Underwater Fireworks

Chemical Demonstration

Introduction

Chlorine gas is bubbled up along with acetylene gas through a large graduated cylinder filled with water. Where the bubbles of the two gases collide, an instantaneous, bright flash of light occurs.

Chemical Concepts

- Electron affinity
- Activation energy

Materials (for each demonstration)

Calcium carbide, CaC_2, 2–3 pebble-sized pieces

Hydrochloric acid solution, HCl, 10 mL, 6 M

Sodium hypochlorite solution, NaOCl, bleach, 100 mL

Erlenmeyer flask, 250-mL

Tubing, thin glass or plastic (3–5 mm OD)

Graduated cylinder, or hydrometer, borosilicate glass, 1-L or 2-L

Rubber stopper, 1-hole (to fit 250-mL flask)

Support stand and clamp

Tubing, flexible plastic (2–4 mm ID), 10–20 cm

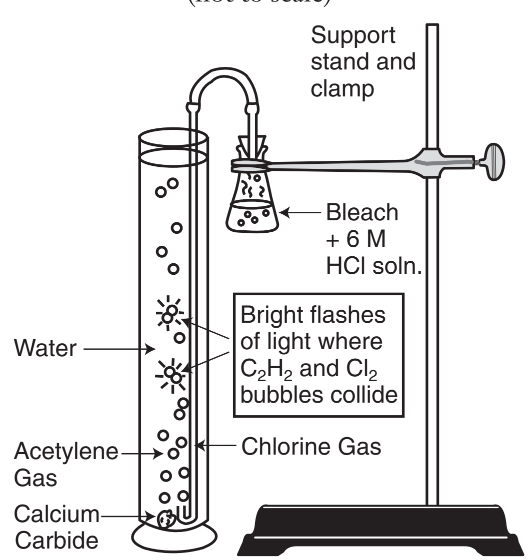
Safety Precautions

Sodium hypochlorite solution (bleach) is a corrosive liquid; causes skin burns; evolves chlorine gas when heated or reacted with acid; toxic by ingestion; avoid contact with organic material. Hydrochloric acid is highly toxic by ingestion or inhalation; severely corrosive to skin and eyes. Calcium carbide is corrosive to eyes and skin; exposure to water or moisture evolves flammable acetylene gas. The reactions in this demonstration release harmful chlorine gas and flammable acetylene gas. Perform this demonstration in an operating fume hood or a well-ventilated room. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Cut a length of glass tubing about 10 cm longer than the height of the graduated cylinder. Cut a second piece of glass tubing about 10 cm in length and insert it into a 1-holed rubber stopper. Attach the two pieces of glass tubing with flexible plastic tubing about 10 to 20 cm in length. Insert the long glass tube into the graduated cylinder as shown in the figure on the next page.
2. Fill the graduated cylinder with distilled or deionized (DI) water to within 1 to 2 cm of the top to prevent gases from collecting at the top of the cylinder.
3. Set up a support stand and clamp to hold the 250-mL flask at the appropriate level so that the rubber stopper can easily be connected and removed when the long glass tube is inserted into the graduated cylinder (see setup assembly at the right). Make sure the setup is located in an area with plenty of ventilation to carry away excess chlorine gas, or in a fume hood.

(not to scale)



Procedure

1. Working in an operating fume hood or in a very well-ventilated room, place 100 mL of bleach solution in the 250-mL flask and carefully pour in 10 mL of 6 M HCl. *Caution:* Bleach and hydrochloric acid solution will react to form chlo-

rine gas, especially when the flask is swirled or shaken. Quickly connect the 250-mL flask to the 1-holed rubber stopper and clamp the flask in place. Do not use a flask smaller than 250-mL. Do not reopen the flask. Use only the exact quantities of each chemical as mentioned above.

2. Swirl the flask slightly until 2 to 3 bubbles of gas rise up out of the tube in the graduated cylinder.
3. Drop 2 to 3 pebble-sized pieces of calcium carbide into the water in the graduated cylinder. Note the immediate generation of acetylene gas.
4. Swirl the flask gently and maneuver the glass tube along the bottom of the graduated cylinder to cause the bubbles of chlorine to collide with the bubbles of acetylene. Turn down the lights to enhance the visual impact of the reaction. The reaction will last approximately 30 to 45 seconds. If the calcium carbide is consumed but chlorine gas is still being produced, additional calcium carbide pieces can be added to the cylinder.
5. If not already in a fume hood, move the setup back to the fume hood when the reaction is complete to effectively degas the solutions.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Allow the solutions to ventilate in an operating fume hood for 12–24 hours until all the chlorine gas has evaporated. The degassed bleach/hydrochloric acid solution can go down the drain with excess water according Flinn Suggested Disposal Method #26b. The chlorine water in the graduated cylinder and bleach/hydrochloric acid solution in the Erlenmeyer flask may also be disposed of using Flinn Suggested Disposal Method #12a. Sodium thiosulfate solutions may be disposed of according to Flinn Suggested Disposal Method #12b.

Tips

- Always use fresh sodium hypochlorite to generate chlorine gas.
- Tipping the cylinder a little can facilitate the reaction, for it causes the bubbles to travel up the inside surface of the clyinder, increasing the likelihood that the bubbles will collide with one another.
- If ventilation is a problem, use the following chlorine trap: Place a plastic bag over the mouth of the graduated cylinder, and secure it in place with a rubber band. Poke a hole through one corner of the bag for the glass tube delivering the chlorine gas and one hole in the other corner for a length of tubing to deliver any unreacted chlorine into a beaker filled with 50% aqueous solution of sodium thiosulfate, $Na_2S_2O_3$. This should filter out most of the chlorine. To make a 50% aqueous solution of sodium thiosulfate: Add 50 g of sodium thiosulfate to approximately 50 mL of distilled water. Stir to dissolve the solid (some heating may be required). Then dilute the solution to a final volume of 100 mL with distilled water.
- Do not use plastic flexible tubing longer than 20 cm. Longer tubing creates more resistance for the flowing chlorine gas and may prevent the gas from flowing through the tube smoothly. This may cause a pressure buildup in the flask that may pop the rubber stopper off the top of the flask and release harmful chlorine gas.
- Tap water may be used in this demonstration as long as the water is not too hard (hard water ions may interfere with the reaction). If you suspect that your school's water is hard, distilled or deionized water should be used.
- To reduce the amount of chlorine gas lost after adding the HCl to the bleach, attach the flask as quickly as possible to the 1-holed rubber stopper, and do not agitate or swirl the flask until it is connected.
- Smaller-sized graduated cylinders or hydrometers may be used. A smaller cylinder will cause the bubbles of chlorine and acetylene to collide more frequently, but it may not be as visible from a distance. Do not use a cylinder smaller than 250-mL.

Discussion

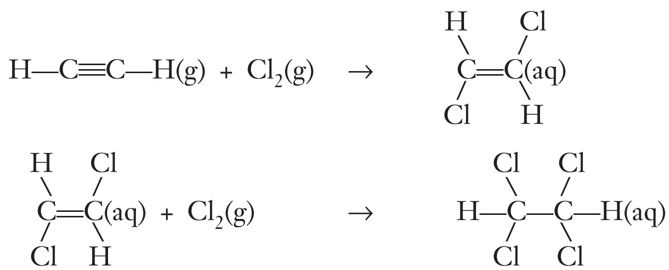
In some hydrocarbons, two or even three pairs of electrons can be shared between two adjacent carbon atoms. These multiple sharings are known as double or triple bonds, and the areas where they occur are said to have high electron densities. Hydrocarbons with double or triple bonds are referred to as "unsaturated." Halogens have seven electrons in their outermost level. Thus, they only need one more electron to form a stable octet. This gives them a high electron affinity. Because of this high affinity for electrons, and the high density of electrons around a multiple bond, halogens will often "attack"—break open and connect onto a double or triple bond in an unsaturated hydrocarbon.

When chlorine and acetylene gas mix, the electrophilic chlorine attacks the triple bond in acetylene and two competing reactions occur. The predominant reaction is chlorine adding across the carbon–carbon triple bond to produce dichloroethylene. Further addition of chlorine will produce tetrachloroethane. In a competing reaction, chlorine abstracts the hydrogen atom from acetylene to produce HCl and carbon. The carbon is visible as black soot which appears near the top of the cylinder. The reactions for the demonstration are the following:

Acetylene generation: $CaC_2(s) + 2H_2O \rightarrow C_2H_2(g) + Ca(OH)_2(aq)$

Chlorine generation: $NaOCl(aq) + 2HCl(aq) \rightarrow Cl_2(g) + NaCl(aq) + H_2O(l)$

Addition reaction:



Abstraction reaction: $H{-}C{\equiv}C{-}H(g) + Cl_2(g) \rightarrow 2HCl(aq) + 2C(s)$

Activation energy is the energy required by reactant particles so that they might collide with enough force to initiate a reaction. Many reactions, even exothermic reactions such as the combustion of hydrogen or methane, require high temperatures or sparks to initiate the process. This particular reaction between acetylene (an unsaturated hydrocarbon) and chlorine (a halogen) has a low enough activation energy that room temperature is "hot enough" for the reaction to occur spontaneously.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, interactions of energy and matter

Reference

Becker, Bob; *Twenty Demonstrations Guaranteed to Knock Your Socks Off!*; Flinn Scientific, Batavia, IL, 1994; pp 33–35.

Materials for *Underwater Fireworks—Chemical Demonstration* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8728	Underwater Fireworks—Chemical Demonstration Kit
C0346	Calcium Carbide
H0033	Hydrochloric Acid Solution, 6 M
S0079	Sodium Hypochlorite Solution, Bleach
GP9020	Glass Tubing, 240 length, 5 mm OD

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

