SNC2D/2P Chemical Reactions/Chemical Reactions and their Practical Applications

Teacher Demo: Acid–Base Rainbow

Topics	Timing
introduction to properties of acids and bases, the pH scale, neutralization reactions	preparation: 5 min demonstration: 10–15 min

Specific Expectations

SNC2D

A1.1 formulate scientific questions about observed relationships, ideas, problems, and/or issues, make predictions, and/or formulate hypotheses to focus inquiries or research
A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions
C3.6 describe the process of acid–base neutralization (i.e., an acid reacts with a base to form a salt and often water)
C3.7 describe how the pH scale is used to classify solutions as acidic, basic, or neutral (e.g., a solution with a pH of 1 is highly acidic; a solution with a pH of 7 is neutral)

SNC2P

A1.1 formulate scientific questions about observed relationships, ideas, problems, and/or issues, make predictions, and/or formulate hypotheses to focus inquiries or research
A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions
C3.4 describe the process of neutralization for simple acid–base reactions (i.e., an acid reacts with a base to form a salt and often water)
C3.5 describe how the pH scale is used to identify the concentration of acids and bases

Introduction

This quick demonstration is a highly visual illustration of the use of acid–base indicators to determine pH. Milk of magnesia is mostly a suspension of magnesium hydroxide in water. Magnesium hydroxide is a strong base that readily neutralizes hydrochloric acid. Universal indicator is a mixture of several acid–base indicators. The changing colours of the indicator during this reaction help students to observe the pH changes that occur during neutralization.

Materials

chemical safety goggles
lab coat or apron
protective gloves
100 mL milk of magnesia (suspension form)
1 dropper bottle of universal indicator solution
200 mL cold water
1 dropper bottle of 2.0 mol/L hydrochloric acid, HCl (aq)
600 mL beaker
magnetic stirrer

Safety Considerations

- Provide MSDS sheets for all chemicals used.
- Hydrochloric acid is corrosive and poisonous. Avoid skin or eye contact. Safety goggles, gloves and apron/lab coat should be worn when handling hydrochloric acid. Wash your hands and flush your eyes immediately if you come into contact with it. Students should not handle hydrochloric acid.
- The universal indicator solution is flammable and should be in a dropper bottle. Keep it away from any heat sources and open flames.

Hazardous Materials Identification System Rating

(0-minimal 1-slight 2-moderate 3-serious 4-severe)

2.0 mol/L hydrochloric acid

HMIS (0 to 4)

Health	2
Fire Hazard	0
Reactivity	1

universal indicator solution

HMIS (0 to 4)

Health	1
Fire Hazard	3
Reactivity	0

Procedure

Wear proper PPE: chemical safety goggles, lab coat or apron, and protective gloves.

1. Place 75–100 mL of the milk of magnesia suspension into the 600 mL beaker. Inform students that milk of magnesia is a suspension of magnesium hydroxide, $Mg(OH)_2(s)$, in water.
2. **Predict/Explain**
3. Tell students that you are going to add an indicator that changes colour depending on the pH of the solution to which it is added. Ask students to predict what will happen to the milk of magnesia when hydrochloric acid is added, and how they will know that this occurs. Students should provide a rationale for their prediction.
4. Add 3–5 drops of universal indicator and 200 mL of cold water to the milk of magnesia.
5. Place the beaker on the magnetic stirrer base and add the magnetic stir bar. Start the stirrer on low/medium speed.
6. **Observe**
   Add drops of the hydrochloric acid slowly until all of the magnesium hydroxide in the milk of magnesia dissolves. Provide time for students to record their observations. (Ensure that they record observations throughout the duration of the demonstration.)
7. **Explain**
   Have students explain the visible changes that they have observed.

Disposal

Sodium hydrogen carbonate (baking soda) or sodium carbonate may be used to neutralize any excess acid in the final solution prior to disposal. Follow procedures that are consistent with school board protocol and appropriate for your municipality.

What happens?

The initial solution will appear blue/purple. As the acid is added, the colour will change to green, orange and then finally red, depending on volume and concentration of acid.

How does it work?

Universal indicator is a mixture of compounds that change colour at certain pH levels. As the magnesium hydroxide, a base, is neutralized by the hydrochloric acid the pH of the solution changes. The colour of the indicator changes in response to the pH of the solution as shown in Fig.1.

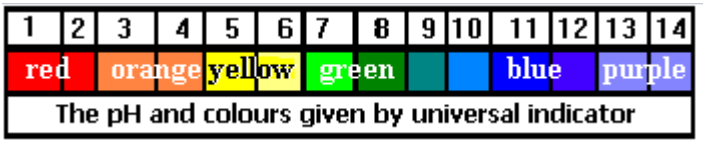

Fig.1 Universal indicator colour chart

Milk of magnesia contains magnesium hydroxide which is a strong base and has a high pH (9–11). Due to the low solubility of magnesium hydroxide, the equation that represents $Mg(OH)_2$ dissociation heavily favours the left side.

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

Consequently, the concentration of free hydroxide ions in the suspension is low enough to permit us to safely consume the suspension.

The addition of acid immediately lowers the pH of the suspension to the acidic range, producing a change in colour from purple to orange. As each addition of the acid is gradually neutralized, the pH of the suspension increases, producing several colour changes until the initial purple colour is reached again. The green colour that is sometimes visible indicates a pH of 7. Eventually you will add enough acid to completely consume all of the hydroxide ions. As this point, the solution remains an orange-coloured solution due to the excess of hydrogen ions from the acid.

Teaching Suggestions/Hints

1. Do this demonstration in front of a white background to help students observe the colour changes.
2. Vinegar may be used instead of hydrochloric acid. However, larger volumes of vinegar are required because the concentration of hydrogen ions in vinegar is lower than in the suggested hydrochloric acid solution.
3. When the reaction is complete, you can add more milk of magnesia and use the solution again for another demonstration.
4. Possible extension questions:
    a. After the first drops of hydrochloric acid are added, the solution becomes orange but returns back to blue/purple. Why does the orange colour disappear?
    b. After continually adding hydrochloric acid, the solution remains orange. Why does the solution not turn back to blue/purple?
    c. What would happen if more milk of magnesia were added? Explain.
    d. What evidence suggests that some chemical reactions are reversible?

Next Steps

Introduce students to other acid–base indicators such as red cabbage juice and grape juice.

Additional Resources

1. Milk of Magnesia (MOM) Rainbow video from Carolina Biological (Note that some of the concepts introduced are at the Grade 12 level): http://www.youtube.com/watch?v=dwNboZesSs4
2. Additional demonstration – Universal Indicator Rainbow: http://www.nuffieldfoundation.org/practical-chemistry/universal-indicator-rainbow