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 Osmania 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-munākh)*, almacantar *(al-muqanṭarah)*, nadir *(nādir)*, zenith *(samt al-rās)*, algol *(al-ghūl)*, altair *(al-ṭā'ir)*, aldebaran *(al-dabarān)*, fomalhaut *(fam al-ḥūt)*, denab *(dhanab)*, vega *(wāqi')*, and the various names of Muslim astronomers given to the craters of the moon.[61]

[61] Mohammad Abdul Rahman Khan, "Names of Thirteen Muslim Astronomers Given to Some Natural Features of the Moon," *Islamic Culture*, Vol. XXVII, No. 2, April 1953, pp. 78–85.

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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.

Abu Yūsuf Ya'qūb ibn Isḥāq al-Kindi[1] 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optics based on the optics of Euclid in Theon's recension was widely used both in the East and the West until it was superseded by the greater work of ibn al-Haitham. He was the first Muslim to write in Arabic a book on music in which he designed a notation for the pitch of notes. Al-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.[2]

[1] See Chapter XXI.

An observatory was opened by the three sons of Mūsa ibn Shākir (236–257/850–870) in their house at Baghdād. The Buwaihid Sulṭān Sharaf al-Daulah (372–379/982–989) instituted another in his palace at Baghdād where 'Abd al-Raḥmān al-Ṣūfi (d. 376/986), Aḥmad al-Ṣaghāni (d. 380/990), and abu al-Wafā' (d. 387/997) carried out their astronomical observations. At the Court of another Buwaihid, Rukn al-Daulah (320–366/932–976) of al-Rayy, flourished abu Ja'far al-Khāzin of Khurāsān 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 Shīrāz, Nīshāpūr, and Samarqand.[3] Banu Mūsa published a work on the balance.

'Uṭārid ibn Muḥammad al-Ḥāsib wrote a book on lapidary which is reckoned among the oldest Arabic works on this subject; abu Zakarīya al-Rāzi quoted from 'Uṭārid in his famous book *al-Ḥāwi*. Al-Rāzi the Iranian was one of the greatest medical men of the Middle Ages. He was an expert chemist and physicist.

Al-Ḥākim the Fāṭimid was personally interested in astronomical calculations. He built on the Muquṭṭam an observatory to which he used to ride before dawn. The intellectual lights of his Court were 'Ali ibn Yūnus (d. 400/1009), the greatest astronomer Egypt has ever produced, and abu 'Ali al-Haitham (Latin Alhazen), 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 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 one on optics, *Kitāb al-Manāẓir*, of which the original is lost but which was translated into Latin in the sixth/twelfth century. Almost all the medieval writers on optics in the West based their works on ibn Haitham's *Opticae Thesaurus*. 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 Italy centuries later.[4]

[2] P. K. Hitti, *History of the Arabs*, 1958, *passim*, pp. 370f.
[3] *Ibid.*, p. 376.
[4] *Ibid.*, p. 629.

Ibn al-Haitham was the greatest Muslim physicist and one of the foremost opticians of the world. He found out the law of refraction in 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 19° vertically below the horizon. He tried by these means to estimate the height of the homogeneous 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 Rushd 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 near the horizon than when vertically higher.

Muslim scientists evinced much interest in the determination of specific gravity of bodies. At Ghaznah in eastern Afghānistān lived abu al-Raiḥān Muḥammad ibn Aḥmad al-Bīrūni (363–440/973–1048), considered one of the most original and profound scientists that the medieval world produced in the domains of physical and mathematical sciences. Al-Bīrūni found accurately the specific gravity of eighteen different precious substances and metals. He realized that the velocity of light was enormously greater than that of sound. Al-Bīrūni 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 how it comes out in artificial wells, and explained these facts in accordance with the laws of hydrostatics. 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-Rāzī's is that of ibn Sīna (Latin Avicenna) (370–428/980–1037). Al-Rāzi was more of a physician than ibn Sīna, but ibn Sīna was more of a philosopher. In this physician, philosopher, philologist, and poet, medieval Arab science culminates and is, one might say, incarnated. Ibn Sīna 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 Sīna 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 *Shaikh al-Ra'īs.*

Jalāl al-Dīn Malik Shāh 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-Khayyām. 'Umar al-Khayyām was born between 430/1038 and 440/1048 at Nīshāpūr 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-Khayyām and his collaborators resulted in the production of the calendar named, after his patron, *al-Tārīkh al-Jalāli*, 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 3,330 years whereas al-Khayyām's leads to an error of one day in about 5,000 years. 'Umar al-Khayyām 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. Muḥammad al-'Aufi was the first to mention it in his *Jawāmi'*. 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.

Naṣīr al-Dīn Ṭūsī's most brilliant pupil Quṭb al-Dīn Shīrāzi (634–711/1236–1311) wrote *Nihāyat al-Idrāk fi Dirāyat al-Aflāk* which is largely a development of the former's *Tadhkirah*, 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 eleventh/seventeenth century. The colours of the rainbow for their correct interpretation had to wait Newton's experiments on the dispersion of light.

Kamāl al-Dīn Fārisi (d. 720/1320) was a famous pupil of Quṭb al-Dīn and under his inspiration wrote *Tanqīḥ al-Manāẓir* (a commentary on ibn al-Haitham's classical work on optics, *Kitāb al-Manāẓir*), which was published with notes by the Dā'irat al-Ma'ārif, Hyderabad, in 1928–30.

Muslim scientists were deeply interested in Archimedes' works on mechanics and hydrostatics. In these subjects they determined the density of a number of substances. Sanad ibn 'Ali, al-Bīrūni, 'Umar al-Khayyām, Muẓaffar al-Asfuzāri,[5] and several others did some work on these branches of physics, but the most important work was done by 'Abd al-Raḥmān al-Khāzini in

[5] G. Sarton, *Introduction to the History of Science*, Vol. II, p. 216.

his *Mīzān al-Ḥikmah*, 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-Bīrūni) 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 interst 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 11/632, 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