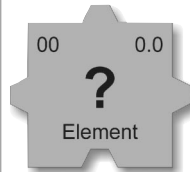


# Integrated Physics & Chemistry



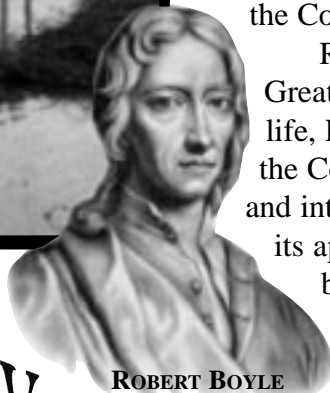
## Lesson 3 Elements

# Chapter 1

## Section 1

Lessons 1-5

**THE MAN  
WHO  
DEFINED AN  
ELEMENT**



ROBERT BOYLE

## VOCABULARY

**Smelting:** to extract a desired metal from an ore that is a mixture of metals

**Density:** the mass of a substance compared to its volume

**Mass:** a measure of the amount of matter that a body contains; Weight and mass are often used as if they have the same meaning.

**Toxic:** a chemical substance that poses a health risk; capable of causing injury or death

**T**he Great Earl of Cork was perhaps the richest man in the world. He was an Englishman who lived at Lismore Castle on his vast estate in Ireland. If not the richest man in the world, then certainly he was the richest Englishman. He did not want his children to grow up to be spoiled and idle. A few months after birth, the children were moved into the homes of tenant farmers who lived on the Cork estate.

Robert Boyle was the seventh son of the Great Earl of Cork. For the first few years of his life, Robert Boyle lived with a peasant family on the Cork estate. Robert Boyle grew to be humble and intelligent and was interested in the Bible and its application to all things scientific. Boyle

became a scientist and is generally credited with being the Father of Modern Chemistry.

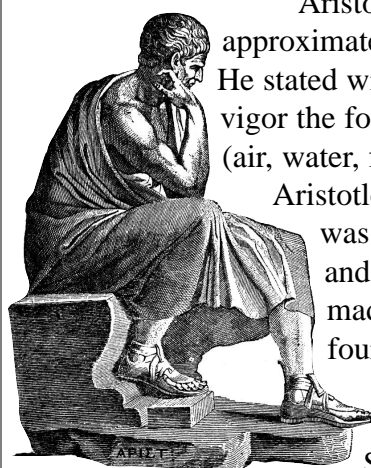
Robert Boyle lived in the 1600s when science was recovering from the Middle Ages (also called the Dark Ages). Galileo had discovered the use of the telescope to study the heavens. During this time, Isaac Newton was born. Isaac Newton would not make his many discoveries about predictable force, motion and gravity until the late 1600s.

The word *chemistry* was derived from Chemeia (a local name for Egypt), establishing that chemistry indeed had its roots in ancient Egypt. The most important river in Egypt was the Nile. When the Nile River flooded, it left behind rich black soil. *Chemeia* is an Egyptian word meaning *black*. In ancient times, one name for Egypt was *Chemeia*, which meant *land of the black soil*.

The first scientists were called natural philosophers. The word *philosopher* means *one who loves knowledge*. To gain knowledge, a natural philosopher studied nature. Many Greek

natural philosophers believed observations and reasoning alone would reveal all that could be learned.

The Greeks stressed the value of human reason so much that they failed to experiment properly. They did not test their ideas with experiments. Aristotle was one of the great Greek philosophers. He was the tutor of Alexander the Great in 342 B.C. Aristotle was a careful observer and a logical thinker. However, he failed to perform the simplest of experiments.



Aristotle wrote approximately 150 books. He stated with force and vigor the four-element theory (air, water, fire and earth).

Aristotle believed gold was not an element and that it could be made by mixing the four elements of water, air, earth and fire.

Scientists after Aristotle applied his ideas to the study of chemistry. In the 1600s, Aristotle's control over science began to vanish as scientists met to exchange ideas and discuss new discoveries.

Like many scientists, Robert Boyle asked, "Can you make gold?" He took a different approach. Rather than putting two or more substances together to produce gold, he asked, "Can you separate gold into two or more substances?" He proposed to separate gold into two other chemical substances, which could then be combined to make more gold.

As Robert Boyle experimented, he became convinced that the four-element theory for matter was incorrect. Instead, he developed a new definition for an element. "A chemical element," he said, "cannot be separated into other elements nor can other elements be combined to give it." A

chemical element is a pure substance that cannot be broken down into any simpler substances by chemical means.

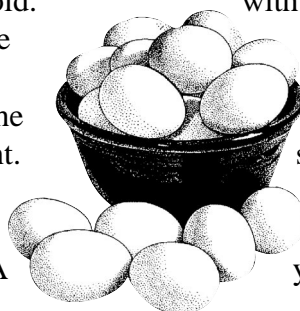
A current definition is that a chemical element contains atoms of only one type. At the time Robert Boyle lived, chemists had not yet learned that atoms existed. Chemists could not analyze a sample of gold to see if all of its atoms were the same. Robert Boyle's definition of an element remained popular among chemists for two hundred years.

Robert Boyle stated that a compound is a substance that can be separated into two or more elements by chemical action. Today, we conclude that a compound contains atoms of two or more different elements in chemical union.

Although you could memorize the definitions, a more important point is to understand the concept. We can illustrate the concept through galena. Galena is a compound that looks metallic. When galena is heated in air, it breaks down into lead and sulfur. The fact that galena can be separated into two other substances, proves that it is not an element.

Alchemists treated gold to thousands of tests for more than two thousand years. They heated gold in furnaces, boiled it in pots and cauldrons, pounded and ground it. The alchemists treated gold with acids and coated it with other substances, but they never did create more gold.

The alchemists also tried to combine a variety of substances in an effort to create gold. Picture an image of an old laboratory with the crude equipment used by an alchemist as he tried to make gold. He cracked open two thousand hen eggs. The shells were then placed in one pot, the whites of the egg in another pot and the yellow yokes in a third pot. The shells

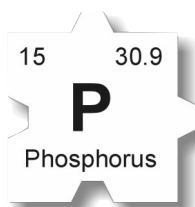


were treated with fire until they crumbled into a brilliant white powder. The whites of the eggs were boiled until they hardened then covered with horse manure (a fertilizer that helps plants grow). This was supposed to contribute some vital force to the egg whites. Next, the yellow yoke was mixed with oil, and the liquid that formed was then distilled. That experiment took a year or more. The conclusion of the experiment was a horrible, smelly and gummy mess.

Because gold is an element, it cannot be made by the chemical combination of other materials. Neither can it be separated into two or more simple substances. A bar of pure gold contains nothing but gold atoms.

As Robert Boyle increased in age, he lived in London and was often met with scholars interested in learning new concepts. He talked with doctors, chemists, astronomers and others. They exchanged ideas ranging from the use of the microscope to the *smelting* of metals from raw ores. Boyle had been educated by many tutors and never attended college. Robert Boyle called his group of friends the “Invisible College.” Later, they became a formal organization known as the *Royal Society*. This was the first group of scientists to meet on a regular basis to exchange ideas. It still meets today. The purpose of the Royal Society was to help scientists publicize their discoveries. The Royal Society also hired a full time employee to demonstrate interesting experiments in order to stimulate further research.

In 1680, Robert Boyle prepared what he thought was a new chemical element, phosphorus. Its chemical symbol is *P*. Phosphorus is the next piece of the puzzle.



Phosphorus is a highly reactive, poisonous and nonmetallic element. It is a waxy, white solid that glows in the dark.

The word *phosphorus* is a Greek word meaning *bringing light*. Phosphorus glows because it combines slowly with oxygen in the air. California beaches glow after sunset because of the high phosphorous content in the beach sand. It is a difficult, dangerous substance that can burst into flames when the reaction with oxygen is more rapid.

Robert Boyle observed that the mere heat of friction caused the new phosphorus chemical to burn. Boyle soaked paper in phosphorus and let it dry. A splinter of wood was dipped in sulfur then drawn across the paper. The splinter of wood caught fire. Boyle had made the first match by applying sulfur to phosphorus.

Because Robert Boyle was a chemist and not an alchemist, he published his discoveries. He described the physical and chemical properties of phosphorus in such detail that two hundred years passed before any new facts about it became known. Later, chemists learned that an alchemist had discovered phosphorus but kept the discovery secret.

Physical properties include color, hardness, odor and density. **Density** is the **mass** of a substance compared to its volume.

$$d = m/v$$

Chemical properties describe the conditions about

*d*: density  
*m*: mass  
/: divided by  
*v*: volume

chemical reactions with a substance. The fact that gold will not tarnish or rust is a chemical property. Copper will react with sulfur (tarnish), and iron will react with oxygen (rust). The fact that sulfur will burn (react with oxygen) is a chemical property.


The chemical properties of phosphorus make a match possible. A “strike anywhere” match contains a compound of phosphorus and sulfur. It is very sensitive to heat. The friction caused by rubbing the head of a match across a rough surface is enough to cause it to burn, which lights the matchstick.

The first matches used white phosphorus, which is *toxic*. Not only did they pose a health risk they also could burst into flame without warning.



### Did you know?

A match with a white tip of phosphorus is a ‘strike-anywhere’ match. A match with a red tip must be struck on the box from which the match came.



Another form of phosphorus, known as red phosphorus, is much less dangerous than white phosphorus. It is also less likely to start fires spontaneously.

Safety matches are even less likely to start accidental fires. Safety matches contain no phosphorus. Instead, the phosphorus is contained in finely ground glass glued on a strike strip of the matchbox or matchbook. When the head of the match is drawn across the strike strip, a spark ignites the match.

Phosphorus and its compounds are used in firework displays, firebombs and tracer bullets. These compounds are also used in fertilizers, in the production of special glass and water softeners.

The next lesson informs you about silver mirrors, copper money and the bronze statue of a magnificent young man.

## Life Principle



“The superior woman stands erect by bending above the fallen. She rises by lifting others.”

—Anonymous