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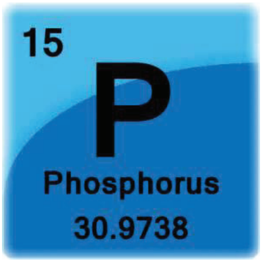
Special 3 Part Series: Part 1

LAKE WINNEBAGO
QUALITY IMPROVEMENT ASSOCIATION
of Fond du Lac County



This is the first part of a three part series examining phosphorus. This first part will look at the nature and chemistry of the element, phosphorus.

The second part will focus on phosphorus in the environment and the phosphorus cycle.

The final part will review the role of phosphorus in living cells.

Understanding Phosphorus, Part 1
Properties and Chemistry

"Phosphorus has long been recognized as the controlling factor in plant and algae growth in Wisconsin lakes and streams."
(http://dnr.wi.gov/topic/SurfaceWater/phosphorus.html)

Phosphorus is element number 15. It is the twelfth most abundant element in the earth's crust at 0.19% by mass. On the periodic table it is grouped with nitrogen and arsenic because the three exhibit similar chemistry. Like phosphorus, nitrogen is also essential for life. While limited phosphorus limits algae growth, limited nitrogen is the controlling factor in terrestrial plant growth—add more nitrogen, get bigger crop yields—just like more phosphorus in water means more algae growth. The three numbers on fertilizer bags refer to nitrogen, phosphorus and potassium, respectively. Arsenic is a known poison. New evidence suggests it may also be required for life, though in only extremely small amounts *(http://www.ncbi.nlm.nih.gov/pubmed/1916090).* In 2010 a report was published about a bacterium found in California's Mono Lake that lived by substituting the usually toxic arsenic for phosphorus. Mono Lake has high levels of arsenic and the bacterium took advantage of its similar chemistry and abundance. More recently, it was shown that the bacterium actually prefers phosphorus and only uses arsenic because of its high concentration in Mono Lake *(http://www.nature.com/news/arsenic-life-bacterium-prefers-phosphorus-after-all-1.11520).*

Weißer_Phosphor.JPG: at de.wikipedia

When phosphorus is pure, it will adopt one of three structures, known as white, red and black phosphorus. White phosphorus is four atoms of phosphorus linked together in a molecule. White phosphorus is chemically very reactive. White phosphorus is stored in water to protect it from exposure to air. Because of its reactivity, it is the stuff of hand grenades and artillery shells labeled "WP" and nick-named "Willy-Pete". White phosphorus will burn in air and burns right through human or animal tissue. Red phosphorus is a chain formed by linking these groups of four to each other by rearranging two of the chemical bonds in each group of four atoms. Red phosphorus is more stable than white phosphorus, but will reform white phosphorus through heating or friction. Red phosphorus is used in safety matches, fireworks, smoke bombs and pesticides. Black phosphorus is made under high pressure. It is the most chemically stable form of pure phosphorus and can conduct electricity. No current products are made from black phosphorus, but research is revealing potential uses in ultra-fast computer chips *(https://www.sciencedaily.com/releases/2015/03/150302130742.htm).*

Phosphorus was first isolated by Henning Brandt in 1669. However, as an alchemist, he kept it as a trade secret, believing it might be the philosopher's stone. A decade later, Robert Boyle described phosphorus to the Royal Society. Both men isolated phosphorus from human urine. Brandt's process required 50-60 buckets of urine and a couple weeks to isolate the phosphorus.

The Alchymist, In Search of the Philosopher's Stone, discovers Phosphorus
Joseph Wright, 1717.

Chemical reactivity and compounds formed: The most common form of phosphorus in the environment is the phosphate ion—the phosphorus-oxygen portion of phosphoric acid (PO43-). This ion is found in combination with metal ions like sodium, potassium, calcium, magnesium and iron. Aluminum and calcium phosphates are insoluble in water and these metal ions limit the concentration of phosphorus (phosphate ion) in the oceans. This property of insolubility is also used to remove phosphorus at sewage treatment plants. The phosphorus captured by this precipitation method is frequently sold as a form of fertilizer. In the laboratory or in manufacturing other phosphorus compounds can be created. A few of the most reactive metals, like sodium and potassium, will form ionic phosphide compounds with phosphorus, Na3P. Phosphorus will react with hydrogen to form a hydride molecule, PH3. Phosphorus, combined with sulfur to make P4S3, is used in "strike-anywhere" match heads. It also reacts with the halogens (Fluorine, Chlorine, Bromine and Iodine make up the halogen family) to form trihalides and pentahalides, combining with either three or five of these other elements, PCl3 and PCl5. All of the halide compounds are chemically reactive and react with water to from phosphoric and halogen acids. Phosphorus forms two compounds with oxygen, P4O6 and P4O10. Like the halide compounds, both oxygen containing compounds react vigorously with water to form acids. Phosphoric acid is one of the top 10 most important manufacturing chemicals. Among other uses, it is added to soft drinks to provide tart taste, it is the form used in fertilizers and the form found in life.

Other sources:

http://www.lenntech.com/periodic/elements/p.htm
Silberberg, Martin, Chemistry, 4th Ed., McGraw-Hill Publishing, Boston, 2006.