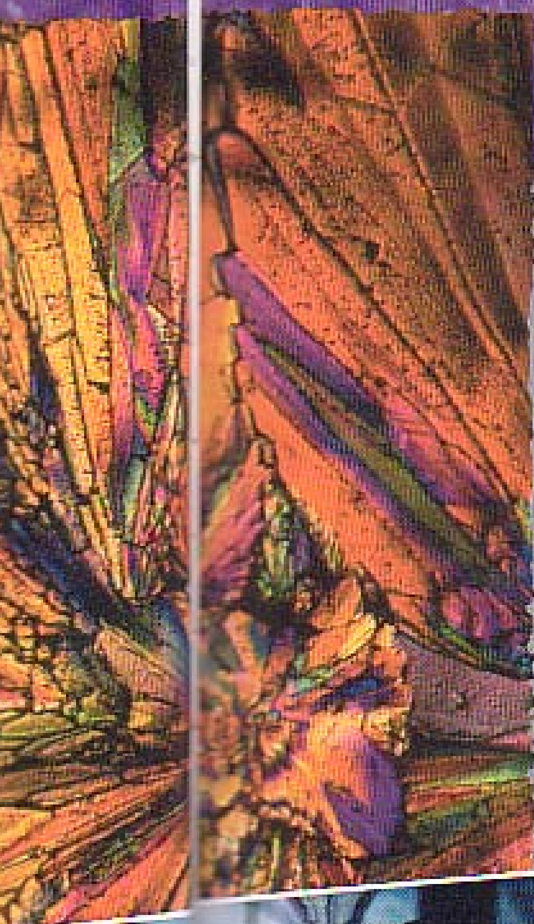
Science, Chemistry, & You 1

What's the Connection?



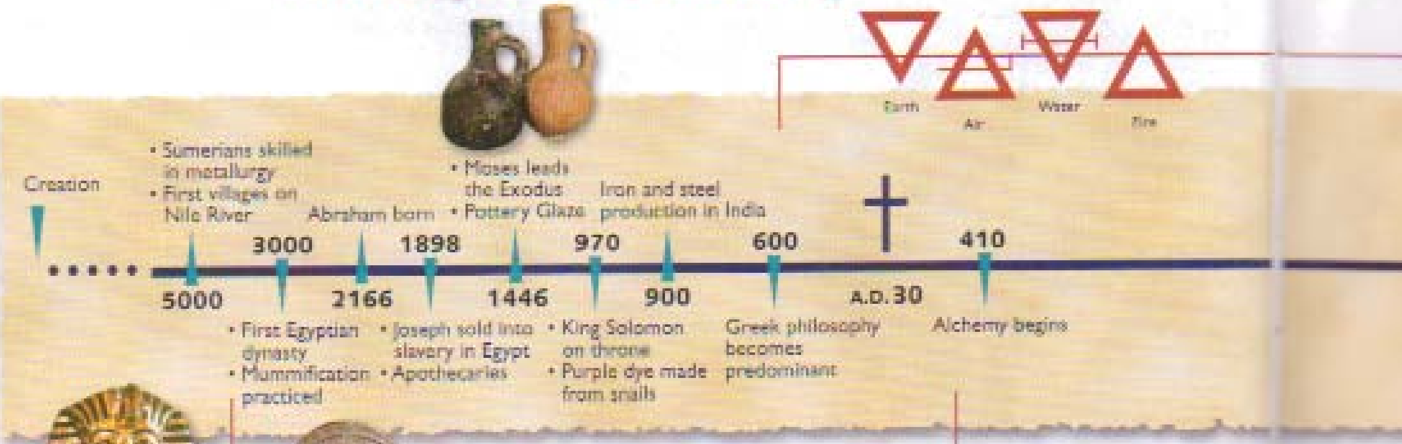
What is science? For centuries science was a branch of philosophy, and scientists were more like debaters than researchers. Scholars reasoned and argued about the nature of truth and the universe. In the late 1500s science changed drastically. Pure reasoning and argumentation gave way to observation and experimentation. This new way of examining the universe developed into modern science. As scientists studied the creation through observation and experimentation, chemistry emerged as a distinct discipline. With the rich legacy provided by Old Testament craftsmen, Greek philosophers, and medieval alchemists, the science of chemistry soon flourished. Chemistry now touches so many areas of our lives that every person should have some knowledge of this subject.

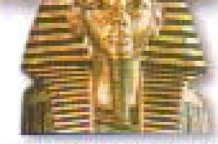
1A Science and the Scientific Method

Inductive Reasoning: Starting with the Facts

Science had remained a stagnant body of knowledge for nearly two thousand years before a certain man received a professorship at the University of Pisa. Within a few months, Galileo asked questions that revolutionized the scientific community. Instead of relying on prevailing secular and religious philosophies,

History of Chemistry




King Tutankhamen's headdress

he made observations and collected data on his own.

He argued that inductive reasoning, not deductive reasoning, was the proper and logical method of approaching a problem. **Deductive reasoning** intends to prove that the conclusion must be true, whereas **inductive reasoning** intends to show that the conclusion is probable or most likely. In sound, valid deductive reasoning the argument is logical and always true. Inductive reasoning can present solid evidence, but still produce a faulty conclusion. Inductive reasoning could then be summarized as proceeding from the known fact to the unknown conclusion. This idea of inductive reasoning was vastly different from the prevailing belief that logic always leads to truth. In the past, observations that went against accepted philosophies were rejected. Many thought that although the senses could be deceived, rational thought could not. Galileo's experiments brought the conflict between logic and physical evidence to a climax. Just how strong was this controversy? Galileo was pronounced a heretic, imprisoned, and exiled by the Roman Catholic Church because he viewed the sun as the center of the solar system. At this time in history the Roman Catholic church firmly believed that the earth was the center of the solar system.

Galileo and his telescope

FACETS of CHEMISTRY

The Scientific Method of Antoine Lavoisier

Substances lose weight when they burn, right? After all, a hefty log turns into a small pile of ashes after a night in the campfire! Observations like this led many scientists to assume that burning always decreases the mass of a substance. Early scientists thought that burning allowed a mysterious substance called phlogiston to escape. The loss of phlogiston supposedly accounted for the decrease in weight during burning. Yet one observant scientist saw something that threatened the widely accepted phlogiston theory. On November 1, 1772, the French chemist Antoine Lavoisier delivered a sealed note to the secretary of the French Academy of Sciences.

"About eight days ago I discovered that sulfur in burning, far from losing weight, on the contrary, gains it; it is the same with phosphorus. This increase in weight arises from a prodigious quantity of air that is consumed during combustion. The discovery, which I have established by experiment which I regard as decisive, has led me to think that what is observed in the combustion of sulfur and phosphorus may well take place in the case of all substances that gain weight by combustion."

Lavoisier had observed a significant gain in weight when phosphorus and sulfur burned. This contradicted the prevailing idea that all substances lost weight when they burned. Lavoisier recognized that this contradiction posed a problem well worth investigating. Were sulfur and phosphorus isolated exceptions to the phlogiston theory, or was the entire theory faulty? After careful study of the matter, Lavoisier proposed a daring hypothesis: Substances gain something from the atmosphere when they burn. This idea went against the accepted theory and would not be listened to without experimental proof. To prove that his hypothesis was correct, Lavoisier knew he must first identify the "something" from the atmosphere that substances gain when they burn.

At first Lavoisier suspected that carbon dioxide caused the increase in mass. Several experiments soon proved that carbon dioxide would not support combustion of any type. The discovery of oxygen by fellow chemist Joseph Priestly gave several valuable clues. When heated, mercuric calx (a compound of oxygen and mercury) releases large quantities of oxygen gas and leaves silvery, elemental mercury behind. Lavoisier duplicated Priestley's procedure with this red-orange compound. The results of this experiment gave Lavoisier necessary insight into his problem. Perhaps oxygen was the component of air that combined with burning substances and increased their masses. To test this idea, Lavoisier developed a controlled experimental procedure to produce mercuric calx from mercury and ordinary air and then from mercury and pure oxygen. Both procedures produced the same compound. Oxygen was the substance in the air that combined with substances as they burned!

Lavoisier began with a problem, made observations, researched and defined the problem, and then developed a hypothesis. He then conducted experiments in which he gathered more observations, chose his solution, and then verified it. His consistent use of the scientific method in his chemical investigation did not guarantee success, but it did keep him on the right path. With the help of other researchers and a keen mind, Lavoisier made a discovery that changed the theoretical framework of chemistry.

Modern chemistry has many practical applications.

Chemistry Today

By 1800 chemistry had become an academic discipline. In the New World several colleges made chemistry a part of their curriculum. Benjamin Rush was the first professor of chemistry in the United States. His lectures at the Philadelphia Medical School set the foundation stone of chemical education in the new nation. At Princeton, professors attacked the old Greek ideas and used demonstrations and experiments in their teaching. These early professors foreshadowed the importance the United States would achieve in chemistry within the next two centuries.

As chemical knowledge expanded throughout the world, specialized branches of chemistry developed. Scientists were soon forced to concentrate in one area. The branch of **organic chemistry** developed as a result of investigations by Friedrich Wöhler. Until 1826 it was commonly believed that organic compounds, those that contain carbon, could be produced only by living organisms. Wöhler amazed the scientific community by synthesizing urea (a waste product from animals) from two "inorganic" compounds. This discovery provided the foundation for a new branch of chemistry: the study and synthesis of organic compounds. Urea is still used today in fertilizers, manufacturing of plastics, and pharmaceutical preparations.

Table 1A-3 The Major Branches of Chemistry

Inorganic chemistry	The study of all elements other than carbon and their components
Organic chemistry	The study of compounds containing carbon
Biochemistry	The study of the chemical processes in living things—plants, animals, and man
Nuclear chemistry	The study of radioactivity, the nucleus, and the changes that the nucleus undergoes
Physical chemistry	The foundational theories that allow detailed examinations of interactions between substances and the accompanying energy changes
Analytical chemistry	The techniques used in all branches of chemistry in which chemists devise equipment and methods to (1) discover what substances are in a sample of material (qualitative) and (2) determine how much of each component it contains (quantitative)