CHEMICAL IMPACT

Phosphorus: An Illuminating Element

The elemental form of phosphorus was discovered by accident in 1669 by German alchemist Henning Brand when he heated dried urine with sand (alchemists often investigated the chemistry of body fluids in an attempt to better understand the "stuff of life"). When Brand passed the resulting vapors through water, he was able to isolate the form of elemental phosphorus known as *white phosphorus* (contains P_4 molecules). The name *phosphorus* is derived from the Latin *phos*, meaning "light," and *phorus*, meaning "bearing." It seems that when Brand stored the solid white phosphorus in a sealed bottle, it glowed in the dark! This effect—a glow that persists even after the light source has been removed—came to be called *phosphorescence.* Interestingly, the term phosphorescence is derived from the name of an element that really does not phosphoresce. The glow that Brand saw actually was the result of a reaction of oxygen from the air on the surface of white phosphorus. If isolated completely from air, phosphorus does not glow in the dark after being irradiated.

After its discovery, phosphorus became quite a novelty in the seventeenth century. People would deposit a film of phosphorus on their faces and hands so that they would glow in the dark.* This fascination was short-lived—painful, slow-healing burns result from the spontaneous reaction of phosphorus with oxygen from the air.

The greatest consumer use of phosphorus compounds concerns the chemistry of matches. Two kinds of matches are currently available—strike-anywhere matches and safety

*An interesting reference to white phosphorus can be found in the Sherlock Holmes mystery, *The Hound of the Baskervilles*, where a large dog was coated with white phosphorus to scare Baskerville family members to death.

matches. Both types of matches use phosphorus (in different forms) to help initiate a flame at the match head. The chemistry of matches is quite interesting. The tip of a strike-anywhere match is made from a mixture of powdered glass, binder, and tetraphosphorus trisulfide (P_4S_3). When the match is struck, friction ignites the combustion reaction of P_4S_3:

$$P_4S_3(s) + 6O_2(g) \longrightarrow P_4O_6(g) + 3SO_2(g)$$

The heat from this reaction causes an oxidizing agent such as potassium chlorate to decompose:

$$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$$

which in turn causes solid sulfur to melt and react with oxygen, producing sulfur dioxide and more heat. This then ignites a paraffin wax that helps to "light" the wooden stem of the match.

The chemistry of a safety match is quite similar, but the location of the reactants is different. The phosphorus needed to initiate all the reactions is found on the striking surface of the box. Thus, in theory, a safety match is able to ignite only when used with the box. For a safety match, the striking surface contains red phosphorus, which is easily converted to white phosphorus by the friction of the match head on the striking surface. White phosphorus ignites spontaneously in air and generates enough heat to initiate all the other reactions to ignite the match stem.

The phosphorus in safety matches helps ignite the flame in the match.

$$4P\ (\text{red}) + \text{energy (friction)} \longrightarrow$$
$$P_4(s)(\text{white}) + 5O_2(g) \longrightarrow P_4O_{10}(s) + \text{heat}$$