

# CO<sub>2</sub> 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 colorless. What has happened inside the jar?

## Concepts

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

## Materials

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

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Excess sodium hydroxide solution may be neutralized with acid and disposed of according to Flinn Suggested Disposal Method #10.

## NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

### Disciplinary Core Ideas: Middle School

MS-PS1 Matter and Its Interactions

PS1.A: Structure and Properties of Matter

PS1.B: Chemical Reactions

### Disciplinary Core Ideas: High School

HS-PS1 Matter and Its Interactions

PS1.A: Structure and Properties of Matter

PS1.B: Chemical Reactions

HS-PS3 Energy

PS3.D: Energy in Chemical Processes

### Science and Engineering Practices

Asking questions and defining problem

Constructing explanations and designing solutions

### Crosscutting Concepts

Cause and effect

Energy and matter

## Tips

- The time it takes for the pink color 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 color 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) color 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 colorless.
- 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 vapor. Candle wax is a mixture of hydrocarbon molecules containing between 20–40 carbon atoms. This is represented as C<sub>31</sub>H<sub>64</sub> in Equation 1 below.



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

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



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



## CO<sub>2</sub> Solubility Demonstration *continued*

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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 colorless, represented as HIn, to pink, represented as In<sup>-</sup>, over a range of 8.2–10 (Equation 4).



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

## Reference

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

**Materials for CO<sub>2</sub> Solubility Demonstration are available from Flinn Scientific, Inc.**

Catalog No.	Description
AP8447	Bottle, Ointment Jar, 480-mL
S0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
AP7235	Magnetic Stirrer, Flinn, 7" x 7"
P0019	Phenolphthalein Indicator Solution, 1%, 100 mL
AP8960	Butane Safety Lighter
AP1353	Stirring Bars, Six Piece Assortment

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