THE BIRTH OF CHEMISTRY

VII.

Avicenna.—Albertus Magnus.—S. Thomas Aquinas.—Roger Bacon.—Raymond Lulli.—Arnoldus de Villâ Novâ.—George Ripley.—Basil Valentine.

THE Schools and Colleges of Arabia soon gave evidence of their value by the development of several considerable geniuses, whose works formed the text-books of Europe during a portion of the Middle Ages. Prominent amongst these learned Arabians was Ali-ben-Sina, or Avicenna, who was born in 980 in the neighbourhood of Shiraz. His abilities were considerable, and no pains were spared in his education; as a boy he read the Almagestum of Ptolemy, the Geometry of Euclid, and the Philosophy of Aristotle, and later in life he studied medicine with great success. We are told indeed that at the age of sixteen he was an eminent physician, and that at eighteen he cured a caliph of some grave disorder, and was hence promoted to great honour.

Avicenna is best known by his celebrated "Canons," which were translated at an early date into Latin, and often printed under the title of "Canones Medicinæ." This work has been translated into the languages of all civilised countries, and for no less than six centuries was the standard medical treatise of the world.

Avicenna also wrote on Alchemy and on Chemistry. If the works attributed to him are genuine he appears to have adopted the Aristotelian theory of the four mutually convertible elements. He speaks of air as the aliment of fire, and of the metals as compounds of a humid substance and an earthy substance. This last idea evidently arose from the observation of the calcination of metals. It was well known that if certain metals, such as lead and tin, are heated for a length of time in the air they are converted into a powdery substance or calx, and it was long before it was proved that this calx is not the metal from which one of its constituents has been expelled by fire; but, on the other hand, the metal combined with another substance. Avicenna divides all minerals into four classes; viz., (1) Infusible minerals; (2) Minerals which are fusible and malleable, that is, metals; (3) Sulphurous minerals; and (4) Salts. He noticed that mercury can, by heat, be caused to unite with sulphur and produce a solid body, having different properties from its constituents.

Avicenna was largely indebted for his knowledge to Alfarabi and to Rhazes. The latter wrote on medicine, and was one of the first to introduce substances formed artificially by chemical means into medicine.

Turning now our attention to European alchemists we meet at the outset with the name of Albertus Magnus (b. 1193, d. 1282), who became Bishop of Ratisbon in 1259. Various works on Alchemy are attributed to him: he wrote on the philosopher's stone, on the origin of metals, and on minerals; and he has described at some length various chemical operations, such as sublimation and distillation, and various forms of apparatus, such as aludels, alembics, and water-baths. He followed Geber in the belief that metals are composed of sulphur and mercury, and that different metals are produced by different combinations, and to some extent by the variations in the purity, of these substances. Albertus Magnus employs the term *affinity* (*affinitas*) to designate the cause of the combination of sulphur with silver and other metals; in this precise sense, applied to all cases of chemical combination, the term is used in the present day. He also speaks of sulphate of iron as *vitriol*, a name which it long retained. He describes the preparation of nitric acid, its principal effects upon certain metals, and its utility for separating silver from gold, inasmuch as it will dissolve the former and not the latter. Cinnabar, or sulphide of mercury, had long been known and used as a source of mercury; Albertus proved that it consists of sulphur and mercury by preparing it artificially, by subliming sulphur with mercury.

Albertus was not alone learned in Alchemy; he was a profound theologian, a scholar, an astronomer, a physician, and some said an adept in magic and necromancy. He embodied his wisdom in twenty-one folios, which were published in a collected form in 1651. M. Lenglet Dufresnoy, in his "Histoire de la Philosophie Hermetique," has mentioned several magical operations gravely attributed to Albertus Magnus by various writers. The most noticeable piece of magic was the sudden transformation of a winter's day into glowing summer:—"Horridam hyemem," says Trithemius, "in florigeram fructiferamque vertit." It is said that once during a very severe winter, he invited Count William of Holland, when he was passing through Cologne, to a feast. The Count, on his arrival with a considerable retinue, was surprised to find the feast spread in the garden, in which there were several feet of snow; and this treatment so angered him that he remounted his horse and prepared at once to leave his inhospitable host.

Then the monk falling on his knees besought
The Count to sit one moment at the board.
He having done so, a most wondrous change
Passed on the instant over all around.
The dark clouds floated off and left a sky
Intensely blue, an air exceeding clear;
The sun shone brightly, and the warm south wind
Laved their pale cheeks and warmed them into life.
They sit on greenest grass, the snow is gone,
Sweet flowers bloom beneath their very feet,
Ripe peaches blush upon the garden wall,
And orange blossoms scent the humid air.
A swarm of insect life on droning wing
Is floating up above them in the breeze.
The voice of birds is heard; the cooing dove
Speaks softly to her mate; the nightingale
Trills a sweet lay, half hidden in the leaves.
All nature is most joyous in her garb
Of brightest summer day, and all things seem
To glory in the flood of warmth and light.

Upon this, the Count expressed considerable astonishment, as although he had heard a good deal of the magical powers of his host, he was quite unprepared to find him capable of changing the seasons. As soon as the feast was ended, Albertus Magnus repeated a magical formula—

Now snow obscures the air, the flowers fade
The trees are torn by pitiless strong winds
And weep their shrivelled fruit upon the earth;
All sound of life is gone, a roar of elements
Succeeds the plaintive quavering of the leaves.
The birds fall dead to earth, and the dark air
Betokens fearful tempests yet to come.

So the Count and his retinue rush off into the house to warm themselves, and thus ends the feast of Albertus Magnus. Some will have it that the story alludes to a winter garden, unknown at that time, which had been devised by Albertus for the preservation of rare plants. Middle Age books on science abound with such stories, and the belief in them was almost universal, as it well might be in an age in which the power of witches and wizards was acknowledged, and the raising of the dead was an admitted possibility. Brücker (*Institutiones Historiæ Philosophicæ*) says:—"Quæ enim de ejus convivio magico narrantur, merito inter inficeti seculi fabulas referuntur, quæ ex ignorantia rerum naturalium. eo tempore crassissima et Alberti mirabili rerum physicarum cognitione prodierunt."

In the church of S. Andreas in Cologne they show to this day the shrine and relics of Albertus—the accomplished churchman, scholar, magician and alchemist, of whom Trithemius says, "Magnus in Magia Naturali, major in Philosophia, maximus in Theologia."

Albertus had for his pupil the "angelic doctor," S. Thomas Aquinas (b. 1225, d. 1274), who was a great alchemist, and who wrote a treatise called "The most secret Treasure of Alchemy," together with some other works on the subject, which are equally obscure and unintelligible. He wrote also on the artificial preparation of gems, by fusing glass with certain substances, like oxide of copper, to communicate different colours; he mentions that if copper be heated with white arsenic, the former becomes white, something like silver. According to some, S. Thomas Aquinas was the first to employ the term *amalgam*, to designate a compound of any metal with mercury. S. Thomas was, like his master, a magician. We are told that between them they constructed a brazen statue, which Albertus animated with his *elixir vitæ*. It was useful as a domestic servant, but very talkative and noisy; nor could they cure it of this propensity. It happened one day that S. Thomas, who was a mathematician, was deeply engaged in a problem, but was continually interrupted by the talking statue; at length in a rage he seized a hammer and smashed it to atoms, to the great regret of his master.

Our great countryman Roger Bacon (b. 1214) also suffered from a charge of magic, and during his residence in Oxford was severely persecuted in consequence. He replied to the charges made against him by the admirable treatise "De nullitate magiæ," and in it clearly showed that what his contemporaries mistook for the work of spirits, were in good sooth the ordinary operations of Nature. In this work he speaks of gunpowder, although somewhat obscurely. "Mix," says he, "together saltpetre, *luru vopi vic*

con utriet, and sulphur, and you can make thunder and lightning, if you know the method of mixing them." Elsewhere he says, "a small quantity of matter properly manufactured, and not larger than one's thumb, may be made to produce a horrible noise and sudden flash of light." The third constituent of gun-

FIG. 11.—An alchemist hermetically sealing a flask containing a solution of gold.

powder is designated under the anagram *luru vopo vir con utriet*, for it was dangerous in those days to speak too plainly; indeed Bacon tells us that he adopted an obscure style both on account of the example of other writers, and of propriety, and also on account of the dangers of plain speaking. According to some writers, the following passage is to be found in Bacon's writings:—"Sed tamen salis petræ, *luru mone cap ubre*, et sulphuris, et sic facies tonitrum si scias artificium." Thus the saltpetre and the sulphur are directly designated, while the anagram *luru mone cap ubre* is convertible into *carbonum pulvere*, the remaining constituent—powdered charcoal. It is improbable that Roger Bacon invented gunpowder, although he was the first to know of its properties in England; he probably procured the knowledge from an Arabic source. Gunpowder was first used by the English at the battle of Crecy in 1346, 61 years after the death of Bacon; at this time it was apparently unknown to other European nations.

Roger Bacon is believed to have been far in advance of his times in all matters of science. To him has been attributed the invention of the telescope and *Camera obscura*, and several discoveries of a later date. The evidence is less conclusive than one could wish, but enough remains in his writings to prove that he was a very learned man and profound thinker. His "Opus Majus" clearly proves that he fully recognised the value of the experimental method, and of the inductive philosophy afterwards so ably advocated by his namesake Francis Bacon. Roger Bacon wrote largely on alchemy. Many of the alchemical MSS. in the British Museum are transcripts of portions of his works, among the more celebrated of which we may mention the "Medulla Alchymiæ," "Secretum Secretorum," and "Speculum Secretorum." He collected together the principal alchemical facts of his predecessors, and appears in many matters to have closely followed Geber. Bacon describes the distillation of organic substances, and alludes to the inflammability of the evolved gases. He proved that air is the food of fire by burning a lamp in a closed vessel.

Raymond Lulli (b. 1235) is by some asserted to have been a pupil of Roger Bacon. He was a voluminous writer on alchemy, his most celebrated treatise being his "Ultimum Testamentum." He also wrote on transmutation, on the Philosopher's Stone, and on magic. Lulli does not appear to have added to the chemical knowledge of his predecessors; he followed Geber closely, and was well acquainted with the processes and compounds which he describes. He describes alcohol under the names of *aqua vitæ ardens*, and *argentum vivum vegetabile*, and was in the habit of

FIG. 12.—Alchemical representation of processes.

rendering it anhydrous by allowing it to stand in contact with dry carbonate of potassium. He was also acquainted with ammonia.

Whatever Lulli's knowledge may have been, he obtained great reputation as a successful alchemist. He asserts in his "Ulfimum Testamentum" that he converted fifty thousand pounds weight of base metals into gold. He is said to have been employed by one of the Edwards to make gold, and to have furnished His Majesty with six millions of money. Dickenson tells us that Lulli had a laboratory in Westminster Abbey, in which, after his departure, a quantity of gold dust was found.

Of the general tone and character of alchemical writings we shall speak more fully in the next article. Of the professors of the art little more need be said; a long list of names might be given, but it would be found that they did little to develop what afterwards became the science of chemistry. Let us glance at the work of a few of the remaining alchemists. Arnoldus de Villâ Novâ (b. 1240) was a great alchemist and physician, and the author of many works on the subject. His "Rosarius Philosophorum" purported to contain a key to all alchemical operations. He followed Geber closely. He considered a solution of gold the most perfect medicine, and we usually find that

such solution was recommended by alchemists as a necessary constituent of the elixir vitæ, and essential for the work of transmutation. In Fig. 11 the solution of gold in the flask is represented by the sun emitting rays. The simple disc of the sun is the more common symbol for gold.

Arnoldus also distilled various oils and essences. He contended that sulphur, arsenic, mercury, and sal ammoniac—all volatile bodies be it noted—are the souls of metals, and are given off during calcination. He also affirmed that silver is intermediate between mercury and other metals, just as the soul is intermediate between the spirit and the body. Arnoldus is said to have had for his pupil Pope John XXII., an accomplished alchemist, who left at his death eighteen millions of florins, which the alchemists fondly cite as a proof of the possibility of transmutation. Our own George Ripley, Canon of Bridlington in Yorkshire (b. about 1460) wrote a poem on alchemy, and passed for a successful disciple of the art, but we cannot point to a new fact which he elucidated. He divided all chemical operations into twelve processes—Calcination, dissolution, separation, conjunction, putrefaction, congelation, cibation, sublimation, fermentation, exaltation, multiplication, and projection. Several MS. copies of his poem exist in the British Museum, bound up with copies of the works of Roger Bacon and earlier writers. Here is a specimen of his rugged rhymes :—

> The fyrst chapter shall be of naturall *Calcination* ;
> The second of *Dyssolution*, secret and phylosophycall ;
> The third of our elementall *Separation* ;
> The fourth of *Conjunction* matrimoniall ;
> The fyfth of *Putr-faction* then followe shall :
> Of *Congelation Albyficative* shall be the sixt,
> Then of *Cybation*, the seaventh shall follow next.

One of the most celebrated of the alchemists was Basil Valen-

FIG. 13.—Alchemical representation of processes.

tine, who was born at Erfurt in 1394. According to Olaus Borrichius his works were accidentally discovered in the wall of a church at Erfurt many years after his death. A thunderbolt struck the church and exposed to view the long-lost alchemistical treasures. Basil Valentine was the author of many treatises, the most important being his "Currus Triumphalis Antimonii," in which he discusses the properties of antimony and of many of its compounds. He regarded the metals as compounds of salt, sulphur, and mercury; and he was acquainted with many metallic compounds, among others nitrate of mercury, sulphide of arsenic, red oxide of mercury, chloride of iron, sulphate of iron, fulminating gold, carbonate of lead, acetate of lead, and the oxides of lead. He was aware that iron precipitates copper from solution, and that solution of potash precipitates iron from solution. He was well acquainted with the preparation of nitric and sulphuric acids, and used them for various purposes of dissolution. In order to obtain nitric acid he distilled powdered earthenware with nitre, or equal parts of nitre and green vitriol, or nitre with finely powdered flints. He obtained fuming sulphuric acid by distilling green vitriol, after the manner still practiced at Nordhousen and elsewhere. Basil Valentine wrote very obscurely and was fond of symbolical designs. Woodcuts 12 and 13 are taken from his works, and represent various processes imperfectly described. Thus the lion in Fig. 12 would represent a solution of a metal, the serpent another solution, or perhaps the serpent a metal, and the lion devouring it a solvent ; the sun and moon are watching the operation, and the symbol of mercury appears between two roses. Fig. 13 represents some operation which is thus thus described by the principal figure :—I am an old, infirm, debilitated man, my soul and spirit (represented by the two boy-headed birds above his head) leave me, and I assimulate the black crow. In my body are found salt, sulphur, and mercury. This may possibly refer to the solution of gold in aqua regia : it loses its metallic nature, its solidity and lustre, and assimulates the acid ; but one may conjecture in vain concerning the enigmatical devices in which some of the alchemists took so much delight, and which they often employed, like Roger Bacon's anagram, to conceal the full significance of their operations or discoveries.

The following extract, in which he treats of the generation of metals, will show the style of Basil Valentine's writing :—

"Therefore think most diligently about this ; often bear in mind, observe, and comprehend that all minerals and metals together in the same time, and after the same fashion, and of one and the same principal matter are produced and generated. That matter is no other than a mere vapour, which is extracted from the elementary earth by the superior stars or by a sidereal distillation of the macrocosm, which sidereal hot infusion, with an airy sulphureous property, descending upon inferiors, so acts and operates, as in those metals and minerals is implanted spiritually and invisibly a certain power and virtue, which fume afterwards resolves in the earth into a certain water, from which mineral water all metals are thenceforth generated and ripened to their perfection, and thence proceeds this or that metal or mineral according as one of the three principles acquires dominion, and they have much or little of sulphur and salt, or an unequal mixture of them ; whence some metals are fixed, that is constant or stable ; some volatile and easily mutable, as is seen in gold, silver, copper, iron, lead, and tin."

Now this is by no mean the most obscure piece of alchemical writings with which we shall come in contact.

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GLACIER MOTION

IN making some experiments on the freezing of water some time ago it was noticed that after the same water had been melted and frozen a number of times it generally burst the tube in which it was frozen. On looking for an explanation of this phenomenon, it became at once evident that the experiment contained the germ of the explanation of glacier motion. Every time the water was frozen in the tube there was a mimic representation of glacier motion. The ice possessed, the first two or three times it was frozen, a certain amount of viscosity which enabled it to adapt itself to the shape of the tube, as was evident from the distortion of the upper surface of the ice in the tube. How came the ice to lose this plasticity or viscosity, this power of adapting itself to the shape of the tube, the loss of which caused it to burst the tube after it had been frozen and melted a number of times? Wherein did the ice which had only been frozen once differ from the other? The answer to this seemed to be, that the ice which had only been frozen once had more air in it than that which had been frozen and melted a number of times, as each succeeding freezing deprived the ice of a quantity of air or some other gases. The natural conclusion, therefore, seemed to be, that ice with air in it is a viscous substance, though pure ice is not. The first question then to be asked is, Is ice with air in it a viscous substance? In order to get an answer to this question, glass tubes ·4-inch in diameter and twelve inches long were filled with water in which was dissolved a great quantity of air. The tubes were then placed in a freezing mixture. After the water was frozen in the tubes the tubes were