Section 6.3 Reactions of Acids and Bases

(Student textbook pages 236 to 246)

Specific Expectations

- **C2.3** investigate simple chemical reactions, including synthesis, decomposition, and displacement reactions, and represent them using a variety of formats
- **C3.6** describe the process of acid-base neutralization

In this section, students learn about acid-base neutralization reactions and relate them to applications such as antacid tablets and environmental cleanup.

Common Misconceptions

- Students may fail to expand their definition of salt beyond the everyday meaning of sodium chloride (table salt). As students read the text, have them use sticky notes to flag other examples of salts, or post the examples in the classroom.
- Students may think that all salts are safe to eat or used to flavour food. Salts are a category of chemicals, many of which are poisonous (e.g., platinum and palladium salts used in conventional printing processes).
- The relative strengths of the acids and base are sometimes overlooked when determining whether neutralization will occur. Equal volumes will only neutralize each other if they are of opposite pH values. For example, 5 mL of weak base will not neutralize 5 mL of strong acid.
- Neutralization reactions may be mistakenly thought to always produce neutral solutions. If the volume and/or relative pH of the substances is not balanced, the resulting solution will be either acidic or basic. Also, the salt formed has its own pH, which may not be neutral (7). Maintain the wording that the original acid and base are neutralized rather than saying a neutral solution is produced.
- Precipitation does not only refer to rain and snow. In the process of recovering metal from contaminated soil, precipitation means forming a precipitate (solid in a solution).

Background Knowledge

Ore is a term applied to any rock that contains valuable material, usually metal. Ores are commonly named according to the valuable content, such as *iron ore*.

Salts are important in biochemical systems. Salt is needed by our cells to conduct nerve impulses, allow muscles to work, regulate blood pressure, and help us retain necessary water. Humans require 5 to 10 grams of salt a day, all of which can usually be gained through healthy eating. Salts are an important economic commodity mined in Canada and around the world.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learning
Learning Check question 1, page 238	Students recognize that neutralization requires both an acid and a base.	Have students measure the pH of safe acids and bases (such as lemon juice and soap) alone and in mixtures, to discover how to reach a neutral pH.
Activity 6-4 Air Pollution and Ontario's Lakes, page 244	Students recognize that the basic chalk neutralizes the acid in the match exhaust.	Have students complete **BLM 6-10 Air Pollution and Ontario's Lakes,** which scaffolds this process.

Instructional Strategies

- Ask students what they already know about neutralization reactions from previous courses or the media.
- Discuss the importance of neutralization reactions in health care and their role in cleaning up chemical spills (e.g., neutralizing stomach acid, treatment of alkalosis and acidosis in drug overdoses, and reducing kidney stones).

- To illustrate the importance of neutralization reactions in cleaning up chemical spills, show students the classroom chemical spill kit, noting each substance, its characteristics (especially pH), and recommended use.
- Review the general form for double displacement reactions, which include neutralization reactions: AB + CD → AC + BD.
- Introduce neutralization using an equation of a simple binary acid and group one metal base (e.g., HCl + NaOH) and have students predict the products based on the double displacement pattern.
- Define salts as more than just NaCl (table salt). Develop a definition of salt as a class. Then, examine the equation on page 238 of the student textbook to see that $CaSO_4$ is a salt.
- Provide a more difficult example of neutralization that requires balancing (e.g., calcium hydroxide and hydrofluoric acid) to emphasize both the double displacement pattern and that the products are still a salt and water.
- Use **BLM A-37 Concept Rubric** to assess students' internalization of neutralization reactions.

Activity 6-4 Air Pollution and Ontario's Lakes (Student textbook page 244)

Pedagogical Purpose

Students will model air pollution in Ontario's lakes by dissolving prepared gases from a burning matchstick in water, observing the pH of the solution and attempting to neutralize the solution.

Planning		
Materials	50 mL water Universal indicator solution Tongs Pinch of chalk dust **BLM 6-10 Air Pollution and Ontario's Lakes** The day before, gather materials and make copies of the BLM.	Two 250 mL Erlenmeyer flasks Wooden safety match Stopper
Time	30 min	
Safety	Wear safety goggles and a lab apron. Be very careful with the open flame.	

Activity Notes and Troubleshooting

- Discuss combustion reactions using a balanced chemical reaction producing carbon dioxide: $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$.
- Review the colour ranges for universal indicator.
- Provide a diagram of a match showing the chemical components of the match head: phosphorous, sulphur, and carbon (from the stick).
- Discuss the composition of chalk: calcium carbonate. Remind students of its use in antacids.
- To wrap up, ask the class to draw an analogy between the match's products (exhaust) and the chalk (liming) in the water (lakes). What relationship is implied between all three?
- Use **BLM A-41 Conduct an Investigation Rubric** to assess students' process.

Additional Support

- Provide students with **BLM 6-10 Air Pollution and Ontario's Lakes,** which contains scaffolding for their observations.

- Encourage students to draw their observations using coloured pencils.
- Allow students to use a pH meter or pH probe if available.

Answers

1. Sulfur oxide, phosphorus oxide, carbon oxide. Students may propose the more precise: carbon dioxide and sulfur dioxide.
2. pH can vary from 2 to 4, meaning the solution is an acid.
3. Yes, and the process is slow.

Learning Check Answers (Student textbook page 238)

1. Neutralization is the chemical reaction of an acid with a base to form water and a salt (a solution with a pH of 7). Example: $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$
2. Graphic organizer should show that the reactants are an acid and a base and the products are a (neutral combination of a) salt and water.
3. Neutralizing spilled acid makes it safer for clean-up crews to handle and helps protect the environment from extreme pH levels.
4. Example: The spill kit contains an "acid neutralizer" powder that should be spread over a spilled acid, and a "base neutralizer" that should be spread over a spilled base. The pH of each powder neutralizes the spill, reducing the hazard due to extreme pH levels.

Learning Check Answers (Student textbook page 243)

5. 5.6
6. 68%
7. Drawings should show emission sources including vehicle exhaust, industrial plants, and electric utilities, as well as the technologies that work to eliminate these emissions including catalytic converters and scrubbers.
8. Examples: Both reduce symptoms without eliminating the cause; or, many factors must be considered to determine the correct dose.

Section 6.3 Review Answers (Student textbook page 246)

Please also see **BLM 6-11 Section 6.3 Review (Alternative Format).**

1. $H_2SO_4 + 2KOH \rightarrow 2H_2O + K_2SO_4$; potassium sulfate; K_2SO_4
2. Antacid contains a base that neutralize stomach acids that cause upsetting.
3. Nitrogen oxides react with water in the atmosphere to form acids; scrubbers; 25%
4. sulfur trioxide
5. Example: A large change in the variety of plankton and moss (loss of some and invasion by others) and loss of some types of fish.
6. Pamphlets should include reactions for the decomposition of calcium carbonate, the synthesis of carbon dioxide and sulfur dioxide, and the synthesis of calcium sulfite. Power generation and metal refinement already use this technology. Ethanol plants and ocean liners (ships) could use the technology.
7. Acid precipitation could leach aluminum from surrounding rocks and soil into the lake.
8. Example: Precipitation continues to be more acidic than is natural, harming organisms sensitive to pH. Many sensitive lakes and forest areas are still vulnerable to acid rain. Regions of Ontario vary in the land's composition, and thus its natural ability to neutralize acid rain.

Plan Your Own Investigation 6-A What Is Your Exposure to Acids and Bases? (Student textbook page 247)

Pedagogical Purpose

In this investigation, students apply their understanding of experimental design to investigate the pH of various household substances.

Planning	
Materials	Universal indicator or pH paper Samples of foods, beverages, cosmetics, soaps, and cleaning materials Equipment (as needed) **BLM 6-7 Testing pH of Common Substances** (optional) The day before, gather materials. You may wish to ask students to bring samples from home in the original containers. The day of the lab, put solutions into small beakers and divide them among stations around the classroom.
Time	20 min to prepare 30 min to perform
Safety	Wear safety goggles and a lab apron. Use caution when handling substances of unknown pH. Oven cleaner and other household cleansing items can be caustic. Students should wash their hands at the end of the activity. Collect and dispose of waste according to school policy.

Background

Students will determine the pH of various household substances and determine that soaps and cleansers are basic while food-based items are acidic or neutral.

Activity Notes and Troubleshooting

- Divide this activity into design and performance phases. You may wish to assign the design for homework, approving or revising students' procedures at least a day before carrying out the investigation to provide time to gather the necessary materials and equipment. Limit test to 8 to 10 substances.
- Have students prepare a lab report template before class, including an observation table.
- Students may find that **BLM 6-7 Testing pH of Common Substances** helps them get started designing the investigation.
- **Suggested materials:** window cleaner, baking soda dissolved in water, drain cleaner, dish soap, liquid abrasive cleaner, shampoo, vinegar, apple juice, milk, ginger ale, tea, coffee, lemonade, hair conditioner, lemon juice, bleach, tap water, tonic water, bottled water, lens cleaner, laundry detergent, cream of tartar, dissolved vitamin C tablet, hair gel, sour candy, stain remover, and make-up such as foundation and mascara.
- **Suggested equipment:** microtrays, microplate, micropipettes or eyedroppers, glass stirring rods, and indicators.
- To minimize congestion, divide materials into stations, each with their own microplate and eyedropper to avoid contaminating samples.
- Demonstrate how to prevent cross-contamination by using separate eyedroppers at each station to drip substances on test strips (do not dip test strips into substances).
- State the safety procedures for cleaning up broken glass and spilled solutions.
- Demonstrate how much of each sample should be tested, to conserve waste.
- Communicate proper disposal of materials per departmental guidelines.

- To wrap up, consolidate test results in a master data table on the board or an overhead.
- Use **BLM A-41 Conduct an Investigation Rubric** to assess students' process.

Additional Support

- DI This is a good hands-on activity for bodily-kinesthetic and visual learners.
- ELL Encourage English language learners to illustrate their observations as well as making notes.
- Model use of equipment or illustrate the set-up on an overhead.
- Allow students to use a pH meter or probe.
- Analyze the data as a class, looking for patterns and grouping substances by pH as described in question 1.

Answers

1. Example: Soaps and cleaners are basic, while foods tend to lie in the acidic to neutral range
2. Example: Common soaps and cleaners are extremely basic, some foods are extremely acidic. Students may be surprised that some are not more harmful, and that some familiar substances could be so caustic.
3. Example: Basic substances are used for cleaning, while substances closer to the neutral or acidic range are eaten.
4. Designs should include decontamination of the meter or probes to ensure accurate results, and use sufficient quantities to activate the device.

Real World Investigation 6-B The pH of Lakes Near Sudbury

(Student textbook pages 248 and 249)

Pedagogical Purpose

This investigation has students examine primary data to evaluate which treatment was most effective in neutralizing acidic lakes surrounding Sudbury.

Planning	
Materials	**BLM 6-9 Investigation 6-B Data Analysis** (optional) One week before, book computer lab or library for research.
Time	75 min

Background

Sudbury is one of the world's largest nickel and copper underground mining regions. Cobalt, platinum, and palladium are also mined. The three underground mines, mill, and smelter stretch throughout a vast 60-km long geological formation called the Sudbury basin. Because this area has been mined for over 100 years, Sudbury has suffered substantial ecological damage, namely the acidification of the local lakes and death of forests due to acid precipitation. Due to an enormous community revegetation program started in 1978 that included the planting of over 11 million trees, much of the region's moon-like landscape has been transformed.

Activity Notes and Troubleshooting

- You may wish to have students first perform Inquiry Investigation 6-C Neutralizing an Acid with a Base to give them first-hand knowledge of the neutralization process before applying the principles to acidic lakes.
- Direct students to the "before" and "after" photos of the moon-like Sudbury area from the 1960s and compare to vegetation of today to illustrate the success of community efforts (student textbook page 236).
- Students may find that **BLM 6-9 Investigation 6-B Data Analysis** helps them get started.
- Guide students through the process of making a prediction. Link the columns (locations) to the approach used. Note that the three approaches do not exclude each other. In each case, emissions were also reduced.
- To wrap up, analyze as a class, the efficacy of analyzing data without taking into account the wider context that includes strikes and other influences, as implied by question 9. Knowing now that a strike occurred in 1979, would they change their answer to question 8?
- Use **BLM A-41 Conduct an Investigation Rubric** to assess students' process.

Additional Support

- Allow students to use spreadsheet software to create a graph.
- Enrichment—Have students research the link between chlorine and dioxins and other carcinogens, or illustrate the concept of bioaccumulation.

Answers

1. Clearwater, 4.3 acidic; Hannah, 4.31 acidic; Lohi, 4.45 acidic
2. 1974. That is when pH changed drastically.
3. The limestone-neutralized, acidic Hannah Lake, as shown by the change in pH.

4. The pH increased over time as the addition of acid rain slowed because of reduced sulfur dioxide emissions, and existing basic compounds in the lake bed and surroundings neutralized the lake.
5. Liming Lohi Lake, since the change in pH did not last, and was in fact, close to the result of doing nothing at all.
6. Hannah Lake showed the best improvement (pH closest to neutral). Liming many square kilometres of soil was probably very expensive, but had a longer-lasting effect on the lake and helped forest recovery by providing a near-neutral lake 33 years sooner than the others.
7. Reducing emissions will have the greatest overall effect, as all of the lakes in the area will likely improve as Clearwater Lake did.
8. 1979 and 1993 as shown by a reduction in sulfur dioxide emissions.
9. A strike occurred in 1978–9, at which point data shows a nearly two-thirds reduction in sulfur dioxide emissions. The pH of the lakes climbed closer to normal at those times.

Inquiry Investigation 6-C Neutralizing an Acid with a Base

(Student textbook page 250)

Pedagogical Purpose

This investigation has students combine an acid and base to examine the point at which neutralization occurs.

Planning		
Materials	Two 25 mL graduated cylinders 35 mL 0.1 mol/L hydrochloric acid 35 mL 0.1 mol/L sodium hydroxide Two 10 mL pipettes The day before, collect the juice from boiled, shredded purple cabbage.	1 mL purple cabbage juice Pipette bulb or pump Two 100 mL beakers
Time	75 min	
Safety	Wear safety goggles, gloves, and a lab apron. Clean up all spills immediately.	

Background

Balanced equations tell us how many moles of each reactant are needed to form products in a neutralization reaction. Acids and bases of equal concentrations will neutralize each other at a 1:1 ratio.

Diatomic acids such as sulphuric acid will require half the volume upon neutralizing sodium hydroxide because sulphuric acid has two protons to provide.

Activity Notes and Troubleshooting

- Have students prepare an observation table in their notes before they begin.
- Remind students not to eat anything in the lab.
- Direct students to place beakers on white paper in order to accurately observe colour changes.
- Remind students to clean up their work area and wash their hands thoroughly at the end of the investigation.
- Remind students how to read a graduated cylinder accurately (from the bottom of meniscus curve). You may wish to have them read Measuring Volume in Science Skills Toolkit 4 on page 539 of the student textbook.
- Show students how to read volume on the pipette.
- Use **BLM A-41 Conduct an Investigation Rubric** to assess students' process.

Additional Support

- DI This is a good hands-on activity for bodily-kinesthetic and visual learners.
- Encourage students to record observations with diagrams as well as in writing.
- Enrichment—Repeat the activity using another household indicator or chemical indicator.

Answers

1. Acid and base volumes are equal.

2. HCl + NaOH → H2O + NaCl

3. 1 mL of sulfuric acid will neutralize 2 mL of sodium hydroxide if the concentrations are the same