CO_2 Solubility Demonstration

Introduction

A candle and beaker of pink phenolphthalein solution are placed inside a jar. The candle is lit and the jar is capped. The flame expectedly goes out as the oxygen is depleted. After the flame is extinguished, the pink solution slowly fades to colourless. What has happened inside the jar?

Concepts

- Acid–base chemistry
- Chemical indicators
- Combustion reactions
- Gas solubility

Materials

Phenolphthalein indicator solution, 1%, 2 drops
Sodium hydroxide solution, 0.1 M, 2 drops
Beaker, borosilicate, 50-mL
Candle, votive
Jar with lid
Magnetic stir plate
Magnetic stir bar
Pipets, disposable, 2
Safety lighter
Water, distilled or deionized

Safety Precautions

Sodium hydroxide solution is a skin and eye irritant and is slightly toxic by ingestion. Phenolphthalein solution is a flammable liquid and is toxic by ingestion and inhalation. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Place the jar on a stir plate.
2. Place a votive candle in bottom of the jar off to the side.
3. Fill the 50-mL beaker with approximately 40 mL of distilled or deionized water.
4. Add two drops of phenolphthalein indicator solution to water. Stir.
5. Add two drops of 0.1 M sodium hydroxide solution to water. Stir.
6. Place magnetic stir bar into the solution.
7. Place the beaker into the bottom of the jar.
8. Start the stirrer at a medium setting.
9. Using a safety lighter, light the wick of the candle.
10. Secure the lid on the jar.

Disposal

It is recommended that you consult your local school board and/or municipal regulations for proper disposal methods that may apply before proceeding.

Publication No. 11466
091718

Tips

- The time it takes for the pink colour of the phenolphthalein to fade can be variable. Adjusting the amount of sodium hydroxide can affect the time delay between the flame extinguishing and the colour fading. Please practice this demonstration before performing it in front of your students.
- Allow students time to observe the candle and basic phenolphthalein solution before lighting the wick.
- The pink (basic) colour of the phenolphthalein may be regenerated by adding one or two drops of 0.1 M sodium hydroxide solution to the beaker. Although, a buffered solution may form which will lengthen the time between the candle extinguishing and the solution turning colourless.
- The concepts of this demonstration allow for its use multiple times throughout the year.
- Larger jars may be used to accommodate larger beakers and candles.

Discussion

Numerous chemical reactions and physical processes can be observed in this demonstration. The chemical reactions can be summarized by the four equations below.

When a hydrocarbon fuel, such as gasoline or a candle, combusts, the products are carbon dioxide and water vapour. Candle wax is a mixture of hydrocarbon molecules containing between 20–40 carbon atoms. This is represented as $C_{31}H_{64}$ in Equation 1 below.

$$C_{31}H_{64}\,(g) + 47\,O_2\,(g) \rightarrow 31\,CO_2\,(g) + 32\,H_2O\,(g) \qquad \textit{Equation 1}$$

It may also be noted that condensation forms on the inside of the jar. This is due to the water vapour condensing on the cooler glass surfaces.

Carbon dioxide is slightly soluble in water creating a carbonic acid solution as seen in Equation 2.

$$CO_2\,(g) + H_2O\,(l) \rightleftarrows H_2CO_3\,(aq) \qquad \textit{Equation 2}$$

The carbonic acid reacts with the sodium hydroxide already present in the solution. A neutralization reactions occurs forming water and sodium bicarbonate solution, represented in Equation 3.

$$H_2CO_3\,(aq) + NaOH\,(aq) \rightarrow H_2O\,(l) + NaHCO_3\,(aq) \qquad \textit{Equation 3}$$

As the sodium hydroxide is neutralized, the pH of the solution becomes more acidic as more carbon dioxide dissolves to form carbonic acid. Phenolphthalein is a pH indicator that changes from colourless, represented as HIn, to pink, represented as In^-, over a range of 8.2–10 (Equation 4).

$$HIn(aq) \rightleftarrows In^-(aq) + H^+(aq) \qquad \textit{Equation 4}$$

Colourless *Pink*

At the conclusion of the demonstration, the pink colour is "recharged" with the addition of sodium hydroxide. The hydroxide ion causes the solution to have a pH greater than 10 causing the pink colour to reappear.

Reference

Sweeder, R. D.; Jeffery, K. A., *J. Chem. Educ.*, 2013, 90, 96-98.

Materials for *CO_2 Solubility Demonstration* are available from Flinn Scientific Canada Inc.

Catalogue No.	Description
AP8447	Bottle, Ointment Jar, 480-mL
SJ0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
AP7235	Magnetic Stirrer, Flinn, 7" × 7"
PJ0020	Phenolphthalein Solution, 1%, 500 mL
AP8960	Butane Safety Lighter
AP1353	Stirring Bars, Six Piece Assortment

Consult www.flinnsci.ca or your *Flinn Scientific Canada Catalogue/Reference Manual* for current prices.