Acid–Base Reactions with Carbon Dioxide

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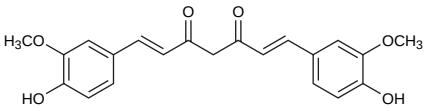
In this Activity, students investigate two acid–base reactions. One contains carbon dioxide as a reactant; the other has carbon dioxide as a product.

Integrating the Activity into Your Curriculum

This Activity can be used when acid–base reactions are introduced in the curriculum or when carbon dioxide is discussed. The reactions included could be used as demonstrations or guided hands-on activities for younger children.

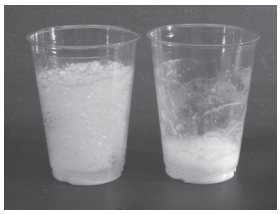
About the Activity



Structure of curcumin (diketone form)

One way to make chemistry appealing to young students is to allow them to actively participate in chemical demonstrations that are safe and fun. This Activity reproduces two well-known demonstrations *(1)* where the chemical reagents have been replaced by common household products. All materials required for the Activity can be found in the home or in a grocery store. The Activity could be used as a take-home assignment. Small clear, colorless plastic or glass bottles with caps can be substituted for Erlenmeyer flasks.

The Activity focuses on two acid–base reactions. In the first, an aqueous solution of powdered laundry detergent is neutralized with the acid formed by the dissolution of exhaled carbon dioxide. This uses the spice turmeric, also known as Indian saffron or curcuma, as an indicator. The active ingredient present in turmeric is curcumin *(2),* which is an acid–base indicator that is yellow in acidic and neutral solutions and orange or reddish-brown in basic solutions *(3).*



In the second reaction, vinegar and baking soda produce carbon dioxide gas. Powdered laundry detergent is added to the reaction mixture to obtain a longer-lasting, thick foam. When detergent is not used, the bubbles of carbon dioxide gas rise to the same level in the cup, but dissipate quickly. Baking powder, which contains weak acids in addition to sodium bicarbonate, can be used instead of baking soda. Food coloring can be added to the vinegar for a more colorful reaction. The vinegar is the limiting reagent; baking soda will remain after the reaction. Students could add more vinegar to observe the effects.

Answers to Questions

1. Carbon dioxide is a reactant in Reaction 1 and a product in Reaction 2. In Reaction 1, the dissolution of the exhaled CO_2 produces carbonic acid that neutralizes the basic detergent solution, thus lowering the pH. When the pH reaches the values of the color change interval of the indicator, the solution turns yellow.

   $CO_2(aq) + H_2O(l) \rightarrow H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

   Carbon dioxide also reacts directly with the base producing hydrogen carbonate ion and at the same time neutralizes the base.

   $OH^-(aq) + CO_2(aq) \rightarrow HCO_3^-(aq)$

   In Reaction 2 the reaction between sodium bicarbonate (baking soda) and acetic acid, present in vinegar, generates carbon dioxide according to the equation:

   $NaHCO_3(s) + CH_3COOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l) + CO_2(g)$

2. Turmeric contains a natural acid–base indicator. It is yellow in a neutral or acidic solution and orange in basic solution. Other compounds that act similarly include anthocyanins, which are found in red cabbage, red onion skins, blueberry skins, and many other plant materials.
3. Performing Reaction 2 without detergent makes it much less spectacular. The detergent allows the bubbles of carbon dioxide gas to last longer. In Reaction 1, the detergent is a reactant. It is a base and produces OH^- in solution, which causes a color change in the indicator.

References, Resources, Sources of Related Activities

1. Summerlin, L. R.; Ealy, J. L., Jr. *Chemical Demonstrations: A Sourcebook for Teachers,* 2nd ed., Vol 1; Washington DC: American Chemical Society, 1998; p 59 and p 166.
2. Anderson, Andrew M.; Mitchell, Matthew S.; Mohan, Ram S. Isolation of Curcumin from Turmeric; *J. Chem. Educ.* **2000,** *77,* 359.
3. *Merck Index,* 12th ed. Compound #2744.

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Acid–Base Reactions with Carbon Dioxide

Most people, even those who have not studied chemistry, can identify carbon dioxide (CO_2) as a colorless, odorless gas that is fairly common in our environment. By applying a little chemistry and using only substances you can find around your house or at the grocery store, you can perform chemical reactions involving carbon dioxide to produce very interesting but perhaps unpredictable results. In this Activity, you will perform two acid–base reactions involving carbon dioxide. Your goal is to learn as much as you can about the chemistry of carbon dioxide and to have fun at the same time!

Try This

Be Safe! Goggles must be worn during this Activity. Do not inhale ammonia vapors. Never taste, eat, or drink anything in the laboratory or anything that has been in contact with laboratory equipment. Turmeric can stain skin, clothing, and equipment. Clean up spilled turmeric immediately.

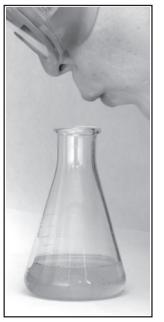
Reaction 1

You will need: measuring cup or graduated cylinder, distilled water, three 250-mL Erlenmeyer flasks with stoppers, marker, spoon or spatula, turmeric (a powdered spice), measuring spoons, vinegar, colorless household ammonia solution, and powdered laundry detergent.

__1. Measure 100 mL (about 1/3 cup) of distilled water into each of three, 250-mL Erlenmeyer flasks.

__2. Using the tip of a spoon or spatula, add pea-sized quantities of turmeric to the water in each of the flasks. Swirl each flask to mix its contents. The turmeric will not dissolve completely. Describe the resulting mixtures.

__3. Label one of the flasks **Acid**. Add 1/4 teaspoon (1–2 mL) of vinegar to the flask. Swirl the flask to thoroughly mix its contents. Stopper the flask and set it aside for color comparison.



__4. Label a second flask **Base**. Add 1/4 teaspoon (1–2 mL) of colorless household ammonia solution to the flask. Swirl the flask to thoroughly mix its contents. Stopper the flask and set it aside for color comparison.

__5. Label the third flask **Experimental**. Add a pea-sized quantity of powdered laundry detergent to the turmeric–water mixture. Swirl the flask to thoroughly mix its contents. What happens to the color? Based on the color changes seen with vinegar and ammonia, how does the addition of detergent affect the acidity of the mixture?

__6. Blow gently into the **Experimental** flask. Stopper the flask and swirl to mix the contents.

__7. Repeat step 6 until a color change is observed. Describe what happens. What happens to the acidity of the mixture?

__8. Optional Extension: Repeat the reaction using 5 mL (1 teaspoon) of red cabbage extract in place of the turmeric. Does this change the chemical reaction? The colors observed?

Reaction 2

You will need: measuring spoons or a balance, weighing paper, and graduated cylinder, powdered laundry detergent, baking soda, three small beakers or plastic cups, spoon or stirring rod, tray or paper plate, and vinegar.

__1. Weigh 0.3 g (or measure 1/4 teaspoon) of powdered laundry detergent and 3.0 g (or measure 1 teaspoon) of baking soda.

__2. Place the two solids into a small plastic cup or beaker. Stir until the solids are well mixed.

__3. Place the container on a tray or paper plate to protect your working surface.

__4. Measure 20 mL (4 teaspoons) of vinegar. If using measuring spoons, pour the measured vinegar into a clean plastic cup. Add the vinegar all at once to the solid mixture from step 2. What happens? Record your observations.

__5. Repeat steps 1–4 with clean containers, but omit the powdered laundry detergent. Record your observations.

Questions

__1. Explain the role of CO_2 in each of the reactions. Write the chemical equations for each of the two reactions.

__2. Why does the solution change color in Reaction 1? Identify another natural product that has a similar effect in acid–base reactions.

__3. Did you notice any difference when you performed Reaction 2 without the powdered laundry detergent? What is the purpose of the detergent in Reaction 2? What is the purpose of the detergent in Reaction 1?

Information from the World Wide Web *(accessed October 2002)*

1. Turmeric—*Curcuma longa; http://www.geocities.com/nutriflip/Naturopathy/Turmeric.html*
2. Science Roadshow—Cabbage Juice; *http://www.roadshow.org/what_now/indicator.html*
3. MSDS HyperGlossary: Carbon Dioxide; *http://www.ilpi.com/msds/ref/carbondioxide.html*