

A Kool Reaction from the Fine Print

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Susan A. S. Hershberger* and Arlyne M. Sarquis

Center for Chemistry Education, Miami University Middletown, Middletown, OH 45042;
hershbs@muohio.edu

The importance of reading reagent labels applies not only to chemistry class, but also to consumer products. Kool-Aid drink mix includes directions for preparation plus the “fine print” directive, “Do not store in a metal container”. This Activity explores the chemistry behind this directive and illustrates properties of acids and metals.

Background

Citric acid is the major ingredient of unsweetened drink mixes. Sugar and water (added by the consumer) combine with the citric acid and artificial flavor and color to produce fruit-flavored beverages. The food dyes, FD&C Red 40, Yellow 5, and Yellow 6 are azo dyes (containing a nitrogen–nitrogen double bond) (1) and are reduced to colorless products under mildly reducing conditions (2). Reducing conditions are produced when the drink mix (including citric acid) contacts metal. The citric acid does not liberate noticeable quantities of hydrogen or significantly dissolve the metals.



Red drink mix (right) turns colorless after combining with steel wool (left).

Integrating the Activity into Your Curriculum

This Activity complements safety discussions, especially the importance of reading labels. The Activity also fits with an introduction to the properties of strong and weak acids (tastes sour, turns litmus paper red, and reacts with a metal). In addition, this Activity illustrates metals as reducing agents. Since fine steel wool with more exposed iron atoms reacts faster than coarse steel wool, the Activity also qualitatively illustrates kinetics.

About the Activity

Instructors could have students test different flavors or brands of drink mix to determine which dyes are most reactive. Red 40, Yellow 5 and 6 turn colorless in the presence of a metal and citric acid, while Blue 1 is not an azo dye and is less reactive (1). The four dye structures are in ref 1 and this issue of *JCE Online*.^W Drink mixes with combinations of red and/or yellow (with no blue) will turn colorless, while those with red and/or yellow, plus blue will turn blue. In addition to the visible color change, the nutritional supplement vitamin C (ascorbic acid) reacts with metals. The flavor of the drinks is also expected to change. Students should **not** consume any of the beverages in this Activity.

Different grades of steel wool are available in hardware stores. If the protective oil is not completely rinsed from the steel wool, results may be unpredictable. Fine (#0000) steel wool and most drink mixes usually finish reacting in 10–15 min. Coarse (#3) steel wool typically requires 45 min or longer. An intermediate-grade steel wool could be substituted for coarse steel wool, for a shorter reaction time. Different flavors and brands of mix have different amounts of red and yellow food dyes, which also influence reaction times. For example, the amount of red dye is greater in strawberry flavor than in grape flavor. Hence, the complete reaction of strawberry drink takes longer than grape drink.

The pH of the control is similar to the pH of the drink mix after the color change. pH is acidic in both cases, although it rises slightly after the color change (e.g., 2.8; 3.2). pH paper can be used in place of a pH meter.

Answers to Questions

- 2.4 grams of iron is 4.3×10^{-2} moles of iron and 2.6×10^{22} atoms of iron.
- Citric acid reacts with the iron on the surface of the steel wool. The finest steel wool has a greater surface of exposed iron atoms so the reaction occurs faster.
- A solid 2.4 g bar of iron would have a much longer reaction time (overnight or longer).
- Aluminum can interiors are coated with a plastic liner, preventing the reaction of acidic beverages and the metal. The plastic liner ensures the beverage color and flavor is similar to when the beverage was canned.

References, Additional Related Activities, and Demonstrations

- Mebane, Robert C.; Rybolt, Thomas R. Chemistry in the Dyeing of Eggs. *J. Chem. Educ.* **1987**, *64*, 291–293.
- Newbold, B. T. Reduction and Synthetic Uses of Hydrazo, Azo, and Azoxy Compounds. In *The Chemistry of the Hydrazo, Azo and Azoxy Groups (The Chemistry of Functional Groups)*, Patai, S., Ed.; John Wiley & Sons Ltd: London, 1975; pp 599–641. Radomski, J. L. *Annu. Rev. Pharmacol.* **1974**, *14*, 127–137.
- Sigmann, Samuella B.; Wheeler, Dale E. The Quantitative Determination of Food Dyes in Powdered Drink Mixes. A High School or General Science Experiment. *J. Chem. Educ.* **2004**, *81*, 1475–1478 and Quantitative Determination of Citric and Ascorbic Acid in Powdered Drink Mixes: A High School or General Chemistry Experiment. *J. Chem. Educ.* **2004**, *81*, 1479–1481.
- Bedrossian, Mindy. A Cool Drink: An Introduction to Concentrations. *J. Chem. Educ.* **2005**, *82*, 240A–B.

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Kool-Aid and other powdered drink mix packages give directions to prepare the beverage in glass, plastic, or nonmetal pitchers. The “fine print” on some packages states “Do not store in a metal container”. Why? What happens to the beverage mixture in the presence of metals? In this Activity, you will investigate the effect of iron on drink mixes.

Try This

You will need: safety goggles; packet of unsweetened powdered drink mix (flavors containing any combination of the three dyes Red 40, Yellow 5, Yellow 6, with or without Blue 1, work well, such as grape, black cherry, cherry, strawberry, and mandarina-tangerine); three 150-mL beakers or 9-oz. clear, colorless cups; fine (#0000) steel wool; coarse (#3) steel wool; gloves; balance; hot and room-temperature water; 2-L plastic beverage bottle with lid; 100-mL graduated cylinder or tablespoon measure; clock; paper towels; white paper; and pH meter or pH paper.

1. Fill a clean, empty 2-L plastic beverage bottle with room-temperature water. Add one packet of unsweetened powdered drink mix. Screw the lid tightly onto the bottle. Shake the bottle until the powdered mix dissolves. Do not add sugar.
2. Label three 150-mL beakers or 9-oz. clear, colorless cups as follows: “control” (no metal added), “fine steel wool”, and “coarse steel wool”. Measure 60 mL (4 tablespoons) of the prepared drink from step 1 into each of the labeled containers.
3. Using gloves, measure a 2.4-g sample of fine steel wool on a balance. Repeat for coarse steel wool. **Caution:** steel wool can be sharp and cut into hands. Compare the appearance of the two samples.
4. Rinse the steel wool samples for ~45 s in hot tap water. If hot tap water is not available, dip the samples in and out of a container of hot water. (Steel wool has an oil coating to prevent rusting in moist air. Rinsing in hot water removes the oil.) Squeeze the samples gently to remove excess water and blot with paper towels.
5. Fluff each steel wool sample to the approximate volume of the beverage in the labeled containers from step 2.
6. Add the steel wool samples to their labeled containers from step 2; push the samples down so they are mostly submerged. Record the start time. Make observations every 5 min for evidence of any reaction. Place the containers on a piece of white paper to aid color observations. You may briefly lift the steel wool out of the beverage for each observation. Record the time when the reaction appears to be complete in each container. If the reaction is not complete by the end of class time, make a final observation the next time you return to class.
7. Measure the pH of the beverage in the “control” and “fine steel wool” containers using a pH meter. If a pH meter is not available, use pH paper to test acidity–basicity. (Take measurements soon after the reaction of the beverage and fine steel wool appears complete.) What does the pH indicate about the reaction?
8. From the list of ingredients on the drink mix package, predict which ingredient(s) react with iron to cause the observed changes. Design an experiment to test your prediction. If permitted, carry out your experiment. You may need additional materials such as citric acid, ascorbic acid, sodium chloride, calcium phosphate, and food color. The color of the drink mix can be simulated using 2 drops of red food color for each 60 mL test solution.



Be Safe! Do not consume any of the beverages or the beverage plus steel wool samples in this Activity. Safety goggles are required.

More Things To Try

Investigate the reaction of drink mix solution and aluminum by placing a 7 cm × 7 cm piece of aluminum foil and 60 mL of drink mix solution in a clear, colorless container. Also, rinse an empty aluminum beverage can with water and add 60 mL of drink mix solution to the can. Set up a control by placing 60 mL of drink mix solution in a clear, colorless container. Observe the drink mix solutions in the containers over several days. Observe the can's drink mix solution by briefly pouring the solution into another clear, colorless container, then pouring it back into the can. What do your observations suggest about the inside of the aluminum beverage can?

Questions

1. How many moles of iron are present in 2.4 g of iron? How many atoms of iron?
2. If the same number of atoms of iron are present in both the coarse and fine steel wool samples, why is the reaction time different for the two samples?
3. Predict the reaction time for a solid 2.4-g bar of iron with 60 mL drink mix solution.
4. A vending machine offers a red, noncarbonated, artificially flavored drink in aluminum cans. When opened months later, is the beverage expected to be the same color as when it was canned? Why or why not? (See WWW site 2.)

Information from the World Wide Web (accessed Oct 2006)

Ask Kraft: Our Top Kool-Aid Soft Drink Questions. http://www.kraftfoods.com/main.aspx?m=contact_us/contact_us&cat1=103&cat2=27&cat3=46

The Aluminum Can: How Cans Are Made. http://www.aluminum.org/Content/NavigationMenu/The_Industry/Packaging_Consumer_Product_Market/Can/TheAluminumCan.htm

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