In this activity, students create an acid-base indicator using red cabbage extract. Students then use this indicator to create a scale using liquids of known acidity. Finally, students use this scale to identify the acidity of unknown liquids.

Topic: Acid/Base Indicators

Real World Science Topics
• An exploration of what acids and bases are.
• An exploration of how to create an indicator that can be used to differentiate between acids and bases.
• An exploration of the acidity of various household substances.

Objective
Students will gain an understanding of techniques for measuring acidity, as well as using known standards to measure the properties of unknown solutions.

Materials Needed for Each Class
red cabbage
blender or sharp knife
a pot or pan for boiling water
bleach
safety gloves
strainer or coffee filters
vinegar
an antacid tablet
liquid soap
soapy water
funnel

Materials Needed for Each Team of 2-4 Students
50-100mL of red cabbage indicator solution (made from cabbage, blender/knife, pot/pan)
bathroom cups
coffee filters
25mL of each of the following:
lemon juice
glass cleaner
milk
orange juice or apple juice
coffee filter
bottled water
rain water (if possible)
tap water
soda (any brand or type)
permanent marker
paper towels
scissors
**Preparation**

1. Use a blender or knife to shred the cabbage into pieces.

2. Prepare the cabbage extract, which will act as the indicator solution, before you start the activity. First, bring a pot of bottled water to a boil (bottled water is more likely to have a neutral acidity). There should be enough water in the pot to cover the cabbage scraps. Once the water has come to a boil, turn the flame off and put the shredded cabbage into the pot. Let the cabbage steep in the water until it is cool enough to touch. If you have a strainer, run the mixture through the strainer to remove the cabbage pieces. Alternatively, use a coffee filter when you pour each cup for the students. The cabbage extract should be purple. If you have prepared the cabbage extract more than one hour before class starts, you should stir it before dispensing it to students. Prepare the cabbage extract no earlier than the day you are doing the activity with the class.

3. If possible collect rainwater, pond water, or puddle water before class. If you use puddle water or pond water, filter the water through a coffee filter to remove solid materials.

4. Prepare a solution of soapy water for use during the activity.

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**NGSS Three-Dimensions**

**Science and Engineering Practices**

**Planning and Carrying Out Investigations**

- Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

**Disciplinary Core Ideas**

**PS1.B: Chemical Reactions**

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

**Crosscutting Concepts**

**Cause and Effect**

- Simple tests can be designed to gather evidence to support or refute student ideas about causes.
1. **Warm-up Activity:** To activate prior knowledge of acids and bases, ask students to name acids that they are familiar with. Some students may know about acids like acid rain or citric acid, although students may not know of any acids by name. Tell them that the sour taste in fruit juices is caused by citric acid and that most acids taste sour.

It is unlikely that students will be familiar with bases. To begin, tell the students that bases are essentially the opposite of acids. Inform them that bases are bitter and ask them to name some foods that are bitter. If the students are unfamiliar with the term bitter, or are having trouble listing bitter foods, ask them if they have ever accidentally gotten soap in their mouth. Tell them that basic compounds in the soap give it a bitter taste.

Show the students a red cabbage. Ask them if they know what it is. Students will probably recognize the cabbage, although they might confuse it with lettuce. Note that all solutions are either acidic, basic, or neutral, but it is usually not safe to test them by tasting or touching. Tell them that juice from the cabbage can be used to find out whether a liquid is an acid or a base without needing to taste it or touch it.

Before beginning the activity, write the names of the liquids that the class will be testing on the board. This list should include lemon juice, bleach, bottled water, tap water, milk, soapy water, glass cleaner, and soda. Tell students that if a solution is not acidic or basic, it is neutral. Have the class make a prediction about the acidity of each solution and record the results on the board.

Tell the students that knowing about acids and bases is important for many reasons. For example, many aquatic animals need the water they live in to have a certain acidity, or they will die. Scientists use indicator solutions to measure the acidity of the water to see if it is healthy for plants and animals.

2. Distribute the By All Indications handout, cabbage extract, bathroom cups, lemon juice, bottled water, and coffee filters to groups of 2-4 students.

3. The cabbage extract will be used as the indicator solution in this activity and should have cooled to a usable temperature. Dispense about 50-100mL of extract to each group. If you have not already strained the juice, then pour it through a funnel with a coffee filter. This will filter out the solid chunks of cabbage that were not removed from the pot.

4. In the first part of this lab, students will observe the color the indicator turns when mixed with liquids of a known acidity. To test the acidity of a solution, have students cut a coffee filter into strips about 1 cm wide, and 10 cm long. They should dip the first 2-3 cm of the strip in the cabbage indicator solution. The wet strips should be placed on a paper towel to dry.

5. Demonstrate this technique to the students using a cup of bleach. Because bleach is caustic, you should wear gloves when performing this activity. After you have done this, allow each group of students to perform the same activity with lemon juice and bottled water. Students should use
a permanent marker to write the name of each solution on the paper towel next to the strip. One
strip should be used for each solution.

6. Have the students record their observations of the original color of the cabbage extract in the
handout. Then have them record the resultant color of the strips in Table 1 in the handout. When
testing the lemon juice, the indicator strip should turn redder. Testing the bleach should cause the
strip to go from purple to greenish-yellow. The bottled water should cause no noticeable change
in the color of the indicator.

7. Before testing out the other liquids, ask the students to guess which liquid was acidic, which
was basic, and which was neutral. They should remember from the introduction that acids often
taste sour, so they should guess that the lemon juice was acidic. If they cannot decide whether
water or bleach is the base, ask them whether water is bitter or sour. They should recognize that
it is neither, and so it is neutral – it is neither an acid nor a base. Tell the students that solutions
can range from very acidic to very basic. Lemon juice is very acidic, and bleach is very basic. Have
students suggest a rule for deciding whether a solution is an acid or a base, and how strong the
solution is. A good rule is that the redder the solution, the more acidic, and the greener the solution
the more basic.

8. Instruct students to make predictions about the acidity of juice, rainwater, and glass cleaner,
and record their answers on the handout. They should put the solutions into one of the following
categories – very acidic, slightly acidic, neutral, slightly basic, and very basic.

9. Students will now use the cabbage indicator strips to find the acidity of other household items.
They should dip each strip into the indicator solution, then into the liquid being tested. They should
then let the strip dry on a sheet of paper, with a label to identify which solution was tested. Supply
students with small bathroom cups of clear liquids such as tap water, rain water, or puddle water (if
available), soda, milk, window cleaner, and soapy water, as well as orange juice or apple juice. If you
or the students have other solutions on hand, allow them to test those as well, while following the
necessary safety precautions. To save on solutions and time, you can have one cup of each solution
at the front of the room. Remind the students that although some of the liquids are actually
beverages, they should never drink solutions that are used in chemistry experiments.
Students should obtain the following results:
Milk – slightly acidic
Soda – very acidic to slightly acidic depending on the type
Juice – very acidic to slightly acidic depending on the type
Tap water – slightly acidic to slightly basic depending on your location
Rain water – slightly acidic to neutral
Soap – slightly basic to very basic depending on how much was dissolved
Window cleaner – slightly basic to very basic depending on the brand

10. **Wrap-Up Activity:** Once students are done with the main portion of the activity, direct their attention to the front of the room. First, dissolve the antacid in a cup of water. Then, pour some vinegar in another cup. Have a student volunteer test the acidity of the two solutions. The indicator test should show that the vinegar is acidic and the baking soda is basic. Then mix the two solutions together. The dissolved antacid will react with the acetic acid in the vinegar, and the solution will start to fizz. Once the fizzing has stopped, have the student perform the indicator test again. The resulting solution should be neutral. Tell the students that when bases and acids mix, they cancel each other out – which scientists call neutralization. Tell the students that antacids work to relieve stomach problems by neutralizing acids with the stomach in the same way that the antacid in the activity neutralized the acid in the vinegar.

**By All Indications Extension Activity**
There are many other types of natural extracts that can act as acid-base indicators. These include beet juice, red onions, and cherry juice. Have students who are interested select different indicators and run a series of tests to find out what range of acidity these indicators are sensitive to. For example, students could select three or four solutions of known acidity and test them using each of three of four indicators. Some indicators will only show changes in color within a narrow range of acidities. Other indicators, like the cabbage indicator, will show changes in color over a wide range of acidity.
What is an acid?
Most acids are sour in taste. The most obvious example of this is citric acid, which is found in citrus fruits. The name itself comes from the Latin word acidus – which means sharp or sour. Strong acids like hydrochloric and sulfuric acids can be very corrosive and must be handled with care.

There are several ways of defining acids and bases and most have to do with how hydrogen ions are distributed when the solution is dissolved in water. Most acids have hydrogen atoms that are loosely bound to the other atoms in the molecule. When these substances are dissolved in water, these hydrogen ions are more attracted to the water. The simplest examples are compounds like hydrochloric acid. When dissolved in water HCl becomes H+ and Cl-.

What is a base?
Most bases are slippery to the touch. This is because they dissolve the fatty acids and oils on your skin, which decreases the friction. They are also bitter. Many medicines, as well as beverages like coffee and beer are actually bases. Bases, like acids are defined by how they behave when dissolved in water. In the case of bases, there are two definitions. The first is that the substance must be able to donate hydroxide ions. For example, sodium hydroxide, which is found in detergents, has the chemical formula NaOH. Dissolution in water leads to Na+ and OH- ions. The other definition – called the Brønsted-Lowry definition expands this. In the Brønsted-Lowry definition, any substance that can accept hydrogen ions, is a base. In other words, according to this definition, acids and bases are opposites.

How does an indicator solution work?
The indicator solution itself is a weak acid or a weak base. If the indicator solution is an acid, then mixing it with a base leads to hydrogen ions moving from the indicator solution to the basic solution. The cabbage solution is a weak acid. When it is in the presence of a base the acid is neutralized. The neutral version of the chemical is greenish. There more basic the solution is the more indicator molecules will be neutralized and the greener the solution will appear. When in the presence of an acid the solution gains protons. This state of the indicator molecule is redder. Stronger acids donate more protons to the indicator molecule, and lead to a redder color.
What color is the indicator solution initially?
[The indicator solution is purple to begin with.]

In each table below fill in the color of the indicator strip after it has been dipped in the liquid being tested. In the second column, record whether it is an acid, base, or neutral.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Label#</th>
<th>Indicator color</th>
<th>Acidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleach</td>
<td></td>
<td>[green yellow]</td>
<td>[basic]</td>
</tr>
<tr>
<td>Lemon juice</td>
<td>[1]</td>
<td>[red]</td>
<td>[acidic]</td>
</tr>
<tr>
<td>Bottled water</td>
<td>[2]</td>
<td>[purple]</td>
<td>[neutral]</td>
</tr>
</tbody>
</table>

Predict the acidity of the following and explain why you picked that acidity.

Orange juice:
[Slightly acidic – Orange Juice is sour like lemon juice, but not as sour.]

Glass cleaner:
[Slightly basic – Bleach is very basic, so I think that other glass cleaner will be too, but not as strong.]

Rainwater:
[Slightly acidic – Bottled water is neutral, but rainwater might contain acid rain, so it will be slightly more acidic.]

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<tbody>
<tr>
<td>Milk</td>
<td>[3]</td>
<td>[light purple]</td>
<td>[slightly acidic]</td>
</tr>
<tr>
<td>Rainwater</td>
<td>[4]</td>
<td>[light purple]</td>
<td>[slightly acidic]</td>
</tr>
<tr>
<td>Window cleaner</td>
<td>[5]</td>
<td>[greenish]</td>
<td>[strongly basic]</td>
</tr>
<tr>
<td>Tap water</td>
<td>[6]</td>
<td>[purple to bluish]</td>
<td>[slightly acidic to slightly basic]</td>
</tr>
<tr>
<td>Soap</td>
<td>[7]</td>
<td>[bluish to greenish]</td>
<td>[slightly acidic to strongly acidic]</td>
</tr>
<tr>
<td>Juice</td>
<td>[8]</td>
<td>[light purple]</td>
<td>[slightly acidic]</td>
</tr>
<tr>
<td>Soda</td>
<td>[9]</td>
<td>[red]</td>
<td>[highly acidic]</td>
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