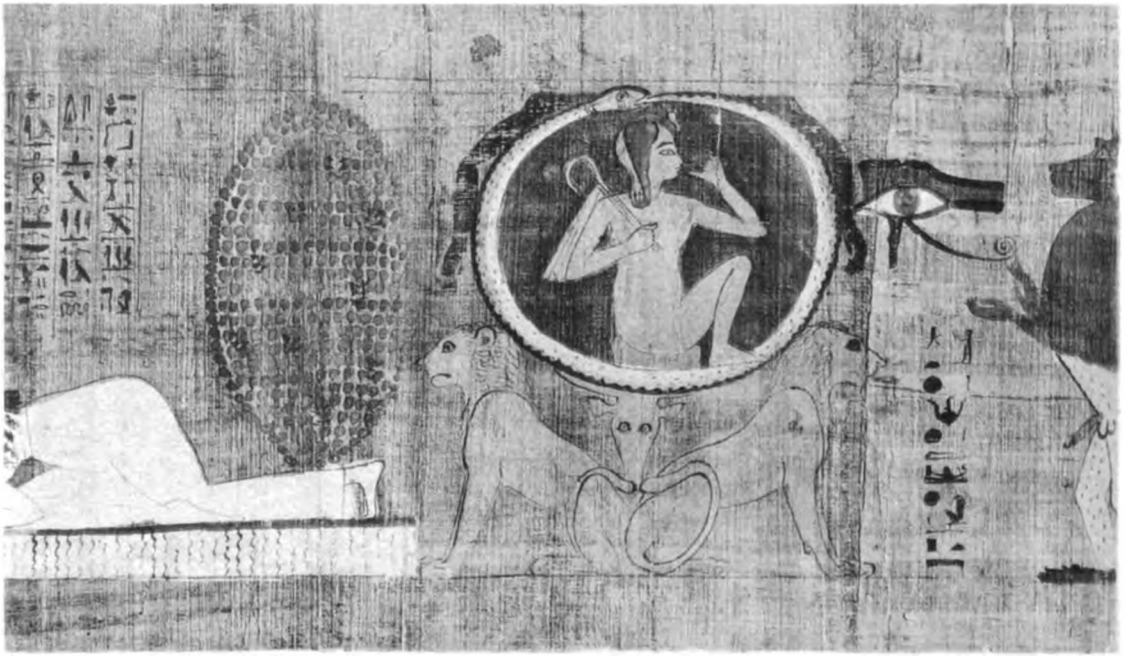
[28] Pliny, *Historia naturalis* (Bohn Translation), XXXIII, 46: "The people of Egypt stain their silver vessels black that they may see represented in them their God Anubis, and it is the custom with them to paint, not to chase, their silver. This usage has now passed to our triumphal statues even, and, a truly marvellous fact, the value of silver has been enhanced by deadening its brilliancy."

[29] A. H. Hiorns, *Metal Colouring and Bronzing*, p. 266.

3. THE METHOD OF MARY

> *"He who could find a way to prepare spirits . . . might do what he wished with the metals."* Jean de Meung. *Roman de la rose.*

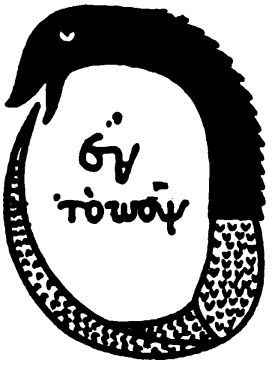
"Mary the Jewess" has left us no writings and is somewhat mythical, yet she is often quoted by other authors. Her outstanding contributions are, first, the inventions of the kerotakis and the water bath, and second, her revolutionary and competitive method. Since the instrument called kerotakis has been shown by Berthelot to have evolved from the painter's palette, it is doubtful if Mary were the inventor, though she may have been instrumental in bringing about this transformation. There seems to be no doubt that her procedure overrode the crystallized steps of the standard established method whose devotees looked upon her technique with horror. Perhaps she rejoiced in this opposition for she was evidently no quiet sufferer but voiced her opinions with vehemence. We can even see a theoretically correct position in her argument and also that the use of her kerotakis must have helped to establish her position. It is clear that the ideas of the importance of vapors and permanent ferments which survived long after the old alchemy had disappeared owed their beginnings to the use of the kerotakis of Mary.



THE OUROBOROS SERPENT

16th century, B.C.

Ὄυροβόροσ.



In certain very ancient Egyptian papyri (*e.g.*, one of the sixteenth century B.C.) is found represented a curious figure called the Ouroboros Serpent, or the serpent biting its own tail. The design forms a circle and is supposed to represent the circle of the universe or the path of the Sun-god. This figure was adopted as a kind of talisman by the later alchemists. In the center of the circle they wrote the words ἓν τὸ πᾶν or, All is one. To them this circle represented Plato's "One" or the universality of matter. At the same time it probably recalled the mysterious circular motion taking place in the reflux condenser or aludel.[30]

Mary's foundation material, in place of the established

[30] Cumont, *Textes et monuments figurés relatifs aux mystères de Mithra*, I, p. 80. "Parfois le serpent, faisant un cercle complet, se mord la queue, comme le soleil, apres avoir fait le tour de la sphère céleste, revient à son point de départ pour recommencer sans cesse sa course perpétuelle et ce *δράκων οὐροβόρος* devient un symbole accessoire de la notion d'Eternité. (Mythog. Vatic., II, p. 53; Macrobius, I, 20, 2; Horopollo, I, 2, avec les notes de Leemans.) J'ai parlé plus longuement de la signification du *δράκων οὐροβόρος* dans le *Festschrift für Otto Beundorf*, 1898, p. 291."

"tetrasomy" was a simple lead-copper alloy. From the earliest times, lead, probably on account of its easy fusibility, or content of "water," had been considered the original form from which all the metals had been derived—a kind of urmetal—and copper played a great rôle as a reservoir of all metal colors.[81] The new alloy (molybdocalc) was evidently an effort at simplification.

After the preparation of this alloy, the first step was the same as in the standard process (melanosis) not because it was necessary, but because in this respect Mary adhered to tradition. But the blackening was accomplished by fusing the pulverized alloy with sulphur which produced a mass "black through and through," since the sulphides of copper and lead are both black.

The following steps seem to have been much the same as in the standard process, except for the insistence, already noted, upon the potency of vapors or spirits.

In the quotations from Mary, there is frequent reference to the "little leaf of copper," the copper foil which was hung on the kerotakis to be subjected to the attack of the vapor of mercury or of sulphur, which was sublimed for this purpose in the aludel fitted with kerotakis.

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[81] The color of copper can be easily changed as we see in the papyrus recipes. The two oxides of copper, red and black, were knowp; and the blues and greens of copper compounds were everywhere in evidence, as in the copper mines of Mt. Sinai. (It had doubtless not escaped their observation that an iron tool left in these blue solutions was "transmuted" into copper.) Crysocole, or copper carbonate, was used by the gold workers as a solder.

It will be recalled that vapors, in their action, were considered "accidental" (or incidental) because the effect produced was dependent upon the coöperation of the metal to be tinctured. This action was temporary, in distinction from the permanent ferments thus produced, for the vapor and the metal were mutually destroyed. Whenever a metal was thus bronzed, especially if a bright-colored tarnish of oxide, sulphide or carbonate was the result, the bronze or "stone" contained all the color virtue stored up in the metal and brought to the surface by the potency of the vapor; and the result of the action of the "spirit" (of the vapor) on the "body" (of the metal) was frequently a "spirit" or color higher in the grade of colors and also "fixed" upon the metal [82] in which body and spirit were united. These bronzes could be used for the production of color upon the surfaces of metals without themselves being destroyed. Frequent reference is made to the use of red cuprous oxide or of ochre (iron oxide) as such a "permanent ferment." For the argyropy or silver process, in place of the vapor of mercury or arsenic, could be used the silvery copper amalgam or arsenide, calling out all the whiteness of the metal; and for the chrysopy, any yellow bronze could be used, developing all the goldenness and

[82] This fell to the bottom of the still as "dregs," the value of which is frequently insisted upon in the texts. (See, *e.g.*, Berthelot, *Collection des anciens alchimistes grecs*, II, IV, 38.)

rejecting other latent colors. Now when the permanent ferment is used, directions are clear that the heat must be low in order that the color may penetrate to the depths of the metal; and kept low lest high heat should change the ferment to a vapor or "nonsubstance" and permit it to escape.

He calls "substances" matters which resist the fire; and "nonsubstances" those which do not resist the fire.[33]

. . .

Although in this process the body of the metal is destroyed, the spirit is not destroyed but penetrates the body.

. . .

If the copper is whitened to a clear color, it becomes a spiritual body and then nothing is lacking.[34]

. . .

If it does not get the gold quality and does not become gold of perfect color, it cannot make gold. . . . It then is necessary to make sure that the yellow is untarnished and appears like the color of gold.[35]

. . .

When they are in the solid state they cannot tint. They ought at first to be pulverized [*fine powders being considered equal to vapors*] and made into spirits in order to tint in the condition of spirit. . . . Now the sulphur water at first re-

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[33] Berthelot, *op. cit.*, III, XVII, 1.
[34] Berthelot, *op. cit.*, IV, I, 6.
[35] Berthelot, *Collection des anciens alchimistes grecs*, III, VI, II.

duces them to powder and then later the crysolith [gold ferment?] spiritualizes them.[36]

. . .

Copper does not tint but it is tinted; and when it is tinted, it tints.[37]

. . .

This [sulphur] water, like yeast, must determine the fermentation, destined to produce the like by means of the like [*silver by silver, gold by gold*] in the metal body which is to be tinctured. In fact, just as yeast, taken in small quantity, ferments a great mass of dough, so also this little mass of gold ferments all the dry matter.[38]

But it was also considered desirable that the metal selected for union with the vapor should be a little higher in the scale of metals (richer in color) than the metal to be tinted. Thus a more powerful ferment, gradually richer in the higher color, could be obtained. Thus we read:

Treat gold by coral of gold; copper by gold; lead or tin by molybdocalc.[39]

The "coral of gold" referred to above as higher than gold is the product of the fourth step, iosis.

It is the tincture which is produced internally which is the true tincture in violet, which also has been called the "ios of gold."[40]

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[36] Berthelot, *op. cit.*, IV, I, 9.
[37] Berthelot, *op. cit.*, III, XIX, 4.
[38] Berthelot, *op. cit.*, III, X, 3; see also p. 76.
[39] Berthelot, *op. cit.*, II, III, 17.
[40] Berthelot, *op. cit.*, III, XXIX, 3.

By operating on gold, you will have the "coral of gold."[41]

Here we have to consider an idea which carried a great significance with the later alchemists. As the whiteness of silver was a ferment more powerful than copper and the yellow (of gold) a more powerful ferment than the white, so violet (produced on gold) is placed highest in the sequence of steps; blackening, whitening, yellowing, iosis! Here was imagined a ferment, characteristic of gold alloys, produced on alloys containing only a trace of gold, higher even than the yellow of gold, so marvelous in its possibilities that it could transmute any substance into gold. Such a bronze, or "stone," was later known as the *philosophers' stone,* because the alchemists considered themselves the successors and expositors of Plato and Aristotle.

The fact that this violet is frequently described as accompanied by iridescent effects makes us certain that the alchemists must have obtained this purple or violet; for their recipes frequently call for the use of vinegar. In this connection, Hiorns states:[42] "There is a tendency to produce iridescent colors, especially on cast work pickled in this [vinegar] solution"; and (p. 226): "The great disadvantage [to the modern worker] of solutions containing

[41] Berthelot, *op. cit.*, II, 1, 7.

[42] A. H. Hiorns, *Metal Colouring and Bronzing*, p. 154.

acetic acid is the iridescence which it [the acid] gives to the bronzed surface."

This may probably be deduced also from a statement from Pliny. A passage in his *Historia naturalis,* XXXIII, 23, has often been quoted as evidence of Pliny's credulity. We know that he derived many of his facts from translation of Greek contemporaries and, knowing this, our alchemy will help us to rebuild the passage (even though the Greek original is lost) so that it may have a perfectly proper meaning. We have only to imagine that the original contained, first, the word ἰός which Pliny translated virus or poison, to which we should give the alchemistic meaning "violet"; and secondly, that the word ἰῷ, dative of ἰός, was mistaken for ἰωή, a noise (stridore). If these suppositions be true, we have here evidence of Pliny's inadequate preparation for translation from the Greek, rather than evidence of his credulity. Here are the two translations:

Pliny, Bohn Edition	The Modified Form
Native electrum has also the property of *detecting poisons* [venera deprehendit] for in such cases, semicircles resembling the rainbow in appearance will form on the surface of the goblet and emit a	Native electrum has also the property of *taking a violet bronze,* and in such cases semicircular iridescence, resembling the rainbow in appearance, will form upon the surface of the goblet, *together*

crackling noise like that of flame [thus giving a two-fold indication of the presence of poison].	*with streaks of violet, like flame.*

That a mistranslation may be very persistent is seen by the fact that Geber says: "When the operation is finished, one has a stone of purple color, scintillating, pearly, dazzling the eyes; and with God's assistance it causes you to hear a crackling sound." Again, Bartholomew Anglicus (in thirteenth-century Latin) states: "[electrum] shineth clearer than all other metal and warneth of venom for if one dip it therein, it maketh a great chinking noise and changeth oft onto divers colors as the rainbow, and that suddenly." [43]

Surrounding the use of the aludel fitted with the kerotakis of Mary, in which the vapors constantly rose to the top to be condensed and fell again to the bottom, only to repeat the cycle, the ancient alchemists wove a sort of spiritual reverence, a mysticism, expressed by the words: "Above are the things celestial and below the things terrestrial." It was this continuous process which was typified by the Ouroboros Serpent. The divinity or spirituality of vapors changing and improving the qualities of the metals, of which qualities the most spiritual was color, found confirmation, if not already sufficiently established

[43] Robert Steele, *Mediæval Lore from Bartholomew Anglicus*, 1924.

in the minds of these alchemist philosophers, in this first vision, through the glass container of the aludel, of the marvelous sublimation process.[44]

It has already been sufficiently explained what was the significance of the last step in the standard process, the iosis, following the gold-making process. Now we probably owe to the kerotakis of Mary that a change of sequence is to be noted, consisting of a merging of the third and fourth steps and a gradual receding of violet in importance before the more brilliant color, scarlet, of artificial cinnabar.

The two substances most frequently used in the sublimation process were sulphur and mercury. They were both active in the attack on the "little leaf" of the kerotakis and were both classed as "spirits." They thus became very important and this importance as we know was not a temporary matter but continued to rule alchemistic thought even to the time of Priestley and Lavoisier. To understand this importance, let us consider the properties assigned to gold by the Greek philosophers. In the scale of elements and the scale of metals, we find respectively highest "fire" and gold. Gold was the only element which

[44] Berthelot, *Collection des anciens alchimistes grecs*, II, IV, 15: "It is evident that metal bodies were at first volatile by fire because they had met nothing which could fix them. When, on the contrary, they had been led to complete fixity, the indelible nature of the tincture made them pass to the state of metals," and transmutation is then a continuation of this spiritualizing process.

could resist fire. It was yellow like fire and was dedicated to the sun whose symbol stood in all the literature for gold. Again, the yellow spirit of gold is constantly referred to sulphur, the yellow "spirit" of the sublimation process. Sulphur was combustible [45] and by its union with the metals added the spirit of color, color most varied; and it was sulphur in the form of sulphur water which was used to bring out upon gold the unique violet or purple bronze. Sulphur, in a word, was the "spirit of fire." On the other hand, gold was fusible, *i.e.*, it contained the "spirit of liquidity" or water, the second of the four Greek elements. Here, therefore, was the analysis of gold—a union of the two Greek elements, fire and water, the two diametrically opposed.[46] For had not Aristotle analysed these two into hot-and-dry and cold-and-moist? Could the alchemist succeed in joining these two opposing elements, he would have, not gold only, but the highest spirit of gold, the spirit of metallicity, higher even than the famed "ios of gold!" And at last the alchemist, by aid of the kerotakis of Mary and the mysterious sublimation process, did succeed in causing the union of sublimed sulphur

[45] Pliny, *Historia naturalis*, XXXV, 50: "There is no substance than sulphur which ignites more readily—a proof that there is in it a great affinity for fire."

[46] Berthelot, *Collection des anciens alchimistes grecs*, II, IV, 41: "How ought I to understand transmutation? How are Water and Fire, enemies and contrary to each other, opposed by nature, reunited in the same body in concord and affection? Oh, unbelievable mixture! Whence comes the unexpected friendship between enemies?"

with mercury in the kerotakis cup; and the product was a color more brilliant than any heretofore obtained, the red or scarlet of artificial sulphide of mercury.[47]

From this discovery, the sequence of colors begins to change in alchemistic literature from black, white, yellow, violet, to black, white, (yellow), red. In the fourteenth century, we read from the Pseudo-Albertus (*Compositum de Compositis*):

> Increase the fire until by its force and power, the material is changed into a stone, very red, which the Philosophers call Blood or Purple, Red Coral, Red Sulphur.
>
> . . .
>
> [Again, from the same:]
> Our stone has three colors. It is black in the beginning, white in the middle, red at the end.

Also, the Pseudo-Lully:[48]

> Increase the fire to the second degree to make the material yellow; immediately raise it to the fourth degree until the matter melts like wax and becomes the color of the hyacinth. It is then a noble matter, a royal medicine which promptly

[47] Zosimus gives a rather obscure description of the preparation of cinnabar (Berthelot, *Collection des anciens alchimistes grecs*, III, XLIX, 14) but ignoring this, Berthelot places the date of this preparation as "certainly somewhat before the eighth century" (*La Chimie au moyen âge*, Vol. I, p. 18). Hammer-Jensen believes that to the fanatic Gnostic-Christians this newly discovered scarlet was a divine manifestation to man of the long-sought "Gnosis," the key to man of the power of the angels, which "Logos" was to make him master of all material happiness and thereby "Lord of Gold," quoting ὁ λόγος δεσπότης ἐστιν τοῦ χρυσοῦ. (Berthelot, *Collection des anciens alchimistes grecs*, III, XXVII, 7.)

[48] See chart, p. 170.

cures all ills. It transmutes every kind of metal into pure gold, better than natural gold. . . . If you cast this material on one thousand parts of common mercury, it will be transmuted into fine gold.

And Geber, in the *Book of Pity*:[49]

The red elixir tends by affinity to mix with the red color which silver contains internally.

But there was one other effect which came, as it were, by reflection of influence—the emphasis, in the minds of philosophers, on the importance of the two spirits, sulphur and mercury. Of these two spirits, giving tincturing properties to the metals, mercury had long been known. Theophrastus and Dioscorides had prepared the metal and Vitruvius had mentioned the amalgamation process for the recovery of gold enmeshed in fabrics.[50] Mercury was often referred to as the water principle of the metals, the principle which gives them fusibility. Synesius states:[51]

Mercury possesses in itself the principle of all liquidity. . . . It always causes color changes. [And again:] As wax takes the color which it has received, so also mercury whitens all metals and attracts their souls. . . . It forms the permanent base, as colors have no foundation of their own.

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[49] Berthelot, *La Chimie au moyen âge*, III, 189.

[50] The alchemists knew how to prepare mercury from cinnabar by distillation or in the moist way by use of copper or lead (Berthelot, *Collection des anciens alchimistes grecs*, Introduction, p. 257. *La Chimie au moyen âge*, II, Traduction, p. 85).

[51] Berthelot, *Collection des anciens alchimistes grecs*, II, III, 8.

Likewise Zosimus:[52] "This conversion is called transmutation after the incorporeal spirits have seized upon a metal body."

And Avicenna:[53]

> Mercury is the mother of the metals. . . . She receives in her womb what is of the same nature as herself. She rejects all others because her nature rejoices more with a like than with a strange nature.

Mercury is the feminine, receptive principle, while the active sulphur is masculine.

Sulphur and gold were both of one nature, possessing the quality yellowness. To obtain gold "one yellows with anything which can yellow"; and the reagent is sulphur or sulphur water. Sulphur was the fire element and gold was the sun metal. Fire was the highest of the "four elements" as gold was the highest of the metals.

The idea in all the later Egyptian alchemy seems to be that spirits (like air and fire) are most important; that metals are that division of minerals which are fusible; therefore they, which were formerly spirits, are now "waters," but they can be given more of the spiritual nature by artificial application of the two spirits, mercury and sulphur. Mercury (including arsenic and antimony)

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[52] Berthelot, *Collection des anciens alchimistes grecs,* III, XXVIII, 7.

[53] Berthelot, *op. cit.,* Introduction, pp. 258-259.

changes copper to silver,[54] giving "leukosis" or whitening; but sulphur changes this silver to yellow ("Xanthosis") by its power of gathering together and exposing all the latent yellow; and thus gold is produced. If an overplus of yellowness is obtained, the resulting bronze acts as a "fixed tincture" which can spare its excess yellow as a seed to change other metals to gold.

All this emphasizes the kinetic property[55] of these two tincturing spirits and the belief that when this power was exercised we have transmutation. It does not visualize the conception of the metals as having a static quality composition (as by different combinations of mercury and sulphur) as one might mix two dye powders to produce a half shade such as purple. This latter is a different conception, a variation which came later and which we find expressed first probably by Geber in the ninth century, later certainly by the Pseudo-Avicenna and the Pseudo-Aristotle.[56]

The Egyptian alchemistic theory conceives of yellowness as a spiritual power which overcomes the earthy, "sublimates" it, "washes away all its sins" and brings it

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[54] "Copper is copper in appearance but in its secret self it is silver" (Berthelot, *La Chimie au moyen âge*, I, p. 278).

[55] "There are certain qualities which give yellowness. For the word quality (ποιότης) has for etymology the word to make or to do (ποιεῖν). See Berthelot, *Collection des anciens alchimistes grecs*, III, VI, 10; also Chap. XII, note 5.

[56] Berthelot, *La Chimie au moyen âge*, I, 277-278.

forth as "higher" in the scale of metals. This is a religious conception applied to metals, a conception which had been acceptable to the Gnostics with their ideas of the chasm existing between good and evil. It was accepted by the late Christian alchemists also—and possibly therefore was unacceptable to Geber and the Mohammedans. With Geber,[57] "The metals are all, in essence, composed of mercury combined and coagulated with sulphur." No such statement is found in the Egyptian writings.

With the Egyptians, mercury and sulphur are spiritual forces which produce the quality which is silver, which may then by these same forces be transmuted into the still higher quality which is gold. Colors with the Egyptians are also spirits and spiritual.[58] Further, as we have seen, a standard sequence of colors is accepted as a check upon the success of transmutation.

With the Mohammedan school, the quality of yellowness is an entity rather than a force. Color sequence still serves as the criterion of success in transmutation but

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[57] Holmyard, *Proceedings of the Royal Society of Medicine*, XVI (1923), 11.

[58] Berthelot, *Collection des anciens alchimistes grecs*, III, XII, 4: "All this sublimed vapor is a spirit and so are the tinctorial qualities." See also Berthelot's interpretation of Zosimus (*op. cit.*, Traduction, p. 134, note 4): [The quality which is gold-coloring or] "the quality, gold, is independent of the metallic substance which is its support. When one possesses a material in which this resides, the essence or *principle of coloring*, it is the philosophers' stone and one can then tint into gold the other metals and thereby make true gold."

what is sought is a combination of the quality "mercury" with the quality "sulphur," which shall be gold.

Here then, in Egypt—not with Paracelsus in the fifteenth century or with Geber in the ninth century—but far back in the early centuries of our era, among the religious enthusiasts of the Gnostic-Christians, arose that mercury-sulphur kinetic theory which passed into the mercury-sulphur composition theory of Geber, into the mercury-sulphur-salt theory of Paracelsus and finally into the Becher-Stahl theory of phlogiston which immediately preceded the birth of chemistry.[59]

Before closing this chapter, let us recall the climax of Aristotle's famous "theory of forms" and compare with it the climax of the alchemistic theory, the philosophers' stone. Here we behold a wonderful analogy. In Aristotle's theory, as illustrated by the oak, there was formulated a series of cycles in which the goal was that stage which could reproduce itself. To Aristotle, organic nature was like man. But to the alchemist, *all* nature was like man—the spiritual overshadowing the material; and reproduction, the greatest of all mysteries, was possible only when

[59] Aidamur Al-Jildaqi (fourteenth century) often reflects the writings of the Egyptian Zosimus, as the following excerpt will show:

"Take gold and transmute it by the simplest method and then produce Gold *par excellence* and it is said that this color-principle, by which it has been colored, if spread, like a leaf, will color other metals. If this body is spiritualized until it becomes a spread and permeating spirit, its soul by means of which the body was colored will also be spiritualized; and thus it colors other bodies" (from *Al Burhan* (*The Proof*), Royal Library, Cairo, no. 9804).

the body of the metal was endowed with excess of the spiritual. The spirit of metallicity was color.

If the copper is whitened to a clear color, it becomes a spiritual body.[60]

. . .

All sublimed vapor is a spirit and such are the tinctorial qualities.[61]

When now the acme of colors is reached in transmutation (the ios) we have conceived a spirit so high and in such abundance formed upon gold that, whereas, per contra, "Common gold has only enough color for itself," [62] we have the "ios of gold" or the "philosophers' stone"—that permanent tincture, which cast upon common metals may produce more gold. This, then, is the alchemistic form of Aristotle's entelechy, the final cause which can reproduce itself. For a complete analogy with Aristotle's philosophy, it was necessary that the alchemistic theory should conceive the philosophers' stone as the *grand finale* of the system.

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[60] Berthelot, *Collection des anciens alchimistes grecs*, IV, I, 6.

[61] Berthelot, *op. cit.*, III, XII, 4.

[62] Al-Jildaqi, *Al Burhan* (*The Proof*), Royal Library, Cairo, no. 9804: "If wise men say that gold is the most precious stone they do not mean common gold, extracted from gold ores, because common gold does not produce a tincture by which other [metals] can be colored, since it contains only just sufficient coloring matter for its own body. It contains no surplus tincture."

Chapter VII

THE FIRST TRANSITION

> *The greatest center of intellectual exchange and syncretism* [*in the sixth century*] *was the Persian school of Jundishapur.* Sarton, *I, 415.*

In the literature of Egyptian alchemy, Zosimus, the "Crown of Philosophers," was the greatest and the last important writer. It was probably through him that there was gathered together a theory of alchemistic thought, a synthesis of the scattered notions which had been previously growing up imperceptibly upon the technical work of the artisan. Ideas which before him had only partially crystallized he collected and exploited and brought into a fairly concordant unity.

But now the scene changes. We must look elsewhere for further developments of this new branch of Greek philosophy—this first union of philosophy with the science of metals. Since alchemy had passed largely from technique to literature, we are constrained to glance over the civilized world of the third and fourth centuries, to discover what academic developments were taking place, where a reverence for literary classics was developing. We are thus compelled to travel with the alchemists to distant lands to find our next advance. Inevitably, our guide

points east to Persia, that mighty empire whose ancient dynasty had fallen before the onward rush of Alexander (see Chart, p. 126). Historically we find that just as in Egypt, *i.e.*, in Alexandria, Greek culture had made its deep impress, so in Persia the people embraced the ideas of Greek philosophy, with the result that Greek and Persian cultures had joined hands. There was this difference that, in spite of conquest, the natives of Persia remained culturally in control.[1]

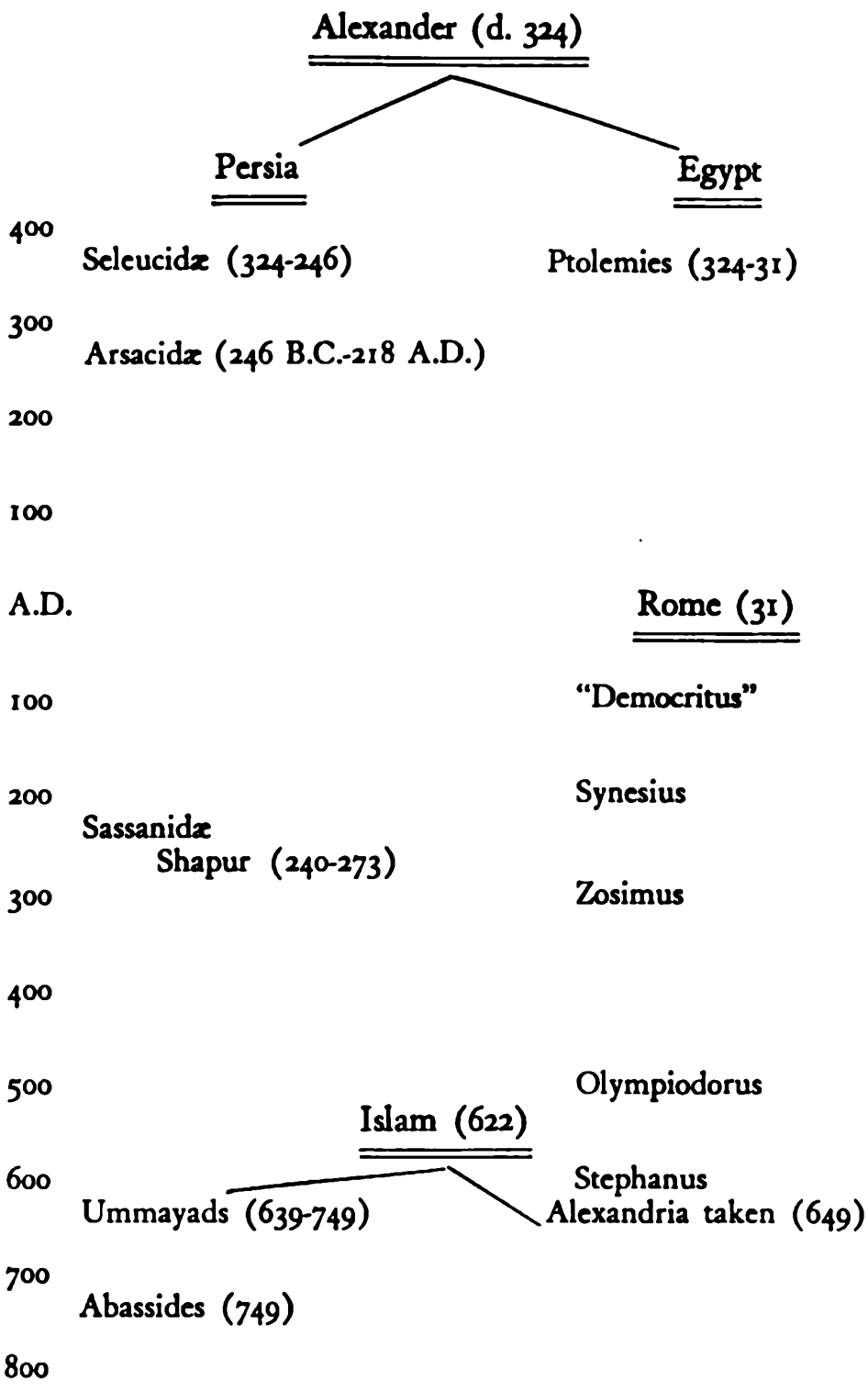
At the early death of Alexander, just as Egypt was piloted politically by the Ptolemies, so Persia fell under the control of the Seleucidae who ruled for five centuries, giving way in 218 to the famous Sassanidae. Of these enlightened rulers, the most famous was the Emperor Shapur (240-273), who captured the great city of Antioch and defeated the Roman general, Valerian, at Edessa in the third century. Shapur founded and made his capital Jundi-Shapur in southern Persia,[2] and established in that city a world-famed school of medicine.

Surrounding the medical school and serving as a center of culture, was an academy to which were invited the learned of every nation and hither probably fled the al-

[1] Speaking of the (later) Baghdad caliphate of the Mohammedan Abassides, P. W. Harrison says that it was in reality a *Persian* empire. (*Johns Hopkins Alumni Magazine*, XIV (1926).

[2] Near the site of Susa, about 300 miles southeast of Baghdad and 120 miles north-northeast from (modern) Basra. *Isis*, XVI (1931), 480.

PERSIA AND EGYPT



chemists of Egypt, escaping from religious and political persecution. The development of Jundi-Shapur was assisted by that Roman intolerance which in the fifth century drove the Nestorians from their academy at Edessa, Mesopotamia, and forced them to seek refuge in Persian territory.[3] In the following century also, the Neoplatonists, exiled from Roman territory, were protected by the Emperor Khusraw (Chosroes), who brought into Jundi-Shapur Indian medicine (and, possibly, Indian physicians) to improve the medical training. Probably there occurred here the first union, afterward so marked, between alchemy and medicine; and alchemy, gradually recovering from the nearly mortal blow of Diocletian's decree, under protection of the established science of medicine continued as an allied science. In the seventh century, however, Jundi-Shapur, the center of Persian culture, fell before the rising tide of the followers of Mohammed. In the pinnacle of its glory, it was destroyed by the Ummayads in 639. We hear no more of its medical school nor of its academy.

There were other libraries and centers of culture[4] and it is related that the Emperor Constantine (who had begun his military career under Diocletian) after establish-

[3] E. G. Browne, *Arabian Medicine*, 1921, p. 21.

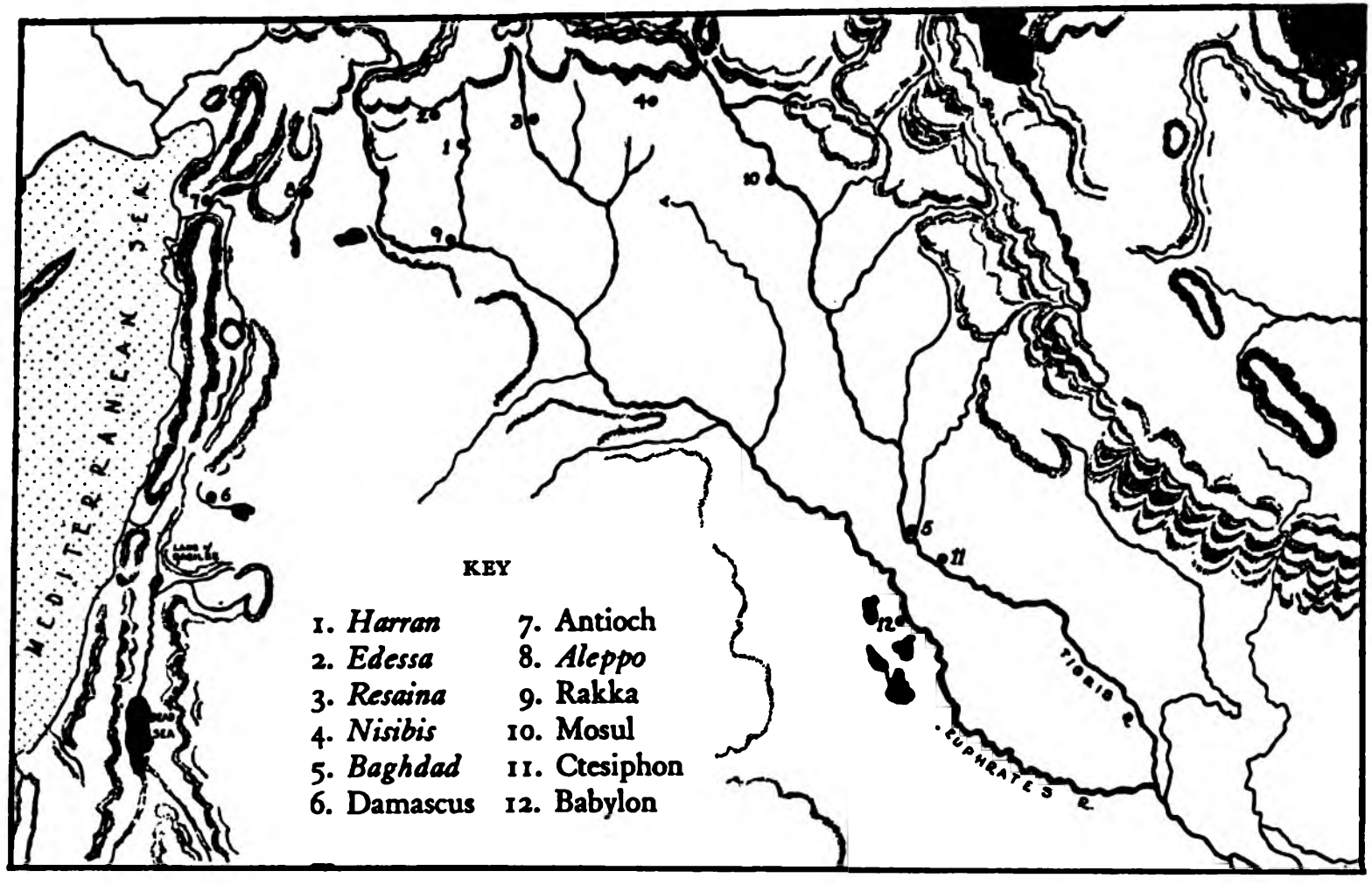
[4] Especially in Northern Syria, Antioch and Aleppo; in Mesopotamia, Edessa and Harran (Charrhae), Resaïna and Nisibis. These were all scattered along the upper reaches of the Euphrates and Tigris and tributaries.

ing his capital at Byzantium (Constantinople), busied himself in collecting the libraries scattered by Diocletian's intolerance. The famous church of St. Sophia dedicated to the "Wisdom of all ages" became noted in the sixth century for its library.

In all centers of culture, there was one occupation carried on, important in the history of science, the careful preservation of the classical literature of Greece and the oriental countries. It is known that Sergius in the sixth century at Resaïna translated the works of Galen and Hippocrates into Syriac and it is probable that the works of these and other medical authors were translated into Persian at Jundi-Shapur.

After the fall of the Persian capital, the Ummayads, impressed with the value of the work of translation and preservation of the ancient literary classics, either restored the academies temporarily closed or built anew, and continued the literary activity in imitation of what they had found.

The military rôle of these Ummayad Mohammedans does not concern us except to note that having, with religious enthusiasm, carried fire and sword into all the near-by eastern countries, they quietly entered Alexandria; and proceeding west joined with the Moors of Northern Africa, crossed over into Spain in 711, and founded the caliphate of Cordova in 755. With conquest



SYRIA AND MESOPOTAMIA

Place names in italic indicate centers of culture.

they acquired wealth and an elegance of living undreamed of by their simple master, Mohammed. The dynasty continued to rule in Spain, but in the East the Ummayads were succeeded by the better-known Abassides who in 750 founded Baghdad, the military capital of the Mohammedan races for five centuries.

Continuing the magnificence of the Ummayads, these Abassides excelled their predecessors in fostering literature and medicine. The period which is rightly known by the Christian nations as the Dark Ages was to the Persian and Islamic nations the Golden Age of culture. At a time when our Christian predecessors were steeped in ignorance, the Abassides were establishing academies and medical centers and continuing the work of the Persians in preserving the literature of the ancient world. At the most famous of these academies, the one at the newly founded capital at Baghdad, translations were made into Arabic (or into Syriac and thence into Arabic) by translators hired for the purpose, Greeks, Persians, Hebrews, or Syrians, who thus kept alive for us the precious works of such authors as Euclid, Archimedes, Ptolemy the astronomer, Hippocrates, Dioscorides, Aristotle, Galen, Theophrastus, as well as those of the alchemists, Zosimus and the Pseudo-Democritus.[5]

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[5] "At the time of Hunein there existed a school of science at Baghdad, based on the model of the Alexandrian school. This school was probably attached

Moreover, under such rulers as Harun-al-Raschid, the members of these academies were honored and given authority, being frequently chosen as ambassadors to foreign countries, for example, to the Roman capital at Constantinople.

Thus there accumulated in all the lands under Islamic control a wealth of priceless literature, reflecting the wisdom of the ancient world. Fortunately, this was transmitted in part to Christian Europe, mostly through Spain, during the twelfth century. The awakening caused by the reception of this amazing literature was one of the efficient causes of the so-called Renascence.

It may be numbered among the tremendous facts of history that, by the zeal of their prophet, the wild hordes of nomadic Arabic tribes were first transformed into world conquerors and then rose to an appreciation of the worth of the gentle arts of the physician, the student, and the alchemist, so that these ignorant races became in a few generations the conservators of the ancient classics.[6] After

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to the 'House of Wisdom' [Bait al-Hikma] in which the manuscripts of Greek science were stored and which had been founded by al-Ma'mun in 832." (Max Meyerhof, *Isis*, VIII (1926), 28, 722.)

[6] It should be noted in passing that we have one important "Collection" of alchemistic writings in Greek, already referred to (see pp. 3 and 60), which shows no trace of Arabic influence, a collection of Alexandrian alchemistic writings to which are added extracts from certain Byzantine-Christian scholars. Transmitted to us possibly through Syrian and then Latin channels, this valuable collection was not known to the Mohammedans and was unappreciated by the Christians until about the time of the invention of printing, when it appeared in portions in such printed collections as the *Theatrum*

the Egyptian era, we find the literature of alchemy following along two lines, that of the Christian writers whose knowledge of alchemy, as the centuries ran on, was less and less appreciative of the Egyptian spirit; and that of the Mohammedan school which seems much more closely acquainted with the early alchemistic thought.

In the Christian school, we have writings such as those of Christianus, Sergius, Anonymus, Photius and Cosmas—besides many technical treatises more or less related to alchemy. Of the latter may be mentioned the *Compositiones ad tingenda,* the *Turba philosophorum,*[7] the *Mappae clavicula, Liber ignium,* etc. In these treatises many recipes are given, some of which appear to be identical, or nearly so, with those of the Egyptian period.

The transition period, from the sixth to the ninth centuries, before the coming of the Mohammedan writers, was for alchemy a period of decline. Aside from reproductions of the original Greek works from Egypt, as developed in the academies, this period offers us nothing of advance in alchemistic thought or literature. When al-

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Chemicum in the sixteenth century. Since this important exponent of earliest alchemy was buried in the dust of the libraries, it was without influence upon either Mohammedan or European alchemy in the Middle Ages, but as an interpreter of ancient alchemy of the Egyptian school it is, of course, of the greatest value at the present time.

[7] Julius Ruska, *Turba philosophorum, Ein Beitrag zur Geschicte der Alchemie.* Band I, Berlin, Springer (1931). German translation with notes. Reviewed by Holmyard, in *Isis,* XX (1933), p. 302.

chemy became separated from the mother country, it lost its popular appeal. However, its literature was preserved by the academicians, some works probably being saved from the ruins of Jundi-Shapur and transferred to the academy at Baghdad. In this extremity, alchemy had need of a conscientious and enthusiastic advocate, one who could rouse the people of the influential class to a renewed interest in the forgotten science. Such a character, we have been told, presented himself in Geber, founder of the Mohammedan school.

Chapter VIII

THE MOHAMMEDAN REVIVAL

> *With the Arabs and the Jews of the middle ages, scientific knowledge was a thing of supreme importance and this spirit of devotion to science passed to the Christians who came in contact with their learning.* Haskins, *Isis, VII, 478.*

It was said by "Majriti," in the eleventh century, that the ancients wrote for people who had a good knowledge of natural science, who knew that the art was true; but that in the time of Geber (Jabir, or Dschabir in Arabic; Geber in Latin), most people did not believe in the possibility of obtaining the elixir while those who did believe were of the most ignorant type.[1]

I. JABIR

In discussing the personality of Geber, I shall follow Professor E. J. Holmyard, whose recent researches have given us a new and intimate view of the man. Holmyard assumes that Jabir was born in the eighth century and lived as a physician in Baghdad under the protection of the Court of Harun-al-Raschid. He is thought to have been the *first* writer in Arabic to become interested in

[1] Holmyard, *Isis*, VI (1924), 303.

alchemy.[2] Geber's knowledge was universal for his day, including the philosophy of Plato and of Aristotle and also that of the Neoplatonists, with whose writings the Mohammedan schools had become acquainted after the accession of the Abassides.

By a study of the composition of things Geber's interest was drawn towards science; and believing that alchemy [3] was real, he undertook the almost superhuman task of bringing this discredited subject up to the same honorable plane as philosophy, medicine or mathematics.

His literary output is said to have been enormous—no less than five hundred works on alchemy alone being attributed to him.[4] About fifty of these are still extant in the original Arabic. From the few which have been translated into a modern tongue we may judge that his attitude toward science was revolutionary and rather modern. Geber naturally reflects the general belief of his times in mystical powers, in the influence of the stars, in the potency of

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[2] Recent investigations seem to relegate the Alexandrian, Prince Khalid, to the realm of Mohammedan mythology (Ruska, *Chalid ibn Yazid*, 1924. Reviewed in *Isis*, VII (1925), 183.) The first letter in Jabir is pronounced like our G, so that both forms, Jabir and Geber, are nearly the same; but by common use Jabir is used to denote the author of the Arabic works, and Geber of the Latin works of the thirteenth and fourteenth centuries. The latter have been translated into German with notes by Darmstaedter (1922).

[3] "Alchemy" in the sense of transmutation. This is also the meaning in the sentence taken from Majriti at the beginning of this chapter: "Who knew that transmutation was a true art but that in Geber's time most people did not believe in the possibility of obtaining the transmutation agent, the elixir."

[4] *Proceedings of the Royal Society of Medicine*, XVI (1923), 3, where nearly a hundred titles of known works are listed.

talismans, and so on, but he also teaches that a man can know nothing of nature who does not study nature in the laboratory. The first duty of an alchemist, he said, is to carry out experiments in order that he may acquire knowledge. He accepted the doctrine of transmutation, but did not baldly inform his contemporaries that transmutation had been accomplished. Instead he gave specific directions for experiments in transmutation, such as "Project some of this substance upon so much copper and you will get silver," thus allowing them to draw their own conclusions and inducing his friends to try experiments.[5]

Geber's fundamental beliefs include the "first matter," the "four elements" and the two pairs of qualities of Aristotle, the derivation of the metals from "mercury" and "sulphur" and the tendency of the metals to become gold. He thought that the lower metals contain unavoidable accidental qualities which it is the business of the alchemist to remove, and that each metal contains occult properties which are the opposite of the apparent qualities.[6] He distinguished between the "body" and "spirit" of the metals and prepared metals by reduction of their

[5] It is noteworthy, as a reflection of Egyptian alchemy, that Geber's successor Maslama Al-Majriti states that the elixir contains the *tinctorial* powers necessary to carry out the transmutation either into silver or into gold; and that the true elixir must be able either to color silver yellow or to whiten copper (Holmyard, *Isis*, VI (1924), 301). Color words abound in Geber's own writings, as for instance in the *Little Book of Pity*.

[6] Berthelot, *La Chimie au moyen âge*, I, 283: "ut ponas occultum manifestum." See also quotation, *op. cit.*, I, 313.

calces. He taught that the only sure proof of transmutation was in actual demonstration.

If all that has been deduced from the writings of Geber is true, he was one of the greatest single constructive influences in science, particularly in the science of the metals, that the world has ever known. Perhaps he should be ranked with Lavoisier as instituting a great revolution in the attitude of the educated people of his time toward the study of chemistry—especially in their attitude toward experiments. Whereas, since the days of Aristotle, to soil one's hands with labor had been considered, except in Egypt, despicable and proper only for slaves, it is related that Geber had some success in teaching his friends at court that laboratory methods are necessary and the only foundation for an exact and reasonable science.

It has seemed best to present, first, the above pleasing view of the "great master" of the Islamic school before passing on to an outline of the Geber controversy.[7] It was while we still thought this presentation of Holmyard's

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[7] Holmyard's many publications on the history of chemistry include the following, in which he presents arguments for the validity of Jabir as a historic character; develops the story of his life and activities according to the legend recorded by late Islamic writers; and discusses the Geber-Jabir problem.

1923 *Nature,* CXI: 191-193, "Identity of Geber."
Chemistry and Industry; 387-390, "Chemistry in Mediæval Islam."
Proceedings, Royal Soc. of Medicine, 46, 57, "Jabir ibn Hayyan."
1924 *Isis,* VI, 293-305, "Maslama Al-Majriti."
Isis, VI, 479-499, "Critical Examination of Berthelot's Work."
1926 *Scientia,* 287-296, "Chemistry in Islam."
1928 *The Arabic Works of Jabir ibn Hayyan.* Vol. I. Paris, Geutner, 1928.

the culmination of the whole argument and while the restful picture still remained with us (bringing a moment of peace) that I wrote the following notes as a caveat against what seemed to me an excess of enthusiasm on the part of this patient British investigator and seductive writer:

If to persuade a people of the truth of a proposition so foreign to their inheritance and education seemed difficult to Geber, for his silent pupils to assume the strange new attitude toward experimental work must have been a possibility only as a temporary compliance with their "father's" orders. Such instruction to the young and wealthy at the court of Harun-al-Raschid must have been lacking in any permanent effect (except in a very few cases) for Geber had to contend with the innate attitude of a people whose wealth and magnificence had been only recently acquired. It is said that even he at times suffered violence and persecution because of his teachings. There is no doubt that his influence upon the intellectual Moslems was very great; but, as is so often the case, he had to reckon also with the tendency of the people to become irritated with those who proclaim new ideas, however correct, and their tendency to revert to the easier, inherited methods of thought which had come down to them from the "good old days." Geber's insistence on the value of laboratory demonstration was gradually lost sight

of by his successors;[8] more and more the theories of alchemy which Geber had declared most difficult to master were exploited without demonstration; less and less was stressed the insistence upon the practical laboratory experiments which the master had pronounced easy, if one had the necessary discipline, preparation, and technique.

Geber's literary successors were either, like Geber, physicians who may have tended to value alchemy only as an aid to their pharmacopœia; or they were philosophers who found in the alchemy of the metals a welcome support for the Aristotelian theory of the universe in which they were primarily interested. However this may be, there has been up to the present little record of any new thing having been produced by the laboratories of this period.

Holmyard's judgment seems to differ from the above. In *Chemistry and Industry* (1923, p. 388), we find these expressions:

> His theory that metals are composed of mercury and sulphur proved extremely fruitful. . . . [He] appears to have regarded mercury as the nearest approach . . . to the *prima materia,* sulphur representing the combustible principle.
>
> . . .
>
> On the practical side, Jabir . . . describes the preparation of various salts such as white lead and cinnabar, the reduction of

[8] Holmyard, *Scientia,* 1926, p. 290: No Moslem among his successors, except Rases, made a contribution of the first order.

metals from their calces, the use of alum as a mordant, methods of waterproofing cloth and of rendering it fireproof, details of dyeing . . . and discusses various operations such as calcination and distillation.

In his introduction to Iraki's *Cultivation of Gold* (1923, p. 5), we find: "Inspired by a wonderful theory which in a way, undreamed of, is at last coming back into its own, they [Islamic alchemists] performed stupendous amounts of chemical research."

If one subtracts from the enumeration above, the theories and facts already known and described by Dioscorides (see Chapter XI, note 2) and by the Alexandrian alchemists (see Chapter XI), the enthusiasm of Jabir for the newly discovered subject would seem to be his greatest contribution—a powerful and fruitful incentive for the establishment of alchemy "as a science of equal nobility with those of philosophy, mathematics and medicine."

2. THE JABIR-GEBER QUESTION

In order to understand this famous controversy, we have to recall that in the fourteenth century there appeared many spurious alchemic writings in Latin, professing to be the original works (or translations) of famous "men of old." Among these were some by one "Geber." At first, no distinction was drawn between the Arabic

writings of Jabir and the Latin of Geber and all of these Jabir-Geber writings became very popular, since they together with those of Rases and Avicenna introduced the "new science" into western Europe. Later, questions arose as to the popular belief that the Geber works of the thirteenth century were actually translations into Latin of the Arabic of Jabir of the eighth century; also as to the reliability and even as to the existence of Geber; and much later as to the date of the Jabir-writings, and as to whether the authorship of the five hundred or more works could be ascribed to a single individual. This discussion involves, therefore, not the intellectual honesty but rather the existence of this wonderful author of the eighth century. An estimate of the value of all the Islamic writings on alchemy is here involved, as the exact date is always a factor in such estimates. It is significant that the great Arabic encyclopedia of science, *Fihrist,* in the tenth century,[9] had already raised the question of Jabir's legendary character.

Passing now to recent times, to the latter half of the nineteenth century (when the whole history of chemistry was being brought into some sort of permanent form by modern authors), very serious doubts on these matters were expressed by certain prominent historians, a list of whom has been carefully collected by von Lippmann.[10]

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[9] Muhammad ibn Ishaq: *Fihrist al-ulum* (987).

[10] *Entstehung und Ausbreitung der Alchemie,* 1919, pp. 485-486.

Among the names on von Lippmann's list are Kopp,[11] Hoefer,[12] and Wiedemann (1878),[13] to which list may be added that of von Lippmann himself.[14]

Berthelot, having completed his famous study of the Greek (Egyptian) alchemists in 1888, passed on to decide the question of the influence of the Egyptian upon the Islamic school and succeeded in establishing a strong affiliation between the two. But Islamic alchemy means essentially Jabir and here undoubtedly Berthelot went much too far, making two mistakes—one personal in that he claimed to be the first to doubt the "identity of Geber," ignoring the judgment of Kopp and Wiedemann in Germany; and, in his own country, the pronouncement of Hoefer. The second error was more serious, being scientific, since Berthelot should have left the question of the identity of Geber open, as he was not fitted to decide a question involving the Arabic language and moreover did not cover the available literature of the subject.[15]

Again unfortunately (as it seems to one viewing this whole episode from a distance), his critics first allowed the great man to die and after waiting many years attacked him with virulence and enthusiasm. Since now the

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[11] *Geschichte der Chemie*, 1843, and *Beiträge*, 1869; also *Die Alchemie in ältere und neuerer Zeit*, 1886.

[12] *Histoire de la chimie*, 1842 and 1866.

[13] *Zeitschrift der deutschen morgenländischen Gesellschaft*, XXXII, 575.

[14] *Abhandlung und Vorträge*, 1906 and 1913.

[15] Berthelot, *La Chimie au moyen âge*, I, 336; III, 18, 126.

defendant at the bar of justice surely is stopped from making any reply, I might without excusing his mistakes, simply observe that pioneers are apt to make errors and are interested fundamentally in establishing their claim; and above all should not be criticized for being unable to grasp the discoveries made *ex post facto*.

As is usual, our extreme ignorance (in this instance ignorance of Arabic) was the cause of this whole discussion. One pleasing result of the controversy has been the recent entry of Arabic scholars into the field of the history of chemistry; and further, the determination on the part of a few of our younger historians to acquire the Arabic language, so necessary for a complete understanding of, let us say, one-third of the life of alchemy. Translations from the Arabic into modern European tongues are even now slowly appearing, which will make this important literature available to the non-Arabist. Darmstaedter, Holmyard, von Lippmann, Partington and the Ruska school are doing valiant work in opening up this whole field.

To return to Berthelot, we find von Lippmann in Germany and Holmyard in England attacking him on different grounds, for the first agrees with Berthelot as to the fraudulent character of the Latin Geber, but attacks him for his presumption and careless approach to the question; while the second, horrified at the conclusion, eager to

rescue Jabir from annihilation, claims that we are justified in doubting the testimony of an expert when unqualified by lack of preparation.

Both arguments seem quite justified; but von Lippmann's will repel many American readers by its unnecessary violence and Holmyard's argument has led him much too far—"in a field of which he was ignorant," as he says of Berthelot. Our doubt concerning the personality of Jabir will not be lessened by picturing the man as "an original experimentalist," since he used methods and made preparations already described by the Egyptian school and by Dioscorides,[16] nor by advising us that perhaps his most important contribution to the progress of science was his theory that all metals are composed of mercury and sulphur.[17]

Holmyard, in defending the existence of Jabir and the "identity of Geber" is following a self-proposed and most unscientific canon: "In case of doubt, it is always safer to follow tradition." [18] The result is that he has accepted as true not only the writings of Prince Khalid and of Geber but has presented the legendary Jabir as historical.

And now comes an interesting contribution from Ruska and his associates. While I was wondering how long it

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[16] See Chap. XI, note 2.
[17] See pp. 84(7); 97; 115-116; 120.
[18] *Scientia*, 1926, p. 288.

would be before the Egyptian school would acquire recognition as well as credit for its real and important contributions, and when its affiliation with Islamic alchemy would be at last worked out, Paul Kraus, working with Ruska, comes forward with the surprising announcement [19] that there might have been a man named Jabir in the eighth or ninth centuries but that the works ascribed to him could not have been written before the tenth century, at about the time of the *Encyclopedia of the Faithful Brothers;* and that the writer of these books was probably chief missionary of the Isma'ilist-Schiist sect (see chart, page 154).

This adjustment of the Geber controversy is so new that it would be rash to say it should be received immediately as correct, although it is attractive. It still seems to require the existence of a Jabir, somewhat legendary, in the previous centuries, since the *Fihrist* (987) discusses that very possibility. But it brings the writings of Jabir nearer in point of time to those of Geber and makes possibly unnecessary the discussion of the "identity of Geber," inasmuch as the differences tend to disappear. The *Fihrist* and the *Encyclopedia of the Faithful Brothers* (Ikhwan al-safa) contain references to discoveries in chemical ma-

[19] Paul Kraus, *Dschabir ibn Hayyan und die Ishmaillijja.* Dritte Jahresbericht der Forschungs-Institut der Naturwissenschaften in Berlin (1930), pp. 23-42. See also *Isis,* XV (1931), 7.

terial[20] corresponding closely to those mentioned by the Latin Geber and written in a more or less scholastic style similar to some of the Latin works. If now we may visualize the Jabir books as written by the brotherhood and issued all under the sanctified name of the *Imam* Jabir, we have an explanation of the "five hundred" titles ascribed to him.

To one who has carefully followed the Geber problem as from the outside and has been intrigued by the brave work of Holmyard sufficiently to accept his conclusions,[21] it is difficult to visualize this new picture correctly, although the arguments for it, as presented by Kraus, seem irrefutable. Let us therefore leave it for time and hard work to develop further; recognizing that, if proved true, it will make many unexpected changes in relationship, e.g., Jabir's most brilliant "successor" Rases will now appear as (very nearly) his contemporary and the important alchemic writings of Islam will cover a period of three instead of five centuries.

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[20] See also Ruska, concerning the writings of the tenth-century Rases, *Isis*, V (1923), 451; holding always in reserve the possibility put forward by Ruska that Geber is an independent writer with Arabic inheritance.

[21] As is evidently the case with Sarton, who in the midst of this controversy has dared to denominate Chapter XXVIII (on the second half of the eighth century): "The time of Jabir ibn Hayyan."

3. SUCCESSORS OF JABIR

Prominently mentioned among the successors of the "eighth-century Jabir" have been three authors eminent in other lines: Al-Razi,[22] Al-Majriti[23] and Ibn Sina.[24] There is doubt however concerning the authorship of the alchemistic works which appear under each of these names.[25]

Sarton[26] writes of Al-Razi (died 924) as the "greatest clinician of Islam and of the Middle Ages"; as also does E. G. Browne: "By virtue of his clinical observation, highest perhaps of all physicians produced by Islam."[27] Rases' outstanding medical work was an enormous encyclopedia, *Kitab al-hawi.*

The tenth-century Maslama Al-Majriti, who died about 1007, was interested in astronomy and mathematics, but not in alchemy. Among his famous works may be mentioned the reëditing and translation of the renowned Persian astronomical tables, adapting them to conditions in Spain.

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[22] *I.e.,* of Ray near Teheran; in Latin, Rases.

[23] Of Madrid.

[24] In Latin, Avicenna, who lived near Bukhara.

[25] Literary frauds were constantly attempted by ascribing a manuscript to some highly honored person as author. In these three cases, it is notable that the real al-Razi and the real Ibn Sina were the most noted physicians in all the history of Islam. In case the major interest of the supposed author is different from that of the manuscript in question, there is room to consider such product as suspect.

[26] *Introduction to the History of Science,* I, 609.

[27] *Arabian Medicine,* 1921.

Lastly, the physician, philosopher and astronomer, Ibn Sina (980-1037) is reckoned the most *universal* scientist of Islam. His medical *Qanon* (Canon) was considered *the* authority in medicine for six centuries, superseding all others—even Galen and Al-Razi—until the time of Paracelsus.

The above facts are well established and we have now to inquire about the alchemical works ascribed to these authorities.

Ascribed to Rases is the *Kitab al-asrar* (*Book of Secrets*).[28]

In the twelfth century are two Latin translations by Gerard of Cremona, *De aluminibus et salibus* (also known as *de spiritibus et corporibus*);[29] and *Lumen Luminorum* (also known as *Aristoteles de perfecto magisterio*).[30] The usual doubt about the authenticity of all three of these works exists but we may safely wait for Ruska's promised book on Al-Razi before pronouncing final judgment.

The *Book of Secrets* has been studied by Stapleton, Azo and Husain and their conclusions reported in a very important communication.[31]

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[28] It is named in a list of twenty-one alchemical books, given by Al-Biruni about a hundred years after Rases' death.

[29] Translated by Robert Steele, *Isis*, XII (1929), 10.

[30] Ruska, *Isis*, V (1923), 47.

[31] "Chemistry in Iraq and Persia in the 10th Century A.D.," *Memoirs of the Asiatic Society of Bengal*, VIII (1927), 317-418. Reviewed in *Isis*, XI (1928), 129.

In regard to Maslama Al-Majriti, Holmyard's study of the *Rutbatu'l-Hakim* (*Sage's Step*) leads him to believe that this book was written about a hundred years after Al-Majriti's death and is therefore pseudepigraphic.

Although there is no evidence that this *Sage's Step* was ever translated from the Arabic or in any way influenced its successors, it presents us today with a valuable historical sketch of the writers preceding the eleventh century. Holmyard derives much of his data on Jabir from this source.[32] He considers the author well informed, acquainted with Aristotle, Democritus and Zosimus, as well as with Jabir and Al-Razi.

Besides the medical works of Ibn Sina, we know of one extensive book on natural science and philosophy called the *Kitab al-Shifa* (*The Remedy*). It deals with (1) physics, mathematics and metaphysics; and (2) ethics, economy and politics. The book called *Liber de mineralibus Aristotelis* (formerly supposed to be the missing book promised by Aristotle, περὶ λίθων) has been recently shown by Holmyard and Mandeville to be a translation of a portion of Ibn Sina's *Shifa*.[33] It is in this section of the *Shifa* on the "formation of minerals"—about a hundred and fifty lines—that there is given the derivation of

[32] *Isis*, VI (1924), 293.

[33] Holmyard and Mandeville, *Avicennae de congelatione et conglutinatione lapidum*, 1927.

metals, according to the general theory, from mercury and sulphur. Here then is all that is authentic on alchemy from the great Ibn Sina! Now, alchemy without transmutation in that day was hardly recognizable as alchemy, so that when he closes this short section with a few famous lines condemning transmutation as impossible,[84] it would seem that those students are justified who consider that Ibn Sina "wrote nothing on alchemy." On the other hand, we have a Latin book appearing under the Latin name of Avicenna, called *De anima in arte alchemiae*.[85] With its lack of structure, it gives one no reminder of the careful and precise language of the real Ibn Sina and is in no way in agreement with his position on transmutation, as expressed in the *Shifa*. It is, however, a strange thing that some book under this name was frequently quoted as an authority by encyclopedists in the thirteenth century, so that we seem forced to conclude that there must have been a clearly written predecessor, either in Arabic or in Latin, superior in form and value to this blind and incoherent edition which alone has been preserved for us. It is possible that this supposed original may some day be discovered.[86]

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[84] See Chap. XI, note 14.

[85] For the opening lines, see Appendix IV.

[86] For some time, the existence of such a copy of the *De anima* in Granada has seemed possible, but this now becomes extremely doubtful. According to correspondence with Dr. Ruska in Berlin, it appears that he has been in touch with the eminent Spanish authority, Dr. Palacios of Madrid, and has been as-

The strange habit of publishing a book under the name and authority of some famous predecessor was very common at this period in all controversial literature—the alchemists did not invent it. This deliberate act on the part of the author gained prestige for his book by sacrificing any chance of fame for himself. The reason for this is sometimes thought to have been ecclesiastical intolerance toward those whose writings contained theories not acceptable to the Church.[87] It has seemed to me that there is another possible explanation: In the case of a political party, ecclesiastical sect or scientific school, which wished to flood the world with propaganda in the form of hundreds of pamphlets by as many authors, prestige would be gained, with little sacrifice, by pretending that all this literature came from the pen of some one famous historic authority. Something of this sort may explain the sudden output of the Eclectic-Gnostic-Shiite sect which was preaching ecclesiastical freedom of thought, and the purifying power of knowledge-from-whatever-source, and this in the midst of an antagonistic orthodox Mohamme-

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sured by him that our hopes are unfounded. In conclusion, it would seem probable that the *De anima in arte alchemiæ* was written by a Pseudo-Ibn Sina some time after the death of the great physician (1037), probably in the twelfth century, since Majriti (who died in 1007?) does not mention him and the *De anima* is frequently quoted by the thirteenth-century encyclopedists. The mutilated form which has come down to us must be of much later date (possibly 1235?).

[87] Examples of suffering from this cause are well known during the struggle to establish the heliocentric theory in astronomy.

dan people, like the fundamentalist group of our own times.

We are justified in supposing that it was by the writings of these three authors: Jabir or "Geber," Al-Razi or "Rases" and Avicenna (in the original form of the *De anima*) that Islamic alchemy became emphasized and advertised. The theories (all being modified forms of those of the Greek-Egyptian school) being more and more fully restated and illustrated by examples, reached the Christian peoples of Spain and France and made popular the "Arabic science." Haskins says:[88] "With the Arabs and Jews of the Middle Ages scientific knowledge was a thing of supreme importance and this spirit of devotion to science passed to the Christians who came in contact with their learning."

The literature of Islamic alchemy after this is represented by the works of Ibn Arfa R'as ("Andalusi") who died in 1197, Al-Iraki (died 1300) and Al-Jildaqi whose death occurred in 1360.

Thus, just as the literary productivity of Islam began to decline and during the period when the Moors were gradually being pushed south in Spain, Christianity had the good fortune to receive from its enemies an acquisition of incalculable value. From a close acquaintance with, and respect for, the highest types of Moorish architecture and

[88] *Isis*, VII (1925), 478.

from the stores of unexpected wealth of literature in the captured libraries of Andalusia, gradually also from personal contacts with highly educated Mohammedan gentlemen, the Christian gained a gift of inspiration which led to a desire for that which he recognized his enemies had in abundance and which he had not. Thus the Christian, through a new contact, absorbed a culture, just as the Egyptian and the Persian had from contact with the Greek—a culture which, though Mohammedan, was again Greek by inheritance. This gift, although never acknowledged, actually repaid Christianity for all the wars and crusades. Thus were sown some of the seeds of the present Christian civilization. Princes, statesmen and warriors awoke to the value of the ancient classics and to the necessity of establishing a firm foundation of knowledge in an actual examination of nature.

Before closing this chapter, let us return for the moment to our four conclusions, namely, (1) the thesis of the Ruska school in regard to the date of Jabir; (2) the opinion that we are not yet prepared to count Al-Razi's *Asrar* among the pseudo group; (3) the judgment of Holmyard on the historical work of Majriti; and (4) our decision to accept nothing from Ibn Sina except the *De anima in arte alchemiae* of the Pseudo-Avicenna. With these facts in mind, we may make a tentative chart to aid us in understanding the relations, old and new, as follows:

CHRONOLOGICAL LIST OF ISLAMIC WRITERS

	Old Order	New Order		
700				
	Jabir			
800				
				Shi-ite
900	Al-Razi		Al-Razi	Ismaliya-Qarmatians
		Jabir		
	Al-Majriti			Encyclopedia (Faithful Brothers)
1000				
	Ibn Sina			
		Al-Majriti		
1100				
		Avicenna(?)		Fitna
	Ibn Arfa-R'as			
1200				
	Al-Iraqi			
	Al-Jildaqi			
1300				

Aside from the evident fact that later dates are assigned in the new chart to all these writings (excepting those of Rases) the most important change of relation developed is that here we have placed, nearly side by side, the two most important writers of Islam.

It seems to me now that (far from being associated in the relation of teacher and pupil, as we had supposed) Jabir and Rases, although both alike stressed the necessity of laboratory work,[39] were the leaders of two ancient rival schools of alchemistic theory.

The teaching of the Jabir school reflects the Egyptian ideas of the mercury-sulphur composition of the metals (which Rases did not mention) and the transmutation theory with which again Rases had nothing to do. It is easy to see that all those who denied the possibility of transmutation—e.g., Ibn Sina in the *Shifa* (see Chapter XI, note 14) and the encyclopedists of the thirteenth century[40]—belong to the school of al-Razi; while the Egyptian school, probably in opposition, spread the transmutation propaganda through its five hundred volumes under the joint name of Jabir; and that this was the school responsible for the *De anima* of the Pseudo-Avicenna and for the fourteenth- to fifteenth-century "pseudo-alchemists" whose goal, like that of Jabir, was the "elixir."[41]

Now the name of al-Razi has been ever associated with

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[39] For Rases, see Stapleton, *Isis*, XI (1928), 129.

[40] The encyclopedists seem to be (by inheritance) of the Egyptian school—but troubled and hesitating because Ibn Sina, with his tremendous authority, declared "it is not in their power to bring about any true change of species."

[41] Ibn Khaldun in his *Prolegonoma* (fourteenth century) clearly stated these two theories of the metals, citing Ibn Sina, the first to voice the theory of specific differences and Al-Farabi (also of the tenth century) similarly the theory of accidental differences (quoted by Holmyard and Mandeville, Introduction, V, to *Avicennae de congelatione et conglutinatione lapidum*).

Harran (the ancient Charrhae) the seat of the Sabian sect,[42] whose religion was derived from Iran and further back from China. Davis and Wu have recently shown that there was in China in the second century B.C. a mystic form of alchemy centering about the idea that if the purest gold could be prepared, it would give one the "seed of immortality"; and Stapleton, Azo and Husain[43] have indicated that the Sabian religion of Charrhae so influenced the alchemy of Rases that the author of the *Book of Secrets* believed in the necessity, before transmutation were possible, of reducing substances to their "first matter," *i.e.*, to an impalpable powder (which Ibn Sina later pronounced impossible) on the theory that each metal belongs to a separate Aristotelian species, as he expressly states.[44]

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[42] The migrations of this sect are given in *Isis*, VIII, 345.

[43] See note 31.

[44] On the other hand, it will be recalled that Zosimus speaks of the *one species: metals*, under which individual qualities characterize the separate metals and that transmutation is possible since these qualities are known to be easily changeable.

Thus we may picture two schools:

1. CHINESE-IRANIAN-SABIAN:
   - Al-Razi (tenth century)
   - Ibn Sina (eleventh century)
   - Encyclopedists (thirteenth century)

2. EGYPTIAN-ISLAMIC:
   - Jabir-Geber (tenth century)
   - "Avicenna" (twelfth century)
   - "Pseudo-alchemists" (fourteenth to fifteenth centuries)

Chapter IX

THE SECOND TRANSITION, IN THE TWELFTH CENTURY

Nature has always had for an end and tries ceaselessly to reach perfection, that is gold. Bacon, *Mirror of Alchemy.*

IN the eleventh century, the Moors who had been firmly established on the Spanish peninsula since their coming in 711, were thrown into more and more serious conflict with the Christian hosts pressing down from the north. The long drawn-out contest, lasting about four hundred years, resulted in the final expulsion of the Moors when Granada fell in 1492. But, in the meanwhile, they were transferring unconsciously to their conquerors that gift, which may be called spiritual, such as could never be reckoned in a treaty of peace—a gift of the utmost consequence to Christendom.

This resulted from the acknowledged fact that culture and learning were preëminently the possession of the Islamic people. One striking illustration of this superiority may be found if we consider medical education. It is well known that in the eleventh century, Persian physicians led the world, for the authority of al-Razi and Ibn Sina still

ruled the profession, continuing until the time of Paracelsus.[1]

The general tendency toward alienation and incompatibility induced by religious fanaticism and barriers of speech was supplemented by this difference in culture and learning. Breaking through this wall, the first and most lasting contact probably occurred in the literary field, especially through translations. This was effected quite early by the Spanish Jews, who were allowed to travel back and forth between the two contending camps and became proficient in both the Arabic and the Latin languages.[2] During the eleventh century, the academies and valuable libraries of Spain which had been protected by the Ummayads were destroyed by religious revolutions—the so-called *fitna,* beginning in 1009. Weakened by this rebellion, the army of the Moors gave way before the northern hosts. First, in 1085, Toledo fell; and then successively Cordova, Seville, and Cadiz were taken by the Christians. As the enemy country was occupied, the Christians acquired more and more respect for the Moors.

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[1] The low state of Christian medicine about this time is well illustrated by an anecdote told by E. G. Browne in his Cambridge lectures and incorporated in *Arabian Medicine,* 1921, pp. 69-70.

[2] These Jews had absorbed all the *corpus* of Aristotle and most of Plato from original sources which were in the hands of the Arabs, their instructors. After the fall of the Ummayad dynasty, at the time of the *fitna,* the learning of the Arabs had been crushed out by orthodox Mohammedanism; but, by the learned Jews, the instruction in Greek learning was never forgotten.

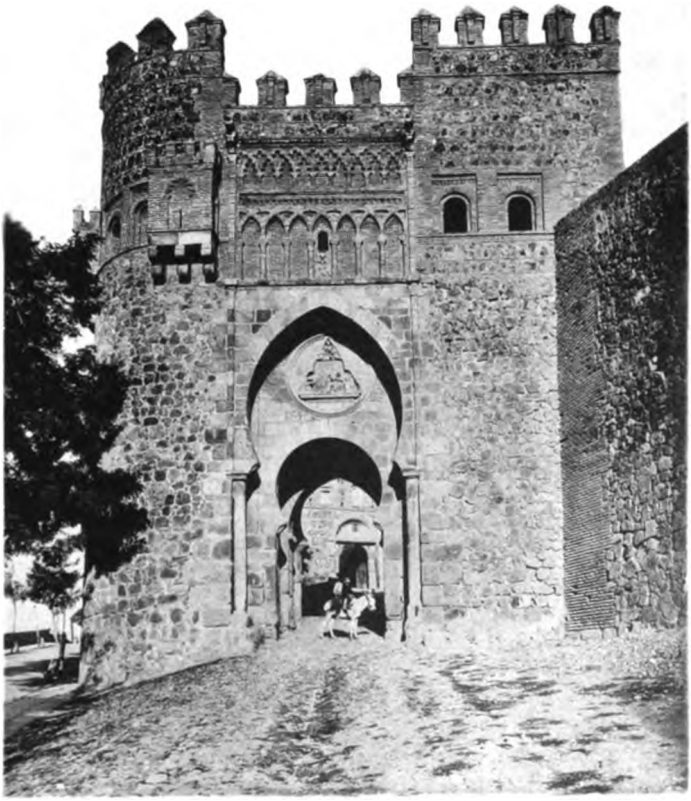
SECULAR OUTLINE I

	Spain	Constantinople	
1000			
		Revival of Greek (Psellus)	
	Toledo taken (1085)		
1100			
	Translations Robert of Chester Gerard of Cremona		
			Era of Crusades
1200	Encyclopedists	City sacked by the fourth crusade 1204	
			Baghdad fell 1258
		Greek restoration 1261	
1300			
1400			
		City taken by the Turks 1453	Fall of the Roman Empire (East)
	Granada taken 1492		
1500			
			Fall of the Roman Empire (West)

Moorish customs were assimilated and as a result of the general weakening of the wall of separation, translations of some of the scattered treasures of the libraries began to appear. Much of this work centered in Toledo. In fact, about fifty years after the fall of the city, Robert of Chester had begun his famous translations, which, like seeds sown on the ashes of the burned libraries, were destined to bear fruit in a new and amazing civilization.

Constantinus Africanus, who died about 1087, was one of the first to begin systematic translations. His work was centered upon medicine. Adelard of Bath, fifty years later, translated the astronomical tables of Maslama Al-Majriti. The famous philosophical classics of Greece early appeared in Latin, bringing a storm of controversy over the works of the newly discovered Aristotle, whose profound thoughts it was difficult, in places, to harmonize with the pronouncements of the Church at Rome.[8] Intellectual Europe was aroused to discover the ancient learning. The watchword was "Return to the past" and in this search, in order to train young men to study the literature,

[8] In the sixth century, Aristotle's logic had been translated by Boethius. Plato was known in a Latin translation of the *Timaeus*. But the interpretation of these books was overlaid by Neoplatonism—especially by the influence of Augustine. The discovery of the authentic works in Constantinople, for the first time disclosing to the Christian world the actual Aristotle and the many-sided Plato (free from Neoplatonic commentaries), produced that excited interest which gave birth to the rise of Humanism and the Revival of Learning in the fourteenth century which, in turn, introduced the Italian classical Renascence in the fifteenth century. (See also Chap. XII.)



TOLEDO GATE

Built by Alfonso VI in 1109. Through this gate issued many important alchemistic manuscripts. Symbols of alchemy fill the circle above the portico.

so long hidden from them, the first universities were founded and there came also the first of the churchly orders, such as the Franciscan and the Dominican. While the incentive of this age of scholasticism was to gain once more an understanding of Greek thought, there followed gradually a desire toward improvement in all those lines of attainment which their Mohammedan tutors were disclosing.[4]

During the ecclesiastical storm over the works of Aristotle, alchemy was coming into recognition, so that a century after the founding of universities, scholars awoke (1) to the fact that there was in alchemy a theory of matter identical with the teachings of Aristotle; and (2) to the valuable confirmation of this theory in the accepted "fact" of transmutation.

In the twelfth century, besides the *Liber de compositione alchemiæ* translated by Robert of Chester, we have

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[4] Attention has been strongly directed in the past to two technical books which appeared in Latin dress at this time: one, the *Liber de compositione alchemiae* of Morienus Romanus (*Book of the Composition of the Elixir*) translated by Robert of Chester about 1142; and the old *Turba philosophorum*. Both of these held (hidden away in the body of the text) extracts taken directly from Egyptian and Arabic sources. This, which would have been an asset had it been recognized, was completely lost, for both texts were the result of two or three previous translations before they reached the Latin. It has sometimes been said that European alchemy began with the *Compositione*, sometimes with the *Turba;* but it is hard to see how these mutilated and quite unintelligible texts could have served for anything more than a puzzle and exasperation. Contrasted with the clarity of the books derived directly from the Arabic, these are so inferior in intelligibility that their influence on the birth of Western alchemy must have been nearly negligible.

two Latin translations by Gerard of Cremona from the works of the Pseudo-Rases, *De aluminibus*[5] and *Lumen luminorum;* also the Latin of the *Liber divinitatis de septuaginta* of Geber and in 1235 the Latin of *De anima* by the Pseudo-Avicenna. The translations of Rases, possibly that of Geber, and especially some earlier form of *De anima,* became the source books and authorities on alchemy for the famous encyclopedias which appeared in the thirteenth century.

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[5] Robert Steele, "Practical Chemistry in the 12th Century," *Isis,* XII (1929), pp. 10-48.

Chapter x

THE THIRTEENTH CENTURY ENCYCLOPEDISTS

> *Platonists and Aristotelians were incompletely right; they did not even cover the truth between them, for there was something else which might be called the Archimidian spirit which would finally lead to the experimental methods.* Sarton, *II, 2, 710.*

A CENTURY or more had passed since the first translations began to appear in Europe from Arabic sources. The movement to establish universities and clerical orders was already in full swing. Academic life was firmly established, bringing with it for the first time a desire for wide-spread education. A demand was thus created in the thirteenth century for textbooks and for encyclopedic collections of all the knowledge of the world, somewhat on the plan of Pliny's *Historia naturalis*—a demand for books containing knowledge in epitome. This demand was supplied by the encyclopedists.

In the meanwhile, two events occurred about the middle of the century, notable as affecting the Mohammedan-Christian relations. In the West, there had grown up a lessening of the profound military antagonism which had so long separated the two hostile camps. This is indicated

by the last crusade, half-hearted and disastrous, which came in 1270.

The second event occurred in the East where a calamity of the most awful magnitude overtook the Saracens in the downfall of Baghdad before the rush of the wild tribes of Mongols, or Tartars, in 1258. With the fall of the city, the intricate system of irrigation about the capital was completely destroyed and thereafter the civilization of Mesopotamia reverted to the desert. Doubtless, as a result, many of the scholars of the East fled into Spain, bringing with them still more literary treasures—an inspiration toward greater interest in academic pursuits.

Arabic alchemy seems to have been reflected, in Christian Europe, first in the writings of the encyclopedists, secondly by their successors, the pseudo-alchemists, and thirdly by the Phlogistonists—all of whom, in matter of theory, were imitators, receiving and copying the thoughts expressed by their predecessors and quoting at length what was to them and to mediæval Europe unintelligible. As knowledge of Greek philosophy became more exact, we find works on alchemy restating the fundamental theories. Thus the Pseudo-Arnaldus of Villanova (fourteenth century) says:

> There is only one first matter of the metals. According to a natural action, according to the degree of cooking, it clothes itself with different forms.

. . .

All metals are resolved into mercury. Therefore mercury is the first matter of all the metals . . . this reduction into the first matter is easy and transmutation is possible and feasible.

Geber says:

Gold is formed from a very subtle mercury and a little very pure sulphur, fixed and clear, having a neat redness. And as this sulphur is not equally colored and one is more tinted than another, so it happens that gold is more or less yellow.

The theory of the ferment, or seed, is frequently found. Thus the title of a well-known book was *Consilium conjugii, seu de massa solis et lunae,* the subtitle meaning *Concerning the Ferment of Gold and Silver.*

But, as regards the Egyptian color theory, the chemists of this period knew nothing except the vocabulary. With this they were very familiar. But the theories which these same words had reflected in ancient Alexandria were unknown; and, had they been known, would still have carried no appeal. The world had outgrown these ideas. Still there are given on nearly every page of these later alchemists color words, the old color sequence and colors taken as indicators of the successive steps of transmutation.

Note how clearly Paracelsus in the sixteenth century copies the sequence of colors:

The demonstrative signs are colors. . . . The first is black. . . . The white color succeeds the black . . . wherein the

philosophers sow their gold. The third is orange. The fourth is ruddy or sanguine. Besides these, almost infinite colors appear and show themselves as vapors, as the rainbow in the clouds.

The somewhat mythical Alexandrian Pelagus is quoted as asking, "Has not the tinctorial art been invented in order to make tinctures which is the end of all art?"

So also we find the name for arsenic sulphide, used in the coloring of metals, was *auri pigmentum*—the tincture of gold—which is now orpiment. We remember also the significant quotation, already given from Jean de Meung (thirteenth century):

> On d'alchemie tant apreng
> Que tous metanz en color tainge.

I.e., Let [art] learn enough alchemy that it may stain all metals to color.

Vincent of Beauvais, the encyclopedist, expresses doubts as to transmutation, yet clings to color:

Artificial gold is best—which is to be understood in the sense of color, not in substance.

It was very significant that color (the spiritual) was held to have the power of reproducing itself, for though many refused to believe that a metal was gold because it was yellow, yet they accepted that more difficult tenet of the Egyptians that yellowness, once introduced, started the base metal toward gold. This was the idea embodied in the old "coral of gold," the "ios," allied to the ecclesi-

astical spirit or spirit of perfection, which, cast on our naked souls, would cleanse us from all sins.

The first of the Christian encyclopedists of whom we have knowledge was Bartholomew Anglicus who brought out, probably about 1240, his *Liber de proprietatibus rerum,* which proved a most successful book.[1] It was used in the universities as a text and also by the clergy. It was translated into Dutch, French, English, and Spanish. Bartholemew's scientific facts are drawn mostly from Pliny and Isidore of Seville (seventh century) as well as from Avicenna's *De anima.* Arabian influence is quite marked, but it is neither a translation from the Arabic nor does it contain much that is original with the author. It is rather a clever compilation from many authors, the source each time being carefully acknowledged; expressions such as "as says Isidore," coming in with strange monotony. As a result of this publication and as a reward for its teaching, the chemical theories and facts of the Mohammedan school became familiar to scholars throughout Europe.

What has been called "A stupendous encyclopedia of human knowledge" appeared about the same time, written by Vincent of Beauvais (*d.* 1264?). This book, entitled *Speculum majus,* is divided into eighty sub-books, one of which, called *Speculum naturale,* contains facts relating

[1] Robert Steele, *Mediæval Lore from Bartholomew Anglicus,* 1924.

to chemistry. In this *Mirror of Nature* we have a great mass of information which reflects very well the condition of chemical knowledge of the time. Many of the quotations are from an Arabian encyclopedia of the tenth century, called the *Book of the Faithful Brothers* (*Ikhwan al-safa*).[2] The origin of the metals in mercury and sulphur is derived by Vincent from this source. Transmutation is discussed cautiously as if theoretically it could be accepted but with the caveat that many frauds were being imposed upon the unsuspecting: "Alchemy may be to a certain degree false, nevertheless . . . by the ancient philosophers and by artisans in our time it has been proved to be true"; again, "by tincturing white to a yellow so that it may seem to be gold, also by removing the impurities of lead so that it may seem to be silver; but it will always be lead; but they may produce in it such qualities that they may deceive men in it."

Toward the end of the century, there came that prolific writer and brilliant scholar, of greater renown than Vincent, the Dominican scholar, Albert von Bolstadt or Albertus Magnus (*d.* 1282). In chemistry he had no practical experience, yet he was an earnest student of Aristotle and by wide reading had made himself acquainted with alchemistic theories, as derived from those of the great Greek. He was the first to express his own views on the

[2] See Sarton, *Introduction to the History of Science*, I, pp. 593, 660 and 752.

topics under discussion, speaking as one of authority, very differently from his more cautious predecessors. Moreover he differs from the pseudo-alchemists of the following centuries in tempering his statements with moderation and in trying to make every assertion clear. His authentic work is *De rebus metallicis et mineralibus.* Like the *Speculum,* it helped to spread abroad the facts and theories of alchemy, as then understood. Like Vincent, he states that the alchemist "ever colors with a yellow elixir into an appearance of gold and with a white elixir to the resemblance of silver." In such statements we see that what had been believed to be actual transmutation in the days of earliest alchemy was reflected in the language of the modern alchemist but that this language was looked upon as the delightfully naïve prattle of children and carried no conviction.[3]

Contemporary with Albertus was Roger Bacon (*d.* 1284) theologian and philosopher, a Franciscan and Platonist, enthusiastic critic of authorities and teacher of mathematics and optics. His writings on science were characterized by an enthusiasm which aroused an interest such as had never before been known in Europe. He was also the first to devote a special section to experimental science, in which, however, he seems to have been before

[3] Lynn Thorndike, *History of Magic and Experimental Science,* II, 568.

his time, for all his works, except this section,[4] were very popular and were often reproduced.

ENCYCLOPEDISTS OF THE THIRTEENTH CENTURY

Bartholomew Anglicus
Liber de proprietatibus rerum (*c.* 1240)
Vincent of Beauvais
Speculum naturale (*c.* 1250)
Albertus Magnus
De rebus metallicis et mineralibus
Roger Bacon
Opus majus (1268)

PSEUDO-WRITERS OF THE FOURTEENTH AND FIFTEENTH CENTURIES

"Albertus"; "Roger Bacon"; "Arnaldus"; "Raymundus Lullus"

These four encyclopedists, together with other writers of the thirteenth century, though they contributed nothing of themselves to the subject of chemistry, either theoretically or experimentally, yet aroused such interest in science that, by systematic propaganda of education and by their enthusiasm, they unwittingly initiated that mad rush to "make gold" which continued through three cen-

[4] Thorndike has shown that what was meant in the thirteenth century by experimental science was quite different from Geber's laboratory experiments and also from our modern understanding of the term. Experimental science was accurate observation. Confronted by many accepted statements of marvelous occurrences, Roger Bacon denounces rumor and called for reliance upon tested observations (Thorndike, *op. cit.*, II, 536-548, 650-658). Also, those whom he calls "experts" are merely trained observers, standing ready to question the authenticity of each popular mystery.

turies. Starting with the publication of recipes, followed by laboratory work (carried on secretly, and in defiance of the edicts of church and state), it ended with all edicts swept aside and every obstacle overcome. A crowd of young men in Paris followed the *ignis fatuus* of alchemy, led as if by mob rule to produce gold by a process which the increase in knowledge and the accumulated experience of ten centuries had already proved impossible! No longer did a sequence of colors, as in Egypt, suffice to bring out any appealing theory which explained their experimental process. The idea of gold in the Aristotelian sense, of gold as the "final cause" in an organic inheritance; or, in the artistic sense, of gold as the highest color toward which all metals were drifting in their striving toward perfection—such ideas, under the stern realities of the practical man, were giving place to gold as an unyielding entity, which defied all efforts toward artificial synthesis. Three more centuries of failure were necessary to bring home the futility of simple belief in a statement founded upon the literal translation of ancient terms. These three centuries of a so-called alchemy, so different from the ingenuous native alchemy of Egypt, will be discussed under Pseudo-Alchemy (Chapter XII).

But first let us review the subject of Islamic alchemy, for in this, as badly interpreted by the encyclopedists, we find the ground material for these years of folly.

Chapter XI

A RÉSUMÉ OF ISLAMIC ALCHEMY

But our gold which has the desired quality can make gold and tint into gold. Jildaki.

It has been shown in previous chapters how, after the alchemy of Egypt had grown to maturity, it was transplanted to a foreign soil and there, languishing for a time until life was nearly extinct, was brought again to activity by the Geber school.

To pause here and review what was accomplished by the Arabian alchemists, what new principles they initiated or compounds they discovered and succeeded in transmitting to the Christian nations and especially to form an estimate of the value of this intermediate alchemy on the progress of science, is the object of this chapter.

It has been demonstrated that the conception of alchemy received from Egypt was modified by Geber, and we have followed its fortunes up to the period when, with increasing points of contact between Islam and Christianity, the literature of alchemy was transmitted, through Latin translations, to the northern nations just awakening to a realization of a culture which had been Greek

but was, as received, the possession of the Moors, their most hated enemies.

We have seen how such writings as those of Jabir, Rases and Avicenna had influenced the encyclopedists to spread the new doctrine abroad and popularize it.

As we are now passing from a purely Arabic alchemy (which had survived from three to five centuries) to that distinctly European propaganda which burst upon Spain and France about the beginning of the fourteenth century, forming an alchemistic cult of proportions hitherto unknown, let us take a last look backward to decide, first, what Islam inherited from Egypt; secondly, what may be called the original Arabian contributions which we owe to these valued conservators of alchemy; and thirdly, what, out of this total, survived the second transplanting and came through the centuries to stir all Europe to the mad dervish dance of pseudo-alchemy.

Conditions in Alexandria had been very different from those at Baghdad. Egypt, with its crafts held in honor and its inheritance of Greek philosophy, had been ideal for the planting of alchemy. Egypt needed no instruction in the value of laboratory technique, and its people found the marvelous inventions in metallic colors fully explained by a philosophy already three centuries old. The triumph of the Egyptian philosophers (who called themselves the "new expositors of Plato and Aris-

totle")[1] consisted in the application of the old Greek theories to the technique of the shops. The survival of Greek alchemy was due to the fact that the theories, thus applied, furnished a plausible explanation of the colors produced and opened up an extensive research into the possible realms of transmutation as illustrating the religious belief of the influence of the spirit on the body; while on the other hand the technical work gave to Greek philosophy an unexpected experimental basis which, taking it out of the realm of pure theory, made it acceptable to practical men of affairs.

As long as this partnership of practice and theory was maintained, real alchemy survived. But this was not to continue. Indeed, by the end of the Egyptian period, the separation had already taken place. Practice had been divorced from theory. There had been a drifting apart—or perhaps a sudden break—of these two partners formerly so much in accord. Alchemy, true alchemy, no longer existed. The separation was permanent and never in the schools which follow do we find transmutation explained in the naïve Egyptian manner.

Still, practice and theory continued to exist, taking up their lives anew on separate lines—practice, continuing down the centuries as the bronzer's art of the workshop;

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[1] Berthelot, *Collection des anciens alchimistes grecs*, I, 9; *Les Origines de l'alchimie*, p. 129.

theory, the theory of the metals and transmutation, continuing in the manuscripts, but all the time becoming more and more a branch of the greater philosophy of Greece, to which laboratory demonstration was deemed unnecessary. It was this speculative philosophy that was inherited as alchemy.

Nearly all the ideas expressed in Arabic alchemy were, and naturally would have been, derived from Egypt, except that the simple Egyptian faith in the potency of color failed to appeal to the alchemists of Islam. The color theory at times seems to have become very hazy, to have descended to a mere jargon of inherited terminology.

This is what we should expect, for alchemy was not transmitted with all its Egyptian traditions to Persia. It was discovered in the libraries of Baghdad, in the literature with which the academy was stocked in the eighth century, the books being salvaged, possibly, from Jundi-Shapur. The writers on Egyptian alchemy, though few, had written with conviction and enthusiasm and some of this spirit the new school seems to have caught. Still many things Egyptian could not be transmitted by the stylus. The Egyptian's love of color, his amazement at the bronze colors produced on metals, would not have appealed to the Mohammedans had they been transmittible. The Egyptian's love of hard work, his adaptability to

laboratory experiments, could not have been stated in the literature nor, if so stated, appreciated by the effete Court of Baghdad.

By this time, there had occurred that separation of the art from the theory of alchemy of which we have just spoken, so that theory alone was recognized under the general term alchemy. Of the truth of this theory Jabir (or the Jabir school) became convinced; but with true scientific spirit he determined to test it by the laboratory experiments which he found interspersed with theory and discussion, on the written page. The experiments which he has recorded are all found in the Egyptian writings but (which he probably did not know) some of them are found, also, in the works of Dioscorides.[2] The laboratory methods which Jabir used were distinctly Egyptian. Distillation and sublimation in reflux condensers were notable inventions of the earliest alchemists. These methods were described in literature accessible to him.[3] Beyond the merely technical processes, those of more theoretical bearing, such as the reduction of the metal to an impalpable powder,[4] purification by calcina-

[2] Dioscorides was the first to mention indigo. He prepared mercury from distillation of cinnabar and charcoal. Also he prepared lead acetate, copper sulphate, quicklime and limewater, as well as lanolin for waterproofing.

[3] Berthelot, *Collection des anciens alchimistes grecs,* III, XLVII, 5, Zosimus among many others.

[4] "The iosis . . . is destined to produce an extreme attenuation" (Berthelot, *op. cit.,* III, LVI, 2; also IV, I, 9; and Traduction, p. 62, note 1).

tion,[5] and purely theoretical ideas, such as transmutation,[6] the doctrine of the hidden and opposite natures existing actually or potentially,[7] and the idea of the ferment[8]—all of these are found as well in the Egyptian literature.

But the mercury-sulphur theory of the composition of the metals, which had been expressed in Egypt as color-principles in a philosophic sense (as "water" and "fire")[9] took on with Jabir, for the first time, the conception of *substantive* principles.

The idea also of el-Iksir, the "elixir," founded upon the Egyptian "ios" or "coral of gold,"[10] had become, by the ninth (or tenth) century, part of the common alchemistic language. It also finds its first expression in the Arabic literature.

With the Jabir school, the preparation of the elusive elixir became the great objective of alchemy—the preparation of a "powder of projection" which cast in small quantities upon a base metal of no matter how great an abundance, would ferment the whole into the purest gold. In this pursuit, Jabir was able to hold the attention and arouse

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[5] *Passim.*

[6] See Chap. VI; also Berthelot, *op. cit.*, III, XXVIII, 4, 7.

[7] Berthelot, *op. cit.*, II, I, 13; II, III, 6, 7, 8; II, IV, 38, 48; III, VI, 21; III, XXIX, 3; IV, I, 4.

[8] See pp. 75, 95, ante; also Berthelot, *op. cit.*, III, LII, 4; III, X, 3; III, XXI, 3.

[9] See pp. 112, 115-116, 119, 120.

[10] See pp. 71, 80, 84-85, 123.

the interest of his contemporaries. As the great master (as he was called) he controlled the scientific thought of the alchemists of Islam to the end so that his name stands even now for *the authority* on Arabian alchemy. Jabir is quoted by all his successors.[11] His example and some of his precepts were transmitted through Rases and Avicenna to Western Europe and his emphatic restatement of the mercury-sulphur theory controlled the world of science, even to the time of Lavoisier in the eighteenth century.

Jabir found alchemy discredited and despised. He ennobled it and tactfully, according to Majriti,[12] built up for it a position equal to that of philosophy or medicine. His insistence upon bringing all science back to an experimental basis, a sign of his wisdom, proved one of his greatest contributions. For though in alchemy he found very few devotees able to follow him actively into the laboratory, yet this attitude toward research was established by him, at least as a record and example; and the question of the composition of the world of matter was placed by him fairly before the tribunal of scientists for ultimate decision.

To return now to the search for the elixir, so strongly stressed by Jabir—we can see how the allure of its possible discovery must have taken a strong hold upon the

[11] But "Avicenna" is not complimentary in his reference.

[12] Holmyard, *Isis*, VI (1924), 293-305.

imagination. By the elixir each base metal was to be transmuted into gold. But, anticipating this elixir which was to be, there was already evidence of transmutation in particular instances. Without waiting for the universal transmuting agent, Jabir was able to advance proofs of transmutation, which were perhaps more practical than those Egyptian proofs which depended on color theories. For instance, copper alloyed with tin was changed into a white metal,[13] presumably silver. In view of this experiment, who could doubt that transmutation had taken place?

But the conclusion drawn from this experiment laid itself open, on the practical side, to opposition. By the tenth century doubts[14] arose as to the actuality of transmutation for which doubts there were two good reasons. First, the individual character of the metals was becoming more and more recognized by men connected with the

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[13] Jabir does not draw attention to the fact that this same transmutation process had already appeared in one of the recipes of the Leyden Papyrus, perhaps six hundred years before.

[14] See Chap. X; also, Berthelot, *La Chimie au moyen âge*, pp. 282, 285, 292. See also, in Holmyard and Mandeville's recent translation of Ibn Sina's *De congelatione et conglutinatione lapidium:* "As to the claims of the alchemists, it must be clearly understood that it is not in their power to bring about any true change of species. They can, however, produce excellent imitations, dyeing the red white so that it closely resembles silver, or dyeing it yellow so that it closely resembles gold." . . . "Those properties which are perceived by the senses are probably not the differences which separate the metals into species but rather accidents or consequences, the specific differences being unknown."

growing mining industry, practical men who knew their metals as such, men whose minds were untrammeled by ancient philosophical "nonsense."[15] Secondly, the mad enthusiasm of the search for the elixir induced some alchemists to claim that they had succeeded in making gold—had already attained the goal! But when these claims were examined, they were unsubstantiated, and in consequence firm opposition to the whole transmutation theory was aroused among the educated and influential classes.[16] During the transmission of alchemy into Western Europe, such great authorities as the encyclopedists, following Ibn Sina in the *Shifa* and Avicenna in the *De anima,* began to reject the arguments in favor of this ancient belief but clung to color. Vincent of Beauvais and Albertus state that the production of a surface color on a metal (which in the old days had satisfied the Egyptians) did not produce pure silver or pure gold.

Thus by the thirteenth century Jabir's arguments for transmutation began to lose ground, just as the Egyptian color theory had failed before Jabir, and a very shattered alchemy was received by Europe. If alchemy were to continue and to succeed, a powerful appeal was needed for

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[15] Avicenna, in the *De anima,* gives seven practical criteria for gold alone (Berthelot, *La chimie au moyen âge,* I, 304). These tests are: Solution, the touchstone, weight, taste, fire, sublimation, fusing.

[16] The Pseudo-Avicenna, with open mind, frankly discusses in the *De anima* the question of transmutation pro and con.

its growth in the new soil and unaccustomed atmosphere.

It seems strange to us of today that the enthusiasm for the newly discovered Aristotelian philosophy, as well as for the ancient and misunderstood claims of the childlike Egyptian, with his love of color, should have so enchained the judgment that men who already understood the specific gravity test of Archimedes (third century B.C.) should not have refuted the claims of alchemy out of hand. It is only another indication of how far removed was the training of the fourteenth century from the precept of Geber—firm reliance upon laboratory experiment.

But we must not inject into the philosophy of those days too modern notions. Rather let us try to place ourselves *au courant* with the ideas of the times. Granted, said the alchemist, that common gold has definite properties of weight, color, hardness, fusibility, etc., yet it is inferior, not having kinetic properties. It cannot act as a tincture to produce more gold.

The use of such Egyptian expressions as "tincture" was still very common. This particular term signified a transmuting agent. Its original significance, as a coloring agent, was still also in use but the connotation had been forgotten. At present we use the expression tincture of iodine in the same forgetful way. Jildaki, in the following passage,[17] seems to come nearest to the connecting idea:

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[17] Al-Burham (*The Proof*), Royal Library, Cairo, no. 9804.

Common gold does not produce a tincture by which metals may be transmuted, since it contains only sufficient color for its own body. It contains no surplus tincture, but our gold, which has the desired quality, can make gold and tint into gold.

According to Zosimus, "spirits" were either sublimates or substances reduced to the finest subdivision, by which, as with the fine material of a dye, metals could be colored. He uses spirit in the theoretical sense of the fire element, the reproductive element, or *quinta essentia,* the fifth or higher element which gives character to and controls and continues the metal bodies. So Zosimus says, "The mystery of the gold-tincture is to change Bodies into Spirits in order to tint to spirituality." But Avicenna, unacquainted with this derivation, knowing only the theological meaning of spirit, perhaps also following Aristotle, chose to name his famous book *De anima in arte alchemiæ* (*The Spirit in the Art of Alchemy*).

Thus the expressions of earliest alchemy were still in current use, having been handed down by successive manuscripts, although the original connotation had been long since lost and forgotten. What a help it would have been in clarifying this situation if there had been present one thoroughly trained philologist who would have interpreted the terms of real alchemy—*e.g.,* the original Egyptian meaning of such expressions as the familiar

SECULAR OUTLINE II

1300

Pseudo-alchemists

1400

Early laboratories

Printing

1455

1492 { Fall of Granada / Discovery of America

1500

Iatro-chemists

1600

1642 { Death of Galileo / Birth of Newton

Boyle

Lemery

Phlogiston

1700 Stahl

1800

"body, soul, and spirit," the "tincture of the metals," the "tempering of copper," the "baptizing of fabrics," and all the color ideas locked up in that oft-quoted and ancient sequence: black, white, yellow, and violet! The Pseudo-Albertus, in the fourteenth century, changing yellow-violet to red, states: "Our stone has three colors. It is black at the beginning, white in the middle, red at the end"—a sequence even then considered necessary for success in the transmutation process although its *raison d'être* had been forgotten. The interpreter never appeared and men continued to grope for the truth, following the blind lead of a literal translation.

Alchemy, on entering Europe, was already discredited; and, as in the time of Jabir, "those who did accept it were of the most ignorant type." Since also there was no master-mind, no modern Jabir, to bring alchemy to a new birth, and no compelling discoveries had emerged from the Islamic laboratories to impress the value of alchemy upon a practical world, the prospects of alchemy occupying a position of helpfulness in the scientific inquiry into the nature of matter were poor indeed.[18] With the excep-

[18] An estimate of the experimental contributions from the Arabian laboratories can be made only in the sense of a general impression. The work of translation of even such important authors as Jabir and Rases is still in its first stages. In Holmyard's recent reviews, it has been shown that Al-Majriti describes the preparation of the red oxide of mercury but it is probable that preparations of a novel character were not numerous as only a very few are mentioned in the extensive writings of the encyclopedists of the thirteenth

tion of the recognition of the mineral acids, to which may be added certain empirical facts developed in the mining industry, the experimental knowledge of the thirteenth and fourteenth centuries was very little in advance of that of the third century of our era.

One fact, however, is to be noted which allowed this more modern alchemy a chance to survive—the mental inertia which (in an age when the existence and reality of matter in its individual forms, such as silver and gold, was impressing itself on human consciousness) still compelled men to revert to the Platonic conception of the non-essential character of "matter" and to the magnification of qualities as entities, qualities kinetic and catalytic, infinitely spiritual and all-controlling!

And now, out of all the ancient theories, what survived? First and most permanently was the mercury-sulphur composition theory, established by Jabir. There survived also the quest for the "elixir," the desire to discover a method of "making gold"; and the conviction expressed

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century and only a few more by the pseudo-alchemists of the following century. There occurred, in the thirteenth century or a little before, the important discovery of the mineral acids, but we do not know whence this came. It is important to distinguish discovery from a casual mention, such as in this case the distillation of salts from alum which produced "solvent waters." The term "discovery" usually carries a more definite import. The alchemists had hydrogen sulphide (Leyden Papyrus X, 89; Zosimus, in Berthelot's *Collection des anciens alchimistes grecs*, III, VIII, 1, 2) many centuries before Scheele's discovery of this gas. Rases' effervescence (Berthelot, *La Chimie au moyen âge*, I, p. 309) may have been eight centuries earlier than Cavendish's discovery of hydrogen.

by Jabir that this end could best be accomplished by laboratory work—and a very valuable incentive to knowledge this proved to be.

When the discredited alchemy had been received from Egypt by Jabir, an earnest attempt was made to reinstate the inventions, discoveries, and the applied philosophy. From the viewpoint of medicine, the need of greater knowledge of materials for use in the cure of the body was also seen; and here again it was realized that laboratory research was the thing needed. Knowing his people, Jabir saw the need of an incentive, and by the allure of the mystical elixir he succeeded in arousing the interest of the Court in Baghdad.

Again, in the thirteenth century, alchemy found itself in the hands of an unappreciative and foreign people. But this time it was to figure in the center of the stage before an excited and noisy populace, led on by the expectation of marvels and wonders such as had previously been beyond the imagination of man. Let us see what was the new incentive and what the development in this new environment.

Chapter XII

PSEUDO-ALCHEMY

Fourteenth, Fifteenth and Sixteenth Centuries

For a very long time this science has been pursued by learned men. If it had been possible, in any way, to gain the end, one would have succeeded a thousand times already. Darmstaedter, *Die Alchemie des Geber.*

DURING the thirteenth century, scholasticism reached the climax of its development. The leaders of Western learning, guided by the newly discovered knowledge derived from Mohammedan sources, enthusiastically supporting the new universities and resting their faith upon the imperfect and partial translations of the Greek classics, colored as they were by the doctrines of Plotinus, had expressed their greatest ambition in the collection and ratification of the knowledge of the ancient world. Nearly everything received was accepted by them as true. Roger Bacon took the *Secretum secretorum* of the Pseudo-Aristotle as his guide, never questioning its authenticity. Doubts, questions leading to original thought, were systematically suppressed, for the ancient world had been drilled under the Roman law of obedience to authority.

The first blow to this childlike faith came in the discovery, in the thirteenth century, of the original works of

the Greek authors. Boccaccio, followed by many others, journeyed to Constantinople, before the fall of that city, bringing back precious manuscripts in the original Greek. Then learning became the fountain of renascent youth—the resurrection of the mightiest spirits of the past. "I go," said Cyriac of Ancona, "I go to awake the dead." While the church had been picturing as the only reality the present and future state of man's soul, this new view brought strength to man's self-esteem and the world awoke to the triumphs of the Italian Renascence which may be said to have lasted from the fall of Constantinople in 1453 to the fall of Rome in 1530.[1] As these newly discovered manuscripts were studied in the universities, there was revealed—in addition to the subject-matter—an enlightening picture of the Greek state with its diversity of opinions and freedom of thought, an image of the individuality of the citizen, in an era before the coming of Christianity, which served as an object lesson not to be disregarded.[2]

The three centuries which followed will be treated here

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[1] See Preserved Smith: Encyclopædia Brittanica (1929).

[2] The Latin occupation of Constantinople occurred in 1204. Michael Psellus, two centuries before, had revived interest in the ancient Greek literature (see chart, p. 159), so that, on the return of the missionaries from the East with the real Aristotle, the condemnation of the Neoplatonic Aristotle (by church decree of 1209) was modified in 1231 to read "allowed under supervision"; and in 1254 Aristotle was reëstablished as a subject of study in the University of Paris.

as a continuous unit. Outside the realm of chemistry they form the most notable period in the history of Christian civilization. The older culture, with its petty strifes, its wars of subjugation and extermination, its herding of the masses and its local issues, gradually gave way to new interests and to a general awakening on broader lines.

In the fourteenth century, in spite of the awful scourge of the "black death" which decimated Europe and brought a distinct pause to all activities, there began the Revival of Learning, which, initiated by the classical translations of Petrarch (fostered by the noble family of the Medici) later spread all over Western Europe and resulted in the great awakening in literature and in art and, still later, in the sudden development of the physical sciences. Owing to this movement, many discoveries were made which increased its initial momentum. In the latter half of the fifteenth century, events so broadening to the mental outlook of the people crowded into a few years, that it was then that the age of scholasticism is said to have closed and the Golden Age of the Renascence, the rebirth of Christian civilization, is said to have begun.

In the year 1453, the Turks, who had been gradually closing about distant Constantinople, finally took the city and, as a result, the classical scholars of the school of Psellus were scattered over Western Europe, bringing, at a most opportune moment, new life to the classical move-

ment already started. The discovery by the Portuguese in 1489 of the new passage to India, followed in 1492 by the discovery of America, broadened the view of the civilization, which had ever centered about the Mediterranean; and when in 1522 Magellan's voyage around the world was completed, civilization for the first time acquired an outlook which was world-wide. In the year of the first voyage of Columbus, occurred another event of great importance to the peace of Spain, the fall of Granada and the final withdrawal of the Moors from the peninsula. The invention of printing with movable type, just in the middle of this period, 1455, had brought about, for the first time, the possibility of a reading and instructed public. Certain results naturally followed this important invention. Individual opinions could no longer be suppressed. The independent citizen of Athens had stepped forth from the picture. Moreover there arose a general revolt against the time-honored scholasticism, as represented by Aristotle, and a tendency to return to the mathematical science of Euclid and his successors, with a general questioning of authority in church and state.

The mind, thus freed, leaped forward to a new experience. The citizen of the state became geographically, socially, politically, even theologically, a citizen of the world. Authority, which had been centered, became divided among the thousands of free individuals who could form

opinions. There came then that greatest aid to civilization, the widespread vitalization of creative thought.

In the hundred and fifty years following the invention of printing, advances came rapidly in art, in architecture, and in literature. Came also the Protestant Reformation, attempting to establish freedom of interpretation in clerical matters. Astronomy, advancing the influence of the hardy navigators who had demonstrated the existence of other lands besides Europe and the littleness of civilized Europe in comparison with the great round world—astronomy, through Copernicus, compelled the attention of the amazed citizen and startled theologian to this tiny dot which we call earth, revolving about the sun as a center. The geocentric theory, held for a matter of fourteen hundred years, was abandoned for the heliocentric. This, later, was confirmed by the use of the telescope in the hands of Galileo and established by the work of Kepler—the latter, in turn, making possible the development of a universal mechanics by Newton. In anatomy and physiology, the work of Vesalius was revolutionary and led up to the discovery of the circulation of the blood by Harvey, stimulating anew the experimental study of biology. Freedom of thought, born of Plato and Aristotle, struggled against the ecclesiasticism and absolutism of the mediæval age. So far was this struggle successful that this period, in contrast with the preceding centuries, stands

forth in nearly all lines of endeavor as an era of great discoveries.

But not so in alchemy! Founded upon a mistake in interpretation and translation, buoyed up by the false hopes of the people, advertised and exploited by charlatans, alchemy remained mediæval while all other sciences advanced. Alchemy and the Church, rooted in sacred tradition, were deprived of freedom of action and remained static. The errors of the Church were to some extent corrected and counterbalanced by the growing intelligence of its devotees, but alchemy, having no such resource, demonstrated by sharper and sharper contrast with the growing uplift its inadaptability to the Western mind.

Entering the thirteenth century, we begin that period when alchemy was received by Western Europe from Rases and Avicenna in its Arabian literary expression, little modified from the ancient Egyptian. But as this Arabian alchemy was misunderstood and distorted by its modern recipients, we find a complex of ideas very different from real alchemy. Thus arose in Western Europe a false alchemy or pseudo-alchemy—an alchemy false in its conception of what the originators of this art had sought to explain and an alchemy vain in its possibility of success.

Fortunately, the very literalness of the expressions used by these false alchemists helps us to see more clearly and

to confirm our conception of that which the ancient alchemy of Egypt had sought, but had endeavored to conceal. In that famous sentence of the Pseudo-Raymond Lully (of the fifteenth century) in which he exclaims, *"Mare tingerem, si mercurius esset," i.e.,* "If the sea were of mercury, I could transmute it [all] into gold"—that very word, *tingerem,* meaning I could *tint* or change its color into that of gold, carries us back to that day when to tint, to baptize (*βαπτίζω*) was the common expression for dyeing and for transmutation.

Since this period has been so widely proclaimed as the only alchemy or simply as "alchemy"—the supposition being that mediæval alchemy with all its errors sprang suddenly into being and so many of our histories of chemistry have devoted a few preliminary pages to this "strange misconception of the Middle Ages"—it becomes important to show that the alchemy of the fourteenth century, which has been described so often and in such lurid colors, was but an incident in the long history of this subject.

We know now that Avicenna's statements were true, that real alchemy was indigenous to the Egyptian soil. We know that true alchemy existed from a date nearly coëval with the birth of Christianity, but that it had been injured by each transplanting. But we know, also—which was not revealed to Avicenna—that the gold which the

true alchemists sought to obtain and succeeded in producing was a gold-colored metal, alloy or bronze; and further that color hunger so filled the minds of the Egyptians that color was the thing desired, was to them an ideal of perfection in the world of metal. In calling color a "spirit" they meant by it a sacred *potentia* or power. In the highest color (that of gold) this spirit was conceived as able to reproduce itself and transmute all metals into perfect gold.

Thus, after the definition of gold had changed, all this ancient interpretation of "transmutation by color" had naturally become incomprehensible, though the vocabulary was on every lip and every page. Thus arose a mad hunt for the means of preparing the philosophers' stone, with its promise of unbounded wealth, together with attendant notions. The objectives of these pseudo-alchemists seem to have broadened out into many forms. They may be listed as follows:

1. The "philosophers' stone" or "elixir";
2. The "alkahest" or "universal solvent";
3. "Palingenesis"—the resurrection of a tree or a plant from its ashes;
4. The "fountain of perpetual youth";
5. The "quintessence";
6. "Potable gold" or "universal medicine."

Before the thirteenth century closed, alchemy had received from the books of the encyclopedists sufficient favorable advertising, with occasional caveats in reference to its malpractice, to arouse the interest of the people; and, at some unrecorded time before the fourteenth century, there had been two important chemical discoveries which had doubtless stimulated popular interest and helped to spread abroad the "Arabian science" of the encyclopedists. One of these was the discovery of gunpowder, foreshadowed by certain recipes for "Greek fire" in the *Liber ignium,*[8] as well as by the gradual recognition of the existence and value of saltpeter as differentiated from soda and other white salts formerly known collectively as "nitron." The second discovery was that (mentioned above) of the mineral acids, as definite reagents. This valuable addition to the list of reagents, fundamental to the progress of chemistry, proved a tool of great importance to the pseudo-alchemists and later to the mining engineers.

On the other hand, there was one side of the popular intelligence or lack of intelligence, in the early fourteenth century, which cannot be passed over, as it illustrates the food upon which pseudo-alchemy was sustained. Although university education was fostered, it was carefully guarded by the Roman Church and the precepts of the

[8] Berthelot, *La Chimie au moyen âge,* I, 89. Marcus Graecus, *Liber ignium ad comburendos hostes.*

Church were accepted universally by the people with an enthusiasm enhanced by the struggle with Islam. It was an age when doubt would have been disloyalty, an age of faith and unquestioning belief among the masses, and, among the educated, of only sporadic doubt or opposition to Rome. But it was an age when the human spirit, weighed down by the drab routine of poverty, cruelty and unrelieved disease, sought an outlet for its activity in fiction and in satisfaction in the wonders of the past, in tales which it was a pleasure to relate and not profitable to deny. Previous centuries had been filled with fables of martyrs, saints, travelers, and military heroes. Alchemy now supplied its quota of strange stories concerning its triumphs and the deeds of ancient alchemists. It was in such a medium that the great error which we know as pseudo-alchemy was born.

One of these tales gives a neat modification of the old Greek account of Jason and the Argonauts, in which the word δέρας, meaning fleece, is interpreted parchment, or book written on sheepskin.

In Suidas' lexicon,[4] under the word Δέρας (skin), is found this statement:

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[4] Suidas, lexicographer of the tenth century, quoting Photius of the ninth century, who claims to have obtained this interpretation from John of Antioch in the seventh century; see also, for a variation of this story, Photius' *Mirobiblon*, CCL, Chap. 2., "Quadruplex etymologia rubri maris": *τρίτος δέ ἐστιν ὁ Αργολικὸς λόγος, ὃς ἐστι (φησὶ) τῇ μὲν τόλμῃ μέγας, τῇδ' ἀποδείξει κενός*, *i.e.*, which is, they say, great in daring but empty of persuasiveness!

"The golden fleece, which Jason with the Argonauts carried into Colchis, going through the Pontic Sea, taking also Medea, daughter of King Aietes." But this, as is told poetically [5] is not so [!] but it was a book, written upon sheep-skin, teaching how gold might be made chemically. They of that time naturally called this parchment golden from the process [described] in it.[6]

Some of the most revered of the Mohammedan philosophers were accounted alchemists or magicians. Here is a story of the very noted Al-Farabi:[7]

Al-Farabi 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 wise men, who were discoursing with the monarch on the sciences.

Al-Farabi, ignorant of, or else ignoring, the usages of society, presented himself in his travelling attire; and when the sultan desired that he should be seated, with astonishing philosophical freedom 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 astonished to find himself understood by the stranger as by the manner in which

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[5] ποητικῶς may be translated *with poetic license* or *in an alchemistic sense*—the latter because the alchemists were known as poets, which originally had the meaning *artificer*, from the Greek ποιεῖν. Thus the alchemists were poets in the old sense; but also in the new, seeing a divinity in color!

[6] For the original Greek, see Appendix V.

[7] From Waite, *Lives of the Alchemystical Philosophers*, 48.

the reply was given. Anxious to know more of his guest, he began to question him and soon found 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 Al-Farabi disputed with so much eloquence and vivacity that he reduced all the doctors to silence.

The sultan than 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, sung it, and accompanied it with great force 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.

There are also many stories of the trickery of false alchemists who pretended to make gold. Such stories are well known to English readers of Chaucer and Ben Jonson, but the following tale, recently found by Holmyard,[8] is especially valuable because it comes from the original Arabic.

Al-Janbari relates that a Persian impostor came to Damascus and, having filed into small pieces a thousand gold dinars, made the bits up into balls with fish glue, flour and powdered charcoal. He then disguised himself

[8] Holmyard, *Chemistry and Industry*, 1923, p. 388.

as a dervish and sold the balls for a few pence to a druggist under the name tabarmaq of Khorassan. He next clothed himself in a rich habit and made the acquaintance of the vizier, to whom he represented himself as an accomplished alchemist. The vizier presented him to the Sultan, who expressed a desire to see a transmutation. The charlatan wrote out a formula in which, among other drugs, tabarmaq of Khorassan was indicated, to the weight of one hundred mithqals. All the other chemicals were obtained easily but a protracted search had to be made for the tabarmaq. At last it was obtained from a druggist who said that a dervish had sold it to him. Needless to say, the experiment proved very successful; the Sultan was delighted and wished to repeat the operation. However, no more tabarmaq was to be found in Damascus, but the Persian said he knew of a cave in Khorassan where it was to be found in abundance. So the Sultan equipped him with every requirement for the journey and gave him a large sum of money, after which he set out—and never returned.

However much the theories of alchemy were held in doubt, however carefully one felt compelled to guard himself against the pretended adept, yet all the world believed that gold could be made and had been made [9] and

[9] The poet, Jean de Meung, of the thirteenth century, writing on art, gives an excellent statement of the commonly held theory, "So might one who was

many there were who, having read the literature of alchemy, stood ready to begin the "magisterium." [10] All that was needed in the fourteenth century to arouse the popular warmth of enthusiasm to active flame was a detailed description of how to go about the business, the method—which the writers of Arabic origin and the experts had continually concealed.

As demand creates supply, there arose about this time a body of alchemistic literature, quite different from anything yet written on this subject, and all of one character, largely recipes for making gold.[11] Differing sharply from

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an adept do with metals and take from the ores their impurities and reduce them to a pure state according to analogous tinctures and affinities for one another. For they all come from One matter, however nature may have brought them forth. For combined in different proportions within the mines, they are formed from sulphur and quicksilver, as the books say."

[10] See Thomas Norton, *The Ordinall of Alchimy* (fifteenth century), Edition Holmyard, 1928. The following estimate of such adepts whom Norton calls "quackes," occurs in *The Ordinall:*

"But many Artificers have byn over-swifte
With hasty Credence to fume away their Thrifte:
And albeit their losses made them to smarte,
Yet ever in hope continued their hearte,
Trusting some tyme to speede right well,
Of many such truly I can tell;
Which in such hope continued all their Lyfe,
Whereby they were pore and made to unthrife:
It had been good for them to have left off
In season, for naught they found but a scoffe."

[11] Again Thomas Norton (*op. cit.*) is heard, this time with a warning—we fear too little appreciated:

"Avoid all Bokes written of Receipts,
For all such Receipts are full of Deceits;
Trust not such Receipts and learn well this clause,
Nothing is wrought but by his proper cause,

the encyclopedists, these pseudo-alchemists wrote as authorities on technique, as from a knowledge acquired in the laboratory, as if to aid the would-be alchemist seeking instruction in the ancient art of preparing the precious metals. They wrote with enthusiasm, in a style interesting and enticing: "Having accomplished this great work, you will next, with God's assistance, proceed to the last stage of the Magisterium," and so forth, and so forth. But always the last stage is couched in mystery. The "composition of the alchemy" is clearly stated but the method of uniting its components or of using the "elixir" to make gold is held just beyond one's attainment. Detailed directions for the preparation of many substances leading up to the final synthesis of the elixir, sometimes sufficiently incoherent in essential points, mingled with extravagant claims of broad experience in chemistry, aroused the readers' interest during the simpler portions of the directions and then confounded him by the impossibility of success.

One of these writers, the Pseudo-Roger Bacon, assumed the name of the great author, doubtless lest he be appre-

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Wherefore that Practise falleth far behinde
Wher knowledge of the Cause is not in minde.

. . .

"But steadfastly your minde must be set
Fols Coloured Metall never to counterfett;
As they that seek Blanchers or Citrinachions
Which woll not abide all Examinacions."

hended and punished for writing on alchemy. He probably wrote a few years after Bacon's death. His most important work is the *speculum alchemiæ*.[12] There appeared about the same time works by the Pseudo-Albertus, among others the *libellus de alchemia* and the *Compositum de compositis*. The *Summa perfectionis* has been ascribed also to a Pseudo-Geber. Somewhat later, probably at the beginning of the fifteenth century, there appeared the writings of a Pseudo-Arnaldus and a Pseudo-Lullus.[13]

Of all these works, the best and possibly the first, of which the others may have been weak imitations, was the *Summa* of "Geber." [14] But the last, by the Pseudo-Lullus, the most extravagant in its claims, and at the same time the least intelligible, seems to have been accepted by the later alchemists as the most impressive and reliable authority to follow. That oft-quoted passage is from Lullus, when in his enthusiasm, so unbounded, he exclaimed:

"Mare tingerem, si mercurius esset,"

"If the sea were of mercury, I would transmute it [all] into gold."

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[12] Tenney L. Davis, *Journal of Chemical Education*, VIII (1931), 1945. As reflecting Egyptian alchemy, this sentence may be quoted: "When you shall find the supereminent whiteness in the vessel, be sure that in the whiteness, redness is hidden."

[13] The claim that Lullus' writings are authentic has been finally disproved by Dorothea Waley Singer in "The Alchemical Testament Attributed to Raymund Lull," *Archeion*, Vol. IX (1928), Roma.

[14] It is thought that the earliest manuscript of the *Summa* dates from the thirteenth century, but it was not known to the encyclopedists.

As a result of this hectic literature, we find Jabir's precept, in regard to the need of the practical examination of matter, followed with diligence. Laboratories sprang up on every side, secret laboratories, defying the law. Indeed, the very danger of discovery added zest to the work. All sorts of material were subjected to the usual alchemistic processes, distillation, sublimation, and so forth, even human blood, excrement or urine, in the hope that the proper sequence of colors, black, white, red, could be attained.

It was generally accepted that metals were composed not of mercury and sulphur but of a quintessence of each, and these more refined forms must first be prepared from the common forms. Directions for these preparations occupy the larger portion of the literature of this period.

As illustrative of the sequence followed in transmutation at this time (and the identity of this sequence with that followed among the Egyptians) note the following excerpts from the *Compositum de compositis* of the Pseudo-Albertus. The style of language, characteristic of the pseudo-alchemists, is also illustrated. The indicated omissions consist of florid repetitions, containing no useful or additional idea:

> By the Grace of God, you have now the second component of the Philosophers' Stone which is the black earth. . . . Let us now with God's permission pass to the second operation

which is the whitening of our pure earth. . . . Let us pass to the third operation which is the fermenting of the white earth. We must animate the dead body and resuscitate it, to multiply its power to infinity, to make it pass to the condition of the perfect white Elixir which changes mercury into perfect and true Luna. Note that the ferment cannot penetrate the dead body except by the intermediation of Water. The ferment of silver is silver, the ferment of gold is gold. . . .

If you wish to change this glorious Stone, this white king, which transmutes and tints mercury and all imperfect metals into true Luna; if you wish, I say, to change it into the red Stone which transmutes and tints mercury, Luna, and the other metals into true Sol, operate thus: . . . until the material is changed into a very red Stone which the philosophers call Blood or Purple, Red Coral, Red Sulphur. . . . Now let us give thanks to God, sublime and glorious Sovereign of Nature, who has created this substance and given it a property which is found in no other body.

Of course, in such a maze of fascinating language, many were attracted and devoted their lives to the pursuit of "gold-making." Many were, ere long, discouraged and turned charlatan. The Englishman, Thomas Norton (of the fifteenth century)[15] ruined himself and some of his friends financially, and this must have been the unrecorded story of many a mediæval alchemist.

How successful these authors, these pseudo-alchemists were, may be judged by a study of their objective, which

[15] Author of *The Ordinall of Alchimy*. The question of the identity of Norton is discussed by Nierenstein and Chapman, *Isis*, XVIII (1932), 290.

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was evidently to arouse enthusiasm. Never had alchemy been so widely accepted, never had the preparation of the elixir seemed so much a matter of "tomorrow"—needing only a little more laboratory examination of materials, a few more workers to try out all formulas. As he followed one lead after another, the practical alchemist in case of failure (failure which was inevitable), since he believed his instructions reliable, always blamed himself and hoped for success next time.

Paracelsus, in the sixteenth century, praises the industry of the alchemists who were his contemporaries, in these words:

> These are not given to idleness, nor go in proud habit, or plush or velvet garments, often showing 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 labors, 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 the sixteenth century there were hundreds of young men of all stations of life working in the laboratories of Paris in the attempt to make gold. In order to give us a picture of the fortunes of these enthusiasts, busy with their alembics and furnaces, we may cite an extended ac-

count of the life of one, Dennis Zachary, from which it will be sufficient to make a few excerpts.[16]

This young Zachary was sent from his home in Guyenne to the College of Arts at Bordeaux under the guide of a tutor, who, being a hermetic adept, initiated him into the secrets of the magisterium. It was at Bordeaux that Zachary collected quite a book of recipes for fabricating gold. He was then sent to Toulouse to study law; but master and pupil wished, above all, to test out the recipes. They filled their room with furnaces for distillation, calcination, fusion, and sublimation. At the end of the year, the two hundred crowns which young Dennis had received from his parents for the support of his master and himself for two years in Toulouse were dissipated in smoke. Then, his tutor spending the hot summer over his furnaces, in consequence of his enthusiasm, contracted a fever and died, leaving Zachary to his own resources.

After sending home for money and after many more futile attempts at making gold, at last Zachary, finding himself in Paris, became acquainted with more than a hundred adepts, among whom he chose a Greek who claimed to know how to change cinnabar into silver. They worked together and the work seemed successful, that is, there was an increase in the weight of silver introduced.

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[16] Hoefer, *Histoire de la Chimie*, 1866, II, 110; T. L. Davis, *Isis*, VIII (1926), 287.

Zachary writes, however: "If there were profit, God knows it,—and I also, for I spent more than thirty crowns on it." At the end of three years, eight hundred crowns had entirely disappeared.

He then received a letter directing him to proceed to the Court of Henry of Navarre, who had heard of his success and promised him four hundred crowns if he would carry out the transmutation at the royal palace. But the result of his labor corresponded badly with the king's hopes, who, disappointed with the artist, dismissed him with many thanks as recompense. When Zachary called for the execution of his promises, the king replied: "Show me, sir, if there are any things in my realm which would satisfy you, such as confiscation, prison, or any such thing; I would give them to you gladly."

Returned to Paris, the Holy Spirit directed Zachary to follow Lullus only. With this inspiration, he returned to Toulouse, where he remained with his furnaces with great diligence, watching all summer for the appearance of the three colors which the philosophers had written should follow in proper sequence before the perfection of the divine work. The three colors, so long delayed, appeared before his ravished eyes, so that a year after beginning the work, with a little of the divine stone thus prepared, he converted some mercury, according to the narrative, into very excellent gold.

Of course, the utter folly of all this European alchemy is apparent to us now. But in the early days of printing, when the methods of alchemy were first being broadcast to the people, when also in the famous *Collection* (see p. 131, note 6) it was discovered that the history of alchemy extended back, far back of Arab days, back to Egypt and the early centuries of the Christian era, novelty and antiquity combined to give added verisimilitude to the subject. If the Egyptian with his primitive methods of centuries ago could succeed, why not the more enlightened European of these modern (sixteenth century) days? [17]

Our modern historians of chemistry, like the encyclopedists of the thirteenth century, have usually accepted as

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[17] As it is generally supposed that the real alchemist disappeared from the world fully a century ago, it may be interesting to note that he still lives, the modern Zachary, scattered throughout the Near East. I have talked with alchemists from Constantinople and from Persia; and was informed in Egypt that there is an alchemist in each village on the banks of the Nile. A very cultured Egyptian gentleman of great wealth, who has spent as many years as Zachary and as much money as Roger Bacon on the preparation of gold, showed an enthusiasm so great that, though he confessed that he had been only partially successful, success seemed to him always imminent, perhaps "tomorrow." I owe to him the following recipe which was guiding his work:

"1. Egyptian alkali, made from chimney soot, is to be distilled seven to ten times.

"2. The distillate is to be added in drops to one pound of common sulphur, over a weak fire, gradually increasing the strength of the fire, until the sulphur turns to liquid and remains liquid at the room temperature.

"3. Place gold foil on the fire and heat to red; and add to it one drop of the liquid sulphur to each drachm of the gold and the gold turns to liquid.

"4. Place one pound of mercury on the fire; add one drop of the gold liquid to each drachm of mercury and the gold appears."

true the tale handed down to them with many repetitions, have reproduced the picture of the mediæval alchemist as the originator of alchemy and represented as the true alchemy this pseudo-alchemy which began in Europe. Chaucer in the fourteenth century and Ben Jonson in the sixteenth, portrayed the false alchemist as they knew him; and in consequence our histories have been filled with expressions of the authors' amazement that thinking and responsible human beings could pretend to have produced gold and that this pretence was accepted by other thinking men, when the truth was that not one ounce of the precious metal ever resulted as a reward for their enormous labors.[18]

The error of ascribing the origin of alchemy to the fourteenth century has been the source of many minor errors. We have labored under the impression that the marvel of mediæval alchemy was inexplicable and that was all there was to the whole matter. There may have been a man named Geber but little was known about him. We have refused to delve further, and this which we now call pseudo-alchemy, this alchemy of charlatans, with its pretensions of knowledge of real alchemy, of which it

[18] The seventeenth-century chemist, Becher, of phlogiston fame, in the face of this implication, seems remarkably content when he exclaims: "The chemists are a strange class of mortals, impelled by an almost insane impulse to seek their pleasure among smoke and vapor, soot and flame, poisons and poverty, yet among these evils I seem to live so sweetly that may I die if I would change places with the Persian King!"

possessed only words and formulas (which it did not understand), this feeble attempt at imitation, has been accepted by us in place of the fascinating story, so rich in meaning, of the rise of alchemy in the wisdom of Greece and its close connection throughout its long development, with that philosophy.

In reviewing this pseudo-alchemistic period, it should be pointed out how strongly false alchemy contrasts with the definite purpose and scientific thought and successful accomplishment which we must ascribe to the alchemist of Egypt or even to the seeker after truth in the Islamic period. In earliest alchemy, we find a theory representing the best thought of the age, adapted to the mysterious results of the artisan, successfully explaining those results and unifying them. That "gold" which they desired was obtained and the concept of the elixir was a logical extension of the original theory.

But these same theories, when accepted by mediæval alchemy, were foreign to the practical experience of the age. The language borrowed from Egypt, while in common use, carried no significance. The sequence of colors was Egyptian in origin, but no one understood its derivation from the Egyptian color theory. And finally the gold, claimed to have been produced, could have been easily tested in the light of the greater knowledge; but very few tested it (and they were not believed) so that gold, in the

modern sense, was claimed as an accomplishment by most famous workers whom a kind indulgence might characterize only as too ignorant to know that they had failed.

But here again we are in danger of taking the easy course so often followed by our historians. It is so much simpler to condemn than to understand, so difficult to make clear to ourselves what is fitting and natural to a people just struggling to free themselves from ignorance, barbarity, and superstition.

Let us again pause to examine conditions. Geber, we remember, believed in talismans and in the influence of the stars, but five centuries later we find superstitions, such as these, apparently quite as common. Everything miraculous was in the fourteenth century accepted as true, partly because it was attractive, being strange and unaccountable, and partly because the tale had come down from some old and revered author. The magnet stone, for instance, may be broken only by means of goat's blood; and rocks are riven asunder by vinegar. Even Roger Bacon, who enthusiastically advocated the careful checking of all evidence by accredited and recent observations, accepted what are to us most obvious absurdities.

A quotation from Boerhaave, a writer of the first half of the eighteenth century,[19] seems to provide a gracious

[19] Hélène Metzger, *Isis*, IV (1922), 476.

and kindly appreciation of this period of pseudo-alchemy, from which he was by only a few years removed:

> When I read the secrets of these excellent artists, who knew so well the works of nature, I am led to suspect that after certain careful observations had led them to very curious discoveries, they, prompt to foresee the consequences, have related as facts things which exist only in their imagination, but which, they conclude, they could have accomplished or which they surely would have accomplished, had they pressed their experience further.

How clear this all seems! In the exaltation of the presence of the miraculous, and trusting, as only the fanatic can, to the old theories received from their most eminent authorities, these alchemists conceived it disloyal in science, as in religion, to doubt that upon which their civilization seemed to be founded. To them faith was greater than fact. Accustomed to believe without investigation, accustomed also to accept all sorts of miraculous phenomena, they considered the tenets of alchemy above dispute and by them, as loyal soldiers, to be defended. Alchemy had then become a matter of faith [20] which is the "evidence of things not seen," and thus differed essentially from the alchemy of Egypt which rested upon tried experiment. In this sense alchemy was a pretense—a pseudo-alchemy—which was destined to lead men astray

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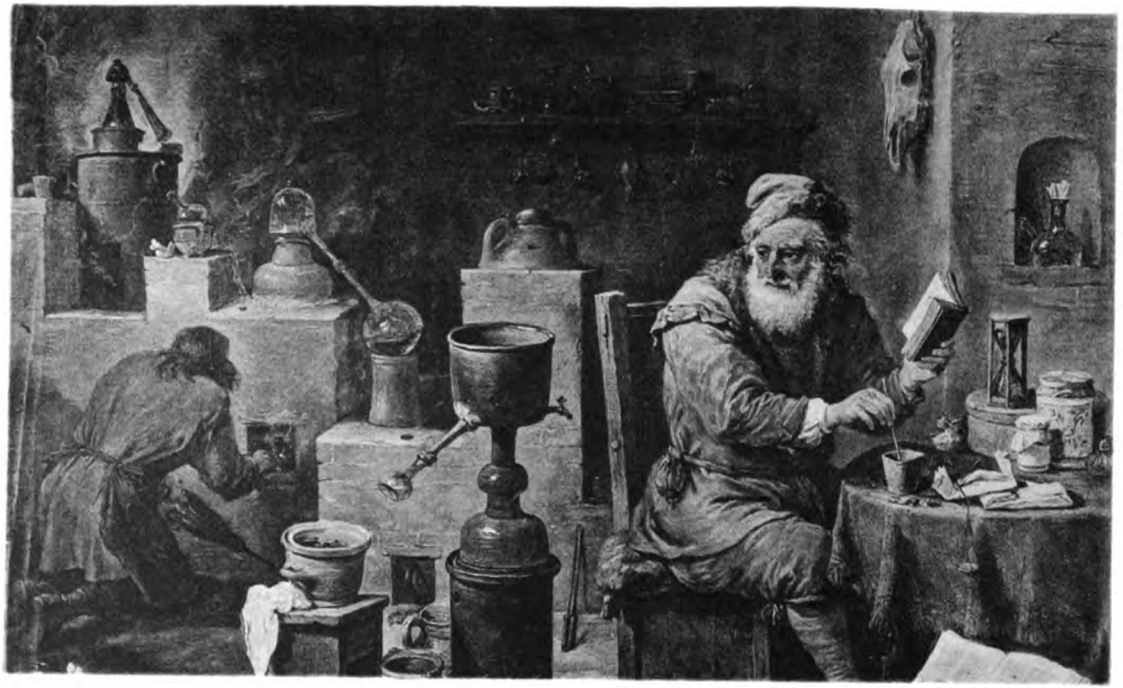
[20] Pattison Muir, *The Story of Alchemy*, 1918, p. 46.



TENIERS: DER ALCHEMIST

and could itself survive only so long as men refused to accept the evidence presented by nature in the laboratory of the inquiring chemist.

Nevertheless, mediæval alchemy, with its charlatans and its dupes, accomplished much good in that it educated an ignorant people, only a few generations removed from barbarism, whose knowledge had been confined to the military arts and the speculations of theology, to the need of an immediate acquaintance with the world of matter in which we live. This has been frequently pointed out by the histories of chemistry but was perhaps most succinctly expressed by Francis Bacon when he wrote:

> 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 mold about the roots of the vines, procured a plentiful vintage.

It has been perhaps not sufficiently pointed out in our histories of alchemy that among the hundreds who sought wildly for the great secret of making gold there were others who considered alchemy from a calmer viewpoint. Some sought in its mysteries a support for philosophy, others for religion.

Alchemy was historically philosophic. The writers tell us that it follows the methods of nature, imitating nature which is always striving for perfection and assisting na-

ture artificially by leading the metals to their highest form.

The Pseudo-Albertus says in the *Compositum de compositis:*

Nature ought to serve as the base and model of Science just as Art works according to nature as much as it can.

Roger Bacon, in the *Speculum alchemiæ:*

Alchemy is the science which teaches how to prepare a certain medicine or Elixir which when projected on imperfect metals, gives them perfection.

Petrus Bonus, in *The Pearl of Great Price* (1330):

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 left only a comparatively small thing for the artist to do—the completion of that which she has already begun.

On the religious side also we frequently find an earnest belief in alchemy as a divine gift. So the Pseudo-Albertus, in the *Compositum de compositis:*

Let him who has ears to hear this divine communication receive the secrets which have been transmitted to me by the Grace of God and which He has never revealed to those who are unworthy of it.

Bonus says:

I am firmly persuaded that any unbeliever who got truly to know this art would straightway confess the truth of our

blessed religion and believe in the Trinity and in our Lord Jesus Christ.

Another alchemist writes:

In the first place, let every devout and God-fearing chemist and student of this art consider that this arcanum should be regarded not only as truly great but also as a most holy art, seeing that it typifies and shadows but the highest heavenly good. Therefore if any man desire to reach this great and unspeakable mystery, he must remember that it is obtained, not by the might of man, but by the Grace of God, and that not our will or desire, but only the mercy of the Most High can bestow it upon us. For this reason, you must first of all cleanse your heart, lift it up to Him alone, and ask this gift in true, earnest and undoubting prayer. He alone can give and bestow it.

This attitude toward alchemy was reflected in the treatises of many of the best writers of this period. But later, in the seventeenth and eighteenth centuries, the excitement of real scientific discovery began to exclude all other interests.

Chapter XIII

THE PHLOGISTON THEORY

Seventeenth-Eighteenth Centuries

In reading phlogistic literature, the use of the word phlogiston to signify a substance renders these writings, reasonings and explanations nonsensical in our modern view; but if we could read into them the idea of property only, and discard altogether the idea of a concrete thing, their doctrines would not seem to us to be so far removed from those of our own day.
J. Campbell Brown: *History of Chemistry.*

In the sixteenth century, pseudo-alchemy had attained the climax of its popularity. Its inevitable decline had already begun. Paracelsus, that mad but enthusiastic physician, that iconoclast overthrowing the medical authority of Galen and Ibn Sina, had aroused the wrath of the profession by denouncing its attitude of reliance upon ancient methods, declaring that the study of nature should be the only source of medical knowledge. As one crying in the desert, he proclaimed that the escape from these ancient shackles was through the study of chemistry, the object of which should be "not the making of gold but the preparation of medicines."

The old transmutation theory, which, we remember, had been the incentive of alchemists from the time of

Geber, no longer aroused enthusiasm. Every attempt to carry out the demands of the theory in practical labora-

PROGRESS IN THE
SIXTEENTH AND SEVENTEENTH CENTURIES

	Phlogiston	Iatro-School	The Physical Sciences	
1500				
		Paracelsus		
			Copernicus	Vesalius
		Libavius		
1600		Sennert	Tycho Brahe	
				Kepler
			Galileo	
				Fabricius
		Van Helmont		
			Harvey	
		Sala	Descartes	Boyle
		Glauber		
	Becher	Sylvius		
		Lemery	Newton	
		Tachenius		
1700	Stahl			

tory work had failed of success. Enthusiasm gave way to an attitude of caution. The theory itself fell to the position of a discredited corollary of the mercury-sulphur theory and, gradually, almost disappeared from alchemistic

literature. Perhaps it would be safe to say that transmutation survived only as the plaything of esoteric philosophers and seekers after the occult; and, in some cases, of those few chemists who still clung to the old belief but thought it necessary to excuse their position. At the same time, the combined influences of Paracelsus and his school, the disruption of the Church, the advances of astronomy and the physical sciences had brought an attitude of such earnest inquiry into the realm of nature as the world had never known.

In the seventeenth century, counting just a hundred and fifty years after that other date which marked the two significant events, the taking of Granada and the discovery of America, we reach the year 1642, the year of the death of Galileo and the birth of Newton. These two latter events, occurring in the same year, it has been said, may suitably mark a turning point in the history of thought—the end of the old empiricism and the birth of modern science. From a purely chemical viewpoint, the date of awakening would be only slightly different, for the incentive to careful inquiry was supplied in 1661 by Boyle's famous *Sceptical Chymist.*[1]

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[1] For the date, see Pattison Muir's excellent introduction to the edition edited by Ernest Rhys in the "Everyman's Library"; as well as T. L. Davis, *Isis,* VIII (1926), 71.

For a view of chemistry in the seventeenth century as a synthesis of iatrochemistry and metallurgy and its liberation by Boyle and Lemery, see Hélène

Using the Socratic method, Boyle places on trial the foundation ideas of alchemy, the four Greek quality elements and the three *principia of Paracelsus,*[2] allowing each to plead its cause. At the end, each is condemned (although represented by most able advocates) on the ground that the evidence presented is unconvincing. Then Boyle presents his conception of a substantive element, opposed to the old idea of the quality element:

"Certain Primitive and Simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the Ingredients of which all those called perfectly mixed bodies are immediately compounded, and into which they are ultimately resolved."

This definition sounds very modern. The incentive to this conception was the rising thought that matter, far from being negligible, was to be seriously taken into account, so seriously that Boyle makes matter the *essentia.* Boyle also was unable to accept the old doctrine that nature, in all its complexity and manifoldness, is a unity. In other words, he believed that the old legend ἓν τὸ πᾶν, affixed to the Ouroboros Snake, marked a fundamental error of Greek science.[3]

Metzger, "Les Doctrines Chimiques en France du début du XVII^{0} à la fin du XVIII^{0} siècle," I, 1923, reviewed in *Isis,* VI, 57.

[2] See p. 221.

[3] It may be emphasized that Boyle used the word "bodies" in the above definition rather than qualities, which distinguishes him from all those who acknowledged the Greek tradition.

But though this definition sounds modern, it was at the time modern only in being destructive; for the world was not yet ready for its constructive side. Boyle shared the general uplift of science but his ideas bore fruit very slowly. His substantive element was historically almost immediately overwhelmed by the fascinating phlogiston theory—and we have to remember that Boyle himself defended the transmutation of the metals! One hundred years of labor were still necessary before the ground could be cleared for the foundations of modern chemistry.

The second half of the seventeenth century marks therefore for chemistry, in common with the other sciences, the beginning of that trend of thought, which, growing almost imperceptibly but growing surely, was destined to undermine that last Granada of alchemy, that old mercury-sulphur theory of the composition of the metals.

In the seventeenth century, the Greek theory of forms, the alchemistic ideas of quality elements, still ruled in chemistry and contributed those common terms of the science such as "mercury" and "sulphur." The composition of the metals, still an absorbing topic, was believed fully expressed by their outstanding qualities, fusibility and combustibility, emphasizing under new names the two most important Greek elements, "water" and "fire." From the earliest days, combustibility and the nature of fire had been the object of speculation, and it still re-

mained a marvel. The "element of fire" of the Greeks had been called sulphur by the earliest alchemists, followed by Geber. Later, Roger Bacon and others had called the fire principle *terra pinguis, i.e.,* "oil earth," because oils are combustible. The term "phlogiston," derived from the Greek word for fire, as a substitute for *terra pinguis,* appeared in 1606 in a little book by Hapelius.[4]

Back in the middle of the sixteenth century, Paracelsus had extended the old mercury-sulphur theory of Geber so that it included three principles: mercury, sulphur, and salt, the latter directing attention to the calx (oxide) or ash. This calx was becoming important, being always produced when the combustibility of the metals was studied. Paracelsus stated very clearly (1556) his conception of the parts played by these three principles, as follows:

> Now to understand the affair, take first, for example, wood. . . . Now let it burn . . . that which burns is sulphur, nothing burns but sulphur; that which fumes is mercury, nothing sublimes which is not mercury; that which turns to ashes is salt, nothing turns to ashes which is not salt.

In 1669, in Becher's *Physica subterranea,* there was a preliminary restatement of the old sulphur theory that all combustible substances (including the metals) contain something (Becher called it *terra pinguis*), the cause of the combustion. But then the author advanced the idea

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[4] See T. L. Davis, *Journal Society Chemical Industry,* XXIX (1925), 725.

that fire was a process of resolution of the combustible matter into its three principles of Paracelsus and that the lightest of these, naturally, escapes upward. This was the germ of the influential phlogiston theory first propounded and elaborated in great detail by Becher's pupil, Stahl, in 1702.[5]

This phlogiston theory for the first time brought together under one unifying thought a long list of experiments and phenomena, not previously associated in men's minds.[6] All phenomena which we now know as oxidation were systematically compared and explained. The advantage of having a single explanation for a great variety of unrelated acts attracted attention and provoked discussion. Especially in regard to the oxidation of metals, Stahl's theory was able to establish a complete cycle. He called attention to the two principles, phlogiston and salt as follows: A metal burns and produces a calx. According to his theory, the metal (from the fact that it burns) contained phlogiston. But fire, resolving the metal into the three principles, allows the phlogiston to escape, as the metal turns to mercury and finally is changed to calx, the principle, "salt." The calx cannot burn. Therefore it cannot contain phlogiston. Therefore it is a simple principle.

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[5] In the *Specimen Becherianum.*

[6] See Kopp, *Geschichte der Chemie,* I, 187-193. The problem of combustion thus introduced and apparently explained gave chemistry a living incentive, all its own, and freed it from the dominance of medicine. *Op. cit.,* I, 146.

Again, to complete the cycle, when a substance rich in phlogiston, such as charcoal, is heated with the calx, the charcoal gives its superfluous phlogiston to the calx; and now the calx plus phlogiston becomes again (or is) the metal, thus restored. For instance, the metal *lead,* when heated alone, loses its phlogiston and we may call the unoxidizable calx resulting dephlogisticated lead, since the loss of phlogiston removes the ability to burn. But when the latter is heated with charcoal, the calx is brought back again to the original metal, lead. Thus the new theory neatly explained the real facts of this well-known experimental cycle. To the phlogistonist, therefore, the calx appeared elementary and the metal complex.

(1) Calx (simple) + phlogiston simple → metal (compound)

(2) Metal (compound) → Calx (simple) + Phlogiston (simple)

The nonmetal, phosphorus, also, when heated, becomes phosphoric acid (anhydride) and when phosphoric acid (or sulphuric acid) is heated with charcoal ("rich in phlogiston") the union of these acids with phlogiston gives respectively phosphorus and sulphur which are inflammable. Stas recognized that when sulphur is burned, the vapor is indeed an acid but weaker than sulphuric acid. He designated it sulphuric acid somewhat phlogisticated (*i.e.,* now reduced). Having heated potassium sulphate

with charcoal and obtained *liver of sulphur,* he discovered that the latter was a solvent for gold.[7]

Toward the end of the period, since it had become known that some metals, like zinc, when placed in acid give off an "inflammable gas," this gas (hydrogen) was considered the same as phlogiston. But, to carry out the theory, the metals must at the same time be changed into their calces: It was known that these calces are soluble in acids. Therefore, it was declared, the metal zinc when placed in acid changes to the (simple) calx giving off phlogiston and it is then the calx which goes into solution in the acid. This interesting sequence of arguments was further confirmed by another discovery that calces, which are changed to the metal by hot charcoal ("rich in phlogiston") are likewise changed at high temperature by hydrogen, "which is phlogiston."

During the eighteenth century, this theory, developed by Stahl in 1702 and in various later publications, seized upon the imagination of nearly all chemists. In the seventy-five years of its existence, its success was so great that investigators whose names fill the annals of the era—Black, Cavendish, Priestley, Scheele, Marggraf, Macquer, de Morveau, Bergmann, and Kirwan—all were phlogis-

[7] Stas even ventured to advance this discovery as an explanation of how, in the biblical story, Moses "burned" the golden calf, dissolved it and gave the solution to the Israelites to drink (cf. p. 208, note 17, Steps 1, 2, 3).

tonists, so trained that to them the later more materialistic theory of Lavoisier was capable of only slight appeal.[8]

Thus the world accepted the interesting new theory, the "first important generalization in chemistry," and profited by it. Under the impetus of this new idea were begun investigations destined to change the character of all chemical thought.[9]

In the meanwhile, it was a great triumph for Greek philosophy—this phlogiston theory. Alchemy seems, as in a swan song, to proclaim that Plato and Aristotle still rule in the world of thought. The last of many alchemistic triumphs, the theory of phlogiston, coming immediately before the extinction of alchemy, reminds us of the sudden flare of the candle before it goes out.

To gain perspective, let us return for the moment to the sixteenth-century alchemy. Bereft of the transmutation theory, the science found itself reduced to only one thesis, the mercury-sulphur-salt conception of the composition

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[8] Priestley, for instance, called his newly discovered gas (oxygen) by the cumbrous title "dephlogisticated air," *i.e.*, an air which cannot burn but which is ready, like a calx, to unite strongly with phlogiston, acting thus as the opposite of charcoal; and Cavendish in 1781 thought of his discovery, hydrogen, as nearly pure phlogiston.

[9] This first generalization in modern times, inspiring a new series of investigations into the secrets of nature (with no material incentive) has been lauded by Thomas Thomson in his *System of Chemistry* (1802) as the "Origin of Chemistry as a Science"; and Becher, wishing to distinguish sharply his attitude from that of the pseudo-alchemists, justly states: "False alchemists seek only to make gold. True philosophers desire the science alone and inquire into the principles of things."

of the metals, due to Paracelsus. Also, in another way, alchemy was handicapped. Paracelsus, while raising the standard of medicine, had sacrificed alchemy; for alchemy, by attaching itself to medicine, was compelled to occupy (as it had in Baghdad) a subordinate position. Its outlook was becoming more and more doubtful. Deprived of the transmutation theory and subordinated to medicine, alchemy could no longer figure as a guide to progress.

As a consequence, during the seventeenth century, the only advances which we may call chemical were such as related to the medical school of Paracelsus. We note the names of certain physicians who contributed, in small degree, to the subject of alchemy: Libavius (sixteenth-seventeenth centuries) noted for his excellent textbook on chemistry; Sala and Sennert; van Helmont, most noted of all, who asserted that he had assisted at a transmutation, but gave us the word "gas," derived from Paracelsus' "chaos"; Glauber "the Paracelsus of the seventeenth century," Sylvius and Tachenius. These all made contributions sufficiently pronounced to bring their names into prominence. Some, like Sala, tried to disprove transmutation while others, especially van Helmont, lent his authority to the great error. The advances effected by these men were largely empirical and carried out in connection with their medical studies. To this generalization we must of

course except Robert Boyle, to whose influential philosophy reference has already been made.

Thus passed the seventeenth century; and in its progress alchemy slowly declined in popular favor,[10] assisted not at all by the profound thoughts of Boyle and gaining no inspiration from the birth of the academies nor from the contemporary rise of the physical sciences.[11]

Then, at the beginning of the eighteenth century, came this surprising thing, this triumph for Greek philosophy and saving incident for tottering alchemy, for chemical investigation also a welcome inspiration.

The phlogiston theory delayed, for a little time, the impending collapse of the whole Greek structure. Like a comet in a darkening sky, it burst forth, bringing light and hope to the chemical world—to fall again, as suddenly, after three-quarters of a century, into oblivion.

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[10] At the same time as the publication of the *Sceptical Chymist* (1661) Glauber (*Opera*, 1658) defines alchemy as "an intention, imagination and studying or considering how or whereby the species of metals are transmuted from one degree and nature into another."

[11] Right here we note a statement of Thomas Thomson (*A System of Chemistry*, 1802, I, 11): "The foundations of the alchymistic system being thus shaken, the facts which had been collected soon became a heap of rubbish, and chemistry was left without any fixed principles, and destitute of an object."

Note also this judgment on alchemy quoted by Figuier, *L'Alchimie et les alchimistes* (p. 187) from Clytemius, Abbot of Wiezenberg: *"Vanitas, fraus, dolus, sophisticatio, cupiditas, mendacium, stultitia, paupertas, desperatio, fuga, proscriptio et mendicitas, perdissaeque sunt chemiæ"*; and Sarton: "It is difficult to imagine anything more confused than chemical philosophy in the seventeenth century."

Again, as in Alexandria, in Baghdad, and later in the fourteenth century, Plato's quality element had captured the minds of chemists—not this time "those of the most ignorant class" but that most brilliant coterie for which the eighteenth century is noted, contributors to the greatest discoveries which had ever been made in the realm of matter.

Under the inspiration of this eighteenth-century theory, certain chemists, deserting the Paracelsan lead towards medicine, became again real scientists in their efforts toward the advancement of chemical knowledge. And since the workers, these phlogistonists, were able men,[12] and inspired, their results were not empirical only, but translated into thought. And here came disaster! In other words, the inspiration of the theory was so great, the results so good and so fundamental, and interpretation so clear in the matter of fire that the weakness of Stahl's intriguing theory when more widely applied became more and more apparent. And finally the facts developed by its most enthusiastic devotees, such as Black, Priestley, and Cavendish, brought an end to the phlogiston theory when these facts were quietly marshaled into one clear incontrovertible statement by a mind unshackled—by one whose

[12] "The phlogistic hypothesis originated in Germany and though the most outstanding of the German chemists supported it, adherence to the theory was by no means confined to the chemists of Germany" (Reilly and O'Flynn, "Richard Kirwan, Irish Chemist," *Isis*, XIII (1930), 298).

liberal education had not been confined to chemistry only, a man who was at once mathematician, astronomer, engineer, chemist—Lavoisier.

The change from alchemy to chemistry constitutes a stupendous revolution, more compelling than the contemporary political revolution in France or than that in the American colonies. It may be shown that it advanced by simple steps, from the precept of Geber to the famous definition of Boyle, to the experimental verifications of the phlogistonists and lastly to the great synthesis of Lavoisier. These steps are simple (the latter of these will be examined in the following chapter) but the accumulated results were far-reaching, for in the fall of the phlogiston theory fell also the four Greek "elements" and the three "principles" of Paracelsus, carrying with them the whole structure of alchemy. And with alchemy in its fall there disappeared forever from chemistry the method of thought which was Greek and the quality entity, its foundation stone.

And because the steps were simple, they passed unnoticed. The final result, although it appears to us inevitable, was to the devotees of Greek philosophy unexpected; and by some bewildered spirits, unrecognized.

How different is the progress of the eighteenth century from the dull monotony of the seventeenth! In what a spectacular way events follow one another! As the cen-

tury opened, at the moment when Stahl introduced his phlogiston theory, alchemy was merely marking time. Then came the general acceptance of the theory, followed by a revival of activity, a period of great labor and great discoveries; and finally, in the short period of seventy-five years from its inception, the tragic fall of the theory and with it of the whole structure of Greek chemical philosophy, due to the brilliant formulation by Lavoisier of the modern conception of the simple material bodies, now called elements.

Thus we have to record in this notable eighteenth century the end of alchemy and the beginning of chemistry. In no century in the history of this subject are important events so crowded and in no century do the scenes shift so rapidly.

Chapter XIV

THE LAST DAYS OF ALCHEMY

Eighteenth Century

> *It is the truth alone that we desire to know and what joy there is in discovering it!* Scheele. *Opuscula physica et chemica.*

THE history of chemistry has been so often and so well told that a repetition would be superfluous, as well as outside the scope of this work. It is the purpose therefore in this chapter merely to point out, in a few concise statements, how alchemy and the Greek method finally were compelled to recede before the cogent thought, the great new idea, upon which modern chemistry was established.

Certain branches of the study of nature had been neglected by the alchemists. One of these was the atmosphere and its secrets; another, the significance of weight. But in the serious investigations begun in the eighteenth century, begun, no doubt, partly because of the incentive supplied by the new phlogiston theory, both of these divisions of knowledge came inevitably under close scrutiny.

The significance of weight as applied to chemical transformations had been partly beclouded by a confusion caused by failure to distinguish between weight and specific gravity, and partly because of the indifference to-

ward matter, as such, which, according to excellent authority, was negligible or nonexistent. No realization of weight in the modern sense was possible until there came,

PROGRESS ON WEIGHT AND GASES

1600

Jean Rey (1630)

Boyle
Skeptical Chymist 1661

1700

Joseph Black
Experimenta 1755

Cavendish
Hydrogen 1766

Water 1783

Scheele
Oxygen 1771

Priestley
Oxygen 1774

1800

first, experimental recognition of the chemical weight equation,[1] the universal applicability of which we owe to Lavoisier.[2]

Different kinds of "airs" had been recognized already, but not in the modern sense of gases, each with its distinguishing characteristics, more as different "kinds of airs"; for air was thought so tenuous, and its activity so subtle,

[1] "During a chemical change, the gain in weight equals the loss in weight."
[2] Mary Louise Foster, *Life of Lavoisier*, 1926, "Smith College Monographs."

that of the two "elements," air and fire (above the realm of man and his environment) attention had been confined to the more active fire alone. Variations in the qualities of air seemed apparent, but so unimportant that to Paracelsus all this division of nature was merely "chaos."

It was upon investigations concerning changes of weight and the characteristic properties of gases that there were built up the new conceptions which Lavoisier first established. Let us see how the foundations were laid for the new structure.

With minds fixed upon the phenomenon of fire, and with all questions apparently safely answered by the mysterious "fire element which escapes," chemists now felt themselves, as phlogistonists, safely started upon the right road.[3] As in the case of many another all-embracing generalization, experiments which seemed to indicate exceptions to the general law were glossed over and neglected. Such was the case when Rey called attention to the *gain in weight* when metals were calcined.

Rey (1630)[4] came to the conclusion that the "elements," earth, water, air, and fire, all have weight. He

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[3] For many years the conception of the ether in modern science has filled a similar rôle, mysterious, unisolated, yet playing an all-important part in the theory of light transmission.

[4] *Essays de Jean Rey, docteur en medicine, sur la recherche de la cause pour laquelle l'estain et le plomb augmentent de poids quand on les calcine.* Reprint by Grimaux from edition of 1632 (1896); English in "Alembic Club Reprints," no. 11.

noted that one may be deceived if he attempts to weigh water in water or air in air. He suggested that this weight of air, when metals are heated in air, is added to the weight of the metal, thus accounting for the fact that the calx is heavier than the metal. This first attempt to connect the air with the observed increase in weight was soon forgotten, because it described a phenomenon incompatible with the phlogiston theory, with the *loss* of phlogiston.[5] In the next few years, an attempt was made to connect the known function of the air in aiding combustion with the violent oxidizer, niter or saltpeter. Thus Hooke (1665) and Boyle (1674) thought that the air contained "nitrous particles" and even more definite was Mayow (1674) who called these particles "nitro-aereal." None of the seventeenth-century writers considered these particles a part of the air. Rey thought that the air itself was added, as water wets the substance submerged in it. Boyle expressed a suspicion of the composition of the air, nearest to the truth, when he said:

> There is scarce a more heterogeneous body [than air] in the world. . . . I have often suspected that there may be in the air some yet more latent qualities or powers,

but this was pure conjecture.

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[5] Unless one could accept the dictum of de Morveau that phlogiston may be considered possessed of *negative* weight, so that a loss of phlogiston would cause a gain in weight.

In all this early work there is certainly indicated a rising interest in the details of the combustion process; but it was nearly a hundred years before, in the middle of the eighteenth century, the first work was published which records the actual checking of gain or loss in weight during a chemical reaction.[6] Black (1755) was working with carbon dioxide, as we now know it.[7]

When Black began his work,[8] mild alkali was considered a simple body, which, when combined with phlogiston, formed caustic alkali, just as a calx combines with phlogiston to give the metal. Black's experiment consisted first in heating magnesium carbonate until it was changed into magnesium oxide, which oxide he noticed dissolved in acid *without* effervescence (Equation I (b)). He knew that salts were produced from the carbonate and acid, *with* effervescence (Equation I (a)), and one such salt obtained from the carbonate (magnesium sulphate) he recognized as identical with one already prepared from the oxide, when there was no effervescence. Since the salt

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[6] Kopp calls attention to the fact that all of Stahl's results were qualitative ("like results from like composition"). It could not be otherwise until weight was taken into account.

[7] This gas had first been prepared by van Helmont (seventeenth century). He had found that by burning 64 pounds of charcoal he got one pound of ash and the other sixty-three became a "spirit." He had also prepared the gas by the action of acid on "mild alkali" (potassium carbonate) and it was probably from the characteristic effervescence of this reaction that van Helmont called the spirit "gas sylvestre" or "wild gas."

[8] *Experiments upon Magnesia Alba, Quicklime, and Some Other Alkaline Substances*, 1756, "Alembic Club Reprints," no. 1.

was the same, the only difference in products was the effervescence or escape or fixed air. He concluded that the fixed air, present in the "mild magnesia" had been driven off by the acid. Finally, dissolving the salt in water and adding potassium carbonate, he found he had produced a new sample of magnesium carbonate, a duplicate of that with which he began his experiments.[9]

These experiments were quantitative; *e.g.*, in one experiment in which he starts with 160 parts of mild magnesia, he succeeds in recovering 150 parts. His work impressed chemists with the value of weight relations as a check on a chain of transformations. Also, the idea of calces, and their transformations into carbonates, was made clear by this work of Black; and "fixed air" was, from this time, the first gas recognized as an entity, differing from common air, and existing in, and a component of, the atmosphere.[10]

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[9] Today these changes would be represented as follows:

$$MgCO_3 \longrightarrow MgO + CO_2$$

I(a). $MgCO_3 + H_2SO_4 = MgSO_4 + H_2O + CO_2$

I(b). $MgO + H_2SO_4 = MgSO_4 + H_2O$

II. $MgSO_4 + K_2CO_3 = K_2SO_4 + MgCO_3$

[10] Still, it is to be noted that Black (1728-1799) at this time (1756) was a confirmed phlogistonist and considered his fixed air a modification of ordinary air, caused by phlogiston.

His letter to Lavoisier is dated 1791; and Kirwan's to Lavoisier, 1791. See Ramsay, *The Gases of the Atmosphere* (1896), pp. 59-60; Kahlbaum and Hoffmann, *Einfuhrung der Lavoirsier'schen Theorie in Deutschland* (1897), p. 133, and an excellent résumé of Black's work in Hoefer, *Histoire de la chimie*, II, 345.

The mystery of the composition of the air was nearing solution. Cavendish (1766) prepared and described hydrogen; and Priestley, known as the "father of pneumatic chemistry," after having isolated various individual gases, crowned his many achievements by preparing (in 1774) the wonderful gas, oxygen.[11] Yet, although the individuality of these gases, as distinct from air, seemed ready for recognition, custom and previous training ruled so strongly that Cavendish called his gas "inflammable air" and Priestley's unwieldy name for his discovery was "dephlogisticated air."

At this time came Lavoisier! Led on by an intense curiosity, he had first attacked the old belief that water may be changed into earth. He succeeded in proving, by giving attention to weight, that the weight of earth produced by boiling water in a glass vessel equaled the loss in weight of the glass. This was in 1770, when Lavoisier was twenty-seven years old.[12]

Next, profiting again by the example of his predecessors in the matter of checking his results by weight, he attempted to find the cause of the recorded gain in weight when metals are calcined. In 1774, he was able to show

[11] Bergmann (1775), after Priestley's discovery of oxygen had been privately communicated to him, was able to state: "We now know that common air consists of three elastic fluids mixed together." This in twenty years!

[12] A chart of Lavoisier's life and experimental work is given in Appendix VI. In this chart, none of his busy public life is touched upon—only those experimental factors which advanced the theory of chemistry.

that the gain in weight of tin, or of sulphur, or of phosphorus, when heated in a *closed* vessel, equals the loss in weight of the air; and is due to a portion of the "air which becomes fixed during the combustion."

But almost immediately there came to Lavoisier Priestley's important discovery of that constituent of air which Priestley had proved to be the cause of combustion; and there followed (1775) a second paper by Lavoisier in which he interprets Priestley's gas, and its rôle, so as to expand his previous thesis. In this new memoir, he proves that the gain in weight of metals on calcination in a closed container is equal to the weight of this "pure air" which disappears. He goes further and proves that the red calx of mercury when heated with charcoal gives, besides the metal, "fixed air" only. He concludes that Black's fixed air is a product of the union of this (oxygen) portion of the air with the charcoal.

Here, for the first time, we have an explanation of oxidation (made convincing by the equivalence of weight relations) in which the hypothetical phlogiston was not invoked, was not even mentioned; an explanation so strange that confirmed phlogistonists—even Priestley and Scheele, codiscoverers of oxygen—were unable to follow or to accept it.

But Lavoisier's curiosity was still unsatisfied. Two gases had been identified as constituents of the air but there re-

BERTHELOT AND LAVOISIER

mained that greater portion of air, then called "phlogisticated air," now known as nitrogen. Also, there was Cavendish's "inflammable air" which the discoverer thought was pure phlogiston but later considered phlogiston combined with water. Also, there was water itself. Always, as long as water was considered elementary, was this Greek "element" available to explain any reaction on the basis of the phlogiston theory.

Lavoisier seemed to have an uncanny ability to interpret clearly and in his own way every new discovery. His opportunity came in 1783 when Cavendish made his important announcement that inflammable air united with Priestley's dephlogisticated air gives *water*—and nothing but water. To Cavendish this proved that oxygen was only water deprived of phlogiston: Water minus phlogiston gives oxygen; phlogiston plus oxygen gives water. But here were obvious difficulties. Water must be *complex* instead of that simple element which the Greeks had postulated. A second difficulty presented itself: Remembering that when things are capable of losing phlogiston they are considered combustible, we are led to the unattractive conclusion that water is combustible!

To the phlogistonists difficulties were increasing, but not so to Lavoisier. To him this new discovery of Cavendish was that for which, for eight years, he had been patiently waiting. Now everything pointed clearly to this

fact: Hydrogen plus oxygen gives water. Thus, by the careful researches of the phlogistonists, Black, Priestley, Scheele, and Cavendish, the great contest was decided clearly in favor of the antiphlogistonist cause.

Up to this time, Lavoisier had never once made a direct attack upon the prevailing theory; but in 1783 he presented before the French Academy a memoir in which he was able to state:

"If everything is explained in chemistry in a satisfactory manner without the aid of phlogiston, it is, by that alone, infinitely probable that this principle does not exist."

In eight years, by the clear conceptions and efforts of one man, the four Greek "elements" were shown to have no elementary character; and, in their fall, they carried with them the *tria principia* of Paracelsus, mercury, sulphur and salt. The quality element of the Greeks, however expressed, was displaced by the material element. Matter, in place of being negligible, became the *essentia*, matter which was checked by weight. These revolutionary conclusions were capped by the astounding statements: (1) No matter is ever created or destroyed; (2) During chemical changes, qualities change but matter (weight) alone is permanent; (3) The total weight before and after a chemical change is the same.

It would be interesting to dwell upon the great achievements of Lavoisier, how he formulated the relations be-

tween bases, acids and salts, established the idea of the element, gave us our present nomenclature, began the study of organic chemistry and the analysis of these difficult compounds by organic combustions. But all this is told in our histories of chemistry.

Looking backward, we can see that it was impossible that alchemy should survive the development of pneumatic chemistry; but the final deathblow was given by Lavoisier in establishing the law of weight. Perhaps more dramatic was the concrete example, offered by Priestley's "dephlogisticated air" which Lavoisier first explained as a material element such as Boyle had described. Thus was the science of material things for the first time removed from the realm of imagery to the realm of fact, "tested and confirmed by experimental work." Thus, also, phlogiston, the last of the hypothetical elements, became superfluous and finally impossible; and with its disappearance the whole structure of alchemy fell to the ground. With the chemical revolution established, our story of alchemy comes to an end.

APPENDICES

APPENDIX I

(Reference, p. 6)

Genesis, VI

1. And it came to pass when men began to multiply on the face of the earth and daughters were born unto them

2. That the sons of God saw the daughters of men that they were fair; and they took them wives of all which they chose. . . .

4. And there were giants in the earth in those days; and, also, after that, when the sons of God came in unto the daughters of men, and they bare children unto them, the same became mighty men which were of old, men of renown.

The Book of Enoch, VI, VII, VIII (R. H. Charles, *The Book of Enoch,* Clarendon Press, 1912.)

VI. 1. And it came to pass when the children of men had multiplied that in those days were born to them beautiful and comely daughters.

2. And the angels, the children of the heaven, saw and lusted after them and said to one another: "Come, let us choose ourselves wives from among the children of men and beget us children."

3. And Semjaya, who was their leader, said unto them: "I fear ye will not indeed agree to do this deed, and I alone will have to pay the penalty of a great sin."

4. And they all answered him and said: "Let us all swear an oath and bind ourselves by mutual imprecations not to abandon this plan but to do this thing."

5. Then sware they all together and bound themselves by mutual imprecations upon it.

6. And they were in all two hundred; who descended in the days of Jared on the summit of Mount Hermon and they called it Mount Hermon because they had sworn and bound themselves by mutual imprecations upon it. . . .

VII. 1. And all the others together with them took unto themselves wives, and each chose to himself one, and they began to go in unto them. . . .

2. And they became pregnant and they bare great giants.

VIII. 1. And Ayayel taught men to make swords and knives and shields and breastplates and made known to them the metals of the earth and the art of working them; and bracelets and armaments and the use of antimony and the beautifying of the eyelids; and all kinds of costly stones and all coloring tinctures.

2. And there arose much godlessness.

The Isis Myth

It came about that one of the angels who lives in the first firmament, having looked upon me from above, desired to have intercourse with me. He came near, preparing to accomplish his purpose but I did not yield to him, wishing to learn from him the preparation of gold and silver. As I asked the latter of him, he told me he was not allowed to explain this on account of the great importance of these mysteries but that the next day there would come a greater angel, the angel Amnael and he would be able to give me the answer to the question.

. . . At last, he showed me the sign and commenced the revelation of the mysteries.

(Berthelot: *Collection des anciens alchimistes grecs,* Traduction, p. 13.)

APPENDIX II

(Reference, p. 9)

SUIDAS ON DIOCLETIAN

From Suidas (edition Bernhady, Halle, 1852). "These are the readings of John of Antioch from the 'Extracts of Constantine Porphyrogenitos.'" A variation is found, also in Suidas, under Διοκλητιανός.

Χημεία. Ἡ τοῦ ἀργύρου καὶ χρυσοῦ κατασκευή. Ἧς τὰ βιβλία διερευνησάμενος ὁ Διοκλητιανὸς ἔκαυσεν. Ὅτι διὰ τὰ νεωτερισθέντα Αἰγυπτίοις Διοκλητιανὸς τούτοις ἀνημέρως καὶ φονικῶς ἐχρήσατο. Ὅτε δὴ καὶ τὰ περὶ χημείας χρυσοῦ καὶ ἀργύρου τοῖς παλαιοῖς αὐτῶν γεγραμμένα βιβλία διερευνησάμενος ἔκαυσε, πρὸς τὸ μηκέτι πλοῦτον Αιγυπτίοις ἐκ τῆς τοιαύτης προσγίνεσθαι τέχνης, μηδὲ χρημάτων αὐτοὺς θαῤῥοῦντας περιουσίᾳ τοῦ λοιποῦ Ῥωμαίοις ἀνταίρειν.

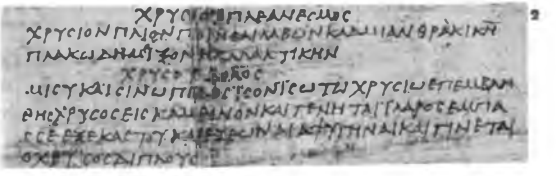
Chemistry: The preparation of silver and gold. Diocletian, having sought out the books on this subject, burned them. Now, because of the revolutions, Diocletian treated the Egyptians harshly and cruelly and having sought out the books written by their forefathers on the chemistry of gold and silver, burned them lest wealth should accrue to the Egyptians through this art and lest they emboldened by riches should in the future revolt against the Romans.

APPENDIX III

(Reference, p. 63)

FROM THE LEYDEN PAPYRUS X[1]

Rs 16 and 17



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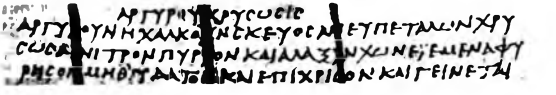
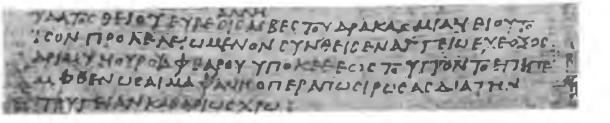


Rs 89



[1] See p. 63 and note 3 for translations.

[2] This title is probably a mistake of a copyist and should be stricken out.

APPENDIX IV

(Reference, p. 150)

FROM THE PROLOGUS OF THE *DE ANIMA IN ARTE ALCHEMIÆ*

Dixit Abuali Abincine: Explanabo tibi, fili mi, quot capitula continentur in unaquaq; dictione sive libro libri unius qui dicitur de Anima: quia librū istum intellectione nominavi eum librum de Anima. Ideo quia anima altior est corpore et non potest videri oculis, sed mente, quia oculus tātum rem accidentem videt et mens videt proprietatem. Ideo altiora sunt ea quę videntur mente quam ea quæ videntur oculis. Et anima est quædam pars circuli gloriæ, et circulus animæ est altior omnibus circulis. Laus ergo sit Deo qui creavit animam.

Avicenna said: I will explain to you, my pupil, as many chapters as are contained in each Dictio or Book of the single book which is called *De anima;* because I have named this book, the *Book de anima* in a figure of speech. This is because the mind is higher than the body and can not be seen by the eyes but [only] by the mind since the eye sees only casual things and the mind the fundamental. Therefore these things seen by the mind are

superior to those which are seen by the eyes and the soul is a certain part of the circle of glory and the circle of the soul is higher than all circles. Therefore praise be to God who has created the soul.

APPENDIX V

(Reference, p. 197)

THE GOLDEN FLEECE[1]

From Suidas (Edition Bernhady, Halle, 1852) see Dionysium Perieg. 639. "Salmas says that this is taken from John of Antioch."

Δέρας· Τὸ χρυσόμαλλον δέρας, ὅπερ ὁ Ἰάσων διὰ τῆς ποντικῆς θαλάσσης σὺν τοῖς Ἀργοναύταις εἰς τὴν Κολχίδα παραγενόμενοι ἔλαβον, καὶ τὴν Μήδειαν τὴν Αἰήτου τοῦ βασιλέως θυγατέρα. Τοῦτο δὲ ἦν οὐχ ὡς ποιητικῶς φέρεται, ἀλλὰ βιβλίον ἦν ἐν δέρμασι γεγραμμένον, περιέχον ὅπως δεῖ γίνεσθαι διὰ χημείας χρυσόν. Εἰκότως οὖν οἱ τότε χρυσοῦν ὠνόμαζον αὐτὸ δέρας, διὰ τὴν ἐνέργειαν τὴν ἐξ αὐτοῦ.

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[1] Translated on p. 197.

APPENDIX VI

LAVOISIER: LIFE AND WORKS

Personal: Born 1743; first paper before the academy 1765; prize from the academy 1765; geological survey 1767; appointed Fermier Général 1768; elected member of the academy 1769; married 1778; died 1794.

EXPERIMENTAL	ARGUMENTS
Early period	
1765 Gypsum and the setting of plaster of Paris.	The weight lost is due to water and equals the weight of water produced. The "earth" produced is equal to the loss of weight of the flask.
1770 Water, boiled in a flask, is not converted into earth.	
Middle Period, 1772-1783	
1772 Paper on *Calcination.*	The gain in weight on calcination is due to a portion of air and equals the loss of weight of the air.
1774 *"Opuscules physiques et chemiques"* Fixation of air.	
1775 Charcoal, heated in a vacuum, is unchanged; heated in air produces "fixed air." A calx, reduced by charcoal, produces "fixed air."	Establishes the nature of charcoal, the diamond and of carbonic anhydride.
1777 Paper on the nature of acids, completing the oxidation theory.	Oxygen, the component of acids. Different "kinds of air."
1782. Composition of "fixed air."	The "loss of phlogiston" is the same as the addition of oxygen.
1783 Paper: *Reflections sur le Phlogistique.*	First formal attack on the phlogiston theory.

Final Period, 1784-1792

Explanation of respiration and the cause of animal heat.
System of chemical nomenclature.
Composition of organic compounds and the foundation of organic analysis.
The "*Traite elementaire.*" Beginning of the Metric System.

Reference page 237.

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