Equilibrium and Milk of Magnesia Rainbow

A Carolina Essentials™ Demonstration

Overview

This demonstration shows a colorful reaction that is a good introduction to Le Châtelier's principle, solubility, stoichiometry, neutralization reactions, and reaction rates. The demonstration uses readily available chemicals, is easy to set up and perform, and will engage your students with brilliant colors. Each color change is a visual indicator of a shift in equilibrium.

This demonstration can also be used as a limiting reactant demonstration and kinetics demonstration. See the product links for instructions.

Physical Science
Grades: 9–12

Essential Question

How are changes in reaction equilibrium demonstrated and explained?

Demonstration Objectives

1. Recognize and identify the properties of an equilibrium reaction.
2. Apply Le Châtelier's principle to explain the color change

Next Generation Science Standards* (NGSS)

The activity addresses the following dimensions of the Next Generation Science Standards:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations • Students will relate the color changes in the demonstration to equilibrium shifts and then apply Le Châtelier's principle.	**Matter and Its Interactions** • By applying Le Châtelier's principle, students will understand the dynamic process of equilibrium.	**Cause and Effect** • Students will use Le Châtelier's principle to explain color changes as a result of equilibrium shifts.

Safety Procedures and Precautions

Wear safety goggles and chemical-resistant gloves while performing this demonstration. Universal indicator solution may stain skin and clothing. It contains ethanol, which is a flammable solvent. Keep flames and sources of ignition away from this solution. Sulfuric acid is corrosive to skin and eyes.

Preparation

1. Fill a large beaker about 2/3 full with tap water. A 1000-mL beaker works best.
2. Add a stir bar to the beaker and place the beaker on the stir plate.
3. Turn the stir plate on to a gentle speed to create a small whirlpool in the center of the solution.
4. Shake the bottle of milk of magnesia well. Measure out about 20 mL of milk of magnesia using a small beaker or measuring cup. Set aside.
5. Pour about 40 mL of 1 M sulfuric acid into the graduated cylinder. Set aside.
6. Hand out the student worksheet.

TIME REQUIREMENTS

PREP	ACTIVITY
20 min	15–20 min

Teacher Prep: 20 min
Demonstration: 15–20 min

SAFETY REQUIREMENTS

MATERIALS (PER GROUP)

4-oz bottle of milk of magnesia with medicine cup

Universal indicator, 2–3 mL

1 M sulfuric acid, 40 mL (vinegar and 1 M acetic acid also work well)

Tap water

1000-mL beaker

50-mL graduated cylinder

Stir plate

Stirring bar

HELPFUL LINKS

MOM's Acid-Base Chemistry

MOM Rainbow (Video)

REFERENCE KITS

Carolina ChemKits®: Milk of Magnesia Rainbow

Milk of Magnesia Rainbow Demonstration Kit

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Disposal

The final solution will be a slightly acidic solution of magnesium sulfate and can be disposed of down a drain with excess water.

Teacher Procedure

1. Add 2 to 3 mL of universal indicator to the water in the beaker.
2. Add all of the milk of magnesia to the stirring water.
3. Wait until the milk of magnesia is evenly distributed and the color is a consistent purple throughout the suspension.
4. Ask students to fill out the first section of their worksheet and begin to record observations.
5. Add approximately 5 mL of 1 M sulfuric acid to the milk of magnesia suspension.
6. When the suspension has returned to a consistent purple color, add another 5 mL of sulfuric acid.
7. Prompt students to describe the changes and inquire what the color changes may be indicating.
8. Continue to add sulfuric acid 5 mL at a time until the solution remains a translucent (clear) red.

Teacher Preparation and Tips

Any universal indicator will work.

Show students the color of universal indicator in neutral water.

Explain the difference between clear and colorless to students. Universal indicator is clear and green. During step 3, ask if the solution is still clear.

When the acid is added, the suspension should turn red, then yellow, green, blue, and finally back to purple. Instruct students to observe carefully.

If students cannot see the color changes encourage them to get closer. They must wear goggles.

The time can vary to fit your schedule, but allow a minimum of 30 to 45 minutes.

Background

Milk of Magnesia, an over-the-counter medication frequently used as a laxative and antacid, is a suspension of magnesium hydroxide, $Mg(OH)_2$, in water. Magnesium hydroxide is only slightly soluble in water (0.012 g/L).

During the demonstration, sulfuric acid (H_2SO_4) is added to a saturated solution of magnesium hydroxide. The hydroxide ion in the solution is immediately consumed when it reacts with hydrogen ions to produce water. The stress of disrupted equilibrium is relieved as more magnesium hydroxide dissociates.

According to Le Châtelier's principle, as the hydroxide ions react with hydrogen ions to produce molecular water, the hydroxide ions (OH^-) decrease, placing a stress on the system. The response to the decrease in concentration is for more $Mg(OH)_2$ to dissociate, re-establishing equilibrium. The process continues until all the magnesium hydroxide is neutralized, leaving only a clear, red solution of magnesium sulfate (due to the low pH resulting in excess sulfuric acid).

Data and Observations

When the acid is added, the solution changes from purple (pH 10) to red (pH 4). The color of the solution then slowly changes to orange, yellow, green, blue, and finally back to violet as the magnesium hydroxide slowly dissolves.

This process continues until all the magnesium hydroxide is neutralized, leaving only a clear solution of magnesium sulfate, which will be red due to the low pH, a result of the excess sulfuric acid. The final solution is also clear, indicating a solution rather than a suspension.

$Mg(OH)_2(s) \rightarrow Mg^{2+}(aq) + 2OH^-(aq)$

$Mg(OH)_2(aq) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + 2H_2O(l)$

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Analysis and Discussion

1. Why does the solution change color very quickly when the acid is added? Explain the reactions or processes that are occurring.

   The neutralization reaction between the hydroxide ions in solution and the acid is very fast.

2. Why does the solution slowly return to the original color? Explain the reactions or processes are occurring.

   Once all the hydroxide ions in solution are consumed, the magnesium hydroxide slowly dissolves to relieve the disrupted equilibrium as described by Le Châtelier's principle.

3. Using Le Châtelier's principle, explain the color changes observed in the demonstration.

   The hydroxide ions (OH–) in solution are neutralized, causing a disruption of the solubility equilibrium for magnesium hydroxide. This causes more of the solid magnesium hydroxide to dissolve. The stress of disrupted equilibrium is relieved as described by Le Châtelier's principle, which states that if a stress is placed upon a reaction at equilibrium, the reaction shifts to relieve that stress.

TEACHER NOTES

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