ACS Chemistry for Life®

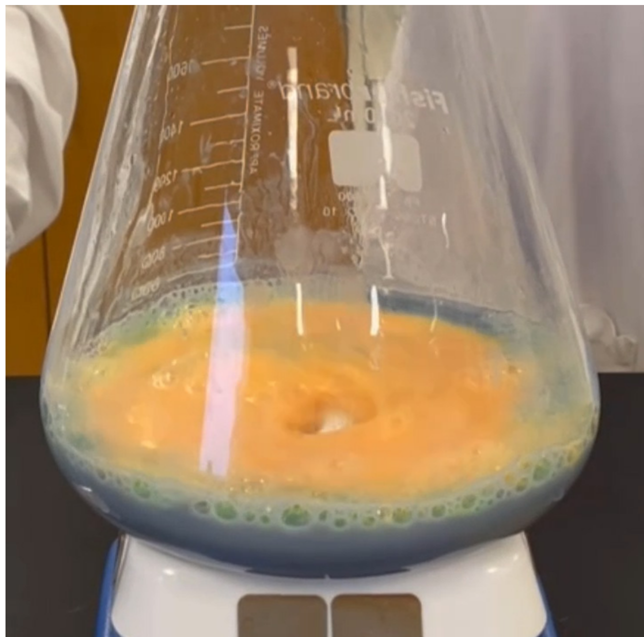
Classroom

Rainbow Tornado

Teach Le Châtelier's Principle by using antacid, vinegar, and universal indicator to create a colorful vortex!

Question to investigate

How many times can you add vinegar before this color-changing chemical reaction comes to an end?



Chemistry concepts

Review with teacher or group leader to identify the appropriate concepts for your group

- ***Acids and bases:*** acids produce H^+ ions in solution while bases produce OH^-
- ***Neutralization:*** acids and bases react to form neutral solutions.
- ***Solubility:*** $Mg(OH)_2$ is slightly soluble in water but dissolves more easily with acid
- ***Indicators:*** acid-base indicators change colors to denote changes in pH
- ***Equilibrium:*** with each addition of acid, the system shifts to restore equilibrium in accordance with Le Châtelier's Principle

Special considerations

If using a magnetic stir bar, be sure to clamp the flask firmly in place to avoid spills

- Potential hazards include:
  - Acids and bases
  - Broken glassware
  - Spills and splashes
- Conduct your own RAMP assessment prior to presenting this activity.

Time required

Preparation: 10 – 15 minutes

Activity: 10 – 15 minutes

Age range

12 – 18 years

Group size

- Participants work in pairs or trios
- 1 facilitator per 5 groups

Materials

For 15 groups

- 2 – 26 fl oz bottles milk of magnesia*
- 3 L water
- Universal indicator or red cabbage indicator†

*. Found with the antacids in most grocery stores and drugstores.

†. Make red cabbage indicator: Shred 1-2 red cabbage leaves and freeze 1 hour in a zip-close plastic bag. Add 1/3 cup warm water, reseal bag, and squish the leaves with hands. When liquid is as dark as possible, decant and discard solids.

- 1 – 1.32 gal bottle white vinegar
- 45 large clear, colorless plastic cups
- 15 long-handled spoons or glass stirring rods‡
- 15 tablespoon measuring spoons or medicinal measuring cups

‡. Magnetic stirplate and stir bars may be used; replace 30 plastic cups with Erlymeyer flasks and add clamps to secure.

- 15 copies of a pH color chart to hand out, or 1 copy to project to the class

Additional materials identified in your RAMP analysis:

Prior to the activity

Customize activity to venue

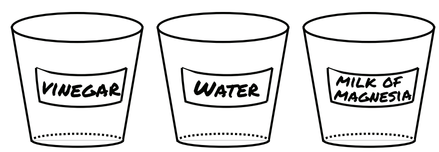
1. Review RAMP safety worksheet for this activity.
2. Revise procedure to adapt to your specific venue and participants.
3. Review activity with the teacher or group leader.
4. List appropriate procedures for accidents, emergencies:

Identify appropriate safety practices

- Wear appropriate personal protective equipment (e.g., goggles, gloves, etc.).
- Secure loose hair, clothing.
- Prohibit eating, drinking.
- Clean work area, wash hands after activity.
- Other practices identified in RAMP worksheet:

Prepare materials

1. Collect materials
2. For each group, label a set of 3 cups with: vinegar, water, and milk of magnesia.



Prepare on site

For each group:

1. Set out 1 set of labeled cups, universal indicator, 1 long-handled spoon or other stirring equipment, 1 measuring spoon or cup.
2. If distributing the pH color charts, place them with the set-ups for each group; if projecting, set up the projection.
3. Place 200 mL white vinegar in the “vinegar” cup.
4. Place 200 mL water in the “water” cup.
5. Place 100 mL milk of magnesia in the “milk of magnesia” cup.

Additional set-up for your specific venue and audience:

On-site activity

<table>
<tr><th>Step</th><th>Details</th><th>Ask participants:</th></tr>
<tr><td>Introduce activity</td><td>Briefly describe the goals:
You will make a color-changing vortex with universal indicator, milk of magnesia, and vinegar.
Along the way, you will explore the properties of milk of magnesia and vinegar.</td><td>What do you already know about milk of magnesia? When do you use it?
What do you already know about vinegar? When do you use it?</td></tr>
<tr><td>Prepare the milk of magnesia</td><td>Direct participants to:
Add water to the milk of magnesia cup until it is about half full.
Add 5-10 drops of universal indicator (or 1 tsp red cabbage indicator) to provide color. Note the color.</td><td>What does the milk of magnesia look like at the beginning?
What does the color of the indicator tell you about the milk of magnesia?</td></tr>
<tr><td>React milk of magnesia with vinegar</td><td>Assign jobs for in each group, such as stirrer, vinegar measurer, and vinegar pourer.

Direct participants to:
Stir until a vortex (or “tornado”) forms. The stirrer will need to keep stirring throughout the activity.
While stirring the solution, add 10 mL (1 tbls) of vinegar.
Continue adding vinegar in 10 mL increments until the color change is permanent, and the solution turns clear</td><td>Do you observe a color change when you add the vinegar? Is the color change permanent?
Why do you think the color change is not permenant at first?
Why do you think the mixture became clear?</td></tr>
<tr><td>Discuss results</td><td>Compare the amount of vinegar each group used to complete the reaction.
Discuss students’ observations and the chemistry of what’s happening (see "Chemistry details")</td><td>How does the pH change throughout the reaction?
Why do you think milk of magnesia is used as an antacid?
What is the role of equilibrium in the reaction?
Where else might the solubility of metal hydroxides be a concern?</td></tr>
</table>

On-site activity

Step	Details	Ask participants:
Clean up	• Dispose of all solids from this activity in the trash. • Dispose of all liquids down the drain. • Clean all work surfaces with water or a damp cloth. • Wash hands thoroughly.	

Chemistry details

Adjust these details to match the level of your audience.

What is milk of magnesia?

Milk of magnesia is a type of mixture of $Mg(OH)_2$ in water called a suspension. It looks cloudy because only 0.012 g $Mg(OH)_2$ can dissolve in one liter of water at room temperature; the rest is tiny particles that can't dissolve but stay dispersed in the water.

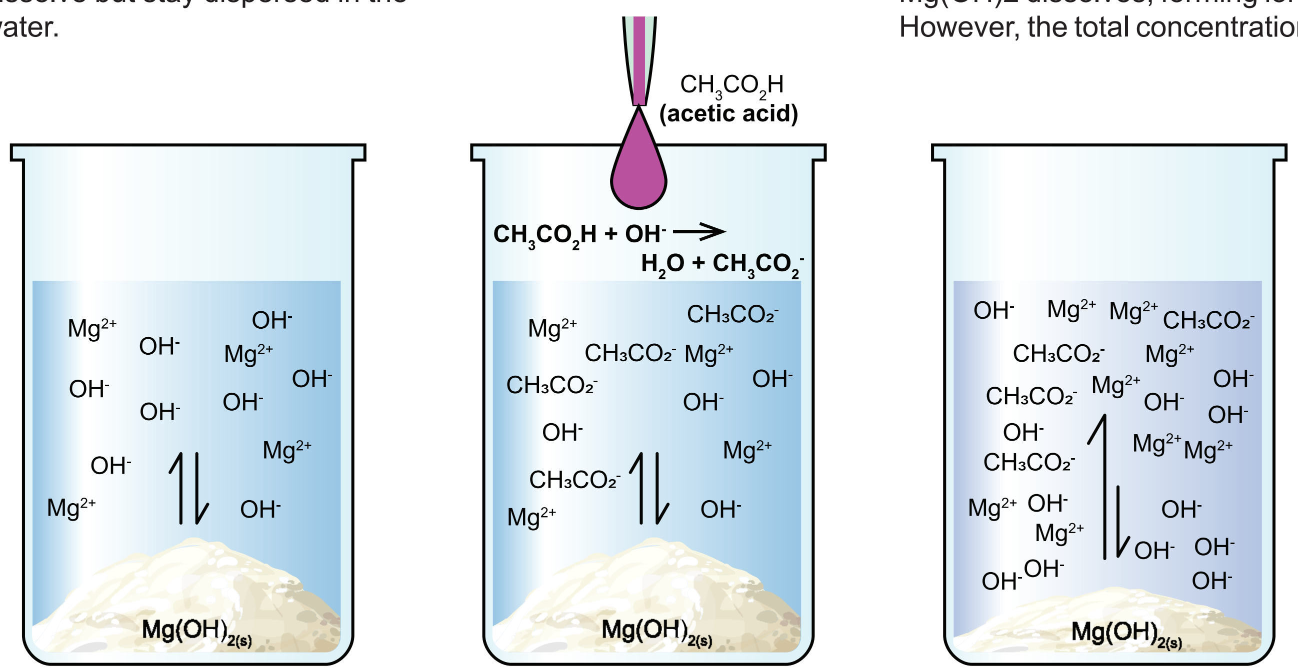
The small amount of magnesium hydroxide that does dissolve releases enough OH^- ions to create a basic solution:

$$Mg(OH)_{2(s)} \longrightarrow Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)}$$

The indicator changes color to indicate that the solution is basic.

What is dynamic equilibrium?

After the water dissolves as much $Mg(OH)_2$ as possible, the remaining solid forms a "dynamic equilibrium" with the solution. Individual Mg^{2+} and OH^- ions continuously come together to form solid $Mg(OH)_2$, while solid Mg(OH)2 dissolves, forming ions. However, the total concentrations



$Mg(OH)_2$ is in dynamic equilibrium with the saturated $Mg(OH)_2$ solution.

The equilibrium is disturbed when acetic acid coverts the OH^- ions to H_2O, leaving acetate ions behind.

More $Mg(OH)_2$ dissolves until solution is saturated with $Mg(OH)_2$ again, restoring equilibrium.

of the Mg^{2+} and OH^- ions do not change.

What's happening with the vinegar?

Vinegar contains acetic acid (CH_3CO_2H). When it is added to the mixture, it neutralizes the OH^- ions to form water:

$$Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)} + 2\ CH_3CO_2H_{(aq)} \longrightarrow Mg(CH_3CO_2)_{2(aq)} + 2\ H_2O_{(l)}$$

When a system in dynamic equilibrium is disturbed, it will shift to restore equilibrium. This is called Le Châtelier's principle. In our system, reacting the OH^- ions to form water removed them from the $Mg(OH)_2$ equilibrium, so more $Mg(OH)_2$ dissolves, until the OH^- ion concentration is restored. The changes in acidity are again reflected in the indicator's color changes.

As more vinegar is added, the process repeats until all of the $Mg(OH)_2$ is dissolved, resulting in a clear solution. When all of the OH^- ions are reacted, the now-acidic solution retains its final color change.

Speeding up or slowing down

You may also notice that the reaction mixture feels warm. As with many acid-base experiments, the reaction of magnesium hydroxide and vinegar generates heat. Adding ice to the system slows down the reaction, allowing more time for you to observe the color changes.

Real-world applications

Because of its ability to neutralize acid, milk of magnesia has been used to treat excess stomach acid since the early 1800s. Other bases, such as calcium carbonate (chalk) or sodium bicarbonate (baking soda) have also been popular through the years.

Le Châtelier's principle is also why metals in drinking water can be a concern. Lead and other metals often precipitate in pipes as hydroxides. While pure water is neutral, standing water absorbs carbon dioxide from the air, forming carbonic acid. The acid then reacts with the metal hydroxides, leaching them into the water. Fortunately, this only occurs in small amounts; running your drinking water for a few seconds prior to filling your glass is usually sufficient to flush out metal build-up.

Additional use

At higher doses, milk of magnesia passes from the stomach to the intestines, where the undissolved solid can increase the bulk of the stool; the minimal Mg^{2+} encourages the absorption of water, which also increases bulk. Because of this, milk of magnesia can also be used to treat constipation.

References

- American Chemical Society, 2023
- ACS Student Chapter at Georgia Gwinnett College
- National Center for Biotechnology Information. "PubChem Compound Summary for CID 73981, Magnesium Hydroxide" PubChem, https://pubchem.ncbi.nlm.nih.gov/compound/Milk-of-magnesia. Accessed September, 2023