CHEMISTRY IN THE TOY STORE

Part 4: Disappearing Ink, Thermobile, Flashes and Fire, Cap Guns, and Big Bang Cannons

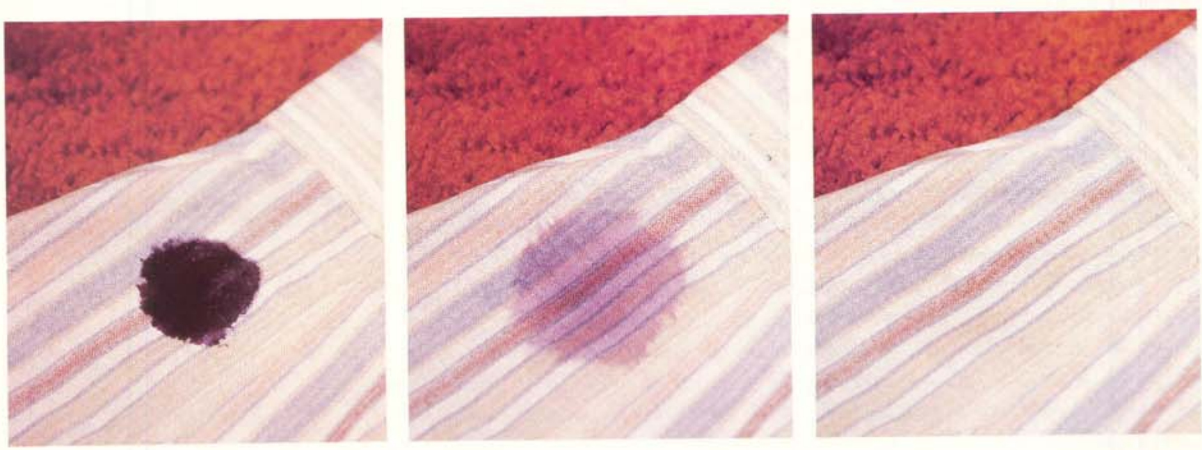
Disappearing ink

Disappearing ink is a bright blue water-based solution that, when squirted on various materials, will disappear within minutes, leaving only a colorless "water spot" that will evaporate slowly. When the spot is dry, a small amount of white residue remains.

The ink solution is a moderate to strong base. When an acid, such as hydrochloric acid, HCl, is added to it, the solution becomes colorless and forms a white precipitate. The addition of a base, such as sodium hydroxide, NaOH, dissolves the precipitate and restores the blue color. If the "ink" is squirted on cloth, the colorless water spot that remains after the color fades is slightly acidic. Adding a base to the water spot causes the blue color to return. The blue color is also obtained if a base is placed on the dried "ink" spot.

The material used to make the disappearing ink is an acid-base indicator called thymolphthalein, $C_{28}H_{30}O_4$. The disappearing ink is produced by dissolving a small amount of thymolphthalein in ethyl alcohol and then diluting it with water. The blue color is obtained by the addition of a sodium hydroxide solution.

The change that causes the color to fade is a result of the reaction of the sodium hydroxide, NaOH, with carbon dioxide, CO_2, in the air to form sodium carbonate, Na_2CO_3, according to the following reaction:



Disappearing ink, a bright blue water-based solution, fades and disappears within minutes after being squirted on various materials. The ink is made from thymolphthalein that is dissolved in ethyl alcohol and then diluted with water. Adding a sodium hydroxide solution produces the blue color. When the sodium hydroxide is exposed to carbon dioxide in the air, the blue color fades.

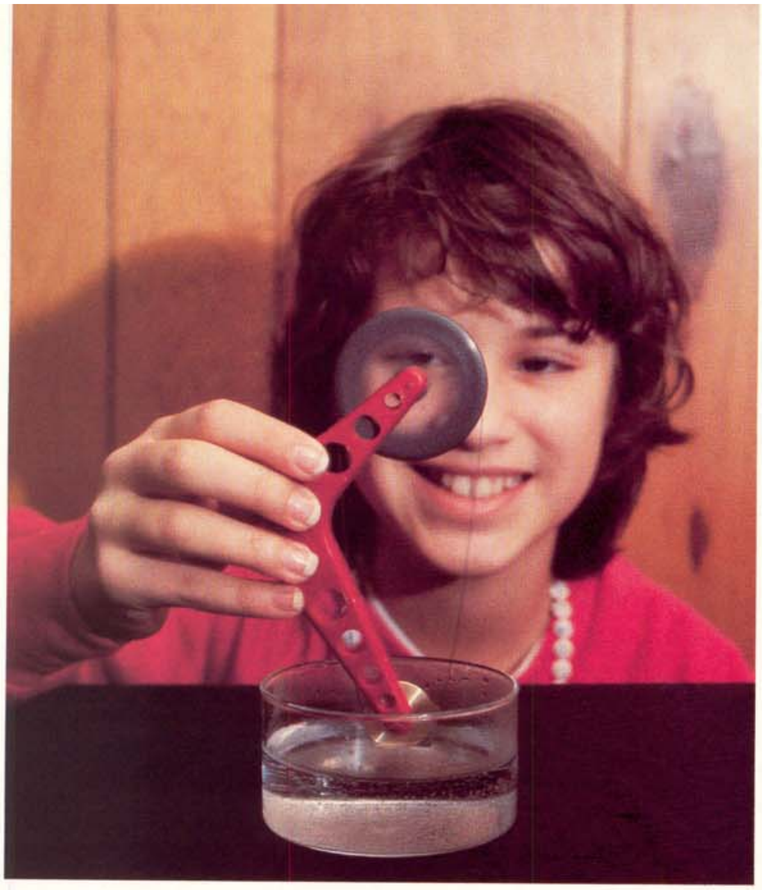
Courtesy, LOFTUS SL/CUT; photos, Cameramann International, Ltd.

$$2\ NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

Once the sodium hydroxide has been neutralized, the acidity of the alcohol changes the "ink" to colorless.

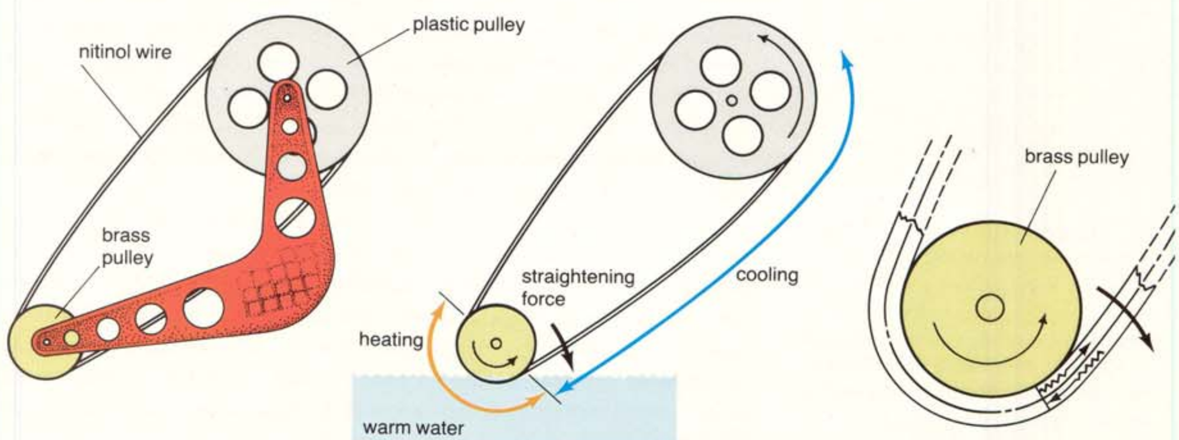
Thermobile

The Thermobile® is a device consisting of a wire loop around two pulleys, one brass and one plastic, that generates power without a motor or batteries. When the bottom edge of the brass pulley is immersed in hot water (between 50° and 75° C [122° and 167° F]), the Thermobile will within a few seconds begin to spin; it continues to do so as long as the bottom is at a temperature above 50° C.



Left, the Thermobile, a device consisting of a wire loop around one brass and one plastic pulley, begins to spin when the bottom edge of the brass pulley is immersed in water between 50° and 75° C (122° and 167° F). The wire loop consists of a nickel-titanium alloy called nitinol. At low temperatures this wire is soft and can easily be bent, but at high temperatures it becomes stiff (below). Thus in the hot water the wire tries to straighten itself out and in so doing causes the pulley to spin.

The principle underlying the Thermobile is the conversion of thermal energy into mechanical energy by means of a wire loop that is made of a nickel-titanium alloy called nitinol. Nitinol wire is soft at a low temperature and thus can easily be bent into simple shapes. At high temperatures the nitinol wire becomes stiff, reverting to its original shape in what is known as a "memory effect." Thus, the wire, bent around the metal pulley, will attempt to straighten itself out and, in the process, will cause the wheel to spin.



(Top) courtesy, Innovative Technology International, Inc.; photo Charles Cegielski; (bottom) adapted from information obtained from Innovative Technology International, Inc.

Magic effect by Ralph Beck; photo, Bill Arsenault

A magician demonstrates Dragon's Breath, which produces a large puff of flame when sprayed into a fire. Dragon's Breath is a fine yellowish powder consisting of club-moss spores and called lycopodium. This powder does not burn in bulk, but the fine particles produced by spraying it into a fire burn because of a high air (oxygen)-to-powder ratio.

Flashes and fires

Photographic flash powder, used for special effects by magicians and in the theater, has two components. The metallic component is a mixture of powdered magnesium and powdered aluminum. The second component is an oxidizer, potassium perchlorate, $KClO_4$. After the two components have been mixed, the powder can be ignited by a spark to produce a brilliant flash similar to that of a modern flash bulb. This material is highly unstable and can explode if contained.

Dragon's Breath, also available from magicians' supply stores, produces a large billow of flame when sprayed into a fire. Dragon's breath is a fine yellowish powder composed of club-moss spores and called lycopodium. Although the lycopodium does not burn in bulk, the process of spraying it into a fire results in a dust explosion as the fine particles burn owing to a high air (oxygen)-to-powder ratio. A magician will spray lycopodium from a small rubber bulb into a fire to produce a large billow of flame for special effects during a performance.

Sparklers in gold, red, green, and blue colors are manufactured in Taiwan and in Hunan, China, and are often used to decorate birthday cakes or similar items for parties or for celebrating holidays. A sparkler consists of a metal wire about three-fourths covered with a silver or colored hard material. The combustible material most commonly consists of sodium and/or potassium nitrates (chlorates may be used) combined with sulfur and carbon. The sparks are provided by powdered metals such as iron, aluminum, or magnesium. The metal powder is coated with paraffin wax to prevent oxidation during storage and to allow the metal to fall off the sparkler as it burns, producing the characteristic sparks. Colors are produced by adding salts of strontium (red), barium (green), and copper (blue); when these salts have been added, however, it is more difficult to light the sparkler. A lighted sparkler should be kept away from the face and body as well as away from any flammable material. At the completion of combustion, the wire will be hot.

Magic Snakes are small pellets that, when ignited, "grow" into long, curving columns of ash resembling a snake. Originally they were composed of mercury(II) thiocyanate, $Hg(CNS)_2$, which was bound into a pellet by using dextrin or a gum. However, because of the toxic nature of the mercury(II) thiocyanate and of the combustion product, mercury vapors, the mercury compound has been replaced. The black, nonmercury snakes now available are composed of a naphthol pitch that has been mixed with linseed oil, treated with nitric acid, washed and air dried, and then broken up and further treated with picric acid. The product is then mixed with gum arabic, pelleted, and dried.

Sparklers (left) are often used to celebrate holidays. A sparkler consists of a metal wire, three-fourths of which is covered with a hard combustible material. This usually is composed of sodium and/or potassium nitrates combined with sulfur and carbon. The sparks are provided by powdered metals such as iron and aluminum. The metal powder is coated with paraffin wax to prevent oxidation during storage and to allow the metal to fall off the sparkler as it burns. Magic Snakes (below) are small pellets (left) that "grow" into long, curving columns of ash when ignited (right). The pellets are made of a naphthol pitch that has been mixed with linseed oil, treated with nitric acid, washed and air dried, and then broken up and treated with picric acid.

Photos, Cameramann International, Ltd.

Cap guns

Cap guns and caps have long been popular items in toy stores. Caps used in cap guns usually contain 0.2 grains or less of a pyrotechnical material composed of potassium chlorate, $KClO_3$; red phosphorus, P_4; manganese dioxide, MnO_2; magnesium oxide, MgO, or calcium carbonate, $CaCO_3$; and sand, SiO_2; glue is also present to bind the material together. The manganese dioxide catalyzes the decomposition of potassium chlorate to form oxygen and potassium chloride. The magnesium oxide or calcium carbonate acts as an antacid to prevent deterioration due to moisture in storage. The sand helps to produce friction. The mixture of potassium chlorate and phosphorus is explosive and extremely unpredictable in any quantity.

The caps can be individual circles, rings, strips, or rolls that are loaded into cap guns and that will explode with a loud bang on impact. Scraping a cap with a rough object can cause the cap to flare or may produce a small explosion.

Big-Bang cannons

A Big-Bang® cannon is fueled by a substance called Bangsite, which consists of powdered calcium carbide. The Bangsite is placed in a breech block on the cannon, and a small amount is emptied into the firing chamber, which contains a small amount of water. The reaction of the Bangsite with water produces acetylene:

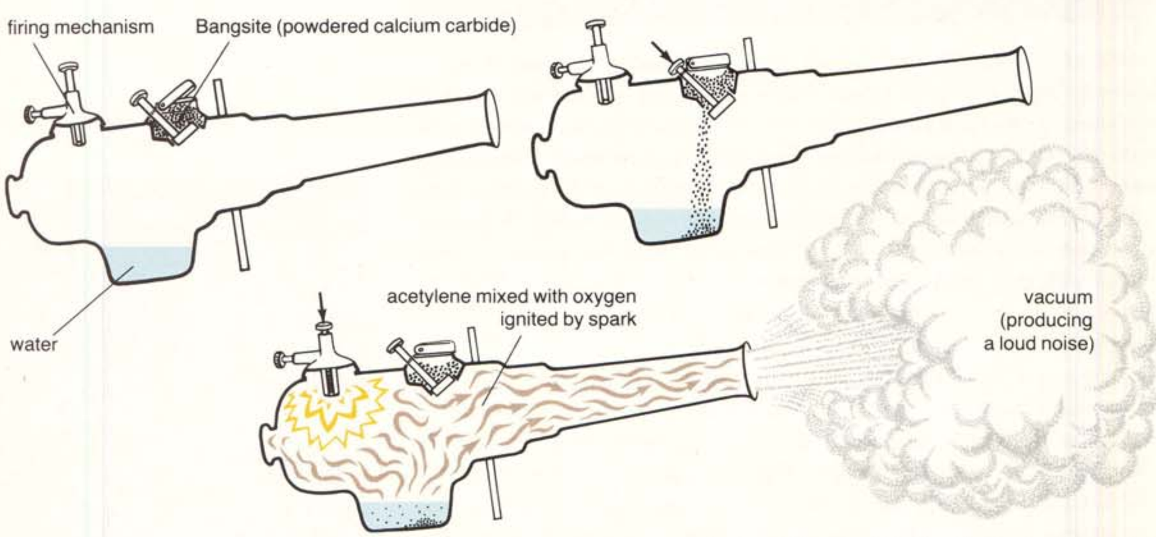
$$\underset{\text{calcium carbide}}{CaC_2} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{calcium oxide}}{CaO} + \underset{\text{acetylene}}{C_2H_2}$$

The acetylene mixes with the oxygen that is in the air within the firing chamber. When a spark is produced by the firing mechanism, the acetylene burns rapidly to produce carbon dioxide and water vapor:

$$2\ C_2H_2 + 5\ O_2 \longrightarrow 4\ CO_2 + 2\ H_2O$$

This rapid burning produces heat and results in the almost instantaneous expansion of the gases. This expansion forces the gases out of the muzzle of the cannon. The combustion of the remaining gases is completed outside the cannon, leaving a partial vacuum outside the muzzle

Diagram below shows the action of a Big-Bang cannon. Powdered calcium carbide, called Bangsite, is placed in a breech block on the cannon (top left), and a small amount of it is then emptied into the firing chamber, which contains a small quantity of water (top right). The Bangsite reacts with the water to produce acetylene, which then mixes with the oxygen that is in the air in the firing chamber. A spark produced by the cannon's firing mechanism begins the process that leads to the explosion (bottom).



Adapted from information obtained from The Conestoga Company, Inc.

Courtesy, The Conestoga Company, Inc.; photo, Charles Cegielski

The fuel Bangsite is loaded into a Big-Bang cannon.

and within the cannon. The resulting "inrush" of the atmosphere to fill the void produces a loud noise. Repeating the procedure without allowing fresh air to enter the cannon will result in a muffled bang—because of the lack of oxygen for complete rapid combustion—along with a yellow flash and black smoke at the mouth of the cannon.

FOR ADDITIONAL READING

Frederick J. Almgren, Jr., and Jean E. Taylor, "The Geometry of Soap Films and Soap Bubbles," *Scientific American* (July 1976, pp. 82–93).

Charles V. Boys, *Soap Bubbles: Their Colors and the Forces Which Mold Them* (Dover, 1959).

Peter S. Stevens, *Patterns in Nature* (Boston, Little, Brown, 1974).

Jearl Walker, "Serious Fun with Polyox, Silly Putty, Slime and Other Non-Newtonian Fluids," *Scientific American* (November 1978, pp. 186–196).

Jearl Walker, "When Different Powders Are Shaken, They Seem to Have Lives of Their Own," *Scientific American* (September 1982, pp. 206–216).