Trina Allen
Chemistry 511

Oxygen Revealed

Oxygen is an odorless, colorless, and tasteless gas, which is essential for life, and combustion. It seems like common knowledge in modern times. Most children know that we need Oxygen to live, but many of them believe that Oxygen is the only gas in the air we breath. This is a common misconception among children and some adults. So who was the first person to discover Oxygen? What experiments did they conduct? Was it an accident or carefully planned experimentation? Why do we call it Oxygen? How did its discovery change science? These were the questions that came to mind as I started to look into the history of oxygen.

Originally this document was to focus on Joseph Priestly. He was a controversial minister and a scientist who is credited with the discovery of oxygen. As I began my research it was not long before I discovered that there were many people involved in the discovery of oxygen.

There were a few indications that some people were starting to realize that air was not a single element. "In the 17th century scientists like the Englishman, Robert Hooke, the Russian, Mikhail Lomonosob, the Dane, Ole Borceh, and the Frenchman Pierre Bayen produced oxygen but none of them identified it as such." (Elmsely 2003) Leonardo DaVinci noted that air must be made of at least two parts (a part that is consumed in burning and another part which is not consumed). The properties of the Chinese yin and yang, which date back to the eighth century, are comparable to the properties of oxygen and nitrogen, the two most abundant gases in the air. (Holmes 2003) Some sources, mention Michael Sedziwoj, a polish alchemist who became aware of oxygen by warming nitre. He referred to the gas given off as the "elixir of life."

Though some were aware of the fact that the air was composed of more than one substance, Scheele is now considered one of the co-discoverers. He was studying the effects of heat on various compounds. "In one experiment he used silver carbonate, mercury carbonate, and magnesium nitrate. When he heated these compounds, he found that a gas was produced. He then studied the properties of that gas. He found that flames burned brightly in the gas. He also found that animals could live when placed in the gas." He discovered this gas in 1772, prior to Priestly's experiments, but he published his findings after Joseph Priestly published his work.

Joseph Priestly isolated 8 gases (ammonia, sulfur dioxide, nitrous oxide, nitrogen dioxide, silicon tetrafloride, and oxygen) through his experiments in which he used various apparatuses he created. (Bowden 1997) He conducted one experiment where he heated mercury oxide in a flame. This produced liquid metal mercury and a gas. In another experiment he lit candles and sealed them in a glass container. He placed a plant in one of the containers. The containers were sealed, so naturally the flames went out since there was no oxygen. After several days, he attempted to relight the wick with a magnifying glass. The candle in the sealed container by itself did not ignite, but the candle in the container with the plant did ignite. Priestly also performed an experiment in which he placed mice in sealed containers. One mouse was alone in the sealed container, while the other had a plant in his seal container. The mouse with the plant survived, but it was not long (about thirty minutes) before the one without the plant dropped dead. Priestley's experiments lead to further knowledge, which not only revealed oxygen to

western civilization, but they also expanded the knowledge of photosynthesis and respiration.

Both Priestly and Steele discovered oxygen, but they did not understand the impact of their discovery. Priestly realized that the gas was more pure compared to common air. He even predicted that it would become a luxury. However, Priestly was convinced that

> "…physical operations on gases (compression or rarefaction, agitation in water, electrification) would somehow transform one kind of air into another kind of air; and his search for mechanical-force explanations in a kind of premature physical chemistry blinded him to the prior necessities of classifying elements and compounds." (Gillispie 1975)

Priestly was a firm believer of the phlogiston theory, and he referred to oxygen as dephlogiscated air". Phlogiston was thought to be a substance that escapes when an object or substance is burned.

Priestly discussed his experiment with another prominent scientist, Antoine Lavoisier. (Note: Lavoisier was originally given credit for the discovery of Oxygen. Scheele and Priestly were recognized decades later as co-discoverers.) Lavoisier, who was not convinced of the phlogiston theory, conducted experiments. He experimented with non-metals as well as metallic substances. He noticed that some substances maintain the same weight even after being burned or heated past the boiling point. If the weight of the substance did not change then there was no loss of mass. If the mass was not lost then no phlogiston escaped. He deduced that the "new air" was not a result of the burning, but a part of the reaction.

> The general theory of combustion that Lavoisier had first proposed in 1778 assumed that the burning of combustible bodies … as well as the calcinations of metals involved not the emission of phlogiston, as previously thought, but the addition of oxygen and the release of "matter heat," or as he later named it, "caloric" (Holmes 2003)

Eventually the phlogiston theory was to become merely a note in the history books. Lavoisier renamed the gas oxygen. "Oxy" is from the Greek word meaning "acidic", and "gen" comes from the Greek word meaning "forming". These Greek roots were chosen because Lavoisier thought that oxygen was present in all acids, therefore oxygen was responsible for forming acids. This proved to be wrong in time. Oxygen is present in many acids, but not all of them.

Once revealed, oxygen changed science. As mentioned above, it eliminated a widely accepted theory of phlogiston. This discovery leads to the knowledge of combustion, oxidation, respiration, and photosynthesis. Today, oxygen (isolated, manufactured and the oxygen in the air) is widely used in the fields of science, manufacturing and medicine. It is also marketed as a luxury (as Priestley predicted) in some health spas and oxygen bars. Mountain climbers use small tanks to help them adjust to the thinning atmosphere as they ascend the mountains. Deep sea diving became possible and invaluable to marine studies due to the use of oxygen tanks. The uses are too numerous to mention. The point is that the discovery of oxygen actually occurred over centuries, but it has changed our lives forever.

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Chemistry 511
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The Story of Chemistry: Oxygen

Oxygen Revealed
Activity

Simulate Priestley's Experiment with the candles and plants in a sealed container.

Note: The instructor should attempt to perform this experiment prior to introducing it to the class.

Essential Questions – Why is deforestation a problem?
How can we improve air quality?

There are many answers to these questions. The primary focus will be the oxygen produced by plants. The purpose of recreating Priestley's experiment is to prove that plants produce oxygen. Start by giving them reading material, which explains Priestley's experiments. Next, discuss it as a class, and then divide the students into groups of 3 to 4. They will be instructed to recreate Priestley's experiment, but they will develop the experiment with little guidance from the instructor. Make sure they know that the experiment will take place over a five-day period. Have one person from each group come gather the material for their experiment. They may not use the lighter. When they are ready for their candles to be lit, they must ask the instructor to light it for them.

Sample (Based on my expectations)

Questions – Will a plant produce oxygen in a sealed jar?
Can a plant in a sealed jar produce enough oxygen to light a candle?
Will different plants produce significantly different amounts of oxygen?
Will plants in shaded areas produce as much oxygen as plants which receive direct sunlight?

Materials

- Two large mason jars.
- Two tea candles
- One small plant
- Duct tape
- Lighter
- Magnifying glass.

Procedures

1. Place the lids on the table with the inner portion up.
2. Place a tea candle on each lid.
3. Arrange the small plant on one of the lids with a candle.
4. Have an instructor light the candle.
5. Place the jar over the lid and close it.
6. Use the duct tape as an additional seal to keep air out.

7. Record any observations over the five days.
8. On the third or fourth day, wearing safety gear, take the jars outside along with a fire extinguisher.
9. Students will try to relight the candlewicks using a magnifying glass. (It may be wise to check the five-day forecast). Prior to lighting the wick, they must decide how they will measure their results (Time in second is recommended, but if they develop an acceptable alternative allow it.)
10. Record your data and observations.
11. Create a graph from the data.
12. Write conclusions.