Science Unit: *Water Quality*
Lesson 1: *pH and Red Cabbage Juice*

School year:	2004/2005
Developed for:	Laura Secord Elementary School, Vancouver School District
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Grade level:	Presented to grade 6; appropriate for grades 6&7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes

Objectives

1. Introduce how to do a science experiment.
2. Learn about how pH is used to measure the acidity and alkalinity of matter.
3. Test the pH of household items and fruits and vegetables using red cabbage juice as an indicator.

Background Information

Just as we use properties of matter such as colour, density, flexibility, hardness etc. to describe a variety of materials, we can also utilize pH. When eating food our taste buds tell us whether something we eat is sour or bitter. These characteristics of a food can be described as acidic or basic and are due to the "chemical" nature of a substance. Chemists have developed the pH scale as a measure of describing the acidity-alkalinity balance of a solution or material. In simple terms, pH is the concentration of hydrogen or H+ (protons). More accurately stated, pH is the negative logarithm of hydronium ion concentration, expressed as moles per litre. A hydronium ion is simply a proton solvated (coated) with water. The pH scale is logarithmic and ranges from 0 to 14. A low pH indicates an acidic compound, whereas a high pH indicates a basic compound. Compounds that are neither acidic nor basic are neutral and are found near the middle of the pH scale. Some general properties of acids are that they often have a sour taste and are corrosive, whereas bases feel slippery or soapy and taste bitter.

Examples of acids include those found in our mouths and stomachs. These weakly acidic solutions help to break down and digest the food we eat. Examples of bases include the major components found in dishwashing liquid and bath soap. Acids and bases are important in many industries. For example, a strong acid named sulphuric acid is used in petroleum refining, steel processing and fertilizer production. Other acids such as phosphoric and nitric acid are used in fertilizer production. The acidity or alkalinity of soil is very important for the grown of plants and crops. Some plants prefer acidic soils whereas others grow best in basic soil. The acidic or basic nature of the soil can even affect the colour of the leaves and flowers of plants.

Special substances called indicators are used to determine whether compounds are acidic or basic based on a change of colour. One common and simple indicator is red cabbage juice, which contains a plant pigment called flavin, which is a pH-sensitive anthocyanin. The chemical structure of the anthocyanin changes when exposed to an acidic or basic solution, resulting in a change in colour. When exposed to acidic solutions the anthocyanin changes pink or red, neutral solutions leave the indicator purple, whereas basic solutions change the anthocyanin pigment to a blue or green colour. Among other things, anthocyanins are also responsible for the colour changes we observe in maple leaves in the fall. Commercial products to measure pH are also available, including electronic pH meters, and pH paper or strips (e.g., litmus paper) that change colour according to the pH of the substance being tested. The colour of the test strip is matched to a colour chart, which gives the pH value.

Vocabulary

pH:	A measure of the acidity-alkalinity balance of a solution or material. In simple terms, pH is the concentration of hydrogen or H+ (protons). More accurately stated, pH is the negative logarithm of hydronium ion concentration, expressed as moles per litre.
Anthocyanin:	Water-soluble pigments that impart to flowers and other plant parts colours ranging from violet and blue to red, according to pH. Anthocyanins are produced exclusively by plants. In flowers, anthocyanin pigments function as pollinator attractants, and in fruits, colourful skins attract animals, which eat the fruit and disperse the seeds. Anthocyanins also function as a "sunscreen" to protect cells from high UV light damage, and as antioxidants. The latter is why fruits and vegetables with high anthocyanin content are also nutritious food sources.
Indicator:	A substance that indicates the presence, absence or concentration of another substance, or the degree of reaction between two or more substances by means of a characteristic change. Red cabbage is an indicator of pH according to colour change.
Acid:	A substance that yields hydrogen ions when dissolved in water. Also, a substance that can act as a proton donor and that has a pH of less than 7. Characteristic properties include sour taste, the ability to turn blue litmus red, and the ability to react with bases and certain metals to form salts.
Base:	A substance that yields hydroxyl ions when dissolved in water. Also, a substance than can act as a proton acceptor and that has a pH of more than 7. Characteristic properties include bitter taste, a slippery feel, the ability to turn litmus blue, and the ability to react with acids to form salts.

Materials:

- 2-3 heads of red cabbage
- 15-20 clear plastic cups (~500 mL) per group
- one plastic pipette or "eyedropper" per group
- cup of ocean water (slightly basic)
- cup of lake, stream, pond and/or river water (neutral to acidic)
- cup of tap water (neutral)
- cup of bottled water (slightly basic)
- cup of fresh rain water (neutral to acidic)
- cup of liquid soap (basic)
- cup of Sprite pop (acidic)
- bar of soap cut into slivers (basic)
- cup of milk (slightly acidic)
- 2-3 lemons, cut into small pieces (acidic)
- 2-3 oranges, cut into small pieces (acidic)
- 2-3 apples, cut into small pieces (slightly acidic)
- 2-3 potatoes, cut into small pieces (neutral)
- 2-3 tomatoes, cut into small pieces (slightly acidic)
- cup of baking soda (basic)
- cup of milk of magnesia (basic)
- cup of vinegar (acidic)
- cup of club soda (slightly basic)
- cup of antacid tablets (basic)
- cup of baking soda (basic)

In the Classroom

Introductory Discussion

1. Begin by asking the students to give examples of acids or bases they might find in their home or classroom.
2. Ask the students to list some of the common properties of acids and bases (e.g., taste, smell, feel, corrosiveness). Provide the students sample definitions of acids and bases appropriate for their grade level and chemistry background.
3. Ask the students to give examples of how acids and bases are important in their daily lives (e.g., acids in our stomachs to digest food, bases used in many of our cleaning products) and the world around us (e.g., industrial processes, agriculture, acid rain).
4. Ask the students if they know what the pH scale measures and how it works. It is helpful here to draw the pH scale on the board ranging from 0 to 14 and list on the scale a few well known acids and bases (but none of the items we will test today). When introducing how the red cabbage indicator works it would be helpful to also list the expected colour changes on the same pH scale.
5. Ask the students if they know what an indicator is used for in scientific experiments. Explain how the red cabbage juice indicator works.
6. Review how to do a science experiment.
    - Make an observation and then ask a question OR start with a question: which of these common household items are acids or bases?
    - Think about what will happen if we use an indicator solution (i.e., red cabbage juice) to measure the pH of different household items. How will the colour of the indicator change for weak or strong acids and bases? What is the pH of each of our test substances? This is your prediction.
    - Set up an experiment (measuring pH), and treat everything the same way. That is, place each test substance in the same type of clear plastic container, add the same amount of red cabbage indicator, and wait the same amount of time to measure the colour.
    - Make observations.
    - Collect data, record and examine results (think about why things happened the way they did).
    - Make conclusions and explain results (compare results to predictions to help you think deeper).
7. Communicate results and conclusions (i.e., your lab report).

Experiment Title: Measuring pH of household items using red cabbage juice.

Purpose of Experiment: To evaluate red cabbage juice as an indicator of pH, and to determine the pH of household items.

Experimental Treatments: For this experiment, we do not change any variable or apply any treatment, rather we are making observations.

Methods:

The day of the lesson:

Divide the class into groups of 3-4 students. Each group will determine the pH of ~20 household items using red cabbage juice as an indicator.

1. A day or two before the lesson, prepare red cabbage indicator by boiling 1-2 cups of shredded red cabbage in 1-2 cups of water in a non-aluminum pot for 5-10 minutes. Remove the pieces of cabbage using a strainer and keep the remaining purple-coloured solution, which contains the anthocyanins. Store for 1-2 days in the fridge or freeze for storage of up to a few months.

2. Select household items for the students to test. Examples include common foods (e.g., apples, oranges, lemons), drinks (e.g., water, pop) and safe household items (e.g., antacid tablets, milk of magnesia). Water samples taken from nearby oceans, lakes, rivers and streams could be interesting to test in the context of topics such as acid rain and environmental pollution. Avoid using any strongly acidic or basic compounds that could be dangerous in an elementary school setting.

3. Ask the students to clearly label a single plastic cup with a permanent marker for each substance to be tested. It may be easier to label the cups with numbers (i.e., 1-20) and then write in their lab book the correspondence between numbers and test substances.

4. Before allowing the students to use the indicator solution, have them make a prediction for each substance as to whether it is a strong acid (very low pH), weak acid (somewhat low pH), neutral (pH near 7), weak base (somewhat high pH) or strong base (very high pH). Be sure the students understand the concept of a prediction or hypothesis.

5. Ask the students to add a small volume (10-20 mL) or piece (1 cm cube) of a single substance to be tested into a clear plastic glass (note: be careful not to contaminate between substances being tested, such as spilling lemon juice on your potatoes).

6. Ask the students to add 3-4 drops of indicator to each substance using a plastic pipette or “eyedropper”. Remind the students to be careful not to touch the test substances with the plastic pipette to avoid contamination. Only a few seconds are required for the colour change, if any, to occur. By using small quantities of the test substances only a very small amount of indicator is required.

7. In order to best visualize the colour changes, have students place the clear plastic cups containing their test substances in a line on top of a strip of white paper. Generally, anthocyanin colour corresponds to the following pH units: pink pH 0-3, red pH 4-5, purple pH 6-7, blue pH 8-9, green pH 10-11, yellow pH 12-14.

8. After the pH of all substances has been measured, ask the students to rank the substances from lowest to highest pH by arranging the clear glasses from pink (low pH) to yellow (high pH). Add 10-20 mL of the red cabbage juice to any empty clear cup to serve as a pH 7 solution standard for comparison. If there is time, ask the students what might happen if they mix a weak acid with a weak base (they neutralize each other leaving a purple colour)?. This can be tested by mixing a single acid and single base from the substances tested.

Science Journal: Activity sheets with different sections can be prepared for students to record:

- Their predictions of pH and weak or strong acid or base for each household item.
- Their observations (colour observed and corresponding estimate of pH) for each household item. Students should also rank each item from strongest acid to strongest base).
- Their conclusions (what happened and why did it happen).

Closure Discussion

1. Review the definitions of pH, acid, base and indicator.
2. Discuss what the students predicted and observed for the pH of each item.
3. Discuss what happened and why it happened.
4. Discuss other methods that could be used to measure pH (e.g., litmus paper, other indicator solutions, electronic pH meter).
5. Review how to do a science experiment and discuss variability in the results across the class and possible sources of error in the experiment.

References

1. http://web.chemistry.gatech.edu/~williams/bCourse_Information/red_cabbage_pH_indicator/cabbage.html (another example of a kitchen chemistry experiment for pH)
2. http://www.csun.edu/~vceed002/BFI/lessons/pH_scale/pH_scale.html (another example of a kitchen chemistry experiment for pH)
3. http://www.ec.gc.ca/acidrain/acidfact.html (Environment Canada educational site on acid rain)
4. http://www.sciencenewsforkids.org/articles/20060927/Feature1.asp (more information on anthocyanins and the changing colours of leaves)
5. http://www.sciencenews.org/articles/20021026/bob8.asp (more information on the function of anthocyanins in plants)

Extension of Lesson Plan

1. Ask students to test other possible pH indicators using other plant sources containing anthocyanins.
2. Have students collect water samples from a wide range of lakes, rivers, streams and ponds to evaluate water quality in the region in terms of pH. Acid rain is generally more of a problem in eastern Canada than in the Lower Mainland, but there may still be some surprises. For each sample collection location, ask students to record where the body of water is located, to describe the body of water, and to note any nearby sources of pollution.