Follow-up Activities

- Encourage students to perform the Vitamin C analysis on packaged drinks and compare their experimental results to the nutritional data found on the labels. Ask them to consider a possible positive control to test and have them explain why a control is necessary.
- Have students perform a titration of HCl with NaOH, using a pH meter to determine the end point of the titration. (When done correctly, the resulting solution will be neutral — pH 7 — neither acid nor base.) Then have them generate a titration curve showing the changes in pH of the analyte versus the volume of the added standard solution.
- Have students familiarize themselves with five strong acids and five weak acids and make molecular models of them.
- Discuss the dissociation constants (Ka) of various acids and relate them to pH.

Suggested Internet Resources

Periodically, Internet Resources are updated on our Web site at www.LibraryVideo.com

- **www.howstuffworks.com/vitamin-c.htm**
  These pages from the "How Things Work" Web site discusses the basics of Vitamin C and why it is important for our health.
- **www-sci.lib.uci.edu/HSG/RefCalculators3B.html#CHEM-ACID**
  The Martindale Reference Web site contains many useful chemistry tools, including acid-base titration simulations.
- **www.chemtutor.com/acid.htm#what**
  The Chemtutor Web site is an online chemistry text that presents an overview of acids and bases as well as titration information and practice problems.
- **naio.kcc.hawaii.edu/chemistry/redox_title.html**
  "Internet Chemistry" elaborates on some oxidation-reduction reactions that have many far-reaching applications in our lives.

Suggested Print Resources

- Hoffmann, Roald. *Same and Not the Same.* Columbia University Press, New York, NY; 1995.
- Houk, Clifford. *Chemistry: Concepts and Problems: A Self-Teaching Guide.* John Wiley & Sons, New York, NY; 1996.
- Sen, Nilanjen. *High School Chemistry Review.* Princeton Review; Princeton, NJ; 1998.

TEACHER'S GUIDE CONSULTANTS

Dr. Robert Orr
Professor of Chemistry
Delaware Valley College of Science & Agriculture

Paula J. Bense, M.Ed.
Schlessinger Media
Curriculum Specialist

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SCIENCE LAB Investigations!

TITRATION

Grades 9–12

Instruction in both scientific ideas and processes is necessary for students to have a well-balanced science education. By practicing the skills of science while solving everyday problems, students will learn to raise good questions and find accurate answers about the objects, forces and organisms in their world.

Inquiry-based teaching and learning goes well beyond the traditional scientific method to focus not only on engaging students in the "doing" of science, but in thinking of science as an active process that allows them to focus on their own questions as they develop the ability to plan and execute a scientific investigation. Students' ability to use a variety of technologies should be an integral component of all scientific investigations. Mathematics should also play a role in all aspects of scientific inquiry. Students find that these skills empower them to engage in problem solving in all areas of their lives.

At various points throughout the video, there are opportunities for the educator to actively involve students in the topic by recreating the investigations or expanding upon the onscreen discussion.

Program Summary

Chemicals make up everything around us, including the products that we use and the foods that we eat. Researchers in many fields use carefully controlled chemical reactions as tools to prepare, analyze and purify substances such as cosmetics, food, medicines and other materials.

Titration is a method of determining just how much of a chemical substance is in a solution by gradually adding a reactant and seeing how much is needed to use up that substance. In order to analyze compounds precisely, the reactant must be a "standard" solution of known concentration. Since the concentration of the standard is known, the concentration of the unknown can be calculated if the volume of each solution is noted.

Acid-base titrations permit the concentrations of acids or bases to be determined with a high degree of accuracy. Acids are substances that produce H^+ (hydrogen ions); bases produce OH^- (hydroxide ions). pH is a way to designate the hydrogen ion concentration of a solution. The pH scale ranges from 0-6 (acid), 7 (neutral) to 8-14 (basic). The chemical reaction that occurs during an acid-base titration is known as a neutralization reaction. This is when an acid and a base react to form water and a salt. When done correctly, the resulting solution will be "neutral" — neither acid nor base. In a titration, this is known as the endpoint of the reaction — the point at which the amount of acid and base are equivalent. The addition of an appropriate indicator to the analyte solution allows us to see the endpoint visually.

There are several ways of expressing the concentration of the dissolved analyte in a solution. One of the most widely used is molarity (M). Since even a million molecules still represents a very small amount of material, chemists usually count molecules in groups called moles, where one mole of a substance is 6.023×10^{23} molecules of the substance.

The amount of Vitamin C (ascorbic acid) in a sample is determined by an oxidation-reduction titration with a standard solution of iodine, using a thyodene indicator to determine the endpoint. The iodine is reduced by the ascorbic acid to form iodide, and the end point is reached when a slight excess of iodine is added to the sample. Excess iodine reacts with the thyodene indicator, and the solution turns a bluish color. Using the amount of titrant delivered, the concentration of the titrant and the stoichiometry of the titration reaction, the concentration of the analyte is calculated. The Vitamin C content of apples, oranges and red peppers is compared and then analyzed to observe the degradation of Vitamin C over time. Students also see how people use titrations in their professional lives through field segments.

Always wear protective eyewear. Dispose of chemicals properly (and legally).

Experiment Protocol

Equipment needed — Gloves, goggles, erlenmeyer flasks, pipet and pipetter, graduated cylinder, weighing paper, weigh scale, a buret with a clamp and stand, magnetic stir plate and stir bar.

Chemicals needed — Oxalic acid, thyodene indicator, iodine solution (10mM), distilled water, liquefied samples of oranges, apples and peppers.

Data (for each trial):

- volume of juice sample
- initial buret reading
- final buret reading
- volume of iodine solution used

(The formula weight for Vitamin C is 176.13.
1 mL of iodine solution reacts with 1.76 mg Vitamin C.)

Vocabulary

titration — A method or the process of determining the concentration of a dissolved substance in terms of the smallest amount of a reagent of known concentration required to bring about a given effect in reaction with a known volume of the test solution.

analyte — The substance being analyzed. If dissolved in solution, it is also known as the solute.

standard solution — A solution whose concentration is accurately known. When delivered from a buret, it is known as the titrant.

accuracy — Freedom from error. How close a measured quantity is to the true value.

acid — A substance that produces hydrogen ions (H^+) or hydronium ions (H_3O+) when dissolved in water.

diprotic acid — An acid that can furnish two hydrogen ions per molecule. Examples of diprotic acids are sulfuric acid, H_2SO_4, and carbonic acid, H_2CO_3.

monoprotic acid — An acid that can furnish one hydrogen ion per molecule. Hydrochloric acid, HCl, is a monoprotic acid.

acid-base indicator — A dye with one color below a narrow pH range on the acid side and a different color for the range on the basic side.

litmus — An organic compound that is red in acid and blue in base; the oldest known pH indicator.

base — A substance that produces hydroxide ions (OH^-) when dissolved in water.

pH — A measure of the negative log of the hydrogen ion concentration in a solution. The pH scale, ranging from 0 (acidic) to 14 (basic), is a way to express how acidic or basic a solution is.

concentration — The ratio of the quantity of solute to the volume of the solution. ***(Continued)***

$C_1V_1=C_2V_2$ — The concentration x volume of solution 1 is equal to the concentration x volume of solution 2.

mole — 6.02252×10^{23} molecules of anything. The number in grams corresponding to the atomic mass of a substance. For example, since hydrogen has atomic mass of 1, a mole of hydrogen is 1 gram.

molarity (M) — The number of moles of solute per liter of solution.

neutralization reaction — When an aqueous acid and base react together to form water and a salt.

redox reaction (oxidation-reduction reaction) — Chemical reactions that involve the loss of electrons (oxidation) of one substance and the gaining of electrons (reduction) of another substance.

meniscus — The curved upper surface of a column of liquid.

buret — A long, graduated measuring tube with an opening and a stopcock at its lower end.

Vitamin C — Also called ascorbic acid. A water-soluble vitamin found in fruits and leafy vegetables.

oxalic acid — A crystalline, toxic organic compound used in the experiment to stabilize the Vitamin C for analysis.

FDA (Food and Drug Administration) — An American public health agency organized to set product standards and analyze the safety of food and drugs.

Discussion Topics

- Ask students to explain why it is important to control variables when comparing different samples.
- Why is knowing the precise amount of substances in a sample important? Have students brainstorm reasons for wanting to determine the caffeine content of popular beverages or the chlorine concentration in pool water.
- Discuss the importance of Vitamin C in our diets. Ask students what foods contain vitamin C.
- Discuss neutralization reactions. Why does it make sense to neutralize industrial waste at pollution treatment plants? How do antacids work on an upset stomach? Use diluted hydrochloric acid (or cola) to simulate stomach acid. Add different antacid tablets and observe the change in pH with a pH meter or paper. Which works the best?
- Provide students with a chart of common indicators and the pH range in which they change color. Discuss the role that choosing an appropriate indicator plays in determining the end point of a titration. (If you titrate a strong acid and a strong base, the indicator should change its color near pH 7. For a strong acid and a weak base, the indicator should change at much less than pH 7. For a weak acid and a strong base, it should change at much greater than pH 7. For a weak acid and a weak base, it should change near 7.)
- The $[H^+]$ of a strong acid is equal to the concentration of the acid. Calculate the pH of a 0.100 M solution of HCl.