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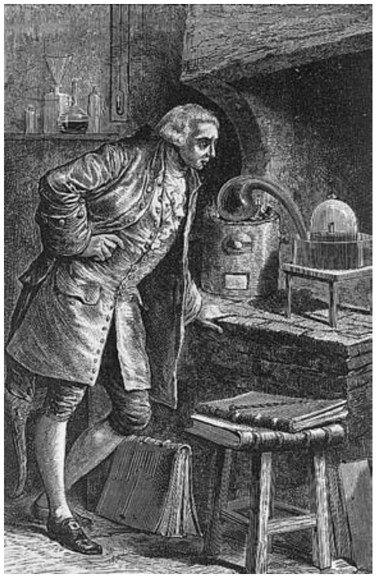
The Phlogiston Fiasco and the Impact of Lavoisier

Chemical investigation in the modern sense—inquiry into the causes of changes in matter—began in the late 17th century but was hampered by an incorrect theory of **combustion,** the process of burning.

At the time, most scientists embraced the **phlogiston theory,** which held sway for nearly 100 years. The theory proposed that combustible materials contain varying amounts of an undetectable substance called *phlogiston,* which is released when the material burns. Highly combustible materials like charcoal contain a lot of phlogiston and thus release a lot when they burn, whereas slightly combustible materials like metals contain very little and thus release very little.

However, the theory could not answer some key questions from its critics: "Why is air needed for combustion, and why does charcoal stop burning in a closed vessel?" The theory's supporters responded that air "attracted" the phlogiston out of the charcoal, and that burning in a vessel stops when the air is "saturated" with phlogiston. When a metal burns, it forms its *calx,* which weighs more than the metal, so critics asked, "How can the *loss* of phlogiston cause a *gain* in mass?" Supporters proposed that phlogiston had negative mass! These responses seem ridiculous now, but they point out that the pursuit of science, like any other endeavor, is subject to human failings; even today, it is easier to dismiss conflicting evidence than to give up an established idea.

Into this chaos of "explanations" entered the young French chemist Antoine Lavoisier (1743–1794), who demonstrated the true nature of combustion. In a series of careful measurements, Lavoisier heated mercury calx, decomposing it into mercury and a gas, whose combined masses equaled the starting mass of calx. The reverse experiment—heating mercury with the gas—re-formed the mercury calx, and again, *the total mass remained constant.* Lavoisier proposed that when a metal forms its calx, it does not lose phlogiston but rather combines with this gas, which must be a component of air. To test this idea, Lavoisier heated mercury in a measured volume of air to form mercury calx and noted that only four-fifths of the air volume remained. He placed a burning candle in the remaining air, and it went out, showing that the gas that had combined with the mercury was necessary for combustion. Lavoisier named the gas oxygen and called metal calxes metal oxides. Lavoisier's new theory of combustion made sense of the earlier confusion. A combustible substance such as charcoal stops burning in a closed vessel once it combines with all the available oxygen, and a metal oxide weighs more than the metal because it contains the added mass of oxygen. This theory triumphed because it relied on quantitative, reproducible measurements, not on the strange properties of undetectable substances. Because this approach is at the heart of science, many propose that the science of chemistry began with Lavoisier.



Scientific Thinker Extraordinaire

Lavoisier's fame would be widespread, even if he had never performed a chemical experiment. A short list of his other contributions: He improved the production of French gunpowder, which became a key factor in the success of the American Revolution. He established on his farm a scientific balance between cattle, pasture, and cultivated acreage to optimize crop yield. He developed public assistance programs for widows and orphans. He quantified the relation of fiscal policy to agricultural production. He proposed a system of free public education and of societies to foster science, politics, and the arts. He sat on the committee that unified weights and measures in the new metric system. His research into combustion clarified the essence of respiration and metabolism. To support these pursuits, he joined a firm that collected taxes for the king, and only this role was remembered during the French Revolution. Despite his contributions to French society, the father of modern chemistry was guillotined at the age of 50.

Discussion

1) To what extent is scientists and scientific knowledge subjective? To what extent can they be objective? Use an example from the story about Lavoisier and Phlogiston.

2) In what sense are scientific laws and scientific theories different types of knowledge? How are they related? Use an example from this story.