UNIT 1 : EVIDENCE & ITERATION IN SCIENCE

ACTIVITY 2

Validating Measurements

LABORATORY

v 2.0

SCIENTIFIC THINKING FOR ALL : A TOOLKIT

In many countries, tap water is clean and drinkable without further filtering.

2 : VALIDATING MEASUREMENTS

GUIDING QUESTION

How do people collect information about the physical world?

INTRODUCTION

The safety of drinking water is determined by many factors, including biological, chemical, and radiological. Most countries today regulate and routinely test drinking water for multiple water quality indicators, including turbidity and pH. Humans can tolerate water in a range of pH levels, with pH levels from 4–11 considered drinkable with minimal health effects. However, pH levels outside of 6.5–9 affect the solubility and toxicity of chemicals such as heavy metals in drinking water.

In the last activity, some of Skipton's residents observed a change in the turbidity of their water. Turbidity is a measure of how clear the water is and indicates the presence of suspended particles such as soil or algae. People in Skipton made visual observations of the water with their senses and then collected scientific measurements of the drinking water. In this way, people used their senses to make a judgment that could be validated by scientific tools and techniques. Validation is a process of determining the accuracy of a measurement. For example, you smell smoke. You then hear the sound of a smoke alarm, a tool that validates the observation of your senses. In this activity, you will use your senses to evaluate a water sample and then use additional techniques to validate pH measurements of different liquids.

If you need to review the concept of pH, you will find a Science Review at the end of this activity.

CONCEPTUAL TOOLS

MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- 100 mL BEAKER OF RED-CABBAGE JUICE
- DROPPER BOTTLE OF AMMONIA
- DROPPER BOTTLE OF DISTILLED WATER
- DROPPER BOTTLE OF VINEGAR
- CUP OF DRINKING WATER SAMPLE
- pH PAPER WITH pH SCALE
- pH METER WITH PROBE
- CUP OF WATER
- EMPTY CUP
- PAPER TOWEL

FOR EACH PAIR OF STUDENTS

- 5 BEAKERS LABELED A–E
- 10 mL GRADUATED CYLINDER
- SHEET OF WHITE PAPER
- DROPPER
- STIR STICK

FOR EACH STUDENT

- SAFETY GOGGLES
- LAB COAT

SAFETY NOTE

You will be making observations of household chemicals with your senses. You should make observations using only sight and smell. Do not eat or drink any chemicals.

PROCEDURE

PART A: USING YOUR SENSES

1 You will be investigating 4 liquids: distilled water, drinking water, ammonia, and vinegar. Copy the following table into your science notebook.

TABLE 2.1
OBSERVATIONS

LIQUID	APPEARANCE	ODOR	PREDICTED pH
A. DISTILLED WATER			
B. DRINKING WATER			
C. AMMONIA			
D. VINEGAR			

2 Use your graduated cylinder to add 10 mL of each liquid into 4 beakers (labeled A–D). Then:

NOTE: Be sure to rinse the graduated cylinder with water before using it to measure the next liquid.

a make observations of the appearance of each sample and record your results in Table 2.1.

b smell each sample by wafting—gently waving your hand across the liquid to push the odor toward your nose—and record your results in Table 2.1.

3 Make a prediction of the pH of each liquid.

a Use the observations made with your senses to predict the pH of each liquid. (You may want to first consider whether the liquid is an acid, a base, or neutral.)

b Based on your prior knowledge and your senses, discuss with your group how accurately you can predict the pH of each liquid.

PART B: DETERMINING pH WITH RED-CABBAGE JUICE

4 Red-cabbage juice can be used to test pH because it changes color depending on if a liquid is acidic or basic. You will determine the pH of the four liquids, using red-cabbage juice. Copy the following table into your science notebook.

TABLE 2.2
TESTING pH WITH RED-CABBAGE JUICE

LIQUID	FINAL COLOR	APPROXIMATE pH RANGE	ACIDIC, BASIC, OR NEUTRAL?
A. DISTILLED WATER			
B. DRINKING WATER			
C. AMMONIA			
D. VINEGAR			
E. CONTROL (CABBAGE JUICE)		7	NEUTRAL

The plant pigment of a red cabbage can be used to make a pH indicator.

5 Place your beakers on top of a sheet of white paper.

6 Add 4 mL of red-cabbage juice to the liquids in each of the 4 beakers: A–D. Note that Beaker E will contain only cabbage juice and will serve as your control.

7 Use a stir stick to stir the liquids in Beaker A and then rinse the stir stick in water.

8 Observe any color change that occurs by comparing the color in Beaker A to the control in Beaker E. Record your color observation in Table 2.2.

9 Repeat Steps 7 and 8 for Beakers B–D, making sure to rinse the stir stick between liquids.

10 Use your observations and the information in Table 2.3, "pH Indicator Scale for Red-Cabbage Juice," to determine approximate pH of the liquid and to identify it as acidic, basic, or neutral. Record this information in Table 2.2 and then empty and rinse your equipment.

TABLE 2.3
pH INDICATOR SCALE FOR RED-CABBAGE JUICE

APPROXIMATE pH RANGE	ACIDIC, BASIC, OR NEUTRAL?
1-2	ACIDIC
3-6	ACIDIC
7	NEUTRAL
8-9	BASIC
10-11	BASIC
12-13	BASIC
14	BASIC

PART C: DETERMINING pH WITH pH PAPER

11 pH paper has been treated with one or more acid-base indicators that change colors at different pH levels. Copy Table 2.4, "Testing pH with pH Paper," into your science notebook.

TABLE 2.4
TESTING pH WITH pH PAPER

LIQUID	PAPER COLOR AFTER TESTING A LIQUID*	pH	ACIDIC, BASIC, OR NEUTRAL?
A. DISTILLED WATER			
B. DRINKING WATER			
C. AMMONIA			
D. VINEGAR			

* varies based on pH paper used

12 Add 15 mL of distilled water to Beaker A. Then add 15 mL of each of the remaining three liquids to Beakers B–D, as listed in Table 2.4.

13 Test the pH of each liquid by:

- a dipping one end of the pH paper into a beaker and then removing it.
- b placing the pH paper on a white paper towel.
- c comparing the color of the paper to the pH scale of the provided pH paper.
- d recording your color observation in Table 2.4.

14 Use your observations and the information on the pH indicator scale to record the pH of each liquid and to identify it as acidic, basic, or neutral.

PART D: DETERMINING pH BY USING A pH METER

15 pH meters have an electrochemical probe that can be used to measure pH. To make sure that it is testing pH accurately, it may need to be calibrated using distilled water. For this reason, it cannot be used to take the pH of distilled water. Follow your teacher's instructions for calibrating your pH meter.

16 Copy Table 2.5, "Testing and Comparing pH with pH Probes," into your science notebook.

TABLE 2.5
TESTING AND COMPARING pH WITH pH PROBES

LIQUID	PREDICTED pH	pH FROM CABBAGE JUICE	pH FROM PAPER	pH FROM METER
A. DISTILLED WATER				*
B. DRINKING WATER				
C. AMMONIA				
D. VINEGAR				

17 Test the pH of each liquid by:

- a following your teacher's instructions for using your pH meter. With many meters, you will first depress the dispenser button on the top of the electrode until a click is heard. You may need to wait until the reading is steady. (There is sometimes a READY indicator, or the meter beeps.)
- b recording the pH in the last column of Table 2.5.
- c rinsing the probe before using it to take the next pH reading.

18 Complete Table 2.5 to compare your pH results from Parts A–D. Discuss your findings with your group.

19 Compare your pH measurements with those of other groups.

20 Follow your teacher's directions for cleanup.

BUILD UNDERSTANDING

1. Explain how using pH probes (or pH paper) did or did not validate the use of red-cabbage juice as a pH indicator. Support your answer with evidence from your experimental results.

   HINT: Consider how similar or different the resulting pH values were for each tested liquid.

2. Scientific explanations depend on relevant, accurate, and reliable data.

   a Compare the pH measurements you made, using different tools. Describe how accurate your measurements of pH were in this activity.

   b Compare your pH measurements with those of other groups. Based on your comparisons, describe how reliable your measurements of pH were in this activity.

3. What does this activity tell you about data from human senses vs. scientific testing?

4. Beginning in the 1920s, electrochemical probes, such as the one shown here, began to be used to measure pH more accurately. Advances in technology have resulted in miniature devices that can test pH inside living cells. Why would these technologies be preferred over color indicators such as pH paper and cabbage juice?

pH meter with probe

5. Levels of pH decrease as temperature increases: a 10°C (50°F) increase in temperature will reduce the pH by 0.2. In order to reduce energy use and save money, a factory sited along the Mizu River in Skipton releases treated wastewater back into the river at a temperature of 27°C (80°F) and a pH of 6.3. The average temperature of the river is 18°C–24°C (65°F–75°F) in the summer and 2°C–7°C (35°F–45°F) in the winter. The factory supervisor calculates that as the water cools, it will result in an acceptable pH.

   Should the local government require additional treatment of the wastewater before it is released? Support your answer with at least three pieces of relevant evidence from this activity and identify the trade-offs of your decision.

   HINT: You may want to first review the Introduction and Science Review for this activity.

CONNECTIONS TO EVERYDAY LIFE

6. Rita makes a recipe, using a large glass measuring cup that holds up to 3 cups of liquid. Her final dish never turns out quite right. Explain how she could validate the accuracy of her measuring tool.

7. Suppose you are using a thermometer to track the temperature in your home, but you suspect it is not working. How could you validate its temperature reading?

EXTENSION

Are you wondering about the quality of your own drinking water? Most public water services provide information about local drinking water quality. Ask an adult in your household for the name of your public water service and look up more information about local water quality and treatment. Or you may want to purchase a commercially available home water quality testing kit to test levels of pH, bacteria, and other water quality indicators.

KEY SCIENTIFIC TERMS

turbidity
validation

SCIENCE REVIEW: pH

The pH scale measures the relative concentration of hydrogen ions (H+) and is an indicator of how acidic or basic a solution is. A high concentration of hydrogen ions indicates a low pH (basic), and a low concentration of hydrogen ions indicates a high pH (acidic). The pH scale ranges from 1–14, where 1–6 is classified as acidic, 7 as neutral (neither acidic nor basic) and 8–14 is classified as basic. Lemon juice, with a pH of 2, is acidic. Bleach, with a pH of around 12, is basic. The pH of drinking water is expected to be within a range of 6.5–9 (see Figure 2.1).

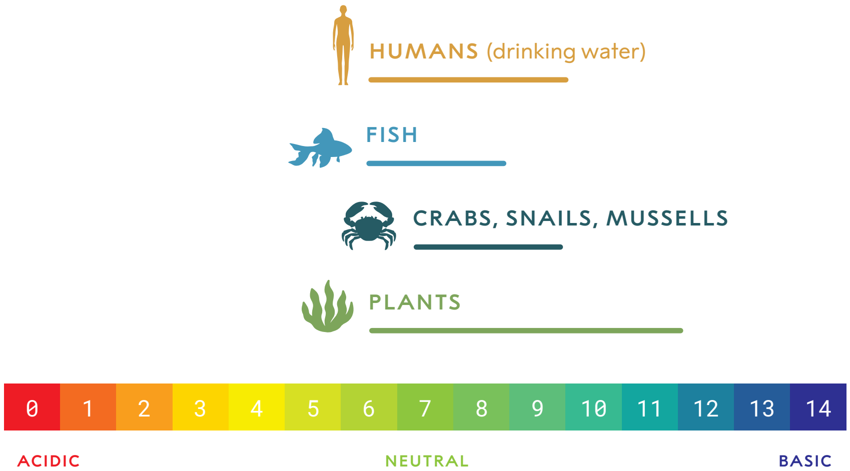

FIGURE 2.1
pH scale with ranges for living organisms

ACTIVITY 2 : VALIDATING MEASUREMENTS

UNIT 1 : EVIDENCE & ITERATION IN SCIENCE