Of Cabbages and Kings

Learning Objectives: *Students will learn about indicators, acids, bases, and the pH scale.*

GRADE LEVEL

K–8

SCIENCE TOPICS

Physical Properties
Techniques
Chemical Reactions

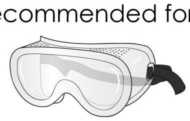
PROCESS SKILLS

Describing and Defining
Classifying
Organizing Data

GROUP SIZE

2–3

If available, goggles are recommended for this activity.



SNEAK PEAK inside …

ACTIVITY

Students use cabbage juice to test for the acidity or basicity of different substances.

STUDENT SUPPLIES

see next page for more supplies

red cabbage
baking soda and/or ammonia
vinegar and/or cream of tartar
plastic cups, etc.…

ADVANCE PREPARATION

see next page for more details

Chop or tear red cabbage
Fill pop-top bottles with vinegar, etc.…

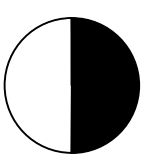
OPTIONAL EXTRAS

DEMONSTRATION
Color Changing Cups (p. B - 22)
Yellow Cabbage Juice (p. B - 23)

EXTENSIONS
Test Household Substances (p. B - 28)
Reverse Color Changes (p. B - 28)
Inquiry Opportunity: Other Plant Indicators (p. B - 29)

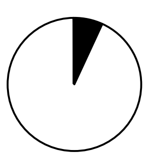
TIME REQUIRED

Advance Preparation



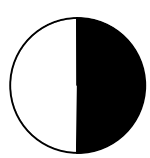
30 minutes

Set Up



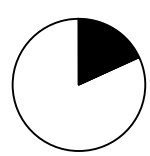
5 minutes

Activity



30 minutes

Clean Up



10 minutes

SUPPLIES

Item	Amount Needed
purple cabbage	1 head per class
salt (optional)	½ cup for preparation
knife (optional)	1 for preparation
strainer	1 for preparation
large bowls	2 for preparation
funnel	1 for preparation
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	3 per group
clear plastic cups, 8 oz.	4 per group **and** 4 per student
plastic spoons	2 spoons per group
cream of tartar*	¼ cup per group
baking soda*	¼ cup per group
ammonia*	¼ cup per group
white vinegar*	¼ cup per group
sugar	¼ cup per group
salt	¼ cup per group
cafeteria tray	1 per group

* In a pinch, the activity only requires one acid (cream of tartar or vinegar) and one base (baking soda or ammonia) to make the cabbage juice change color.

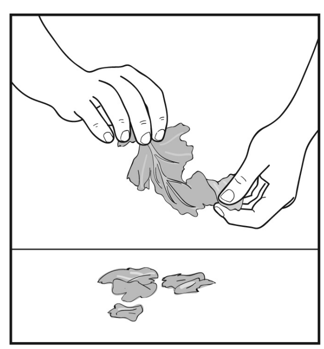
For Extension or Demonstration supplies, see the corresponding section.

ADVANCE PREPARATION

Supplies Preparation

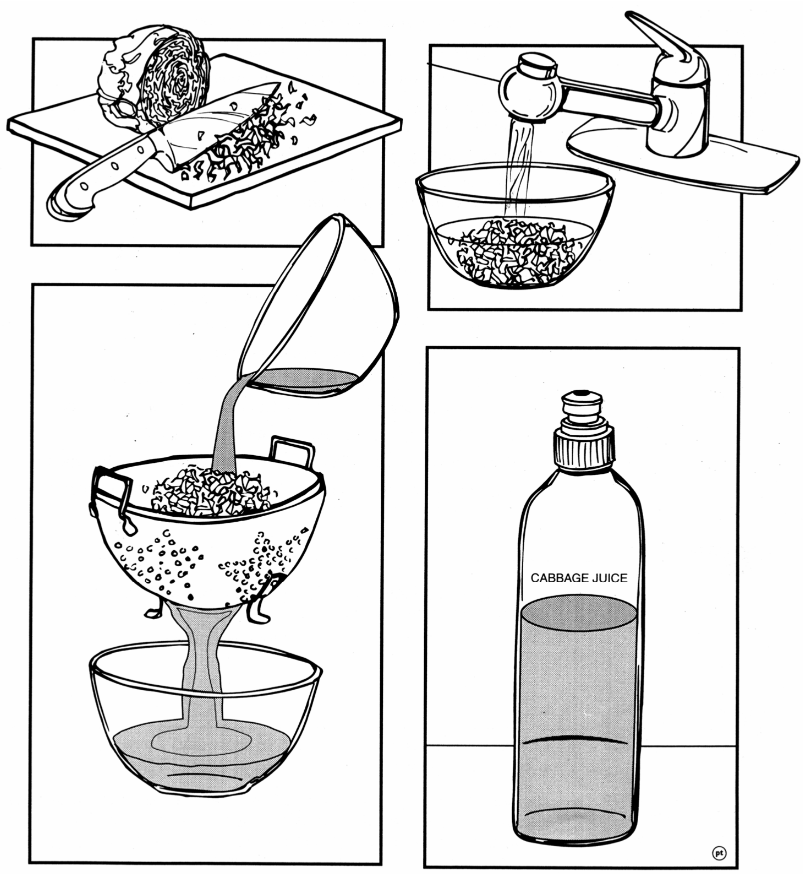
Cabbage juice indicator:

- Finely chop cabbage with a knife. (Alternatively, have kids tear the cabbage with their fingers.)
- Place at least 2 cups of cabbage in a large bowl.



Young children can tear cabbage with their fingers.

- Add hot tap water until cabbage is just barely covered.
- Wait 2–5 minutes.
- Place strainer over large bowl. Pour cabbage and hot water through strainer, collecting water into a bowl. The water should now be purple.
- If you want to store the cabbage juice for more than a few hours, add ½–1 cup salt to the mixture and stir until dissolved. Store cabbage juice in refrigerator if it is prepared more than a few hours in advance.
- Dispose of solid cabbage as you would other vegetable scraps.
- Dilute cabbage juice as necessary to have enough for all students. One cabbage can make up to a gallon of cabbage juice indicator.
- Fill pop-top squeeze bottles with about 2 cups of cabbage juice for each group.
- Label the bottles "cabbage juice."



CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Solids to Test

- For each solid the students will test (cream of tartar, baking soda, salt, and sugar) put ¼ cup in a plastic cup for each group.
- Label the cups with their contents.

Liquids to Test

- For each liquid the students will test (vinegar, ammonia) put ¼ cup in a pop-top squeeze bottle.
- Label the bottles with their contents.

CAUTION: Ammonia is irritating to eyes. In case of contact, flush eyes immediately with ample water.

SETUP

For each group

- ¼ cup vinegar in labeled pop-top squeeze bottle
- ¼ cup ammonia in labeled pop-top squeeze bottle
- ¼ cup baking soda in labeled plastic cup
- ¼ cup cream of tartar in labeled plastic cup
- ¼ cup sugar in a labeled plastic cup
- ¼ cup salt in a labeled plastic cup
- two plastic spoons
- 4 plastic cups per student
- two cups cabbage juice in labeled pop-top squeeze bottle
- cafeteria tray

At a central location (or with the teacher)

- paper towels for spill cleanup

INTRODUCING THE ACTIVITY

Let the students speculate before offering answers to any questions. The answers at right are provided for the teacher.

Choose questions that are appropriate for your classroom.

In this activity students test various household ingredients for pH using purple cabbage juice as an indicator.

What are some of the different food groups, or in what ways do we classify foods?
Fruits and vegetables, grains, proteins (meat), dairy (milk, cheese, etc.).

Right, some foods are more similar than others. For instance, many vegetables are green, most nuts are small, and many dairy products are yellow or white. Scientists also put chemicals into different groups. These are the **acid** group, the **neutral** group, and the **basic** group.

What are some examples of acids?
Lemon juice, battery acid, stomach acid, vinegar.
If these are all acids, they must share some characteristics. The only two we can taste are lemon juice and vinegar (the others are too strong for our mouths!). How do lemons and vinegar taste similar?
They are both sour. Acids taste sour to our tongue. Lemons have citric acid, and vinegar has acetic acid.

What are some examples of bases?
Detergent, floor cleaner, drain cleaner, kitchen cleaner.

These are all things we can't taste, but if we could, we might notice they taste bitter. Notice that many cleansers are bases.

Scientists cannot use taste to identify acids and bases, because most chemicals are very poisonous. They use a special class of chemicals called **indicators** for this.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

Color Changing Cups
A purple liquid is in a clear container; three other clear containers have a very small amount of clear liquid in the bottom. The purple liquid is poured into the clear liquids, and different colors appear.

Supplies
- four clear containers (~2 cups is a good size)
- cabbage juice indicator from the activity
- vinegar (can substitute lemon juice)
- ammonia (can substitute baking soda dissolved in water)
- water

CAUTION: Ammonia is irritating to eyes. In case of contact, flush eyes immediately with ample water.

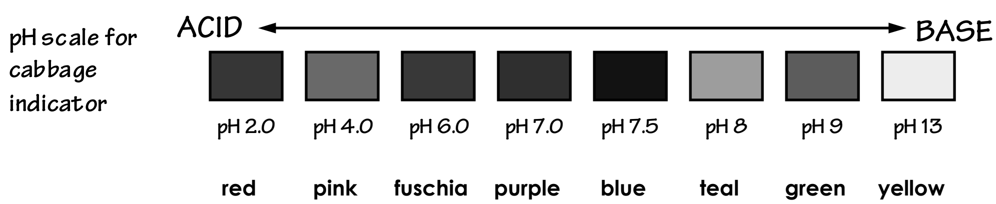
Demonstration
- Prepare four clear containers. Fill one with cabbage juice. In each of the other three, add ~1 tablespoon of vinegar, ammonia, or water. You do not need to remember which container has which colorless liquid.
- Show students a clear container containing cabbage juice indicator and ask them what they think is inside.
- Entertain guesses, but remind students that we only <u>know</u> that it is a liquid and that it is purple.
- Show students three other clear containers holding small amounts (~1 tablespoon) of colorless liquid (one has vinegar, one ammonia, and one water).
- Ask students what they think is in each, and if they think the same ingredient is in each. ("Water" will come up. Clear liquid is a good answer; discuss how not all colorless liquids are water.) Ask the students what they think will happen when you pour the purple liquid into one of the other containers.
- Pour about one third of the cabbage juice into one of the other containers. What happened? What color did it turn?
- Repeat for the other two containers. What happened in those containers?
- What happens when you pour some liquid from one container into another?

At some point, students will encourage you to mix all of the liquids together into one container. If you are using any combination of acids and bases suggested, this will be safe to do. However, if you have chosen baking soda as your base, it will react with vinegar or lemon juice to produce bubbles of carbon dioxide. This may be foamy enough to escape the container. Using vinegar and ammonia does not cause a foaming reaction and can lead to a wide variety of colors in the cabbage juice.

Explanation

Even though three containers all had a small amount of what looked like water, they were not all water. Scientists come across unknown chemicals and chemical mixtures often, and they need to determine their properties. An **indicator** like purple cabbage juice is a good way to discover some properties of unknown chemicals.

The indicator used in this demonstration shows changes in color of acids and bases. Bases turn cabbage juice blue or green; acids turn it red or pink. The water shouldn't change the color of the cabbage juice.



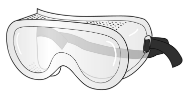
Yellow Cabbage Juice

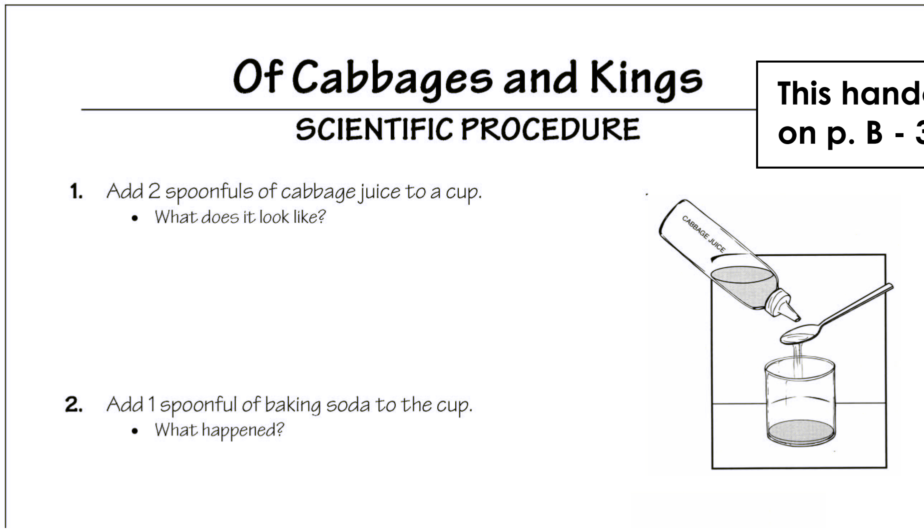
You can make the cabbage juice turn yellow by adding a very strong base. Lye or solid drain opener is strong enough to make the cabbage juice turn yellow. Some liquid drain openers will also work. Test before demonstrating to the class.

Have students follow the Scientific Procedure on page B - 32, working in groups of 2–3. Below are suggestions to help the teacher facilitate the activity.

NOTES

If available, goggles are recommended for this activity.





Of Cabbages and Kings

SCIENTIFIC PROCEDURE

1. Add 2 spoonfuls of cabbage juice to a cup.
   - What does it look like?

2. Add 1 spoonful of baking soda to the cup.
   - What happened?

This handout is on p. B - 32.

Running Suggestions

- To control spills, have students do experiments on a cafeteria tray.
- Each group has two spoons they can use. Have them measure dry ingredients with one spoon and wet ingredients with the other.

At some point, students will want to mix all their ingredients into one container. If you are using any combination of acids and bases suggested, this will be safe to do. However, if one of the ingredients is baking soda, it will react with any acid to produce bubbles of carbon dioxide. This may be foamy enough to escape its container.

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Ongoing Assessment Questions

- After students have tested a couple substances, ask them what colors they see.
- Do acids and bases come in different strengths? Or are all acids the same, and all bases the same? How can everyone explain the different types of colors present?
- Ask students to put their reactions in order according to color.

Safety and Disposal Information

- If available, goggles are recommended for this activity.
- Liquids can all be poured down the sink with the water running.
- All other materials can be thrown away as solid waste.

CAUTION: Never put lab supplies in your mouth. Even if lab supplies are foods, they may be contaminated by other items in the lab.

CLASSROOM DISCUSSION

Ask for student observations and explanations. Let the students guide the discussion and present their hypotheses before discussing explanations.

Choose questions that are appropriate for your classroom.

Acids and bases are two classifications of chemicals. Indicators, such as cabbage juice, can help us identify what sorts of chemicals are acids and which are bases.

What color is cabbage juice when it reacts with an acid?
Red or pink. HINT: Another name for cream of tartar is tartaric acid.

What color is cabbage juice when it reacts with a base?
Blue or green. HINT: Baking soda is a base.

Which chemicals in our experiment are acids?
Vinegar, cream of tartar, lemon juice, citric acid.

Which are bases?
Baking powder, ammonia, milk of magnesia, antacids, soap flakes.

Have students work in groups to physically arrange the acids and the bases. You may want to show students the pH scale for cabbage juice to help them order their cups from acid to base.

Do all chemicals have to be either an acid or a base? Did you test any chemicals that did not change the indicator?
There are many chemicals that are neither acids nor bases, in this experiment, salt and sugar are both neutral chemicals. In addition, students might point out that adding water does not change the color of the indicator.

When would you want to use an indicator to know if something is an acid or a base?
When identifying unknown substances, or when needing an acid or a base for a specific task (like cleaning your kitchen floor).

EXPLANATION

This background information is for teachers. Modify and communicate to students as necessary.

There are millions of chemicals in the universe, all with slightly different properties. To understand this tremendous variety a little better, scientists put chemicals into different families with similar properties

BACKGROUND FOR ALL GRADES

Acids, Bases, and Indicators

Two of the most important families scientists put chemicals into are the **acids** and the **bases**. To find out whether a chemical is an acid or a base, scientists mix it with a color-changing chemical, such as the cabbage juice in this activity, which functions as an **indicator**.

Acids and **bases** are opposites in chemistry. Examples of acids are vinegar, battery acid, stomach acid, etc. Some acids are non-poisonous (such as citric acid, which is found in oranges, lemons, and limes) and, when they are eaten, the taste can be sour.

Examples of bases are household cleaners like ammonia, detergent, and drain cleaner; blood and baking soda are also basic. When people taste non-poisonous bases (such as small amounts of baking soda), the taste is often bitter or soapy.

Many chemicals can be classified as either acids or bases. For instance, rocks such as limestone are bases, and they will react with weak acids such as vinegar. Plants often produce bitter bases in their leaves that discourage animals from eating them.

There are also many substances that do not act as acids or bases. For instance, gasoline, table salt, mineral oil, and most plastics do not have appreciable acid or base character. In addition, distilled water is neither an acid nor a base. Such substances are said to be **neutral**.

Indicators are chemicals that turn different colors, depending on whether they are exposed to an acid or a base. Cabbage juice, for instance, can change to either yellow green or blue in bases, and it can change to red or pink in acids.

EXTRA BACKGROUND FOR GRADES 6–8

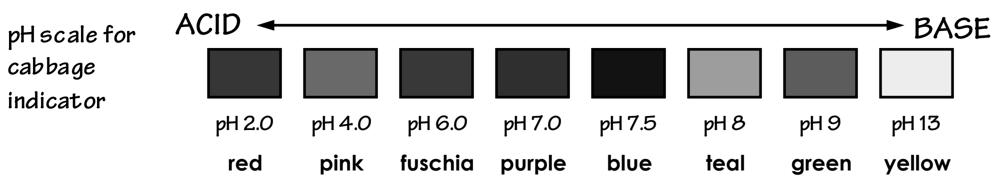
Defining Acids and Bases

Technically, acids are defined as chemicals that release **hydrogen ions** in solution. Bases are called the "opposites" of acids because they are chemicals that tend to take up hydrogen ions.

Not all acids and bases are the same strength. Strong acids and strong bases are both **corrosive** and hazardous because they either release or take up a lot of hydrogen ions. Weak acids and bases release or take up less hydrogen ions, and they are therefore less harmful. For example, stomach acid is a strong acid and is able to eat away

concrete by releasing lots of hydrogen ions. Vinegar, on the other hand, is a weak acid that releases much fewer hydrogen ions. It is so weak that if it is accidentally spilled onto skin, it can be safely washed away. (It can be very dangerous in contact with the eyes, however!) Some people even eat this non-poisonous acid on salads, in the form of vinaigrettes.

Defining pH
Scientists use the **pH scale** to specify how much acid or base is in a solution. The pH scale goes from 1–14. A low number on the scale indicates an acid, the number 7 indicates a neutral compound (such as water), and higher numbers indicate bases. The cabbage juice pH scale is as follows:



Plant Indicators
Many times people use a type of chemical called an **indicator** to detect acids or bases. Indicators are usually weak acids or bases that change color when they release or take up hydrogen ions. Cabbage juice produces so many colors because it contains several indicators that react with acids and bases. The indicators in cabbage juice are all **anthocyanins**, a class of color-changing chemicals often found in flower petals and fruit juices.

In fact, many plants contain "natural" acid and base indicators that produce vivid color changes. We see these color changes as flowers bloom or as fruits ripen. (See Extension C for hints on how to structure an inquiry investigation into these other indicators.)

Other Indicators
Chemists use a variety of indicators to detect and observe other types of chemicals. For example, some indicators can detect the amount of oxygen dissolved in water. Another indicator can detect the presence of certain metal ions, like the indicator you may use to test paint in your house for lead. Other indicators change color when they release or absorb **electrons**, and so they can help chemists find out how electrons move from molecule to molecule.

Using pH in the "Real World"
As anyone who has taken care of a chlorinated pool knows, the pH of a water solution affects how all the chemicals in it behave. This is because changes in pH can cause changes in molecules (by adding or subtracting hydrogen ions) and in how they react with each other. For instance, if the pH of blood in the lungs is too low (too acid), the protein **hemoglobin** loses some of its ability to pick up oxygen. (This situation can arise in people who climb to extreme heights.)

For another example of how proteins change when exposed to different pH, see the activity **Sticky Situation**.

Similarly, botanists need to know the pH of soil, because many plants grow better in acidic soil, which is common in volcanic places like western Washington and Oregon. Rhododendrons and azaleas, which are very common in these areas, thrive in acidic soil. Some plants, like hydrangeas, have flowers which change color depending on soil acidity. By understanding pH, scientists can learn more about how the world works.

EXTENSIONS

Extension A: Testing Household Substances
Repeat the classroom activity above, substituting or adding additional ingredients. Have students hypothesize which ingredients would be acidic and which ones basic. Students can also bring other chemicals from home to test.

Extra Supplies

- milk of magnesia (¼ cup per group)
- lemon juice (¼ cup per group)
- soap flakes (¼ cup per group)
- laundry detergent (¼ cup per group)
- antacid tablets (1–2 tablets per group)
- Tylenol™ (1–2 tablets per group)
- citric acid or Tang™ (¼ cup per group)
- vitamin C (¼ cup per group)

CAUTION: Students should never put lab supplies in their mouths. Even if lab supplies are foods, they may be contaminated by dirty hands or poisons in the lab.

Extension B: Reversing Color Changes
Is the color change caused in cabbage juice reversible? Students can explore this question by adding one of the basic cabbage juice solutions to one of the acid solutions. With some experimentation, they should be able to get the color back to purple. It's easier to start out by mixing only two chemicals. You might discuss controlling variables with the students.

Extension C: Inquiry Opportunity—Plant Indicators
Many plants besides purple cabbage can be used as natural pH indicators. Test other plant extracts/fruit juices for indicator properties.

Extra Supplies
- fruits or berries (blackberry, blueberry, plum)
- flower petals (rose, pansy, petunia)
- grape juice—diluted to half strength
- turmeric powder
- rubbing alcohol (70% isopropyl alcohol)

Extra Instructions
- If using fruits or berries, prepare in the same way as the cabbage juice indicator
- For flower petals, prepare the same way as the cabbage juice indicator. Some more fibrous petals may need to be crushed.
- For grape juice, use the juice half strength or lower to make the color change more apparent.
- Turmeric powder (often found in curry or on its own) contains an acid-base indicator that can dissolve in alcohol. To prepare, mix 1 tsp. turmeric powder with 2 cups of 70% isopropyl alcohol and stir.
- To keep the solutions fresh for more than a couple of days in the fridge, add ½–1 cup salt per quart of indicator.

CAUTION: Isopropyl alcohol is flammable and poisonous. Use care and keep it away from all sparks and flames. It can be flushed down the sink with lots of water.

Explanation
Most plants and juices have the same type of chemical indicator—an **anthocyanin**—as the cabbage juice. Students might notice that the color changes observed in different plants produce similar colors (except for turmeric). For instance, most anthocyanins change color to green upon addition of base.

In turmeric, the indicator curcumin changes color from red to yellow—see the activity ***Reaction: Yes or No?*** for more information on curcumin.

CROSS-CURRICULAR CONNECTIONS

PHYSICS

The Color Wheel
Study the color spectrum, prisms, and rainbows.

HEALTH

Color Test Strips
Research different types of indicators you can find at the store. Some examples are: lead paint tests, diabetes test strips, urinalysis tests, swimming pool test kits, and pregnancy tests.

LANGUAGE ARTS

Alice in Wonderland
The name of this activity, **Of Cabbages and Kings**, is a reference to a poem in the book, *Alice in Wonderland*, by Lewis Carroll. Read this book with your class.

BIOLOGY

Anthocyanins
Anthocyanins are the chemicals that give flowers and plants their pigment. Research how changes in pH affect anthocyanins and why plants would need this function.

The Amazing Stomach
Have students research the mysteries of the stomach. For instance, it contains very strong acid and digestive enzymes designed to break down proteins, fats, etc., but why doesn't it digest itself?

RESOURCES

Web – http://scifun.chem.wisc.edu/chemweek/fallcolr/fallcolr.html
Anthocyanins are responsible for the beautiful reds and oranges in autumn leaves. This site explains the chemistry of these color changes and includes discussions of other colored plant pigments like carotenes and chlorophyll.

Web – http://en.wikipedia.org/wiki/Acid-base_indicator
A good introductory website to the topic, with a list of flowers and plants that contain acid-base indicators.

VOCABULARY

acid: a compound with an excess of available hydrogen ions; often sour in taste

anthocyanin: a class of chemicals found in plants; these chemicals are often responsible for color changes

base: a chemical or compound that takes up hydrogen ions; often bitter in taste

corrosive: causing visible destruction of human skin tissue or able to damage metals or minerals

electron: a tiny negatively charged particle found in atoms and molecules

hemoglobin: the pigment in red blood cells that carries oxygen

hydrogen ion: a hydrogen atom that is missing one electron; often produced by acids and taken up by bases

indicator: a chemical that changes color to show the presence or amount of another chemical

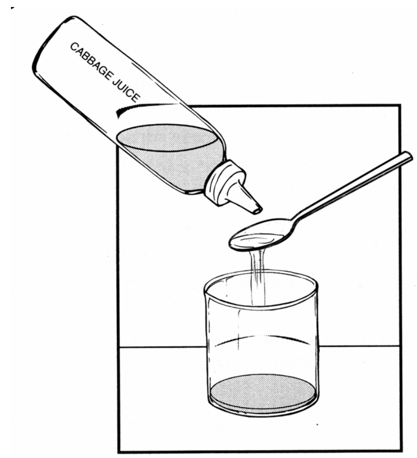
neutral: a chemical that is neither acid nor base and typically has a pH of 7

pH: a measure of the acidity or basicity of a solution, numbered on a scale where 1–6 indicates acidic, 8–14 is basic, and 7 is neutral

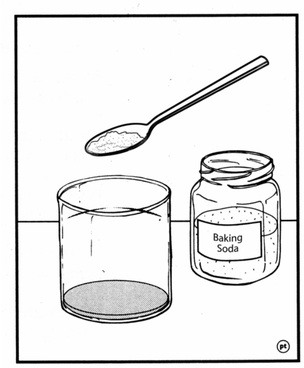
Of Cabbages and Kings

SCIENTIFIC PROCEDURE

1. Add 2 spoonfuls of cabbage juice to a cup.
- What does it look like?



2. Add 1 spoonful of baking soda to the cup.
- What happened?



- What does the cabbage juice look like now?

3. Test the reaction of other powders and liquids with cabbage juice, and record your observations.

4. Clean up your area.
- Follow your teacher's directions.

Of Cabbages and Kings

DATA SHEET

Record your observations in the table below.

Name of the Chemical Added	Cabbage Juice Color Before	Cabbage Juice Color After	Conclusion: Acid or Base?

SUPPLY WORKSHEET

This worksheet is available online at **www.omsi.edu/k8chemistry.**

Of Cabbages and Kings

Recommended group size: 2–3

Number of Students: ☐ Number of Groups: ☐

Supplies	Amount Needed	Supplies on Hand	Supplies Needed
purple cabbage	1 head per class		
salt (optional)	½ cup for preparation		
knife (optional)	1 for preparation		
strainer	1 for preparation		
large bowls	2 for preparation		
funnel	1 for preparation		
pop-top squeeze bottles (e.g., water or sports drink), 16 oz. or larger	3 per group		
clear plastic cups, 8 oz.	4 per group **and** 4 per student		
plastic spoons	2 spoons per group		
cream of tartar*	¼ cup per group		
baking soda*	¼ cup per group		
ammonia*	¼ cup per group		
white vinegar*	¼ cup per group		
sugar	¼ cup per group		
salt	¼ cup per group		
cafeteria tray	1 per group		
Extension A			
milk of magnesia	¼ cup per group		
lemon juice	¼ cup per group		
soap flakes	¼ cup per group		
laundry detergent	¼ cup per group		
antacid	1–2 tablets per group		
Tylenol™	1–2 tablets per group		
citric acid or Tang	¼ cup per group		
vitamin C	¼ cup per group		

Supply Worksheet continues on next page.

Extension B			
no additional supplies needed			
Extension C			
fruits or berries (blackberry, blueberry, plum)	1 cup per class		
flower petals (rose, rhododendron, pansy, petunia)	1 cup per class		
grape juice	1 cup per class		
turmeric powder	1 tsp per class		
rubbing alcohol (70% isopropyl alcohol).	2 cups per class		
Teacher Demonstration			
Color Changing Cups			
clear containers (about 2 cup size)	4 for class		
cabbage juice indicator	2 cups		
vinegar (or lemon juice)	1 tablespoon		
ammonia (or baking soda dissolved in water)	1 tablespoon		
water	1 tablespoon		
Yellow Cabbage Juice			
lye or solid drain opener	1–2 tsp per class		
clear container (2 cup size)	1 per class		
cabbage juice indicator	2 cups