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observatory. Its unique position was recognized by international organizations, and it had an important share in the preparation of the International Catalogue of Stars. After the establishment of the Omania University, it became a constituent unit of that University.

The influence of the Muslims in this field is traceable from the many Arabic names and words that have become an integral part of the astronomical sciences. A long list of such words can be compiled, but it would be sufficient to mention a few: almanac (al-mamlık), almacantar (al-maqṣūratāk), nadir (nādir), zenith (sam al-rās), algin (al-qāl), altair (al-ulār), lōbarah (al-dabarān), fomāhīr (fam al-bāl), denah (dahnah), vega (wāqi'ī), and the various names of Muslim astronomers given to the craters of the moon.42


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Chapter LXIV

PHYSICS AND MINERALOGY

The Muslims contributed enormously to exact sciences such as mathematics, astronomy, physics, chemistry, botany, and zoology since they had succeeded in acquiring the knowledge of the sciences which had developed before the advent of Islam.

Abū Yūsuf Yaḥī‘ ibn Ishāq al-Kindī was the first Muslim scientist-philosopher. His pure Arabian descent earned him the title “The Philosopher of the Arabs.” Indeed, he was the first and last example of an Aristotelian student in the Eastern Caliphate who sprang from the Arabian stock. His principal work on geometrical and physiological optics based on the optics of Euclid in Thoer’s recension was widely used both in the East and the West until it was superseded by the greater work of Abū al-Hālijām. He was the first Muslim to write in Arabic a book on music in which he designed a notation for the pitch of notes. Abū Kindī’s three or four treatises on the theory of music are the earliest extant works in Arabic showing the influence of Greek writings on that subject. Of al-Kindī’s writings more have survived in Latin translations than in the Arabic original.43

An observatory was opened by the three sons of Muḥammad ibn Shaqīr (323-357/850-870) in their house at Baghdād. The Buwāshid Sunnāt Ṣafar al-Danbāl (372-379/982-989) instituted another in his palace at Baghdād where ‘Abd al-Rahmān al-Ṣūfī (d. 379/986), Ahmad al-Ṣāhghī (d. 380/990), and Abū al-Walī (d. 387/997) carried out their astronomical observations. At the Court of another Buwāshid, Zikr al-Danbāl (390-396/993-997) of Abū Rayyāf, flourished Abu Ja‘far al-Khāzīn of Khurasān who ascertained the obliquity of the ecliptic and solved a problem in Archimedes which led to the discovery of a cubic equation. Other astronomers made a systematic study of the heavens in Shākra, Šīkhāp, and Samarqand.44 Ibn Mūsā published a work on the balance.

‘Uṯnārid ibn Muḥammad al-Ḫabīb wrote a book on lapidary which is reckoned among the oldest Arabic works on this subject; Abu Zakariya al-Rāzī quoted from ‘Uṯnārid in his famous book al-Ḫafṣ. Al-Rāzī the Iranian was one of the greatest medical men of the Middle Ages. He was an expert chemist and physician.

Abū Bakr ibn Fāṭimīd was personally interested in astronomical calculations. He built on the Maqtātān an observatory to which he used to ride before dawn. The intellectual lights of his Court were ‘Ali ibn Yūsuf (d. 400/1009), the greatest astronomer Egypt has ever produced, and Abu ‘Ali al-Ḫālijām (Latīn Alhasen), the principal Muslim physicist and student of optics. The latter was undoubtedly the foremost physicist of the Middle Ages. His researches into geometrical and physiological optics were considered to be the most important and useful up to the time of the Renaissance. His explanation of the vision and functions of the eye was far in advance of the ideas of the ancients. The chief work for which he is noted is on optics, Kitāb al-Manṣūrī, of which the original is lost but which was translated into Latin in the sixteenth century. Almost all the medieval writers on optics in the West based their works on Ibn Hālijām’s Opticon Theorum. In this work he opposed the theory of Euclid and Ptolemy that the eye sends out visual rays to the object of vision, and presented experiments for testing the angles of incidence and reflection. In certain experiments he approached the theoretical discovery of magnifying lenses which were manufactured in centuries later.45

44 Ibid., p. 376.

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Ibn al-Haitham was the greatest Muslim physicist and one of the foremost opticians of the world. He found out the law of refraction it transparent bodies; laws of reflection of light; spherical and parabolic aberrations; and the law of refraction which later came to be known as Snell’s Law. He discussed the magnifying power of a lens, refraction of light in the earth’s atmosphere, and beginning or termination of twilight when the sun is 10° vertically below the horizon. He tried by these means to estimate the height of the homogenous atmosphere. He gave a better explanation of vision, though he erroneously assumed the lens of the eye to be the organ of sight. Later on ibn Ruhad corrected this error and showed that sight is the function of the retina. Ibn al-Haitham explained the vision of a body by the aid of two eyes and the more magnified appearance of heavenly bodies when seen: the horizon when than vertically higher.

Muslim scientists evinced much interest in the determination of specific gravity of bodies. At Qâsham in eastern Afghanistan lived an al-Rahîm ibn Ahmad al-Birûnî (973-1048), considered one of the most original and profound scientists that the medieval world produced in the domains of physical and mathematical sciences. Al-Birûnî found accurately the specific gravity of eighty different precious substances and metals. He realized that the velocity of light was enormously greater than that of sound. Al-Birûnî developed the mathematical part of geography, improved mensuration, and determined quite accurately the latitude and longitude of a number of places; he devised easy methods of stereographic projection. He showed how water flows in natural springs and now it comes out in artificial wells, and explained these facts in accordance with the laws of hydraulics. His observations led him to the conclusion that the Indus Valley was at one time a part of the sea which became solid by the deposit of alluvial soil.

The most illustrious name in Arabic medical annals after al-Râzi’s is that of Ibn Sina (Latin Avicenna) (370-428/901-1037). Al-Râzi was more of a physician than Ibn Sina, but Ibn Sina was more of a philosopher. In this physician, philosopher, philologist, and poet, medieval Arab science culminates and is, one might say, incarnated. Ibn Sina wrote on the theory of numbers. For accurate measurement of distances he invented an apparatus involving the same principle as our modern Vernier. He made a masterly study of a number of physical subjects like motion, contact, force, vacuum, infinity, light, and heat. Ibn Sina expressed his views on all the information that could be gathered in physics philosophically. He showed that however great the velocity of light may be, it must be limited. He did valuable research in music also, but his principal subject was medicine for which he earned the title of Qâbal al-Ra’is. Jâhil al-Din Malik Shâh patronized astronomical studies. He established in 467/1074 at Rayy an observatory where there was introduced into the civil calendar an important reform based on an accurate determination of the length of the tropical year. To this task of reforming the Persian calendar he called to his new observatory the celebrated ‘Umar al-Khayyâm. ’Umar al-Khayyâm was born between 430/1048 and 440/1048 at Nishâpûr where he died in 517/1123. He is known to the world primarily as a Persian poet. Very few people realize that he was a first-class mathematician and astronomer as well. The researches of al-Khayyâm and his collaborators resulted in the production of the calendar named, after his patron, al-Farâbî al-Jâzî, which is even more accurate than the Gregorian calendar. As mentioned in the preceding chapter, the latter leads to an error of one day in 2,320 years whereas al-Khayyâm’s leads to an error of one day in about 5,000 years. ’Umar al-Khayyâm performed experiments to find the specific gravity of various substances.

The attraction of iron by natural magnet was known to the Greeks; magnet’s acquiring a definite direction when suspended freely was known to the Chinese. But it appears that this property was first utilized by Muslims in their marine navigation. Muhammad al-‘Ubayd was the first to mention it in his Jâzîrî. The directive position of the magnetic needle was known to the Chinese from a very long time, but they used it only for geomantic purposes. Most probably Muslim sailors were the first to employ it in navigating their ships as is evident from Chu Yu’s account of sailing vessels using it between Canton and Sumatra.

Naṣr al-Din Tâj’s most brilliant pupil Qâbî al-Din Shâhârû (834-711/1236-1311) wrote Nîqkât al-jāhîl & Dîqqāl al-‘âdâk which is largely a development of the former’s Tâqqih, a work on astronomical topics; it also contains valuable discussions on geometrical optics like those on the nature of vision and the formation of the rainbow. He was the first scientist to give a correct and clear explanation of the formation of a rainbow. The primary bow was explained by him to be due to two refractions and one internal reflection, and the secondary to two refractions and two internal reflections of solar rays in minute spherical drops of water suspended in the air; essentially the same explanation was given by Descartes in the seventeenth century. The colours of the rainbow for their correct interpretation had to wait Newton’s experiments on the dispersion of light.

Kasâ’î was the great pupil of Qâbî al-Din and under his inspiration wrote Tâqqih al-Madhâbî (a commentary on ibn al-Haitham’s classical work on optics, Kitâb al-Madhâbî), which was published with notes by the Dâ’îr al-Ma‘ârif, Hyderabad, in 1329-30. Muslim scientists were deeply interested in Archimedes’ works on mechanics and hydraulics. In these subjects they determined the density of a number of substances. Nasal ibn ‘Ali, al-Birûnî, ‘Umar al-Khayyâm, Maqâlar al-Asfuzî, and several others did some work on these branches of physics, but the most important work was done by ‘Abd al-Rahîm al-Khzâin in...
his Mīzān al-Hikmah, written in 618/1221 and considered among the masterpieces of the Middle Ages. In this work, al-Khāzini discussed mechanics, hydrostatics, and physics in a masterly way. He gave tables of specific gravities of liquid substances (on the lines adopted by al-Biruni) and detailed studies of the theory of gravitation (universal force directed towards the then considered centre of the universe, i.e., the centre of the earth); weight and buoyancy of air; rise of water in capillary tubes; aerometric measurement of densities and the temperature of liquids; theory of the lever; levelling by balance; and measurement of time.

The Muslims took keen interest in clocks to find out the correct times for prayers. Their artisans acquired great mastery in this work, as may be judged from Hārūn al-Rashīd’s presenting Charlemagne with a water-clock in 192/807.

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Chapter LXV

CHEMISTRY

Alexandrian Alchemy.—With the advent of Islam, the Arab tribes, many of them still nomadic, were united into one nation. Their conflicts with the neighbouring peoples which used to end as skirmishes bringing immediate defeat on the scattered tribes, now changed into regular wars often crowning them with success. What that meant can be realized from the fact that within a hundred years of the Prophet’s death, which occurred in 11/662, Islam had spread from Spain in the West to Sind in the East. As an advancing nation the Arabs came in contact with different races, and when Egypt was conquered, during the regime of the Caliph ‘Umar, in 21/641, they came to know the Hellenized Egyptian culture as it then existed. Its centre was Alexandria, founded by Alexander in 332 B.C. Very soon it became an emporium of international trade attracting merchants from all over the world. Above all, the Greeks had migrated there in numbers, giving rise to a mixed culture of Egyptian and Greek origin. The Egyptians used idols in their temples and chapels, preferring those of bronze, particularly when they were gilded. The artisans of Alexandria excelled in this craft, and the manufacture of gilded bronze statues apparently became a lucrative industry. From gilding bronze

some of the artisans began to dream of making gold itself and devoted their main attention to achieve this end. Thus arose alchemy, not found before either in Egypt or in Greece. It was existing when the Arabs acquired Egypt and was one of the elements of Alexandrian culture which diffused into Arabian civilization. There are several treatises and even books which suggest that Greek science, which flourished between 300 B.C. and 200 A.D., subsequently passed on to the Arabs who functioned as its intermediate preservers delivering it to Europeans during the Middle Ages. Such is the accepted origin of alchemy.

It now becomes necessary to offer a brief sketch of alchemy as it was founded at Alexandria. The oldest existing manuscript on alchemy is not prior to about 891/1000. But it is supposed to be a copy of a work originally written in about 100 A.D. During this early period alchemy was a semi-secret science pursued by a few obscure persons. As Taylor² says, “although the earlier alchemists wrote in Greek, they were not Greeks, but in all probability Egyptians or Jews. They were not Christian.” And what did they call their art? This knotty problem is conspicuous by its absence in Taylor’s book. When Wilson³ came to review it, he supplied the missing information on “the derivation of the Greek name of the art.” “The word unmistakably goes back to the craft of the foundryman and metal-worker. First, there is the Greek verb χειμίζω, to melt and pour, as in the casting of a bronze statue, then its derivative χειμία, an ingot of cast metal, and finally from this another derivative χειμιεῖον, the art of preparing metal ingots. This in time became a technical term for the artificial preparation of the precious metals, but at first, as in Zosimus, about 300 A.D., it acquired a qualifying phrase, the χειμία of silver or gold. Before the Arabic period, however, chemia could stand alone to denote the art of transmutation. Also before Arabic times, about 81700 or earlier, it seems to have been confused with chemis, apparently a Greek derivative of the Egyptian word chem, meaning black. The reasons are obscure but the fact of the confusion is hardly to be questioned. Later, the Arabs took over both spellings, chemeia and chemis, prefixed their own definite article of, and handed the word on to the Europeans in about the sixth/seventh century.” Thus kinyis is the Arabicized form of the dual word chemis/chemia.

The Greek and Arabic Terms Compared.—Now it is even more important to know what the Arabs received under the name kinyis from the Greek-speaking alchemists—to know what the word chemis signifies and how the Arabic word kinyis compares with it in meaning. Gildemeister⁴ explains that “kinyis with the Arabs primarily is not an abstraction (or the science of alchemy) but the name of a substance, of an agent, by which transmutation of metals is brought about, thus of the Philosophers’ Stone, or rather of

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