Upset Tummy? MOM to the Rescue!

LeChâtelier's Principle

Introduction

Mix milk of magnesia (MOM) with universal indicator and observe the dramatic rainbow of colors as the antacid dissolves in the simulated stomach acid! This is a great demonstration to teach concepts of acids and bases, solubility, equilibria, and LeChâtelier's principle.

Concepts

- Acid–base neutralization
- Solubility equilibria
- Consumer chemistry

Materials

Hydrochloric acid, HCl, 3 *M*, approximately 20 mL
Milk of magnesia, 20 mL
Universal indicator solution, 1%, 4–5 mL
Water, distilled or deionized, 800 mL
Beaker, 1-L (or other large beaker)
Beral-type pipets, 2
Graduated cylinder, 25-mL or 50-mL
Ice, crushed (or ice cubes)
Magnetic stirrer or stirring rod
Magnetic stir bar

Safety Precautions

The milk of magnesia used in this demonstration is intended for laboratory use only; it has been stored with other non–food-grade laboratory chemicals and may not be used for human consumption. Hydrochloric acid solution is toxic by ingestion and inhalation and is corrosive to skin and eyes. Universal indicator solution is an alcohol-based flammable solution. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Measure 20 mL of milk of magnesia using a graduated cylinder and pour it into a 1-L beaker.
2. Place the 1-L beaker on a magnetic stirrer and add a magnetic stir bar to the beaker.
3. Add ice water (water and crushed ice) to give a total volume of approximately 800 mL. Turn on the magnetic stirrer to create a vortex in the mixture.
4. Add about 4–5 mL (about 2 pipets full) of universal indicator solution. Watch as the white suspension of milk of magnesia turns to a deep purple color. The color indicates that the solution is basic (pH ≥10).
5. Add 2–3 mL (1 pipet full) of 3 M HCl. The mixture quickly turns red and then goes through the entire universal indicator color range back to purple.
6. Repeat this process, adding HCl one pipet full at a time, waiting after each addition until the mixture turns back to blue–purple.
7. The process can be repeated a number of times before all of the $Mg(OH)_2$ dissolves and reacts with the HCl. As more acid is added, the color changes will occur more rapidly and eventually the suspension will be completely dissolved. The final result is a clear, red solution.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Neutralize the final solution according to Flinn Suggested Disposal Method #24b. Excess milk of magnesia can be disposed of according to Flinn Suggested Disposal Method #26a.

Tips

- If a 1-L beaker is not available, use a 600-mL or 400-mL beaker. Adjust chemical amounts accordingly. The actual milk of magnesia concentration is not critical for the demonstration to work.
- If a magnetic stirrer is not available, use a stirring rod to continuously stir the mixture.
- The acid used in the demonstration is 3 *M* hydrochloric acid (HCl). Actual stomach acid ranges is approximately 0.1 to 1 *M* HCl. The higher concentration is used in this demonstration in order to limit the total acid volume and allow the reaction to go to completion with a reasonable volume of acid. If desired, dilute the 3 *M* acid to 1 *M* and perform the experiment as written. The volume of acid needed will be three times greater.
- The reaction is performed on ice in order to slow down the color changes so that all colors in the universal indicator color range can be viewed. The reaction may also be performed without the use of ice.
- An excellent follow-up to this antacid demonstration is the Antacid Testing Lab Kit—*How Powerful Is Your Antacid?* (Catalog No. AP1741), available from Flinn Scientific.

Discussion

The active ingredient in milk of magnesia is magnesium hydroxide, $Mg(OH)_2$. Magnesium hydroxide forms a suspension in water since it has a very low solubility—0.0009 g/100 mL in cold water and 0.004 g/100 mL in hot water.

Initially in the demonstration the solution is basic due to the small amount of $Mg(OH)_2$ that goes into solution. The universal indicator is purple, indicating a pH of about 10. (See Universal Indicator Color Chart below.) When hydrochloric acid (the simulated "stomach acid") is added, the mixture quickly turns red because the acid disperses throughout the beaker, first neutralizing the small amount of dissolved $Mg(OH)_2$, and then turning the solution acidic from the excess acid that is present.

Universal Indicator Color Chart							
Color	Red	Orange	Yellow	Green	Green–blue	Blue	Violet
pH	4	5	6	7	8	9	10

The excess acid causes more $Mg(OH)_2$ from the suspension to gradually dissolve. As more of the $Mg(OH)_2$ goes into solution, the acid is neutralized and eventually the solution becomes basic again from the excess $Mg(OH)_2$ that is present. The presence of universal indicator allows this process to be observed. During the process, the color of the mixture goes through the entire universal indicator color range—from red to orange to yellow to green to blue and finally back to violet. By adding more "stomach acid," the process can be repeated several times before all of the $Mg(OH)_2$ is dissolved and eventually neutralized.

Magnesium hydroxide is classified as a weak base due to its very limited solubility in water. This limited solubility makes it an ideal compound to use in commercial antacids since it slowly dissolves as it neutralizes stomach acid rather than dissolving all at once. The neutralization reaction is the reaction between $Mg(OH)_2$ (a weak base) and HCl (a strong acid). The overall equation for the reaction is shown in Equation 1 below.

$$Mg(OH)_2(s) + 2H^+(aq) \rightarrow 2H_2O(l) + Mg^{2+}(aq) \qquad \textit{Equation 1}$$

The reacting species for the strong acid, HCl, is the hydrogen ion, H^+. In contrast, since $Mg(OH)_2$ is a weak base, the principal reacting species is the undissociated $Mg(OH)_2$ compound. The acid–base reaction involves $Mg(OH)_2$ and H^+ ion as reactants. The products are H_2O molecule and a Mg^{2+} ion in solution. Because the chloride ion, Cl^-, from HCl is a spectator ion, it is not included in the net ionic equation.

While $Mg(OH)_2$ is practically insoluble, a very small amount of $Mg(OH)_2$ dissociates into ions when put in water. The extent of dissociation of $Mg(OH)_2$ is indicated by its solubility product constant, K_{sp}. The K_{sp} at 25 °C for $Mg(OH)_2$ is 6×10^{-12}, indicating that the reaction equilibrium lies far to the left, according to Equation 2.

$$Mg(OH)_2(s) \rightleftarrows Mg^{2+}(aq) + 2OH^-(aq) \qquad \textit{Equation 2}$$

In the demonstration, the initial milk of magnesia suspension in water contains very few Mg^{2+} and OH^- ions before the acid is added. As HCl is added to the beaker containing milk of magnesia, the H^+ ions from the HCl react with the OH^- ions (those that are actually in solution from the $Mg(OH)_2$) according to Equation 3.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \qquad \textit{Equation 3}$$

The reaction between H^+ (stomach acid) and OH^- (antacid) to form water uses up some of the OH^- ions and drives Equation 2 to the right, causing more $Mg(OH)_2$ to dissolve and dissociate into ions. As OH^- ions are removed from solution by the H^+ ions, more and more $Mg(OH)_2$ is forced to dissociate to replace those ions, according to LeChâtelier's Principle. As more acid is added, the $Mg(OH)_2$ continues to dissociate until all of it is dissolved and Equation 2 lies all the way to the right. The final solution in the milk of magnesia demonstration will thus be clear and acidic (red in color from the universal indicator), indicating that the $Mg(OH)_2$ has fully dissolved and reacted. At this point, the "antacid power" or "acid-neutralizing ability" of the milk of magnesia is depleted.

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 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard F: Science in Personal and Social Perspectives; personal health
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions
Content Standard F: Science in Personal and Social Perspectives; personal and community health

Answers to Worksheet Questions

1. Describe what happened in this demonstration.

   Universal indicator was added to a mixture of milk of magnesia and ice water, turning the solution purple, indicating a pH of around 10. Hydrochloric acid was added one pipet-full at a time. Each time the solution flashed red before going through a series of color changes, from red to orange to yellow to green to blue to purple again. This process became more and more rapid, until finally the cloudy suspension was replaced by a clear, red solution.

2. Write the balanced chemical equation for each of the following reactions.

   a. Neutralization reaction between magnesium hydroxide and hydrochloric acid

   $Mg(OH)_2(s) + 2HCl(aq) \rightarrow 2H_2O(l) + MgCl_2(aq)$

   b. Dissociation of magnesium hydroxide

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

   c. Reaction between hydrogen ions from the acid and hydroxide ions from the base

   $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

3. Using LeChâtelier's Principle, explain why adding hydrochloric acid causes more magnesium hydroxide to dissolve in solution.

   The reaction in Equation c uses up hydroxide ions from Equation b. To reestablish equilibrium Equation b therefore shifts to the right, causing more magnesium hydroxide to dissolve and react with the acid. As more acid is added, more magnesium hydroxide dissolves until eventually there is none left.

4. Explain why the solution is red and clear at the end of the demonstration.

   All the solid magnesium hydroxide, which was responsible for the milky appearance of the mixture, has dissolved, and the solution is clear. The red color is due to the universal indicator, which is red in the presence of an acid, in this case the excess hydrochloric acid.

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Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Upset Tummy? MOM to the Rescue!* activity, presented by Irene Cesa, is available in *LeChâtelier's Principle*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Upset Tummy? MOM to the Rescue!* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Upset Tummy? MOM to the Rescue!—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP5934	Upset Tummy? MOM to the Rescue!—Chemical Demonstration Kit
AP1741	How Powerful Is Your Antacid?—Antacid Testing Laboratory Kit
AP1349	Magnetic Stirrer—Thermolyne Cimarec™
M0122	Magnesium Hydroxide, Saturated Solution, 500 mL
U0001	Universal Indicator Solution, 3 M, 100 mL
H0034	Hydrochloric Acid Solution, 3 M, 500 mL

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

Upset Tummy? MOM to the Rescue! Worksheet

Discussion Questions

1. Describe what happened in this demonstration.

2. Write the balanced chemical equation for each of the following reactions.

   a. Neutralization reaction between magnesium hydroxide and hydrochloric acid

   b. Dissociation of magnesium hydroxide

   c. Reaction between hydrogen ions from the acid and hydroxide ions from the base

3. Using LeChâtelier's Principle, explain why adding hydrochloric acid causes more magnesium hydroxide to dissolve in solution.

4. Explain why the solution is red and clear at the end of the demonstration.