IKS-121

Introduction to Indian Knowledge System

Unit I: Science in Ancient India

C. Vedic Metallurgy/Chemistry from the medical schools of Ancient India

Vedic Metallurgy: Metallurgy in India

For over 7000 years, India has had a high tradition of metallurgical skills. The two important sources for the history of Indian metallurgy are archaeological excavations and literary evidences. The first evidence of metal in Indian subcontinent comes from Mehrgarh in Baluchistan, where a small copper bead was dated to about 6000 B.C.E. It is, however, thought to be native copper, which has not been extracted from ore. Archaeological excavations have shown that Harappan metalsmiths obtained copper ore from Aravalli Hills, Baluchistan or beyond. Many bronze figurines of humans and animals have been unearthed from Harappan sites.

Systematic excavations at Mohenjodaro in Sindh and Harappa in Punjab show that during the mature Harappan period, the metal workers perfected the metallurgical skill. Harrapans used metals like tin, arsenic, lead, antimony, etc., for alloying. They had also perfected the wax technique of metal casting in as early as the third millennium B.C.E. They melted and forged a variety of objects from metals such as lead, silver, gold and copper. They improved the hardness of copper for making artefacts by using tin and arsenic.

Copper

Copper metallurgy in India dates back to the beginning of Chalcolithic culture in the sub-continent. Copper and bronze were used for making weapons, tools and cheaper ornaments. Copper found at Mohenjodaro contains an appreciable amount of lead and also some objects made of copper which also contain nickel. An alloy of copper and arsenic was also used at Mohenjodaro. Copper was smelted from ore and afterwards refined in clay crucible. The fragment of such

crucible with slag sticking at the edges has been found at the excavation of Mohenjodaro.

One of the resource zones for copper was Aravalli range. There are deposits of copper, lead, silver and zinc ores in the Aravalli hills. The copper ore of this region contains 4 per cent to 8 per cent arsenic. Many copper objects obtained from Harappa and Mohenjodaro contains high level of arsenic. This suggests that metal workers of Harappan civilisation obtained copper ore from this region of Aravalli hills. In Rajasthan, the copper mining areas are along the eastern flank of Aravalli hills extending from Bharatpur, Alwar and Khetri region in North East to the South of Udaipur.

There are evidences of deep mining in the Rajpur Dariba in the district Udaipur. Radiocarbon dating shows that the mines are of the last quarter of the second millennium B.C.E. Large heaps of broken stones have been found near the mining area. It seems that ore bearing rocks were taken to the valley, where they were roasted, crushed, concentrated and smelted.

Now, archaeological and analytical data are available to prove that the objects excavated from later Chalcolithic sites were made in India. A number of axes, chisels and mirrors have been unearthed by archaeological excavations in pre-Harappan settlement sites—Nal, Mehi, and Kot Diji. A chemical analysis of a fragment of an axe from Nal shows that it is made up of 94% pure copper with 5% of nickel in it. This shows that smelters and smiths of the Indian subcontinent, who made these articles, had advanced

knowledge of copper metallurgy. In an excavation in 1962, at chalcolithic site at Ahar near Udaipur in Aravalli Hills, heaps of semi fused glass-like material together with copper tools and quartz in stratified layers were unearthed. Radiocarbon dating of the material shows it to be of the period from 1800 to 1600 B.C.E. Analysis of the glass-like material showed it to be copper metallurgical slag which is the waste product of the copper smelting industry. It establishes the evidence of copper smelting activity in Ahar during Chalcolithic period. More than fifty such sites have been located and some of these are Gilund, Meroli, Kumaria and Kadukota. This also shows that the Indian chalcolithic metal objects were, most probably, indigenously made. Extensive copper ore deposits are located in the Aravalli Hills within the area inhabited by Chalcolithic communities. Aravalli copper ore deposits can, therefore, be considered as the source likely used by the Chalcolithic metal workers. Though chalcopyrite ore is abundant in Aravalli Hills, the percentage of copper is poor in the ore but the percentage of copper in many examined samples was found to

be 98 per cent. This purity in copper is equivalent to the purity of present time blister copper. Evidence of ore dressing, roasting, fluxing and extraction of copper consistently in 98 per cent purity prove that advanced stage of metallurgical processes was reached and maintained in Chalcolithic period.
There is fairly extensive evidence for ancient mining of copper ores from Khetri region of Rajasthan in north-western India dating to about the third–second millennium B.C.

Iron

Recent excavations in the central parts of Ganges Valley and Vindhya Hills have shown that the art of iron smelting and manufacturing of iron artefacts was well known in eastern Vindhyas and it was in use in the Central Ganga Plain. In the recent excavations conducted by Uttar Pradesh State Archeological Department, iron furnaces, artefacts, tuyers and layers of slag have been obtained. Radiocarbon dating places them between 1800 and 1000 B.C.E. The quantity and types of iron artefacts and the level of technical advancements in India indicate that the introduction of iron work took place even earlier.
Asur Munda and Agaria tribes of India have been the main tribes concerned with the manufacture of iron. Agaria tribe practiced iron smelting on large scale. This tribe has been living in Andhra Pradesh, Madhya Pradesh, Eastern Uttar Pradesh, Bihar and Orissa. The ancient practice was considered to be extinct till 1963, when Ghose of TI

located the tribsman at Kamarjoda, Chiglabecha and Jiragora, who could construct their traditional furnace and operate them to produce wrought iron bloom.
These furnaces were meticulously designed and constructed using pre-shaped curved clay bricks. The refractory clay used in the bricks was obtained from the places close to the site of operation.
The design criteria such as shaft taper, bosh to top diameter and bosh angle in these primitive furnaces have been found to be almost same as in modern blast furnaces of 1960–70. The ancient furnaces have relatively large hearth diameter because these produced semi-solid sponge iron and liquid slag instead of molten cast iron and slag because forging operation is not possible on cast iron due to brittleness.

Iron smelting and the use of iron was especially established in South Indian megalithic cultures. The forging of wrought iron seems to have been at peak in India in the first millennium C.E. Greek accounts report the manufacture of steel in India by crucible process. In this process, iron, charcoal and glass were mixed together in a crucible and heated until the iron melted and absorbed the carbon. With the passage of time, blacksmiths of ancient India gained specialised skills in the hot and cold working and hot and cold forge welding. They gained experience about the effect of carbon on the physical properties of iron. They developed the process of carburisation. This resulted in hardening of the material. This process has been known as 'steeling'. This was used for making arrow heads, swords and knives, etc. *Suśruta* (500 B.C.E.) has also described this procedure and heat treatment for making of the surgical knives having such sharp edges that could bisect human hair longitudinally.

India was a major innovator in the production of advanced quality steel. Indian steel was called 'the wonder material of the Orient'. A Roman historian, Quintus Curtius, records that one of the gifts that Porus of Taxila (326 B.C.E.) gave to Alexander the Great, was some two-and-a-half tons of Wootz steel. Wootz steel is primarily iron containing a high proportion of carbon (1.0 – 1.9%). Wootz is the English version of word *'ukku'* which is used in the language in Karnataka and Andhra Pradesh for steel. Literary accounts suggest that Indian Wootz steel from southern part of Indian subcontinent was exported to Europe, China and Arab World. It became prominent in Middle East where it was named as Damascus steel. Michael Faraday tried to duplicate this steel by alloying iron with a variety of metals including noble metals, but failed.

When iron ore is reduced by charcoal in solid state, it forms porous iron blocks. Therefore, reduced iron blocks are also called sponge iron blocks. Any useful product can only be obtained from this material after removing the porosity by hot forging. The iron so obtained is termed as wrought iron. The process control achieved by the ancient iron smelters was so high that they could produce 6–10 tons of wrought iron of almost uniform quality used for the manufacture of objects like the world famous Iron Pillar at Delhi. Engraved Sanskrit inscription suggests that it was brought here from elsewhere in the Gupta period. The average composition of the components present in the wrought iron of the pillar besides iron are 0.15% C, 0.05% Si, 0.05% Mn, 0.25% P, 0.005% Ni, 0.03% Cu and 0.02% N. The most significant aspect of pillar is that there is no sign of corrosion in spite of the fact that it has been exposed to the atmosphere for

about 1,600 years. High purity of the metal (> 99 per cent) and presence only of traces of injurious elements, and clean environment prevented it from rusting. Also most recently, Balasubramaniam has explained that a composite layer of iron hydrogen phosphate formed on the pillar prevents it from rusting. Rapid industrialisation and the increase in traffic in and around Delhi is raising the sulphurous gases in the environment. If this remains uncontrolled, corrosion may occur and weaken the matrix of the pillar. Another famous iron pillar is located at Mookambika temple in Kodachari Hill in a town near Mangalore. It also belongs to the same period. The iron beams lying in the Surya temple at Konark are still bigger in size. Non corroding iron beams were being used extensively in the construction of temples in Orissa dating back to the sixth and thirteenth centuries C.E. Evidences of iron smelting are available in North East region also. Radiocarbon dating of charcoal from the iron slag obtained in this region provides evidence of continuous smelting in Khasi Hills. Meghalaya is the earliest iron smelting site studied in the entire region of North East India. The slag layer, which is dated to 2040±80 years BP (253 B.C.E. – A.D. 128) is the remnant of former iron ore excavation and iron manufacturing visible even now in the landscape of Khasi Hills.

Zinc

There is archaeological evidence of zinc production in Rajasthan at Zawar around the sixth or fifth B.C.E. Due to low boiling point, zinc tends to vaporise while its ore is smelted. As a result, its vapours present in the furnace are reoxidised and the metal is lost. Therefore, zinc is produced by distillation technique. India was the first country to master zinc distillation. The technique used for distillation in Zawar was designed for downward distillation in which vapours were condensed in a lower container. The distillation of the pallets of roasted ore mixed with charcoal powder, salt, etc., and borax as flux was carried out in brinjal shaped retorts. In excavation at Zawar, these retorts have been found. Each distillation unit had two chambers. Lower chamber was separated from the upper chamber by perforated bricks. Charged retorts were fixed in the perforations with their mouth projecting out in the lower chamber. The mouth of the retort was sealed and fixed in the collecting earthen pots. Earthen pots were kept in the lower chamber of the distillation unit. Earthen pots were dipped in a water trough for cooling the vapours of zinc coming out of the retort. Upper part of the retort was heated by making fire in the upper chamber. Zinc vapours

coming in the earthen pot cooled inside it due to cold water surrounding the earthen pot. This technique was also applied to mercury. Indian metallurgists were masters in this technique. This has been described in the Sanskrit texts of fourteenth century.

Gold and Silver

Harappans also used gold and silver as well as their joint alloy electrum. Variety of ornaments such as pendants, bangles, beads, rings, etc., have been found in ceramic or bronze pots. Early gold and silver ornaments have been found from Indus Valley sites such as Mohenjodaro (3000 B.C.E). These are on display in the National Museum, New Delhi. India has the distinction that the deepest ancient mines in the world for gold are in Maski region of Karnataka with carbon dating from mid first millennium B.C.E. A sample of silver containing Ag 94.5; Pb 0.42; Cu 3.68; insoluble 0.38 per cent was found in Mohenjodaro. The process of extracting silver was known to the people of Mohenjodaro.

Hymns of *Ṛgveda* gave earliest indirect references to the alluvial placer gold deposits (i.e., deposits of gold minerals formed in stream) in India. The river Sindhu was an important source of gold in ancient times. It is interesting

that the availability of alluvial placer gold in the river Sindhu has been reported in modern times also. It has been reported that there are even now, great mines of gold in the region of Mansarovar and in Thokjalyug. The *pāli* text *Aṅguttara Nikāya* narrates the process of the recovery of gold dust or particles from alluvial placer gold deposits. Although evidence of gold refining is available in vedic texts, it was Kauṭilya *Arthaśāstra*, authored probably in third or fourth century B.C.E., during Mauryan era, which has much data on the prevailing chemical practices in a long section on mines and minerals including metal ores of gold, silver, copper, lead, tin and iron. Kauṭilyas' *Arthaśāstra* describes a variety of gold called *rasviddhā*, which is naturally occurring gold solution, Kalidas also mentioned about such solutions. It is astonishing how people recognised such solutions.

The native gold (i.e., gold found in nature) has different colours depending upon the nature and amount of impurity present. It may be that the different colours of native gold were a major driving force for the development of gold refining.

Chemistry from the medical schools of Ancient India

ORIGIN OF ALCHEMY

In India the origin of alchemy can be traced back to the Vedic age. Medicinal plants are classified into two categories according to Atharvaveda; ayusani (promoting longevity) and bhaisajya (curing diseases). In the Ayurvedic period the term ayusani gave place to Rasayana. Therefore Rasayana represents drugs which improve the circulation of body fluids and thus helps in prolongation of life.The Vedic people had a strong appeal for gold and for an exhilarating drink called soma. Both were exalted to a divine position. The Atharva Veda mentions about gold as a heavenly blessing which confers longevity on a person who wears it. Soma rasa according to Rig-veda was drink of immortal gods. The extraction of juice of soma was itself an elaborate ritual. It was offered to the gods by priests. Soma rasa like gold was also considered to bring immortality.

BENEFITS OF RASAYANA

About the benefits of Rasayana, Alberuni has written, “its principles restore the health of those who were ill beyond hope, and give back youth to fading old age, so that people become again what they were in the age at puberty; white hair become black again, the keenness of senses is restored as well as the capacity for juvenile agility, and even for cohabitation and life of the people in this world is extended to a long period”. Rasayana was believed to control premature ageing, weakness, disease and even death. Thus through Rasayana benefits to be achieved were; prolongation of life, boosting memory and intelligence, regulating immunity against diseases, keeping up a youthful state , improving complexion and voice, enhancing body strength and strength of sense organs etc . Susruta Samhita mentions about the treatment of diseases of ear generally by the practicing rasayana . According to Ayurvedic texts two types of Rasayana were practiced.

1) Kuti Praveshika
2) Vatatapika

1) Kuti Praveshika: It was undertaken in a specially built three chambered (concentric) house. By this method every cell of the body gets rejuvenated. It is designed on the basis of first state of life in mother's womb.

2) Vatatapika: This method was for those who who found it impossible to undergo the first method because of its strict rules. In this method one was exposed to sun and wind during Rasayana therapy .

MATERIAL AND PROCESS

During medieval period alchemists were busy in their activities. In order to develop new methods they used earlier knowledge of metals, minerals and plant materials. different types of inorganic substances such as; minerals including

gems and metals and organic substances which include plant as well as animal products were used but it was inorganic products that were largely used .Among the metals most frequently used were gold, silver, iron, lead, copper, zinc, tin and mercury. Besides these arsenic, sulphur, orpiment (arsenious sulphide, As2S2), realgar (arsenic sulphide, As2S3) and cinnabar (mercuric sulphide Hg2S2) were also used .The important minerals were generally called rasas which were further divided into maha (superior) and upa (subsidiary) rasas. The metals were called dhatus. Although mercury is a metal but it was considered maharasa, the king of rasas. In the alchemical texts it is mentioned by various names like; parada, sita, rasendra, svarnakaraka (maker of gold), sarvadhatupati, Sivaja (born of Siva), Siva virya (semen of Siva) and Harabija (seed of Siva).
The metals which have been mentioned in rasashastra texts are gold, silver, copper, & iron which are considered pure while lead and tin are considered as odorous (puti). In the alchemical texts various plants have been mentioned some of which have medicinal value. The roots, leaves or seeds of these plants aid indigestion. According to Alberuni most of the medicines prepared in Rasayana Were from plant sources .Regarding animal products, their excreta, flesh or some other parts of their bodies were processed and used but comparatively the use of metals and minerals in alchemy was more pronounced. According to rasavadins minerals and metals couldn‟t give desired alchemical properties unless they were treated or digested with some medicinal plant. Even mercury that was considered the king of rasas had to undergo treatment with different plants . It was solidified using plant juices, metals and sulphur. Gold was also used in preparing a variety of medicine. Various methods of preparing compounds of mercury having medicinal value were developed by the alchemists. The alchemical texts have given the details of processes for the preparation of different types of bhasmas. In the preparation of bhasmas the desired substance is heated for a long period which plays an important role in obtaining an effective product of fine particle size. Some of the bhasmas prepared by rasavadins showing their experimental skills are:

Gold bhasma: In this thin gold leaves were to be coated with a paste made of mercuric sulphide and the juice of custard lime, dried and incinerated. This process was to be repeated ten times, after which bhasma could be used as medicine. It could also be prepared by a process that involved cinnabar, sulphur, realgar and sal ammoniac (ammonium chloride) as well as gold and citrus juice.

Silver bhasma: One method of preparing this was that silver foils were to be coated on both sides with kajali prepared from mercury and sulphur, and ground in citrus juice. These were dried and powdered sulphur was spread over them above and below. These were then placed between two earthen plates, sealed and heated in a sand-bath for a day, over a strong fire. When it got cold, the product was mixed with powdered pyrites in equal quantities and ground well

with lime juice and then heated for a long time till the silver was reduced to its bhasma form.

Copper bhasma: It was prepared by keeping copper leaves immersed in cow's urine for 15 hours and then taken out. Copper leaves are placed in the paste of Cangeri (oxalis corniculata) and kajali (prepared from mercury and sulphur) is also put in it. The pot was closed with lid and heated on high flame for three hours. After cooling it, the mass is powdered and thus the product called copper bhasma became ready for use.

Lead bhasma: For its preparation mercury was added to molten lead along with barks of arjuna (Terminalia arjuna), vibhitaki (Terminalia belerica), ashwagandha (Withania somnifera), pomegranate and apamarga (Achyranthes aspera). These were heated together for 21 nights, all along constantly stirring by an iron ladle. The product obtained is finely powdered. According to alchemical texts lead bhasma was excellent for rasayana therapy.

References:

1. Knowledge Traditions and Practices of India, Book code 11151, Chemistry and Metallurgy in India, Class XI, NCERT Publication
2. Jyoti Pathak, Chemistry in Ancient India, International Research Journal of Management Science & Technology, Vol 7 Issue 3, 2016, ISSN 2250 – 1959 (0nline) 2348 – 9367 (Print)