Tick Tock, a Vitamin C Clock

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This Activity uses supermarket chemicals to perform a clock reaction. The endpoint is signaled by an abrupt change in the appearance of the reaction solution from colorless to blue-black. Students vary the concentrations of the reactants and observe the resulting changes in the time required for the reaction to reach its endpoint. A complete discussion of the chemistry involved, experimental procedure, and notes for successful reproduction of this reaction as a Tested Demonstration is presented in this issue and the references cited therein (*1*).

Integrating the Activity into Your Curriculum

This Activity can be used to explore reaction kinetics, and in particular the effect of reactant concentrations on the apparent rate of a reaction. It can also be used in a discussion of redox chemistry, the descriptive chemistry of iodine, and the chemistry of vitamin C.

About the Activity

In this Activity students collect information about the rate of the reaction

$$2H^+(aq) + 2I^-(aq) + H_2O_2(aq) \rightarrow I_2(aq) + 2H_2O(\ell) \qquad \text{(reaction 1)}$$

The reactant I^- is generated from I_2 by adding an excess of vitamin C (ascorbic acid, $C_6H_8O_6$) to tincture of iodine dissolved in water

$$I_2(aq) + C_6H_8O_6(aq) \rightarrow 2H^+(aq) + 2I^-(aq) + C_6H_6O_6(aq) \qquad \text{(reaction 2)}$$

When H_2O_2 is added, reaction 1 begins, but because reaction 2 uses up the I_2 as fast it is formed by reaction 1, the concentration of I_2 in the solution remains very small and no blue-black starch–iodine color appears. Only after all of the vitamin C is used up does reaction 1 produce a concentration of I_2 high enough to form the blue-black color. The faster reaction 1 produces I_2, the faster reaction 2 uses up vitamin C, and the shorter the time until the blue-black color appears. Available on *JCE Online*W are videos of the vitamin C tablet and orange juice versions of the clock reaction.

In the Activity, vitamin C tablet(s) are finely crushed under water and dissolved. Some variability in the time required to reach the endpoint may be encountered, depending upon how completely the vitamin C in the tablet(s) is dissolved. Do not use tablets marked “chewable” or “flavored” as they contain ingredients that may interfere with the reaction. For best results, use only distilled or deionized water for all solutions. If purified water is unavailable, use white vinegar. Softened water can give erratic results. Be sure to use antiseptic tincture of iodine, USP 2%. Similar products such as 7% tincture of iodine and “tincture of iodides” (also known as “decolorized iodine”) are not suitable.

CAUTION: Tincture of iodine is poisonous and flammable. Tincture of iodine and the clock reaction mixture must be kept away from children. Before disposal, the clock reaction mixture should be reduced by the addition of ascorbic acid (vitamin C).

Linit and Sta-Flo laundry starch were used in testing, but other laundry starches may also be used. If laundry starch is unavailable, an alternative can be prepared by mixing 5 grams (1–2 teaspoons) of cornstarch with 30 mL (2 tablespoons) of cold tap water until a uniform thin suspension is formed. Pour the suspension slowly into 500 mL (2 cups) of vigorously boiling water with stirring so that the boiling does not stop. Allow it to cool before use.

Answers to Questions

1. A difference is that a clock reaction’s endpoint is accompanied by a visible change in the reaction mixture. In this example, the change is brought about by a second reaction that occurs rapidly when the first reaction is exhausted.
2. The red-brown color of the iodine rapidly disappears. This suggests that elemental iodine has been reduced to iodide (I^-) ion. Ask the students what was oxidized in this reaction.
3. Reaction times may vary among groups, even though the same procedure was followed. Variability can occur in the dissolution of the vitamin C tablets and in measuring liquid volumes. Experiment 2 is the fastest, followed by experiment 1 and experiment 3. The more concentrated the reaction mixture, the faster the reaction takes place. Experiment 2’s mixture is more concentrated than 1’s, which in turn is more concentrated than 3’s.
4. Vitamin C can be accurately determined by titration with standard iodine solution. You might be able to estimate it by how long it takes before the clock-reaction color change occurs.
5. The insoluble substances are typically starches and waxes. They are added to the tablet mixture to help form and maintain the shape of the tablet and facilitate its breakup in the stomach.

References, Activities, and Resources

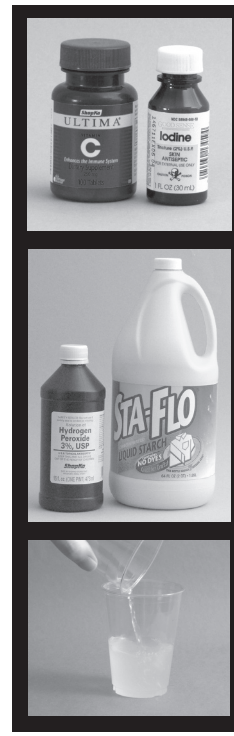
1. Wright, Stephen W. The Vitamin C Clock Reaction; *J. Chem. Educ.* **2002**, *79*, 41–43.

***JCE Classroom Activities* are edited by Nancy S. Gettys and Erica K. Jacobsen**

Tick Tock, a Vitamin C Clock

Clocks have been used to measure time since antiquity. They have been fashioned from various materials, as simple as stones arranged to form a sundial and as complex as a liquid crystal display. A clock can also be constructed from molecules that react at a rate that allows an interval of time to elapse between the mixing of the chemicals and the completion of the reaction. Such "clock reactions" are important regulators of biological cycles in nature. In this Activity, you will make a chemical clock using chemicals found in the supermarket. You will then investigate what happens to the speed of the clock when the reactant solutions are made more or less dilute.

Try This



You will need: distilled or deionized water, 1000 mg of vitamin C tablet(s), tincture of iodine (2%), hydrogen peroxide (3%), liquid laundry starch, stopwatch or clock, plastic measuring spoons or graduated cylinders, marker pen, six 6–8-ounce colorless transparent plastic cups, metal spoon, plastic coffee stirrers. **Optional:** orange juice, one 10–20-ounce colorless transparent plastic cup.

Use distilled or deionized water for all solutions.

__1. Prepare a vitamin C stock solution by using a metal spoon to crush 1000 mg of vitamin C tablet(s) in a plastic cup with 4 tablespoons (60 mL) of water. This is easier if the tablets are allowed to stand in the water before crushing. Break up the tablet(s) until no pieces of solid can be seen. The solution will be slightly hazy owing to small amounts of other substances in the tablet that will not dissolve in water. Label the cup "Vitamin C stock solution".

__2. Label another plastic cup "Solution A". Place 4 tablespoons (60 mL) of water in the cup. Add 1 teaspoon (5 mL) of the vitamin C stock solution and 1 teaspoon (5 mL) of tincture of iodine. What do you observe? Stir the mixture with a coffee stirrer. What do you observe?

__3. Label another plastic cup "Solution B". Place 4 tablespoons (60 mL) of water in the cup. Add 1 tablespoon (15 mL) of 3% hydrogen peroxide and 1/4 to 1/2 teaspoon (1.2 to 2.5 mL) of laundry starch. What do you observe?

__4. Label another plastic cup "Experiment 1". Pour Solution A into the cup. Add Solution B all at once, record the time, and stir with a plastic coffee stirrer for about 5 seconds. What happens? Continue to watch the mixture until you note a change and record the time again.

__5. Label another plastic cup "Experiment 2". Repeat steps 2, 3, and 4 but this time use 2 tablespoons (30 mL) of water when preparing Solutions A and B.

__6. Label another plastic cup "Experiment 3". Repeat Steps 2, 3 and 4 but this time use 6 tablespoons (90 mL) of water when preparing Solutions A and B. Predict what will happen.

Be Safe! Tincture of iodine is poisonous and flammable. Check with your instructor for disposal instructions for all solutions.

Orange Juice Option: Prepare Solution A in a 10–20-ounce plastic cup by adding 1 teaspoon (5 mL) of tincture of iodine to 18 tablespoons (270 mL) of room-temperature orange juice. Stir thoroughly, then add 1/4 to 1/2 teaspoon (1.2 to 2.5 mL) of laundry starch. Add 4 tablespoons (60 mL) of 3% hydrogen peroxide to start the reaction.

Questions

__1. What is the difference between a "clock reaction" and the many other chemical reactions that take seconds, minutes, or hours to complete?

__2. What happened when the tincture of iodine was first added to the vitamin C solution? When it was stirred? What does this suggest might have happened?

__3. Compare your time to endpoint in experiment 1 with the times recorded by others. Are they the same? If not, why might they be different? How do the rates of experiments 1, 2, and 3 compare? Why?

__4. How could you accurately determine the amount of vitamin C in a sample of orange juice?

__5. What are the substances in the tablet that don't dissolve in water? Why are they included in the tablet?

Information from the World Wide Web *(accessed November 2001)*

1. Vitamin C Web sites: *http://www.encyclopedia.com:80/articles/13531VitaminC.html*; *http://www.howstuffworks.com/vitamin-c.htm*.
2. Iodine Web sites: *http://www.encyclopedia.com:80/articles/06436.html*; *http://www.webelements.com/webelements/elements/text/I/key.html*.