UNIT 2

Construction materials in the ancient times

In ancient times, people used a variety of materials for building and making tools. Early humans made tools from bone, ivory, stone, wood, animal fibers, and metals like gold, copper, and silver. They crafted tools such as hand axes, choppers, scrapers, and levers for different tasks. For building, they used materials like mammoth bones, hides, stone, metal, bark, bamboo, and animal dung. Bricks and lime plaster were also common, with evidence of mud bricks and clay mortar dating back to 9000 BCE in Jericho. These early bricks were shaped by hand and often had unique patterns made by the brick-maker's thumbs.

Around 5000 BCE, the use of copper began, which was stronger and more versatile than stone and led to the development of better tools.

Indus Valley Civilization is known for its technological knowledge in variety of fields. Archaeological findings show that baked bricks were used in the construction work. Gypsum cement has been used in the construction work in which lime, sand and traces of $CaCO_3$ have been found.

In ancient China, fired bricks were invented around 4400 BCE and were used for floors and other structures. The Mesopotamians used clay sewer pipes around 4000 BCE, and by 3200 BCE, they had built latrines with raised brick foot platforms. The Egyptians, around 3100 BCE, popularized the post-and-lintel construction method using large stone blocks for temples and monuments like the Great Pyramid of Giza.

During the Iron Age (1200–500 BCE), humans began using iron and later steel, which is a combination of iron and carbon. Steel was stronger and could be sharpened, making it ideal for creating more effective tools such as hammers, chisels, and knives. In regions like present-day Britain, roundhouses were common. These were built using stone or wooden posts, wattle-and-daub panels, and thatched roofs.

In Mesopotamia, mud bricks were the primary building material. They varied in size and shape, and by 3500 BCE, fired bricks became common. In ancient Egypt, sun-baked mud bricks (adobe) were used for regular houses, while large stone blocks were reserved for grand structures. The Romans later developed a special type of cement called Roman cement by mixing lime mortar with volcanic ash, which hardened even underwater. This allowed them to build strong and durable structures that have lasted for centuries.

The iron pillar of Delhi

The Iron Pillar of Delhi is a 7.21-meter-tall iron structure with a 41-centimeter diameter. This was built by King Chandragupta II around 375–415 CE. It stands in the Qutub complex in Mehrauli, Delhi, India. The pillar is famous because it has not rusted even after being in the open for over 1,600 years. This rust resistance shows the advanced skills of ancient Indian ironworkers.

The Iron Pillar was likely made using a technique called forge welding. In this method, large pieces of iron, each weighing about 18–23 kilograms, were heated and hammered together. The top part of the pillar, known as the capital, was made of seven separate pieces, which were put together over a hollow cylinder and then attached to the main pillar.

There are different ideas about why the pillar doesn't rust. One idea is based on the climate in Delhi, where the humidity is usually below 70%. This low humidity might help keep the pillar from rusting. However, this theory is based on weather data collected between 1930 and 1960, which is too short to explain the pillar's rust-free condition over 1,600 years. Another idea, supported by metallurgist Ramamurthy Balasubramaniam, focuses on the chemistry of the iron. The iron used in the pillar has a high amount of phosphorus (0.25%) and small amounts of other elements like carbon, manganese, nickel, silicon, copper, nitrogen, and sulfur. As the pillar goes through wet and dry cycles, a slow chemical reaction takes place on its surface. This process turns the iron into a hard, crystalline form of iron hydrogen phosphate hydrate. This hard layer forms a strong barrier that stops more rust from developing. This shows how both the environment and the special iron composition work together to protect the pillar from rust. Over time, this layer has grown very slowly and is only one-twentieth of a millimeter thick even after 1,600 years. Balasubramaniam suggested that ancient Indian ironsmiths knew that iron with high phosphorus would rust less. He believed they intentionally chose iron with more phosphorus to prevent rusting.

The Iron Pillar of Delhi is a great example of the high level of skill in ancient Indian metallurgy. It also gives us ideas for modern methods to make rust-resistant materials.

Science and Technology in the West

Alchemy in Latin Europe

The Western Europeans first made peaceful and close contact with the Islamic world during the Crusades. The First Crusade began in 1096, and by 1099, Western Christians had captured Jerusalem. For nearly two centuries, a Christian kingdom existed on the Syrian coast, surrounded by the Islamic world. This led to a blending of cultures, and some Christians returning to Europe brought back an appreciation for Arabic science. During this period, Christians in Spain were also gradually reclaiming territories lost to Islam in the early 8th century. Through these interactions, Europeans became aware of the advanced Moorish civilization in Spain and the valuable books the Arabs had, including translations of Greek works like those of Aristotle, as well as original Arabic writings like those of Avicenna.

A movement began to translate these Arabic works into Latin so European scholars could study them. One early supporter of this movement was the French scholar Gerbert (c. 940-1003), who later became Pope Sylvester II. The English scholar Robert of Chester was among the first to translate an Arabic alchemical text into Latin in 1144. Many others followed, and the most notable of these translators was the Italian scholar Gerard of Cremona (c. 1114-87), who translated 92 Arabic works. From around 1200, European scholars could study these texts and build upon the alchemical knowledge they contained. Around the time when Arabic works were becoming known in Europe, significant progress was being made in distillation. In the 12th century, Europeans began distilling wine with various moisture-absorbing salts, producing a concentrated alcohol distillate that was inflammable. In the 13th century, the efficiency of this process was improved by Thaddeus Alderotti (1223-1303), who introduced a water-cooled condenser. This condenser consisted of a coiled tube about a meter long, immersed in a vessel with a continuous flow of cold water. The inflammable alcoholic solution created by these methods was called aqua ardens, and repeated distillation produced aqua vitae, or "water of life," which was soon used for medicinal purpose.

The first significant European alchemist was Albert of Bollstadt (c. 1200-80), better known as Albertus Magnus, or "Albert the Great." He studied Aristotle's works deeply, helping to make Aristotelian philosophy important to later medieval and early modern scholarship. In his alchemical experiments, Albertus Magnus described arsenic so clearly that he is sometimes credited with its discovery, even though earlier alchemists likely knew about it in an impure form.

Another important figure was Roger Bacon (1214-92), an English scholar and monk. Bacon aimed to write a universal encyclopedia and was one of the first to describe gunpowder, though he was not its discoverer. Gunpowder, over time, played a significant role in ending the medieval social order by providing a way to destroy castle walls and giving infantrymen the ability to take down armored horsemen. This shift marked the beginning of European technological dominance, which lasted for the next five centuries.

Some alchemical works were attributed to Spanish scholars like Arnold of Villanova (c. 1235-c. 1311) and Raymond Lully (1235-1315). These works focused on the idea of turning base metals into gold, with Lully, according to legend, even making gold for King Edward II of England.

The most influential medieval alchemist, however, is known only as "Geber," a name borrowed from the famous Arabic alchemist of six centuries earlier. This "false Geber," probably a Spaniard writing around 1300, made groundbreaking contributions by describing sulfuric acid, a key chemical still used today, and strong nitric acid. These strong acids were obtained from minerals, unlike the weaker organic acids like vinegar used by the Greeks and Arabs. The discovery of strong mineral acids was the most important chemical advancement since iron production about 3,000 years earlier. These acids enabled many new chemical reactions and dissolutions that were not possible with weaker acids like vinegar. Despite the significance of these acids, the quest for gold remained the primary focus for many.

However, after a promising start, alchemy in Europe, much like it had among the Greeks and Arabs, began to decline. The pursuit of gold became dominated by fraudsters, leading to laws banning alchemy. Pope John XXII issued such a ban in 1317, forcing genuine alchemists to work in secrecy.

After Constantinople's fall

Meanwhile, Europe was experiencing dramatic changes. The Eastern Roman Empire, or Byzantine Empire, was on its last legs. In 1204, it was brutally sacked by Western European Crusaders, leading to the loss of much Greek learning preserved in Constantinople. Though the Greeks regained the city in 1261, it never regained its former glory. By 1453, the city fell to the Turks, who still control it today.

Before and after Constantinople's fall, Greek scholars fled to Western Europe, bringing whatever parts of their libraries they could save. Although only fragments of Greek knowledge made it to the West, they had a significant impact.

This was also the time of great explorations, which were made possible by the discovery of the magnetic compass in the 13th century. Explorers traveled along the coast of Africa, and in 1497, they sailed around the continent. By reaching India by sea, Europe could trade directly with the Far East without passing through Islamic territories. Even more surprising were the voyages of Christopher Columbus from 1492 to 1504. These journeys soon led to the discovery of a new half of the world.

During this period, Europeans discovered so many things that were unknown to the great Greek philosophers that people began to think that the Greeks were not all-knowing. Europeans, having shown they were better at navigation, believed they might be superior in other areas too. This removed a mental barrier and made it easier to question the teachings of ancient scholars.

In the same “Age of Exploration,” a German inventor named Johann Gutenberg (c. 1397–c. 1468) created the first practical printing press. It used movable type that could be rearranged to print different books. For the first time, books could be produced in large quantities and at a low cost without the risk of errors from hand-copying (though there could still be mistakes in setting the type).

With printing, unpopular ideas did not have to disappear just because no one wanted to copy them by hand. For example, one of the early printed books was a poem by Lucretius, which spread the idea of atomism widely across Europe.

In 1543, two groundbreaking books were published that, before the invention of printing, might have been ignored by traditional thinkers. Now, they reached everywhere and could not be overlooked. One was by a Polish astronomer, Nicholas Copernicus (1473–1543), who argued that the Earth was not the center of the universe, as the Greek astronomers had claimed, but that the Sun was. The other was by a Flemish anatomist, Andreas Vesalius (1514–1564), who provided a highly accurate portrayal of human anatomy based on his own observations, challenging many ancient Greek ideas.

This simultaneous challenge to Greek views on astronomy and biology (though these views still held on in some areas for another century or more) marked the beginning of the "Scientific Revolution." This revolution slowly influenced the fields of alchemy, but it had some impact on the study of minerals and medicine.

As Europeans began making new discoveries that went beyond the knowledge of the ancient Greeks, their confidence in their own scientific abilities grew. This realization, coupled with their own discoveries in areas like astronomy, physics, and biology, led to a questioning of the old authorities and the birth of new methods of inquiry. This period marked the beginning of the "Scientific Revolution," a time when Europeans increasingly relied on observation, experimentation, and evidence-based reasoning rather than simply accepting ancient texts. This revolution gradually began to affect alchemy as well. While alchemy initially remained focused on mystical goals like the transmutation of metals and the quest for immortality, the new scientific approach started to reshape it. Alchemists began applying more rigorous methods to both their mineralogical experiments and medical practices, paving the way for the development of modern chemistry and medicine.

Iatrochemistry and the End of Alchemy

In the early 16th century, it became clear that learning more about minerals and medicine was far more valuable than searching endlessly for ways to turn metals into gold. This shift was supported by the works of two contemporaries, both physicians, a German, Georg Bauer (1494-1555) and a Swiss, Theophrastus Bombastus von Hohenheim (1493-1541) alias ‘Paracelsus’. Georg Bauer, better known as ‘Agricola’ published his book ‘De Re Metallica’ ("On Metallurgy") in 1556, gathered practical knowledge from miners and provided a detailed look at mining techniques, highlighting the importance of minerals in medicine and metallurgy.

This new branch, called iatrochemistry, changed the goal of alchemy from turning metals into gold to making medicines. The main figure in this movement was Paracelsus (1493-1541), a Swiss physician. His name, meaning "better than Celsus," referred to a famous Roman medical writer. Paracelsus believed that the real purpose of alchemy was not to turn base metals into gold but to create remedies to treat diseases. Unlike earlier alchemists who mostly used plants for medicine, Paracelsus believed in using minerals. Paracelsus was different from herbal healers because he did not use the whole flower or herb as medicine. Instead, he made an extract from the flower using chemical methods like distillation with alcohol. With his knowledge of chemistry and metals, he prepared and used small amounts of metallic salts and liquid extracts for treatment.
His ideas, thus, helped lay the groundwork for modern chemical medicine.

Because of his work, people began to see chemistry as a vital part of medicine, and universities started including it in their teaching. This laid the foundation for modern pharmacology and pharmaceutical chemistry a crucial part of medical education.

However, Paracelsus still held on to some old alchemical ideas. He believed in the ancient Greek concept of four elements (earth, water, air, and fire) and the three principles (mercury, sulfur, and salt) from Arab alchemists. He extended the sulphur-mercury theory of the Islamic alchemists by adding a third principle, namely salt. Thus, when wood burned, the combustible component was identified with sulphur, the volatile component with mercury and the ashes that remained with salt. The composition of all substances could be expressed in terms of these three principles, or ‘tria prima’. He also searched for the philosopher's stone, thinking it was the "elixir of life" that could grant immortality. Even though Paracelsus focused on medicine, after his death, his ideas became more mystical, which did not fit well with the growing trend of clear and rational thinking in science.

Later iatrochemists

Andreas Libau (1540-1616), also known by his Latin name Libavius, was another key figure in moving from alchemy to chemistry. His 1597 book Alchemia, often seen as the first real chemistry textbook, criticized the mystical ideas of the "Paracelsians" and argued that alchemy should focus

more on practical uses, especially in medicine. Libavius was the first to describe the preparation of hydrochloric acid, of tin tetrachloride, and of ammonium sulfate. He described also the preparation of aqua regia ("royal water"), a mixture of nitric acid and hydrochloric acid which receives its name from the fact that it can dissolve gold. He
even suggested that mineral substances could be identified from the shape of the crystals produced when a solution is evaporated. Even though he believed that turning metals into gold was possible, he stressed that studying minerals and medicines was more important.

In 1604, a more specialized textbook was published by a German publisher named Johann Tholde. Although little is known about Tholde, he is believed to have used a pseudonym for himself by attributing the book to a medieval monk named Basil Valentine. The book, titled "The Triumphal Chariot of Antimony," focused on the medicinal uses of the metal antimony and its compounds. This work explored the potential health benefits and applications of antimony in medicine, reflecting the ongoing interest in chemical and medicinal innovations during that period.

One of the most important figures in practical chemistry in the seventeenth century was Johann Rudolph Glauber (1604-1670). Unlike many of his contemporaries, he was not medically qualified, and he learned his practical chemistry by visiting a number of laboratories in different parts of Europe. He devised new types of furnaces, which enabled higher temperatures to be achieved. He is particularly remembered for his preparations of the mineral acids and their salts. He realised that oil of vitriol (Sulphuric acid) prepared by burning sulphur under a bell jar was the same as that obtained by heating green vitriol (iron(II) sulphate). He obtained hydrochloric and nitric acids by the action of oil of vitriol on chlorides and nitrates. Glauber made some of his chemicals on a large scale, and he made his living by selling them. He can be regarded as an early industrial chemist. One of his most famous products was salt mirabile, hydrated sodium sulphate, for which he claimed marvelous medicinal properties. This compound is still known as Glauber's salt. He found it useful as a laxative and marketed it as a cure-all, showing that practical chemistry could be useful and profitable.

Jan Baptista van Helmont (1577-1644)

Jan Baptista van Helmont was a Flemish physician and chemist who was important in the early development of chemistry. He focused on careful measurement and experimentation.

Van Helmont is known for a famous experiment to find out where a plant's living tissue comes from. He planted a willow sapling that weighed five pounds in a pot with 200 pounds of dried soil. For five years, he added only rainwater or distilled water. After this time, the willow weighed 169 pounds, while the soil had lost only two ounces. Van Helmont concluded that the tree's weight came from water alone, believing water was the main substance from which plants grow. Although he was wrong—he did not know plants also take in carbon dioxide from the air—his experiment was important because it used measurement to solve a problem in both chemistry and biology.

Van Helmont disagreed with the traditional Greek idea of four elements (earth, water, air, fire) and Paracelsus's idea of three principles (mercury, sulfur, salt). Instead, he believed there were only two real elements: air and water. However, he thought air could not change into any other substance, making water the basic component of all materials.

Van Helmont was the first to study gases carefully and see how they were different from air. Before him, people only knew about air as an "air-like" substance and considered it one of the four elements. While alchemists had noticed vapors in their experiments, they did not study them closely. Van Helmont changed this by examining the vapors released in chemical reactions. He found these vapors looked like air but had different properties. He named them "gas," a word he created from the Greek word "chaos."

Van Helmont saw that different gases had different properties. For example, he studied a gas produced when wood burned, which he called "gas sylvestre" ("gas from wood"). This gas is what we know today as carbon dioxide. He noticed that when 62 pounds of charcoal burned, only one pound of ash was left. He concluded that 61 pounds of "gas sylvestre" had escaped into the air. He also identified other gases, such as a red gas (nitric oxide) formed when nitric acid reacted with silver, and "gas pingue," an inflammable gas produced from the dry distillation of organic matter, which was mainly hydrogen, methane, and carbon monoxide. Van Helmont described gases as "wild spirits" or "untamable gas," showing how hard they were to control. He noticed that gases could break containers when created in sealed vessels, like when nitric acid reacted with sal ammoniac. This understanding of how gases behave helped develop gas chemistry.

Van Helmont also supported using minerals to treat diseases, following Paracelsus's ideas. This was part of iatrochemistry, which aimed to use chemistry in medicine. Van Helmont's most famous work, Ortus Medicinae ("The Origin of Medicine"), was published after his death in 1648. This book became very important in the history of medicine and chemistry. It explained his ideas on gases, digestion, and vital forces in the body. The book contains the results of numerous experiments and establishes an early version of the law of conservation of mass.

This shift in focus from making gold to making medicines from minerals marked the decline of alchemy. The focus shifted to observation and experimentation, moving away from mystical goals like transforming metals. By the 18th century, alchemy had evolved into modern chemistry, a field dedicated to understanding matter and its changes through scientific methods.

Alchemy's contributions to modern chemistry

Although alchemy could not provide any conceptual frame to modern chemistry, it contributed substantially to the development of chemical operations, techniques, apparatus, and theoretical ideas that laid the groundwork for scientific chemistry. Here are some key contributions:

1. Chemical Operations and Manipulations:

Alchemists developed several chemical processes that are still in use today, such as distillation, sublimation, filtration, calcination, dissolution, and crystallization. These methods were originally developed to purify substances and explore the possibility of transmuting base metals into gold or creating the "philosopher's stone." Distillation was refined to produce concentrated alcohol (aqua vitae) and essential oils, which are still foundational in modern chemical and pharmaceutical industries. Sublimation (transforming a solid directly into a gas) was another alchemical process for purifying materials. This technique is now widely used to purify substances in chemistry.

2. Techniques and Apparatus:

Alchemy led to the invention and refinement of various laboratory equipment that laid the foundation for modern chemistry. These include:

Alembics and retorts for distillation.

Crucibles for heating substances at high temperatures.

Funnels, filters, and beakers for separation techniques.

Mortar and pestle for grinding and mixing materials.

Zosimus of Panopolis, a notable alchemist, contributed to this development by describing the water bath (later called bain-marie).

3. Theoretical Ideas and Corpuscular Composition:

Alchemists introduced early ideas about the corpuscular composition of matter, proposing that all substances are made up of tiny, discrete particles. This concept was a precursor to the atomic theory that forms the basis of modern chemistry.

4.Chemical Nomenclature:

Alchemists developed early forms of chemical symbols and nomenclature to describe substances and processes. Although these symbols were often shrouded in mysticism, they represented an early attempt to create a language for chemistry.