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Chemistry in Soap Bubbles

Química en las pompas de jabón

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Abstract

Common chemical gases such as hydrogen, oxygen, and carbon dioxide from gas cylinder or generated from chemical reactions are trapped inside soap bubbles. The physical and chemical properties of the gases such as relative density and combustion are examined. Using a syringe with wetted needle, gas can be transferred from one bubble to another. Chemical vapour can also be introduced into a gas bubble. Chemical reactions inside the bubble cavity or at the membrane surface then could be observed.

Keywords: soap bubbles, chemistry, gases, chemical reactions

Resumen

Gases comunes como el hidrógeno, oxígeno, y dióxido de carbono del cilindro de gas o generados en las reacciones químicas se colocaron dentro de las burbujas de jabón y se examinaron las propiedades físicas y químicas de los gases como la densidad relativa y combustión. Usando una jeringa con la aguja húmeda se puede transferir el gas de una burbuja a otra. Se observan las reacciones químicas dentro de la burbuja o de la superficie de la membrana .

Palabras clave: pompas de jabón, gases, reacciones químicas

Introduction

The study of the physical and chemical properties of gases is an important topic in secondary school and general science curriculum. Typically, densities of the gases are compared and their solubilities in water are discussed. Some chemical properties such as combustion or support of combustion are also of interest. Traditionally, the gas of interest is generated through a chemical reaction and trapped inside a test tube through displacement of air or water. Sometimes, there is a concern about the safety issues in handling these gases trapped inside the test tubes, especially in secondary school setting.

Everyone, in particular children, enjoys blowing soap bubbles and watching them flying freely in air. The uses of soap bubbles to illustrate some scientific principles or as teaching aids had been explored by several authors (Chattopadhyay, 2000; Hughes, 1993; Matsuyama, 1997; Ramme, 1998; Sato, 1988). In this article, we report that water insoluble or slightly soluble gases can be trapped inside soap bubbles. Through there, some of their physical and chemical properties can be examined.

Methodology

Materials

Soap bubble solution with the plastic bubble blower and the detergent were obtained from a local toyshop and supermarket respectively. Other chemicals are reagent grades and used as received.

The Apparatus

A simple gas generator with a bubble controller is depicted in Figure 1. The liquid reagents were added to the gas generator using a plastic dropper. A short granulated calcium chloride drying tube was placed in between the gas outlet and the bubble controller. The bubble controller was made from a rubber septum (Aldrich, www.sigma-aldrich.com) for a 14/20 quick-fit joint. A hole was punched through the septum. One end of the septum was connected to the drying tube. The plastic ring of the bubble blower that came with the bubble solution was cut out and inserted into the other end of the septum. A cotton ball soaped with the bubble solution was used to apply the bubble solution to the surface of the bubble controller.

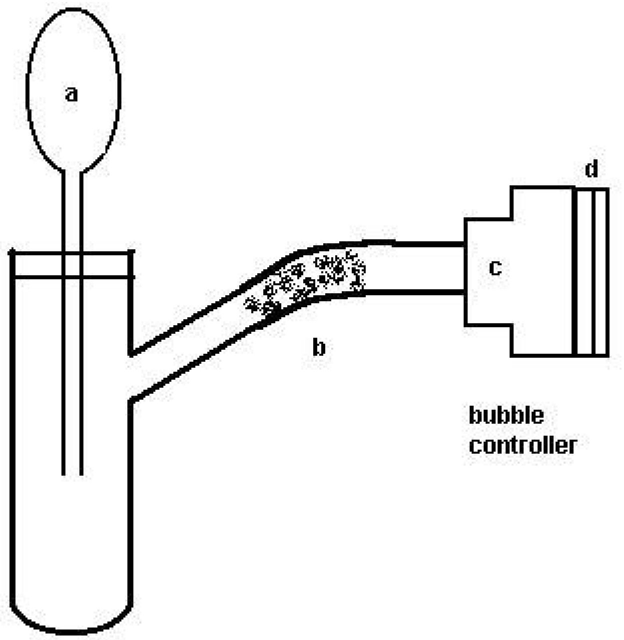

Figure 1. Gas generator with bubble controller (a: plastic dropper; b: $CaCl_2$ drying tube; c: 14/20 joint rubber septum; d: plastic ring cut out from a bubble blower)

Gas generation reactions

Hydrogen: 6 M hydrochloric acid was added dropwise to about 1 g of granulated zinc mixed with a tiny amount of copper sulfate. Oxygen: 30% hydrogen peroxide was added dropwise to about 1 g of iron dust. Carbon dioxide: 6 M hydrochloric acid was added dropwise to about 1 g of solid potassium carbonate.

Hazards

Some of the reagents used are corrosive and hydrogen peroxide is a strong oxidizing agent. Proper safety procedures of handling and disposing of these chemicals should be observed. The amount of gases generated in these experiments is relatively small. Nonetheless, safety goggles should be worn throughout the demonstration.

Results and Discussion

Three common gases, hydrogen, oxygen and carbon dioxide were studied. Of course, one can always blow the soap bubbles with the corresponding gases from gas tanks or lecture bottles. However, we would like to add some chemical flavor into the exercise. The gases were generated by typical chemical reactions: zinc metal with hydrochloric acid for hydrogen; solid potassium carbonate with hydrochloric acid for carbon dioxide and decomposition of 30% hydrogen peroxide with iron dust for oxygen. A small-scale gas generator with a bubble controller is shown in Figure 1. We found that it is important to add a short drying tube in between the gas generator and the bubble controller. This will prevent small droplets of reagent entering the bubbles. Otherwise, good-sized bubbles cannot be easily formed. A film of the bubble solution was applied to the end of the bubble controller using a cotton ball soaped with the bubble solution. Soap bubbles around 2 to 3 cm in diameter with trapped gas can be formed at the end of the bubble controller. The bubble can be gently blown off from the controller or transferred to the plastic bubble blower that came with the bubble solution (Figure 2) after it is formed.

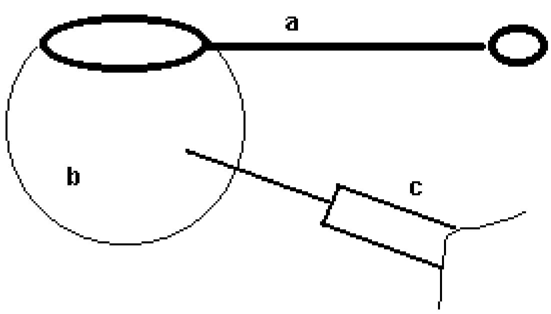

Figure 2. Gas or vapor transfer (a: plastic bubble blower; b: bubble; c: syringe with wet needle)

The first thing we observed was the relative density of the three gases. The oxygen filled soap bubbles floated freely in air as the normal air filled soap bubbles. Hydrogen filled bubbles ascended quickly to the ceiling while the carbon dioxides filled bubbles sunk to the floor. By this simple experiment, the relative density of hydrogen, oxygen and carbon dioxide can be clearly demonstrated without using any sophisticated set-up.

The combustion property of hydrogen and oxygen was the next thing we tested. Using a gas-stove lighter, the hydrogen filled bubble can be ignited. Oxygen and carbon dioxide filled bubbles are non-combustible. On the other hand, when a glowing splint was in touch with an oxygen filled bubble, it was relighted. This clearly demonstrated that oxygen, although non-combustible, supports combustion.

We also discovered that one could transfer gas from one bubble to another using a plastic syringe with its needle wetted with some soap solution. Chemical vapour can also be injected into a bubble by the same mean. The oxygen and hydrogen filled bubbles were hanged onto two separate plastic bubble blowers (Figure 2). About 1 ml of oxygen gas was withdrawn from the oxygen filled bubble by a syringe and injected into the hydrogen bubble. The oxygen-hydrogen mixed bubble was ignited with a gas lighter. A vigorous combustion with a loud “pop” sound was observed. Under these conditions, the soap bubble is not just a gas container. It has become a reaction chamber for the two gases.

To further demonstrate that soap bubbles can serve as a reaction vessel, two more experiments were carried out. The first one was the reaction between HCl vapor and NH_3 vapor to form ammonium chloride. Concentrated ammonia solution was mixed with equal volume of undiluted detergent solution obtained from a local supermarket. An air filled bubble of about 3 cm in diameter was blown from this ammonia containing detergent solution and held up side down onto the plastic bubble blower. About 1 ml of HCl vapor was drawn by a plastic syringe from the air space of a bottle of concentrated hydrochloric acid. The HCl vapor was injected into the ammonia vapor filled bubble. The formation of ammonium chloride as white fume can be clearly seen inside the bubble that subsequently burst.

The second experiment was a Tollen’s reaction inside a bubble. A Tollen’s reagent solution (Pavia, 1997) was mixed with equal volume of the detergent solution. An air filled bubble was blown from this detergent mixture and hanged up side down onto the plastic bubble blower. About 2 ml of acetaldehyde vapor was taken from the air space of a bottle of the reagent and injected into the Tollen’s reagent bubble. The reduced silver metal particles were so fine that cannot be easily visible. Nonetheless, after a minute, some grayish brown particles were seen to accumulate at the bottom of the bubble. In this case, the membrane of the soap bubble served as the medium of the reaction.

Summary

We demonstrated that water insoluble or slightly soluble gases can be trapped inside soap bubbles. Their chemical and physical properties could then be examined. Using a simple transfer technique gas can be transfer from bubble to bubble. Reactant vapour can also be introduced into a bubble trapped with gas or containing another reagent. Chemical reactions inside the cavity or at the membrane surface of the soap bubble can then be examined.

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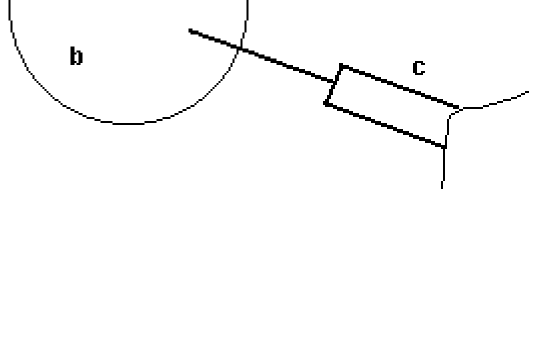
a
b
c

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