Section 6.2 The pH Scale and Indicators

(Student textbook pages 229 to 235)

Specific Expectations

- **C3.7** describe how the pH scale is used to classify solutions as acidic, basic, or neutral

In this section, students explore the acidity and basicity of substances using the pH scale and a range of natural and chemical indicators to distinguish among representative substances. The concentration of hydrogen or hydroxide ions is used as the fundamental difference among the range of pH values.

Common Misconceptions

- Students may think that all acid-base indicators change colour at a pH of 7. Litmus does change at a pH of 7 but many indicators change colour over a range of pH values, as summarized on pages 233 and 234 of the student textbook.
- Students may think that pH stands for percentage hydrogen. Though the actual meaning is often debated, it is generally accepted to be an acronym for potential of hydrogen (ions).
- Some students forget that the pH scale extends to 14, opting for the more familiar base of 10. Similarly, they mistake 5 as the value of neutral substances, rather than the midpoint of the scale, 7.
- Students often transpose the pH scale, mistaking 14 for the acidic end of the scale. This mistakenly links base to a lack of acid-forming ions. In fact, the scale measures the hydrogen ions at one end (acid), and hydroxide ions at the other end (base). They might find a memory aid helpful, such as always stating "acid and base" as they read the scale naturally from left (acid) to right (base). Memorizing two or three key (familiar) examples is also useful, such as lemon juice is a sour acid at 2, and baking soda is a bitter base at 9. These particular examples have the added advantage of taste cues (which should not be tested in the classroom).
- The pH scale is often mistaken as having a definite beginning (at 0) and end (at 14). Values of less than 0 and greater than 14 do exist. A more accurate representation of the scale would be arrows extending from either end to indicate that the scale continues. The logarithm function yields negative values at these concentrations.
- Students may conceptualize other forms of pH scales, closer to mathematical integer lines, with 0 as neutral and positive numbers indicating acidity and negative numbers indicating basicity (alkalinity). Explain the significance of the pH scale as a logarithmic function of ion concentration.
- Students may use the words dilute and weak interchangeably with concentrated and strong when discussing acids and bases. The meanings are quite different. Dilute and concentrated (in this case) refer to the concentration of the substance mixed with water. (Water weakens the reactivity of the substance.) Strong and weak, however, refer to how readily an acid releases hydrogen ions (or a base releases hydroxide ions) in solution. This means, for example, that acetic acid (vinegar) can be concentrated but it will never be strong (it does not easily donate its hydrogen ions to a solution).

Background Knowledge

In order for chlorine to effectively disinfect swimming pool water, the correct pH must be maintained using chemicals such as sodium hypochlorite.

As a scale, pH measures the acidity or basicity (alkalinity) of a substance. The pH scale is a reverse log function representing the hydrogen ion concentration found in solution. A shift up or down by one value represents a tenfold change in the concentration of hydrogen ions, expressed without units. For example, a substance with a pH of 4 has one hundred times the hydrogen ions of a substance with a pH of 3.

Literacy Support

Using the Text

- ELL Have English language learners use coloured pencils to prepare a chart covering the different grades and hues of colours for indicators along the entire pH scale.
- As students read the section, have them create a graphic organizer to show the links between the various pH indicators, the scale, and acid or base substances. The one shown on page 218 of the student textbook may provide a useful starting point.

Using the Images

- As a class, flip through the section, noting the subject of each image. Ask students to predict what the section is about. Do the headings confirm this? Ask students why Figure 6.14 shows a pomegranate. Most images in this section show pH detectors. What role might this fruit play?
- This section contains many tables and figures that summarize and present information. Review with students, for example, those on pages 233 and 234 of the student textbook, noting how to read the information across the rows, and noting relationships indicated by the columns. Draw links between all of these.
- View Figures 6.7 and 6.8 together, linking the two scales and examples. What pH would students read for the samples in 6.7? What food or product does this compare to?
- View Figures 6.11 and 6.12 together, linking the colour scale on the container of universal indicator to the examples of actual indicators in solution. Ask students how the test tube scale was produced. (Answer: Each solution contains a different substance with a different pH.) Note the difference between the universal indicator soaked on paper strips (Figure 6.11) and liquid indicators dripped into samples.
- Compare the universal indicator (Figure 6.12) and pH meter (Figure 6.9), asking the class to consider advantages of each. For example, the meter eliminates individual variation in the ability to detect colour differences, provides precise measure between colour ranges, and will not be affected by the colour of the substance (e.g., white milk clouds colour results).

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 231	pH values are correctly divided into acid, base, and neutral categories.	Review the properties (summarized in Table 6.6) of sample substances across the full pH range, using Figure 6.8 as a framework. Have students carry out Activity 6-3 A Universal Rainbow. Have students use coloured pencils to colour a pH scale on their rulers, labelling the acid, base, and neutral ranges.
Section 6.2 Review questions, page 235	Effective acid-base indicators are selected and correctly interpreted.	View the section's tables and figures with students, linking similarities and interpreting meaning as a class. Have students carry out Plan Your Own Investigation 6-A What Is Your Exposure to Acids and Bases?
Activity 6-3 A Universal Rainbow, page 232	Students correctly identify signs of a chemical change. pH is correctly identified by colour change.	**BLM 6-6 A Universal Rainbow** scaffolds this process.

Instructional Strategies

- Demonstrate Crayola's® "Color Wonder™" markers. Two chemical compounds are present: one is dissolved in the paper and one in the pen. When the markers draw on the special paper, the chemicals mix and change colour due to indicators in the paper.
- Survey the class for personal understandings and experience with pH. On the board, record where students have heard of pH. Save the list for possible pH testing later in the section.
- Have students re-analyze their results from Activity 6-1 Cabbage Detector, determining what the colours meant—translating their qualitative into quantitative observations.
- Show students a sample of pH paper to introduce the term, values, and meaning of the pH range. Demonstrate a pool-water test kit to introduce pH tests and their use.
- Discuss the pH of human blood (7.3) and the need to maintain homeostasis. Relate this to pool chemistry, noting that acidic water favours algae growth so pH is maintained between 7 and 8.
- Discuss indicators and review the list provided in Table 6.4 and Figure 6.13 on page 233 of the student textbook. Note the names of the different chemical indicators, their colour change, and pH range. Discuss universal indicator and how it got its name (page 232 in the student textbook).
- Use **BLM A-47 Communication Rubric** to assess students' interpersonal skills.

Activity 6-3 Universal Rainbow (Student textbook page 232)

Pedagogical Purpose

This activity provides experience using universal indicator to identify acids and bases.

Planning		
Materials	2 test tubes Test-tube rack 20 mL 0.1 mol/L hydrochloric acid Plastic pipette **BLM 6-6 A Universal Rainbow** (optional) Two days prior, prepare solutions and fill universal indicator bottles. Make copies of the BLM.	Marker or wax pencil Universal indicator 20 mL 0.1 mol/L sodium carbonate
Time	30 min	
Safety	Safety goggles and aprons must be worn. Dispose of the indicator solution as any other chemical waste.	

Background

Universal indicator contains several types of indicators mixed together, allowing it to react with distinct colours for many different pH values (hence the name universal).

Activity Notes and Troubleshooting

- You may substitute an eye dropper for the pipette. The purpose is simply to add the substance very slowly. No measuring is required.
- Distribute **BLM 6-6 A Universal Rainbow**.
- Explain how to use the universal indicator colour key.
- At step 2, direct students to use only three drops of indicator.
- Use **BLM A-41 Conduct an Investigation Rubric** to assess students' performance.
- Link to prior learning by evaluating the names and formulas for the chemicals used.

Additional Support

- ELL Create a master list of colours labelled with their names for reference as students write out their observations.
- Allow students to draw observations using coloured pencils.
- Provide the procedure in pictures or in a flow chart.

Answers

1. bubbles, change of colour
2. red, orange, yellow, green, teal, blue, purple
   a. pH increases gradually toward the bottom of the test tube.
   b. Colours at the red end of the spectrum (red, orange, yellow) indicate an acidic solution. Green indicates neutral pH. Colours at the blue end of the spectrum (teal, blue, purple) indicate a basic solution.

Learning Check Answers (Student textbook page 231)

1. acidic
2. Graphic organizers should indicate that pH 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic.
3. 1000 times more concentrated
4. Example: So that swimmers will not get irritated, the structure will not be corroded, and so that the chlorine can be effective.

Learning Check Answers (Student textbook page 233)

5. Any substance that changes colour in response to a certain range of pH.
6. basic
7. Bromothymol blue, because it changes colour closest to pH 7
8. Proposals should be logical and persuasive, including points such as reduced preparation time, fewer materials to stock (reduced cost and space), more efficient investigations, and increased safety because fewer chemicals are stored and used.

Section 6.2 Review Answers (Student textbook page 235)

Please also see **BLM 6-8 Section 6.2 Review (Alternative Format).**

1. acidic
2. pH meter or indicator(s)
3. Diagram should show the concentration of hydrogen ions decreasing as pH increases.
4. Example: Each colour of litmus paper changes in opposite pH ranges. A negative test with both is required to confirm neutrality.
5. Example:

Common Household Product	Use(s)	Acid or Base	Evidence of Acid or Base
soap	cleaning	base	turns red litmus paper blue
baking soda	cleaning, cooking	base	tastes bitter

6. Any three of: apple, blackberry, blueberry, cherry, mountain cranberry, grape, plum, pomegranate, raspberry, cabbage, hydrangea flowers, black tea
7. phenolphthalein
8. 7.6 to 8.2