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STUDY OF MUSLIM ALCHEMY IN THE MEDIEVAL AGES & SOME VALUABLE CHEMICALS TRANSMITTED TO MODERN CHEMISTRY

AFTAB SAEED
Department of Academic Research, Bait al-Hikmat,
Hamdard University Library, Madinat al-Hikmat, Karachi-74700, Pakistan

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Out of the two basic objectives of the art of Alchemy, viz., transmutation of base metals into gold and silver, and discovery of a universal remedy — *soma* — chemistry was born when the Alchemists gave up the attempt to fathom the constitution of matter and confined their investigations to the study of other chemical problems. However, the medieval history of Alchemy forms part two of the broad history of chemistry where important contributions were made by the Muslim Alchemists. Among them, Jabir ibn Hayyan, Dhu-n-Nun al-Misri of Ikhmin, Ibn al-Wahshiya, Zakariya Razi, Al-Tamimi, Al-Farabi, Al-Majriti, Al-Khwarizmi, Al-Tughrai, Al-Jildaki and Al-Kindi shall ever be remembered for their literary work and applied contributions towards the existing knowledge of chemistry. In this article, a survey is attempted of their works and major chemical processes oriented by Muslim scientists.

Paracelsus in the 16th century introduced the idea of "*Quinta Essentia*" and extraction of active principles from vegetable drugs and is regarded as the first to introduce laudanum (morphine tincture) and tartar emetic[1]. Throughout the middle ages, the medical suggestions especially regarding Alchemicals had been made within the framework of ancient Galenic medicine and Aristotelian natural philosophy. It was Paracelsus (1493-1541) who argued that the primary goal of the Alchemists was to heal man rather than to produce gold[2]. Thus, out of the two basic 'objectives' of the art of Alchemy, viz., (a) *transmutation of base metals into gold and silver*, and (b) *the discovery of a universal remedy — Soma — or the drug of longevity*), the medical benefit surpassed the transmutational approach for being practical or workable, and hence chemistry was born when the Alchemists gave up the attempt to fathom the constitution of matter and confined their investigations to the study of other chemical problems[3]. Alchemical theory of transmutation of matter, therefore, finds some corroboration today in the discoveries of nuclear science and genetic engineering. By altering the nucleus of the atoms (and biologically on the chromosomal level) scientists of the 20th century have succeeded in the transmutation of one element into another. This is actually the result of untired experiments carried out by the Alchemists of the medieval ages.

Medieval history of Alchemy forms part two of the broad history of chemistry and is denoted usually as the *Alchemical period* (AD 350-1500) from the time of its origin in China (600 BC) to the 16th century with the two objectives described above. The other four parts are as follows:

(1) *The ancient period of Alchemy* (up to AD 350) includes the period of older civilizations of China, India, Egypt, Greece and their contemporaries. As an example, Egyptian word "*Khemi*" with Arabic '*Al*' made Alchemia[4].

(2) *Iatrochemistry* (AD 1500-1650): With a definite change of motivation after Paracelsus, the Iatrochemists devoted their chemical pursuits to the alleviation of diseases.

(3) *Phlogistan Period* (AD 1650-1774): The era of discovery of gases, calcination of metals, correct interpretation of combustion by Lavoisier (referred to as the father of modern chemistry).

(4) *Modern Period* (1774 to date): In 1618, Boyle described a clear distinction between chemistry and Alchemy and in his important book '*The Sceptical Chymist*', he challenged the idea that all matter consisted of a few elementary substances. He exemplified through experiments that gold could not be broken into simpler matter and thus it was an element.

Basically, the Muslim Alchemists of the medieval age speculated regarding the origin of Alchemy as an art and entity. They went back as far as Adam as being the first. They considered Hermes Trimegistus or Idria (*Enoch of Genesis*, V:18-24 and Jude, V: 14-15) as a pioneer promoter. After him many names of the Old Testament prophets and sages are listed, including patriarchs Abraham, Issac and Jacob, prophets and kings as Joseph, Moses, David, Soloman, Ezakiel and Daniel in reference to accounts or *Genesis* XXVI: 2-5, 26-35; XXX: 25-43; XXXVII: 5-10 and *Exodus* VII: 10-21. Alchemists went to great trouble to prove such excesses and assumptions[5] and again, according to Arabic sources, Indians and Persians took over where the Hebrew prophets left off. There were no clear or direct references of impact from other sources, such as Egyptian, Babylonian or Chinese, although such interactions and influences evidently existed[6].

The importance of Alchemy in the development of exact sciences being what it is, a clear understanding of the subject and the prominent practitioners of this art is necessary to understand the formation of the basis of modern science of chemistry.

Prominent Muslim Alchemists of the Medieval Age

The *Fihrist* (Ibn Nadīm) probably gives most of the names (p. 351); according to Stapleton, al-Kathi gives another; M. Berthelot has given a number of names and books from *al-Wafi fi Tadbir al-Kafi* of Muhammad bin Ahmad al-Masudi; al;Jildaki mentions those who seemed most important to him in the introduction to his *al-Misbah fi Ilm al-Miftah* (Lights of the Science of Key): there are also numerous references in the section *Kashf al-Zanūn* on Alchemy in Haji Khalifah. It is also remarkable to find among his writings a work by Ibn-Sina, *Mirat al-Ajaīb* (Mirror of Wonders)[7]. However, the best known Muslim Alchemists of the medieval period include:

Khalid b. Yazid, an Umaiyad Prince (d.AH 85; AD 704): There are three letters ascribed to him; his master and teacher is said to have been a Syrian Byzantine monk

Morienus, who had been a student of Stephen of Alexandria. Khalid is said to have dedicated a treatise on alchemy to him: *Liber de compositione Alchemiae, quem edidit Morienus Romanus Colid regi Aegyptorum*, translated in 1182 by Robert Castrensis. Compositions ascribed to Khalid and translated into Latin are published in the *Theatrum Chemicum* and in the *Bibliotheca Chemica*, the Arabic texts of which are no longer extant[8].

Jabir bin Haiyyan (Also known as Geber): A reliable tradition represents him as usually residing at Kufa, sometimes connected with the Bermecides and flourished about AH 160 (AD 776, died 815 AD). He was a great Alchemist and is believed to have discovered the processes of distillation and sublimation. The credit for the discovery of spirit of wines, mercuric chloride and mineral acids also goes to him. The proof of the fact that substances on burning gain in weight is also attributed to him. It is narrated that Jabir saved the life of a slave girl of Yahya bin Khalid Barmaki by means of an elixir[9]. A book *Summa* (Latin: *Geberi regis Arabum Summa Perfectionis ministerii*)- Gedani (Dantzig 1682) was published in Europe in the 13th century and the author's name was given as Geber (and regarded as a mythical personage by Brockleman, but J. Ruska does not admit this view)[10]. Actually, Geber is the Latinized and distorted version of Jabir ibn Haiyyan and most of the people believe in the genuine authorship of Jabir for *Summa*. He, however, describes the preparation of nitric acid as follows:

> "Let us distil a pound of cyprian virtial (iron or copper sulphate), one and half pound of saltpetre, a quarter of pound of alum, and obtain the water (acid). This water dissolves metals very well. Its effect will be even greater by adding a quarter of a pound of salmiac (sal ammoniac) to it (aqua regia)"

Berthelot and Houdas have published five of the series of works ascribed to Jabir, whose titles are generally symbolic and *in toto* their number exceeds two hundred. The titles of the above-mentioned five treatises are[11]:

(i) *Book of Royalty* (*Kitab al-Mulk*);

(ii) *Small Book of Balances* (*Kitab al-Mawazin*);

(iii) *Book of Mercy* (*Kitab al-Rahmat*), a book revised by a pupil; extracts from the *Book of Concentration*;

(iv) (*Kitab al-Riyadhat*); and *Book of Oriental Eastern Mercury*; and

(v) (*Kitab al-Zibaq al-Sherqi*).

These works exhibit a fairly advanced stage of chemical science, whereas according to other treatises like *Liber Misericordiae* (mid-ninth century), the *One Hundred Twelve, the Liber de septuaginta* (late ninth century) and the *Five Hundred Books* (mid-tenth century), metals are composed of four elements (fire, air, earth and water), of their basic qualities of sulfur and of mercury; and their relationships are expressed in arithmetic terms (the principle of balances)[12].

Jabir thus mentioned sulphuric acid obtained by distilling alum. In his work, the name for sulphuric acid is *aleum*, a name which is still used. Specific weight is also referred to by him as a characteristic criterion for metals. His description of metals is quite interesting. Metals, he has mentioned in *Summa perfectionis magisterii*, can be similarly characterized also by their melting point, colour, lustre, and ductility. His views regarding some specific metals are as follows:

Gold: It is a metallic substance, lemon yellow in colour, heavy, lustrous and ductile. It can be alloyed easily with lead and mercury. It is soluble, giving a red solution and renovates the body. With the greatest effort it can be fixed with the spirits (dissolved in acids). (This he has described to be a great secret of the art).

Silver: It is a white clinging ductile metal and resists the fire test. It melts very easily. Its mixture with gold cannot be separated by fires. Its ores are not as pure as the ores of gold, and generally are mixed with many strange substances.

Lead: It is a heavy, non-clinging metal with a dull white colour. It has a low melting point and is easily malleable and ductile. It forms cerussa (lead white) with acetic acid and munium when it is roasted. With our art we can change it to silver.

Tin: It is a somewhat clinging metal, dirty white in colour, and melting easily. It is malleable and ductile and does not resist fire test. The tin ore easily fuses with copper and in this processing it becomes yellow. It is easily affected by air and acid.

Iron: It is a high melting greyish white metal. It is very clinging, not very ductile and malleable with difficulty. Because of its high melting point, it is very difficult to work with. Metals having high melting points are not suitable for transmutation (Alchemical viewpoint of the transformation of elements)[13].

Jabir gives a clear description of the determination of noble metals by cupellation[14], and notes that only gold and silver are resistant to this test. He has very well mentioned methods for refinement of metals, praparation of steel, dyeing of cloth and leather, preparation of varnishes to water-proof the cloth and protect iron, use of manganese dioxide in glass making, use of iron pyrites for writing in gold and distillation of vinegar to concentrate acetic acid, etc.[15].

The Asafia Library of Hyderabad has about 50 manuscripts of Jabir's works[16]. Some of them are mentioned below:

— *Bāb al-a'zam*: The book deals with the chemical preparations and philosophical thoughts of Alchemia. All the four elements (earth, air, water, fire) in this book have been dealt with in separate chapters.

— *Jannat al-Khuld*: The book deals with chemical preparations and the properties of minerals and plants.

— *Kitab al-Khawas al-Kabīr*: The book has 71 chapters in all out of which in 21 chapters *'ilm al-mizān* (Subject of Balances) has been discussed and the rest deal with science.

— *Risala al-Tadabir*: This small booklet deals with the composition (consistency) of stones.

— *Risala Jabīr*: This book deals with chemical preparations.

— *Risala fi Sharh Kitab al sab 'in al-Mawazinat*: This book deals with metals and their compositions.

— *Risala mā al-Illahi*: Properties and other names of Divine Water are described and the method for its isolation has been mentioned.

— *Al-riād al-Kabīr*: The author in this book has described all the Alchemical secrets. He has mentioned that the book has been presented in an easy language; most of the devices mentioned have been introduced and verified personally by the author.

— *Kitāb al-sirr al-maknūn* (in three volumes): The book has been divided into three parts, the first part dealing with metals.

— *Kitāb al-Ard*: The two ancient elements, earth and fire, have been dealt with in great detail.

— *Kitāb al-Tadbīr*: The book is based on *Ilm al-Kīmīyā*. The author has made certain improvements and has discussed those topics also which were unnoticed by the ancient scholars.

— *Kitāb al-tartīb*: Chemical preparations have been described.

— *Kitāb al-rahma*: Identification of substances has been described.

— *Kitāb al-sahl*: In this book, *Bāb al-a' zam* has been presented in a simple language.

— *Kitāb al-damīr*: The book gives description, properties and composition of minerals.

— *Kitāb al-Malāghim*: Seven metals have been discussed in this book and each metal as influenced by a particular star has been described.

— *Kitāb al-wasūl ilā ma' rifat al-ūsūl*: The book has seven chapters in which different chemical subjects have been discussed.

— *Kitāb al-wasīya*: Certain secrets of *Ilm al-Kimīya* (Alchemy) have been disclosed in an easy language.

— *Kitāb al-āthār*: Minerals have been discussed.

— *Kitāb al-hajar*: The book is based on descriptions of stones.

— *Kitāb al-nūr*: The book is a glossary of his book *Kitāb al-rahma*.

— *Kitāb al-ustuqus*: Chemical aspects of various substances have been discussed.

— *Kitāb al-tajrīd*: The book is based on the description of human and animal souls. Some chemical actions have also been discussed.

A large number of Jabir's works have been translated into several western languages. Jabir generally held the view that all metals are composed of sulphur and mercury, which are mixed naturally in different proportions. He believed that ordinary sulphur and mercury were different from his hypothetical samples of sulphur and mercury, but they closely resembled each other in properties. Philosophically or rather practically, in both the ways, he is the pioneer of modern chemistry, a fact that cannot be denied at any time or at any standard.

Dhu-n-Nun al-Misri of Ikhmin (d. AH 245; AD 859): Ascribed to him are three works on Alchemy — in poetry, dialogue and miscellany[17].

Ibn al-Wahshiya (*c*. 870 AD) concerned himself with the secrets of the planets, Alchemy, sorcery, etc., and wrote in addition to *al-Falaha al-Nabatiya* (Nabataean agriculture which contains some useful information), a Treasury of Wisdom or Secrets (*Kanz al-Hikma or Kanz al-Asrar*) based on the system of Alchemy. Ibn al-Wahshiya is said to have taken advantage of the Alchemical works compiled by two rather unfamiliar authors, *Abu Talib al-Zaiyat* and *Shams al-Din al-Dimashki* (The author of *Cosmography* — referred to by Brockelman, 242 — in *Encyclopaedia of Islam* 1927 edition).

Abu Bakr Muhammad b. Zakariyya al-Razi (AD 923/24): This medical philosopher and celebrated physician was an enthusiastic student of Alchemy and almost a martyr to this science. He presented in addition to *al-Mansuri* (on medicine) the *Kitab ithbat al-Kimiya* (The Establishment of Alchemy) to the Samanid prince, Abu Salih Mansur. In addition to this book, his *Kitab al-Asrar* (Book of Secrets) gives full account of Alchemical equipment and a *Preparatio Salis Aromatici* placed under his name is published in the *Theatrum Chemicum* (iii, No. 64). His systematic approach, as depicted in *Liber Secretorum*, towards experiments for the first time led to a clear classification of chemical compounds into inorganic (mineral and derivatives) and organic (animal and vegetable) groups. He described a number of compounds (especially salts of mercury and corrosive liquids) belonging to each of these classes.

His detailed studies on inorganic minerals led him to classify them into six sub-groups[18]:

(i) Spirits: quicksilver, sulphur, arsenic (sulphite) and salammoniac;

(ii) Bodies (metals): gold, silver, copper, iron, lead (white/red), zinc and tin;

(iii) Stones: pyritions, magnesium, iron oxide, cinnabar, lime, tutty, lapis lazuli, litharge, green verdigris (basic copper acetate), malachite, turquiose, haematite, arsenic/copper oxides, antimony, galena (the actual *surma* — lead sulphate), stibnite, talcum, gypsum and glass.

(iv) Vitriols: green (iron sulphate), white/blue (copper sulphate), black/yellow plumbage;

(v) Borates: red/goldsmith borax: natron, gun arabic and tinker; and

(vi) Salts: common/rock salts, ash, naphtha, quicklime, cenders, alkalis and dyes.

He described differences between calcium and potassium carbonates, the process for the preparation of white arsenous oxide, silica compounds from bamboo, the treatment of sulphur, arsenic and organic compounds and preparation of salammoniac. The use of heated gypsum mixed with egg white as plaster for broken bones was also described by him.

Razi gave a full account of Alchemical equipment in his *Kitab al-Asrar* (The Book of Secrets) dividing it into two broad categories: (a) those used for smelting and for other heating processes, and (b) those used for processing chemical substances (*tadbir*).

Additions and modifications were made in such equipment in later times. Examples of such instruments are as follows:

Type a: *Misbakah*: (or *Rat*) (smi-cylindrical iron mould).
Mibrad: (file).
Mukassir: (hammer or pestle).
Mikta: (shear).
Ambur: (tongs/blacksmith's pincers).
Mashu: (*Mighrafah*): (ladle).
But bar-but (descensory, crucible on a crucible).
Butaqah (a crucible).
Minfakh (or ziqq): (bellows).
Kur (blacksmith's hearth), etc.

Type b: Equipment used in Alchemical processes (*tadabir*).
Qar (retort for distillation).
Ambic (alembic or head of a still with delivery tube).
Uthal (closed vessel in which reactions occur).
Qadah (beaker), *Batyah* (a larger vessel).
Kuz (glass cup).
Qinninah (bottles or flasks).
Qawarir (phials).
Mawardiah (rose-water phials).
Barniyah (earthenware/glass jars with lid).
Mirjal/Tanjir (cauldron in which substances were dissolved).
Qudur (earthenware pots glazed inside).
Tannur (large, baker's oven).
Mauqid/Mustauqad (small cylindrical).
Tabashdan/Qanun (chafing dish similar to that used by food hawkers, glowing charcoal being contained in a tray on the top of an oven).
Mihras (mortar) and *nisab* (pestle).
Salayah (flat stone mortar).
Kurah (round mould — in which filings mixed with suitable reagents were placed in order to subject the mixture to the action of fire).
Miqlat (covered iron pan — a frying pan used in the preparation of salammoniac/chloride of ammonia).
Rawuq (filter made of linen — *Khaish*).
Sukurrujah (dish/platter).
Sallah (basket) or *Qafas* (felt covered cage) in the process of burial under a cover of dung.
Qandil (lamps — for imparting gentle heat).
Al-Uja — the apparatus which is curved or bent, etc.

Various Chemical Processes and Terms used for Them

The medieval Muslim genius concerned with chemical processes used well-known Alchemical terms, some of which were later adopted in scientific chemistry. These include, for example:

Tadbir — The treatment of body in general.
Sahaq — grinding, etc.
Tafsil — breaking into pieces.
Mizaj and *tamzij* — mixing/combination.
Hall and *Tahlil* — dissolving/solution making.
Taqtir — "distillation".
Taswil — suspension.
Tasqiya — spraying.
Tasfiya and *Takhlis* — cleaning and purifying.
Iqama — solidifying.
Tashwiya — stewing/roasting.

Sabk — melting.
Istinzal — allowing to flow from the upper to lower crucible purification.
Tas'id — "sublimation".
Tarjim — storing (a kind of sublimation).
Tashmi — making soft like wax.
Taklis — "calcination".
Tasdiya — to turn into rust.
Ilgham — amalgamation.
Aqd — fixation/coagulation.
Naft — crude oil or the light distillate, etc.

Terms like the above-mentioned ones are frequently used by Razi in his Alchemical works, and a large number of technical words of Alchemy were adopted as such in Latin, which are still in use. Typical examples are:

Arabic	Latin	English
al-qali	Alcali	Alkali
al-kuhl	Alcohol	Alcohol
al-sabun	Alsoban	Soap
al-hajar	Hejer	Stone
Natrun	Natrium	Sodium

A detailed study of Razi's works reveals Razi as a strong supporter of Alchemy and a defender of its claims and it was quite fortunate that his approach being that of a physician to Alchemy was experimental, rational and scientific, so that his work actually enhanced Alchemy's image. His writings established the foundation for empirical Arabic chemistry, experimental chemotherapy, and objective Alchemical procedures today being practised on a large scale.

Muhammad ibn Umail al-Tamimi (8th/10th century), influenced by Zosimus and Hermes Trismegistus, tended towards allegorical explanation to his *Epistola solis ad Lunam crescentem*. He composed among other things an essay on Egyptian paintings and wrote *Miftah al-Hikma al'Uzma*[20].

Abu al-Nasr al-Farabi (AD 870-950): This famous Muslim philosopher made the study of logic much easier by dividing it into categories[21] of *takhayyul* (idea) and *thubut* (proof). He wrote on Alchemy under the title "On the Necessity of the Art of Arts", i.e. *Elixir*[22]. Al-Farabi is regarded as the only major Arabic philosopher who seems to have been personally involved in Alchemy.

Muslama b. Ahmad al-Majriti (d.AH 398/AD 1007): This important writer, distinguished mathematician and astronomer from Madrid (Spain) was the author of *Tabaqat al-Ulama*. This learned encyclopaedist after travelling in the East brought thence to his native country a collection of the famous works of the "Brethren of Purity" of which he probably made a new recension. Being skilled in Alchemy, he wrote especially on this subject a *Kanz al-Fadail* (Treasury of the Accomplishments).

Abu 'l Hakim Muhammad b. Abd al-Malik al-Salihi al-Khwarizmi al-Kathi (*c*. 425 AH/AD 1034) wrote *'Ain al-Sana wa'aun al-Sina'a, Haq-'āiq al-Istishhad*, etc.

Muaiyad al-Din al-Tughrai (d. AH 515/AD 1122), the famous vazeir and poet, often mentioned by Ibn Khaldun, wrote *Kitab al-Anwar wa 'l-Mafatih, Mafatih al-Rahma, Anwar al-Hikma, Al-Jawahar al-Munir fi Sana't al-Iksir*, etc. Gildemeister calls him the Artephius of the west (Brocklemann, i., 247 sq.).

'*Encyclopaedia of Islam*' (1927 edition) refers to three other noted scholars on Alchemy who wrote books like *Shudur al-Dhahab* (the gold spangle), *Al-Muktasab fi Zirat al-Dhahab* whose authors were identified as Abu'l Hasan b. Musa b. Arfa Ras and Ahmad al-Iraki al-Simawi respectively, whereas another Abu'l Asba b. Tammam al-Iraki has also been mentioned by Brocklemann in the same age.

Ali b. Aidamir b. Ali al-Jildaki (*c*. 743 AH/AD 1342), who flourished during the eighth century, was one of the most prolific writers on Alchemy. A list of books mentioned below provide evidence of his masterly grasp of the subject and his familiarity with a wide range of chemical substances and operations from first hand experience. His writings and commentaries, for example, include some like[24]:

- *Al-Badr al-Munir fi Asrar al-Iksir*
- *Bughyat al-Khabir fi Qanun Talab al-Iksir*
- *Al-Burhan fi Asrar 'Ilm al-Mizan*
- *Al-Durr al-Maknun fi Sharh Qasidat Dhi'l Nun*
- *Ghayat al-Surur*
- *Al-Ikht isas wa - Durrat al-Ghawwas fi Asrar al-Khawas*
- *Al-Misbah fi Asrar 'Ilm al-Miftah*
- *Nihayat al-Talab fi Sharh al-Muktasab fi Zirat al-Dhahab*
- *Sharh al-Shams al-Akbar li-Balinūs*
- *Al-Taqrib fi Asrar al-Kimiya, etc.*

Jildaki's view about the nature of Alchemy is quite specific. Referring to Hermes, he is of the view that it is the art to make apparent what is hidden and to hide what is apparent. Alchemy was an occult science. The immediate purpose of 'the art' was to cure diseased (meta), remove their accidental qualities and make them perfect and healthy, which in effect means gold. Quoting Jabir, he observes:

> Hotness and coldness are active in form, moisture and dryness and passive in other, of the four principles water and earth are apparent, and fire and air are hidden"[25].

Jildaki is of the opinion that 'Elixir is strong and active by nature'. It is produced from the raw material.... Properties of the elixir are potentially present in all substances. Water, oil, tincture and earth form the basic constituents of all substances (present in nature).... 'the cause of elixir is very noble, the acquisition means unlimited wealth and eternal power'.

This renowned Alchemical philosopher-scientist seems to have been a practical expert in Alchemical knowledge as is apparent from his many works; he knew the basis of this art right from cosmology to astronomy, the common chemical procedures of distillation, sublimation, combustion, combination, putrefaction, elementary chemistry, physiologic substances like chyme, strong knowledge of the base metals and their transformation into various forms, the nature of theriacs, and even compound medicines formation and nature to advanced industrial subjects of mining and metallurgy. The Alchemical and chemical treatises of al-Jildaki are ranked along with the works of Jabir and Razi[27] and undoubtedly this is the position just second in importance to al-Biruni and al-Kindi in the history of chemical sciences.

Abu Yousuf Yaqub Ibn Ishaq al-Kindi (AD 800-873): Al-Kindi is credited with no less than 36 works on technology and chemistry[26]. One of these, which has been published recently on the extraction of perfumes, indicates that the often fantastic distillation apparatus of Maria[27] had by the time of al-Kindi taken a more modern and utilitarian form. Distillation equipment used by al-Kindi is very well described in his *Kitab Kimya al-'Itr wa al Tas' idat* (Book of Perfume, Chemistry and Distillation). After describing the apparatus (glass retort) used for distillation he says: "In the same way one can distil wine using a water bath, and it comes out in the same colour as rose-water"[29].

Cretics of Alchemy[30]: The philosopher-mathematician, physician, physicist, astronomer and music expert, al-Kindī and the naturalist al-Jahiz were among the staunchest critics of Alchemy. Ibn-Sina was a moderate opponent of the theory that base metals could be converted into gold. Abd al-Latif al-Baghdadi believed in Alchemy early in life, but as he grew older he came to consider its theories corrupting to its adherents and became critical of its followers.

Some Major Chemical Processes and Chemicals Discovered and Oriented by the Muslims

Distillation: Distillation was the most important process in Islamic chemical technology. It was utilized on a large scale in making pharmaceutical preparations and in industrial chemistry. The Muslims became masters of this art and their knowledge and experience were transmitted to the West; indeed, the very terms for distillation equipment in European languages are derived from the Arabic.

The Muslims are credited with the development of the distillation apparatus classically known in chemistry.

Alcohol: The most important of the great chemical discoveries in the Middle Ages were alcohol and the mineral acids. The key to finding them was distillation and, as masters of the art of distillation, the Arabs obtained both at an early date. We find that the Arabs clearly described the distillation of wine using specialised distillation equipment.

Addition of sulphur to distilled wine is found in the work of al-Farabi (fourth century AH/tenth century AD), while Abu al-Qasim al-Zahrawi (d. *c.* 404 AH/AD 1013 and known in the West as Abulcasis) described the distillation of vinegar in an apparatus similar to that used for rose-water adding that wine could be distilled in the same way. Again, Ibn Badis (d. 453 AH/AD 1061) in his *Kitab 'Umdat al-Kuttab* (Book of the Supports of the Scribes) described how silver filings pulverised with distilled wine could provide a means of writing in silver.

The properties of alcohol were also noticed by Jabir. Thus, he says: 'And fire which burns on the mouths or bottles (due to)...boiled wine and salt, and similar things with nice characteristics which are thought to be of little use, these are of great significance in these sciences'.

Perfumes, Rose-water and Essential Oils: The distillation of rose-water as well as other perfumes and the scented oils in plants and flowers — the 'essential oils' — grew to become a true industry. We do not come across this industry in the old civilisations nor in contemporary ones, and this has led historians to believe that *it was a genuine Muslim industry* that originated during the Islamic era. The industry 's products were exported, being sent for instance from Damascus and Jur to other Muslim countries and even as far east as India and China.

How significant this perfume industry was thought to be is exemplified by the fact that a number of technical books were prepared for the use of manufacturers. Al-Kindi's treatise, which contained 107 methods and recipes, has already been mentioned but unfortunately it is the only one to have survived out of nine Arabic titles on the subject mentioned by Ibn al-Ishbilī. However, some later books are still in existence, such as al-Jawbari's *Kitab al-mukhtar fi kashf al-Asrar* (Book of Disclosure of the Secrets) from the seventh century AH (thirteenth century AD), which describes the preparation of rose-water, and one of 664 AH/AD 1266 by the historian 'Umar b. al-Adim. In the next century, the rose-water industry in Damascus was described by al-Dimashqi (d. 727 AH/AD 1327) in his *Kitab Nukhbat al-Dahr* (Book of the Flower of the Age).

There was another source of books on the subject other than those obviously concerned with it. This arose because distillation was also of importance in the agricultural industry, with the result that we sometimes find mention of the preparation of rose-water, for instance, in books on agriculture. Thus, in the sixth century AH (twelfth century AD) al-Ishbili gave a technically important account in his *Kitab al-Filaha* (Book of Agriculture) where he cited the method of distillation used by the famous physician and surgeon al-Zahrawi (Albucasis to the West) who worked two centuries earlier.

As well as rose-water and the essential oils produced by distillation, the industry included the manufacture of such preparations as musk, ambergris, 'abir (a perfume), mahlab (an essence from the *Prunus mahaleb*), ban (another from the horse-radish tree *Moringa oleifera*), ghalia (a perfume from musk and ambergris), and several others. Clearly, the perfume and cosmetics industry was a flourishing one, reflecting a better quality of life.

Petroleum and Petroleum Refining: It is not generally realized that petroleum and its allied products were also significant in Islamic history. Crude petroleum (*naft*) was produced and distilled extensively: it has a strategic importance in war and was also used in everyday life.

The word *naft*, which can mean either crude oil or the light distillates, was defined more specifically by Muslim scientists. Usually they called crude oil 'black *naft*' and the distillates 'white *naft*'. As to the distillation process, we have excellent descriptions in Arabic literature, such as that in al-Razi's *Kitāb Sirr al-Asrār* (Book of the Secret of Secrets), mentioned above. From this book we learn that black *naft* was first mixed with clay or sal-ammoniac into a 'dough like a thick soup' and then distilled. Such light distillates or white *naft* were used by him to 'soften or loosen' some solid substances, such as certain gems and minerals. Moreover, in his chemical and medical work, al-Razi made use of oil lamps (*naffata*) for gently heating chemicals; the fuel for these was either vegetable oils or petroleum.

The oilfields of Baku were developed on a commercial scale by the Muslims at an early date, and it is reported that in 272 AH/AD 885, the Caliph al-Mu'tamid granted the revenues of the *naft* springs to the inhabitants of Darband. In the seventh century AH (thirteenth century AD), wells were dug in Baku to get down the source of the *naft*, and it was at this time that Marco Polo reported that a hundred shiploads might be taken from it at one time'.

Other Arabic sources record crude oil production in Iraq, where there were oil seepages on the eastern bank of the Tigris along the road to Mosul. Arab travellers reported that it was produced on a large scale and was exported. Dawud al-Antaki (David of Antioch) wrote that the crude oil was black and that 'it is distilled, and the first fraction (*daf'a*) of the distillate is white, the next black. If the black fraction is distilled again it joins the first (fraction). Other Arabic reports give information on crude oil production at Sinai in Egypt and Khuzistan in Persia.

Besides crude petroleum and its distillates, asphalts were also abundant. Particularly in Iraq *qir* or *qar* (pitch) and *zift* (pitch or asphalt) were produced and exported, having been known and used in this region by earlier civilizations, though their use was extended in Muslim times.

Distillation and Extraction of Industrial Oils and Fats: Another industry that was important in both peace and war was the extraction and distillation of those vegetable and animal substances from which oils, fats and waxes could be prepared.

Al-Kindi's compendious *Book of Perfume Chemistry and Distillation* described the method of extraction of oils from cottonseed, from mustard and from other seeds, and the military writer Hasan al-Rammah (d. 694 AH/AD 1294) wrote about the distillation of *qitran* (tar), pine wood, pine resin, apricot seeds and other materials.

Acids: The surprise of some historians over the achievement of the discovery of mineral or inorganic acids is probably due largely to a widespread neglect of Alchemical treatises devoted to the transmutation of metals and the processes involved in the hunt for an elixir of eternal life. Yet it was during their extensive experiments with elixirs that Muslim scientists discovered much of the basis of modern chemistry of which the mineral acids are a part. Nitric acid, Aqua Regia, sulphuric acid, hydrochloric acid, acetic acid and silicic acid are worth mentioning.

Alkalis: Soda and potash were in great demand for making glass, glazes and soap. Natron and plant ash were the sources.

Natron: This is crude sodium carbonate; it was found in its natural state in Egypt in the Western Desert and was exported widely. It was from the Arabic *natrūn* that the European variant 'natron' was derived and thus the symbol 'Na' for sodium.

Al-Qali: This was obtained from the fused ashes of a low, woody shrub found in Syria and variously called *ashnan, ushnan* and *shinan* (*Sạlsola* species N.O. Chenopodiaceae).

The ashes of wood, especially oak (*Quercus infectoria*), were also utilized. Al-Razi described the concentration and purification of *al-qali* and of oak ashes to give pure potassium and sodium carbonates. Abu Mansur Muwaffaq (fourth century AD) was, however, the first to make a clear distinction between sodium carbonate (soda) and potassium carbonate (potash), which are similar in so many respects.

Caustic soda: Caustic soda or sodium hydroxide was never produced on a commercial scale, but it is of historical importance to note that al-Razi knew how to prepare it.

Lime: Lime (*kils*) was quite abundant. Used in soap-making, as a building material, and for military purposes, it was produced by burning stones or marble. When slaked with water it was known as *nura*.

Soap: Hard soap was first produced by the Arabs, only later spreading to Europe. Soap manufacture became an important industry, especially in Syria. Coloured perfumed toilet soap as well as some medicinal soaps were made and exported, and Syrian towns like Nablus, Damascus, Aleppo and Sarmin were famous for their products. The basic process used olive oil and *al-qali*, though sometimes *natrun* was added.

Some treatises of Daud al-Antaki and those of al-Razi sometimes also give recipes for soap. It is worth noting too that al-Rāzī also gave a description of a process for producing glycerine from olive oil.

Inks and Pigments: Several Arabic technological manuscripts are rich in details connected with the production of inks, pigments and glues, as well as with papermaking, bookbinding and other related subjects. One such is *Umdat al-Kuttab*.... (The Handbook of Scribes and the Tool of the Wise) by al-Mu'izz Ibn Badis (*c*. 416 AH/AD 1025), though there are several others which dealt with similar subjects.

For permanent ink, gum arabic (obtained from a species of Acacia) was commonly used as a binder, though glair (made from whipped white of egg) was an alternative. However, other inks were also described in Arabic manuscripts, among them a blue-black ink derived from crushed gall-nuts and ferrous sulphate which is still in use today.

In the Handbook of Scribes and the Tool of the Wise, ibn Badis gives details not only of coloured inks but also of oil paints and lacquers. Such pigments were applied by pen or brush, and were used for writing and for painting miniatures on paper, leather, wood and other surfaces.

For black pigment, the normal colouring substance was carbon obtained from lamp-black or special charcoals, as already described.

A white pigment came mainly from white lead (*isfidaj*), though non-white was also mixed with it sometimes.

Red pigments were available in a variety of shades. The main constituents were cinnabar (*zanjfar*) — the red or crystalline form of mercuric sulphide — and red lead (*isrinj*), though sometimes a clayey ironstone containing red veins among the clay was used. Lac, a dark red resinous incrustation deposited on certain trees by the lac insect (*Laccifer lacca*), was also processed for its pigments and detailed instructions for its preparation were published.

Yellow pigments were derived mainly from orpiment (*zarnikh asfar*) — arsenic trisulphide — though yellow ochres (forms of clayey iron ores) were also used. In addition, massicot (monoxide of lead) was mentioned in Arabic texts, as also saffron, which was employed together with other pigments.

Blue pigments came from the mineral lapis lazuli, though azurite (a form of copper carbonate) was also used, as was indigo.

Green pigments were mainly derived from the basic copper carbonate, verdigris (*zinjar*) and from mineral malachite. In addition, different greens, including those with plant-like hues, were manufactured by mixing other varieties of pigment.

If they were water-based, all these pigments required a binding medium, which was usually mixed with the pigment. Here also, gum arabic was usually used for this purpose. Oil paints were mainly used for miniatures in books and for coating such surfaces as wood. From a manuscript of the tenth century AH (sixteenth century AD) we have detailed information on the preparation of such paints and the techniques of applying them.

Dyes: Dyeing was an important and specialised industry, closely related to the manufacture of textiles. Until the advent of modern synthetic dyes, only vegetable and animal substances were available for dyeing. Even so, sufficient research into the dyeing techniques mentioned in Arabic sources has not been undertaken so far.

Red dyes were very important, because they provided a lively and luxurious colour. One significant source was the lac insect itself and others of the Coccidae family, the bodies of the females giving colours ranging from a brilliant red to scarlet. In Arabic literature, they were referred to as *Qirmiz*, hence our words 'crimson' and 'carmine', and dyes of this kind were reported in several texts. There were other insect-based dyes, however. One known as 'cochineal' and derived from another insect of the same family (*Coccus cacti*) came from Armenia and was distributed to Muslim countries, while there was also the type called 'Qirmis proper' (*Kermococcus vermilio*) that came from Mediterranean lands and from Persia. There are descriptions of how to extract dye from both.

A third source of red dye was the privet henna (*Lawsonia inermis*) that was grown in Syria and Egypt.

The main source of blue dyes was an indigo plant (*nit* or *nila*) (*Indigofera tinctoria*). A major product, it was grown in most Islamic lands, especially Palestine; it was also being imported from India.

A variety of materials were available for yellow dyes, important among them being safflower (*usfur* or *qurtum, Carthamus tinctorius*); colouring matter was obtained from its petals and florets. Three other major sources were saffron (*za'faran*, *Crocus sativus*), turmeric (*kurkum: Curcuma longa*) and *wars* (*Memecylon tinctorium*). In addition, pomegranate rinds and sumach leaves were used both as dyes and as tanning agents. Usually, the green dyes were obtained by dyeing with blue and yellow.

Tyre and Sidon were famous from ancient times for their purple dyes. They used the secretion of the tiny shellfish murex for this purpose.

Black dyes were made primarily from galls with added iron sulphate (*zaj* or green vitriol). Sometimes this was superimposed on deep indigo.

Mordants or fixatives were required to make most dyes adhere to cloth fibres, and aluminium sulphate or alum, known as 'alum of the Yemen' (*shabb Yamani*), was used. Pure alum was, therefore, always an important ingredient in the dyeing process.

SUMMARY

The above account is a modest attempt to identify some medieval Muslim Alchemists and their contribution to the origin of chemistry. The study reveals that a high standard of industrial chemical technology persisted and developed in this Golden Age of Islam and enables us to understand that *there is not much to be gained by attempting to differentiate between Alchemy and chemistry*. It would just be an attempt to differentiate between the first room size computer with today's micro-chip. Thus, how admirable it seems that the Arabic word *al-Kimiya* was used to denote both Alchemy and chemistry in their technological aspect, covering all processes concerned with the distillation of perfumes, petroleum, with metallurgy, as well as with the manufacture of dyes, inks, sugar, glass and many more other products used on a large scale around the globe.

In addition to its deep concern with technology, in some cases Alchemy became associated with more mataphysical and philosophical aspects, such as matters concerned with the cosmos and spirit. Reactions to this side of Alchemy varied; although some distinguished scientists, such as Jabir and al-Razi, believed in the transmutation of metals, others equally distinguished, such as Ibn-Sina, al-Kindi did not. But both sides, affirmative or negative, dealt with technological subjects quite seriously. The works of Jabir, al-Razi, al-Kindi and others are full of technological knowledge to which modern industrial chemistry and chemical engineering owe a great deal. Indeed, the medieval Muslim scientists worked with sound cosmological background on Alchemical aspects in great detail; they will ever remain distinguished in the history of modern chemistry and chemical technology, for their individual efforts and combined works, in parallel or otherwise, exerted an everlasting dominating influence on later generations of Muslims and Europeans.

Ibn-Khaldun calls Alchemy the Science of Jabir, whereas Dr S. Mahdihassan beautifully sums the knowledge of Alchemy as:

"By its claims Alchemy tried to make everything ever-lasting, man immortal, a base metal gold. By its practical achievement it made colloidal metals as drugs of longevity"[31].

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11. *Idem, Op. Cit.* p. 290.
12. *Idem, Op. Cit.* p. 136.
13. *Idem, Op. Cit.* pp. 211-12.
14. *Cupellation*: Method of the separation of silver, gold and other *noble* metals from impurities which are oxidized by hot air. The impure metal is placed in a cupel (a flat dish made up of porous refractory material) and a blast of hot air is directed upon it in a special furnace. The impurities are oxidized by the air and are partly swept away by the blast and partly absorbed by the cupel.
15. *Idem, Op. Cit.* p. 213.
16. *Idem, Op. Cit.* pp. 213-14.
17. cf. R.A. Nicholson in *J.R.A.S.*, (1906), p. 311 ff.
18. *Idem, Op. Cit.* pp. 12-13.
19. *Idem, Op. Cit.* pp. 216-17.
20. cf. Leiden, Cat. No. 1274, Broklemann.
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