Chapter 3: Vegetables

COOKING WITH CHEMISTRY

Did you know vegetables can change color?

A vegetable's color depends upon ***pigments***. The substance that provides color in plant and animal cells is called a pigment. For example, ***melanin*** is the pigment that provides color to your hair and skin. This pigment is important because it protects our bodies from the sun.

There are five types of pigments in vegetables: Chlorophyll, Carotenoids, Anthocyanins, Anthoxanthins, and Betalins.

Pigment	Chlorophyll	Carotenoids	Anthocyanins	Anthoxanthins	Betalins
Vegetables	Broccoli Asparagus Celery	Carrots Sweet Potatoes	Eggplants Red Beans	Onions Turnips Cauliflower	Beets Swiss Chard

Certain vegetable pigments change color when cooked. Heat alone will cause changes to occur for each of the vegetable pigments. However, the addition of an acid or base will cause different reactions, or changes to occur for each of these pigments.

Chemical changes occur when one substance changes into another substance. ***Physical changes*** occur when a substance changes form, but not its chemical structure. Melting butter, for example, is a physical change because it can be transformed back to a solid state. When heated, the red anthocyanin pigment in red cabbage will irreversibly break down as a result of a chemical change.

This chemical change causes the solution to become more basic. If an acid is added to the solution, it will physically transform the pigment

Note the difference in color between raw broccoli (left) and cooked broccoli (right).

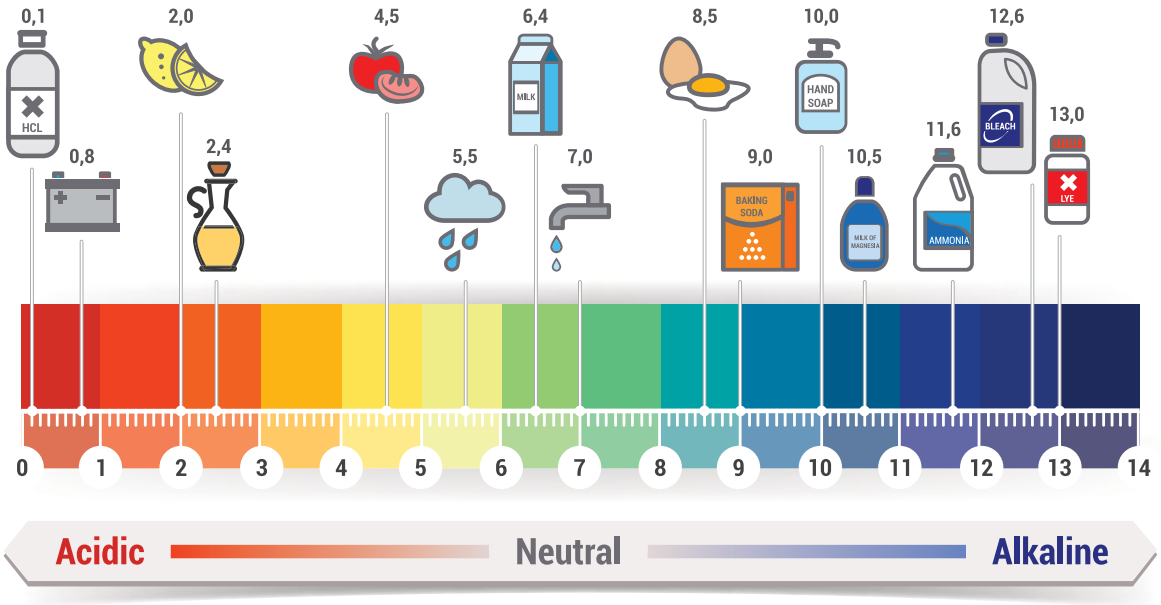
back to its original color. The addition of a base, such as baking soda, will cause the pigment to completely change color. Because the solution can change color with the addition of acid or base, it is considered a physical change that is reversible. You will observe these types of physical and chemical changes in *Food Lab Explorations Lab I* of this chapter.

The structure of a vegetable can also change when it is heated. Asparagus, for example, will become brighter green and softer because the heat causes tiny air pockets to explode. You will observe these types of chemical changes in *Food Lab Explorations Lab II* of this chapter

Acids cause a sour flavor in foods. ***Bases*** are used to neutralize those acids. Chemistry explains this relationship simply by the gain and loss of hydrogen ions. Acids want to lose a hydrogen ion, while bases want to gain a hydrogen ion. This makes for a great collaborative relationship! Acids and bases are categorized based on a ***pH scale*** ranging from 0-14. An item with a pH of 7 is considered neutral. If the pH is below 7, it is considered an acid and, if it is above 7, it is considered a base.

Acids, such as vinegar and lemon juice, are often used in cooking. The most common base used in cooking is ***baking soda***. Baking soda is used for a variety of purposes. However, its primary function in cooking is to raise baked products. When vegetables are cooked in an acid or a base, their color and/or structure may be affected. The ***cell wall*** of a plant cell gives the plant its shape. The cell wall contains ***cellulose***. Cellulose is a type of fiber necessary in our diets for intestinal health.

Cooking is simply a combination of chemical reactions. Recipes wouldn't be the same without an understanding of the chemical reactions that allow them to blend together properly. Experiment with food and become a chemist!



Think About It

Food Explorations Lab I

1. What pigment is found in red cabbage? anthocyanin

2. When red cabbage is heated a chemical (physical or chemical) change occurs.

3. If the chemical structure of a substance is changed, it is a chemical (physical or chemical) change.

Food Explorations Lab II

1. What can happen to vegetables visual appearance and texture when they are heated?

They can become brighter and softer

2. Name an example of an acid used in cooking. cream of tartar, lemon juice, vinegar

3. Name an example of a base used in cooking. baking soda

Food Explorations Lab I:
Exploring Acids & Bases

STUDENT LAB INVESTIGATIONS

Name: _____

Lab Overview

In this investigation, you will use cabbage juice indicator to determine if two unknown samples are acids or bases. Based on your results, you will determine if other household substances are acidic, basic, or neutral and the identity of the unknown samples.

Lab Objectives

In this lab, you will learn how to…

1. Use cabbage juice (pH indicator) to determine if substances are acidic, basic, or neutral.
2. Determine the identity of unknown substances.
3. Identify acids as substances that lose a hydrogen ion and bases as substances that gain a hydrogen ion.

Lab Safety: Before beginning ANY investigation you should put on your safety goggles and apron. It is important to avoid getting chemicals on your hands. Always wash your hands following completion of an investigation. When handling food, you should also wash your hands prior to beginning an investigation.

PART A: Identification of Unknown Substances

MATERIALS

Powder sample A
Powder sample B
200 mL red cabbage juice (pH indicator)
250 mL jar or beaker
2 plastic spoons
1- 100 mL graduated cylinder or metric measuring cup
pH Color Chart
safety goggles
aprons (optional)

PROCEDURE

1. Obtain unknown sample A and B from the teacher.

2. Obtain 200 mL red cabbage juice (pH indicator) from the teacher in a jar or beaker.

3. Describe your visual observations of each unknown sample in Table A.

4. What do you think will happen upon mixing the pH indicator with each sample?

Prediction for Sample A: _____

Prediction for Sample B: _____

1. Measure and pour 100 mL of the pH indicator into Sample A and stir with a plastic spoon.

2. Measure and pour 100 mL of the pH indicator into Sample B and stir with a different plastic spoon.

3. Record your observations in Table A. Use the pH color chart to identify if each sample is an acid or a base.

4. Set aside the cups of Sample A and B to allow for comparison of samples in Part B of this lab investigation.

Table A. Unknown Sample Testing

Sample	*Before* mixing with pH Indicator	*After* mixing with pH Indicator	Acid or Base?
Sample A	White Powdery	Blueish-green	ACID **(BASE)**
Sample B	Clear Liquid	Pinkish-red	**(ACID)** BASE

Conclusion:

1. Explain how your original responses compared to the actual results.

Student responses will vary.

2. Including both physical and chemical changes, compare and contrast the reactions.

Both changed colors. Sample A bubbled, and Sample B did not. End colors were also different.

3. Using the *pH Color Chart* provided and your observations, determine if Samples A and B are acids or bases. (Circle your answer in Table A.)

4. Based on the reading *Cooking with Chemistry*, describe the reactions observed in Sample A and Sample B in terms of hydrogen ions present in the solutions.

Sample A gained a hydrogen ion and Sample B lost a hydrogen ion.

PART B: Identifying the Unknown Substances

Lab Question

Which of the following household substances are acids, which are bases, and which are neutral?

Cream of Tartar Acid

Baking Soda Base

Salt Neutral

Vinegar Acid

Table B: Predictions: (Fill in the following chart to record your predictions)

Substance	Predicted color change when mixed with pH indicator	Predicted pH - Acid, Base, or Neutral?
Cream of Tartar	Pink	Acid
Baking Soda	Green	Base
Salt	Blue	Neutral
Vinegar	Red	Acid

Two of the household substances from above are identical to unknown substances A and B. Based on your observations, predict what Sample A and Sample B are.

Sample A (prediction) = Baking Soda

Sample B (prediction) = Vinegar

MATERIALS

Unknown Sample A (from Part A)
Unknown Sample B (from Part A)
4 Pre-labeled clear containers with pre-mixed solutions
pH Color Chart

PROCEDURE

1. Obtain the 4 containers from the teacher. Each container should have one of the following substances mixed with red cabbage juice (pH indicator).
   - 100 mL pH Indicator and 1 tsp. Cream of Tartar
   - 100 mL pH Indicator and 1 tsp. Baking Soda
   - 100 mL pH Indicator and 1 tsp. Salt
   - 100 mL pH Indicator and 100 ml Vinegar
2. Using the pH color chart, order each substance by color (red to yellow) and determine if it is an acid or a base.

Table C: Testing pH of Substances

	Substance	Color	pH	Acid, Base, or Neutral
1	Vinegar	Red	0	Acid
2	Cream of Tartar	Pink	4	Acid
3	Salt	Purple	6	Neutral
4	Baking Soda	Green	12	Base

Conclusion

1. Using your data, explain if your original responses were correct.

Student responses will vary.

2. Compare and contrast the chemical reactions that occurred in this activity.

Vinegar and cream of tartar turned the indicator a similar color, but vinegar was more transparent than cream of tartar. The other solutions created very different colors.

3. Based on your observations, what is each sample?

Sample A: Baking Soda **Sample B:** Vinegar

4. Complete Table D:

Table D: Other substances

Substance	Hydrogen ion (Gain, Lose or None)	Acid, Base or Neutral	Color
Rain water	Lose	Acid	Pink
Lemon juice	Lose	Acid	Red
Soap	None	Neutral	Blue
Ammonia cleaner	Gain	Base	Green

Food Explorations Lab II:
Cooking with Acids & Bases

STUDENT LAB INVESTIGATIONS

Name: _____

Lab Overview

In this investigation, you will compare and contrast physical and chemical properties of raw vegetables and vegetables cooked in acidic or basic solutions. You will also view an onion skin cell under a microscope and reflect on the effects an acid or base has on the cell's structure.

Lab Objectives

In this lab, you will learn how to…

1. Observe the effect of acids and bases on vegetables during the cooking process.

2. Prepare a wet mount slide of an onion and draw the organelles of the onion cell.

3. Infer how acids and bases affect a plant cell's structure.

Lab Safety: Before beginning ANY investigation you should put on your safety goggles and apron (optional). It is important to avoid getting chemicals on your hands. Always wash your hands following completion of an investigation. When handling food, you should also wash your hands prior to beginning an investigation.

Lab Question

How will the physical properties (e.g. color, texture) of raw vegetables (broccoli, carrot, and onion) change when cooked in an acidic solution and when cooked in a basic solution?

The vegetables cooked in an acidic solution will become dull and mushy. The vegetables cooked in a basic solution will become bright and soft.

Predictions: I predict …

Example: Broccoli will become bright green when cooked in a basic solution.

Broccoli in Acidic Solution: _____

Broccoli in Basic Solution: _____

Carrot in Acidic Solution: _____

Carrot in Basic Solution: _____

Onion in Acidic Solution: _____

Onion in Basic Solution: _____

MATERIALS (FOR CLASS)

Pre-cooked vegetable samples in labeled plastic sandwich bags

MATERIALS (PER STATION)

Safety goggles
Aprons (optional)
Plastic bag with pre-cut vegetables (broccoli, carrots, onion)
2 paper plates
1 black permanent marker

PROCEDURE

1. Obtain and observe each piece of raw vegetable. Take note of color, texture, and structure.

2. Record your observations in Table A.

3. Label one paper plate acid and one paper plate base.

4. Divide each paper plate into three sections. Label the sections onion, broccoli, and carrot.

5. Your teacher has already boiled broccoli, carrots, and onion in two large pots. While cooking, vinegar (acid) was added to one pot and baking soda (base) to the second pot.

6. As the sample bags of broccoli, carrots, and onion are passed around the room, place the samples on the appropriate plate and section.

7. Record your observations of each vegetable cooked in the acidic and basic solution in Table A.

Table A: Vegetable Observations

Vegetable	Raw Vegetable	Vegetable in Acid	Vegetable in Base
Broccoli	Dark Green	Yellowish Green	Mushy Bright Green
Carrot	Dark Orange	Orange No big change	Mushy Orange
Onion	White	Opaque White	Mushy

Conclusion

1. Compare and contrast the raw, cooked in acid, and cooked in base vegetables.

   All the vegetables softened when cooked. The vegetables cooked in the acid become dull. The vegetables cooked in the base become bright and mushy.

2. Using your observations, explain how the results compared to your original responses.

Student responses will vary.

3. In the following chart, write "acid" or "base" depending on which will give the anticipated result:

Table B:

Desired Result	Broccoli	Onion	Carrot
Color change	Both	Acid	None
No color change	None	Base	None
Crisp	Acid	Acid	None
Soft	Base	Base	Base

4. Describe a situation when an acid and when a base would be appropriate to use in cooking.

You would use an acid when you want to add flavor through a marinade. You would use a base to have a more visually appealing vegetable, add "however the addition of the base may affect quality (e.g. mushy texture).

Student Investigations Lab Extension

MATERIALS

Thin onion slices
Microscope slide and cover slip/Microscope
Cell stain
2 droppers
Cup of water

PROCEDURE

Directions to Use a Microscope

1. Plug the microscope in (if applicable) and turn it on.
2. Adjust the magnification to the lowest power.
3. Make sure the stage is lowered all the way and place the slide on the microscope stage. Slowly raise the stage using the coarse focus knob (large knob) so you can see the object clearly through the ocular lens. Do not let the slide touch the objective lens.
4. Using the fine focus knob (small knob), adjust the focus so the object looks clear.
5. If the object is too dark or too bright, adjust the diaphragm until you can see all the details.
6. Once the object is in focus, you may change to higher powers. However, be sure the lens does not hit the slide.

View Onion Cell under Microscope:

1. Obtain a few thin slices of onion from teacher.
2. Make a wet mount slide. Place a drop of water on a clean slide. Using a different dropper, place a drop of cell stain on the water drop.
3. Place a thin slice of onion on the drop and cover with cover slip.
4. Observe using the microscope under 4X power and then 10X power.
5. Draw your observations in high power (10X). Label the nucleus, cytoplasm, and cell wall.

Onion Cell Drawing

Conclusion:

1. Describe the functions of the plant structures you observed in the onion cell.

The nucleus serves as the "brain" of the cell; it contains the DNA and therefore controls the functions of the cell. The cytoplasm is the fluid that fills the cell; it holds everything in place and supports the cell structure. The cell wall protects and maintains the structure of the cell.

2. What are other structures within a typical plant cell that were not visible?

Chloroplasts

3. Based on your observations of the cooked vegetable samples, infer how the cell wall of an onion cooked in an acidic solution would look under a microscope.

   Opaque and thinner because the structure will have been compromised through cooking and the addition of an acid.

4. Based on your observations of the cooked vegetable samples, infer how the cell wall of an onion cooked in a basic solution would look under a microscope.

   Darker and thinner because the structure will have been compromised through cooking and the addition of a base.

Investigating Your Health:

Fabulous Phytochemicals

Name: _____

Objective: Investigate vegetables by keeping a log of how many you eat in a week and learn about ways you can add vegetables to your diet.

The phytochemical content of vegetable pigments provide many benefits for the body. ***Phytochemicals*** are natural compounds found in vegetables, fruits, and other plants. Plants need them to protect themselves from harsh weather, insects, injuries, and harmful predators. When we eat plants with phytochemicals, their benefits are passed on to us. The color of the vegetable is usually a sign of what phytochemical it contains. Red vegetables, such as tomatoes, contain lycopene. ***Lycopene*** reduces the risk of cancer and protects the heart and lungs against diseases.

Flavonoids are found in red/purple vegetables and reduce the risk of heart disease, cancer, blood clots, and stroke. Some examples of red/purple vegetables are red cabbage and red bell peppers. Orange vegetables, like carrots and sweet potatoes, contain ***beta-carotene***, which can help your immune system, protect your eyes, skin, and bones, and prevent heart disease. ***Lutein*** is found in yellow/green vegetables, such as corn, green beans, spinach, and green bell peppers. Lutein helps keep your eyes and heart healthy. Green vegetables include broccoli, Brussels sprouts, cabbage, kale, and cauliflower. These green vegetables contain ***indoles***, which helps to protect against cancer. Onions and other white vegetables contain ***allicin***, which also helps to prevent cancer.

There are different kinds of phytochemicals, vitamins, and minerals in different vegetables. Therefore, it is important to eat a variety of vegetables every day. You should eat at least 2 ½ cups of vegetables every day! Most Americans are not eating enough fruits and vegetables. There are many things you can do to increase the amount of vegetables in your diet. The first step is to notice how many vegetables you come across every day. Every time you see a vegetable, try it! Once you know your favorite vegetables, bring them to school as a snack. You can bring carrots, peppers, cucumbers, and broccoli in a snack bag. You could also try to eat vegetables at every meal!

PART A: Vegetable Phytochemicals

1. Research the different phytochemicals. Identify at least 3 different phytochemicals, describe the health benefits, and provide 2-3 example vegetables for each. Use the Internet and or the reading above to help with your search. Make sure to use reliable sources of information.

Phytochemical	Health Benefits	Example Vegetables
Lutein	Keeps eyes and heart healthy	1. Corn 2. Green Beans 3. Spinach
Indoles	Help protect against cancer	1. Cabbage 2. Kale 3. Cauliflower
Beta-Carotene & Alpha-Carotene	Helps immune system Protects your eyes, skin, and bones Prevents heart disease	1. Carrots 2. Sweet Potatoes 3. Pumpkins
Lycopene	Reduces risk of cancer Protects the heart and lungs against diseases	1. Tomatoes 2. Tomato Products
Flavonoids	Reduces risk of heart disease, cancer, blood clots, and stroke	1. Red Cabbage 2. Red Bell Peppers 3. Radicchio
Allicin	Helps to prevent tumors from forming	1. Onions 2. Garlic

2. Name three organs/body systems that can be impacted positively by phytochemicals.

   Student answers may vary. Heart, lungs, skin, eyes, bones, and immune system.

3. Based on what you discovered in the table on the previous page, why is it important to eat a variety of vegetables every day?

   Different vegetables have different phytochemicals, vitamins, minerals, and health benefits. Therefore, to gain all of the health benefits, you need to eat a variety of vegetables.

PART B: Everyday Vegetables

1. Over the next week, count how many times you eat a vegetable or recall the vegetables you normally eat in a typical week. Describe the color and phytochemical of each vegetable in the table on the next page. Based on your research in Part A, identify the potential health benefits of each vegetable.

   Student answers may vary.

Date	Meal	Vegetable	Color and Phytochemical	Health Benefits
	Breakfast			
	Lunch			
	Dinner			
	Snack			
	Breakfast			
	Lunch			
	Dinner			
	Snack			
	Breakfast			
	Lunch			
	Dinner			
	Snack			
	Breakfast			
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	Snack			
	Breakfast			
	Lunch			
	Dinner			
	Snack			
	Breakfast			
	Lunch			
	Dinner			
	Snack			

1. On average, how many vegetables did you eat each day?

   Student answers may vary.

2. Review the reading provided at the beginning of the investigation. How does your vegetable intake compare to the recommendation?

   Student answers may vary.

3. Research ways you can increase the number of vegetables you eat each week. Describe three ways below.

   Student answers may vary.

TRY THIS AT HOME:

Pita Pocket Bouquet

Makes 2 servings

You will need:

1 pita bread pocket
2 tablespoons grated cheese
¼ cup ricotta cheese
Pinch of dried herbs (i.e. oregano, basil)
Small pieces of fresh raw vegetables, such as:

- **broccoli**
- **carrot sticks**
- **celery sticks**
- **onions**
- **green bell peppers**
- **cauliflower**

INSTRUCTIONS:

1. Preheat oven to 350˚F
2. Slice the whole pita bread circle in half to make two pockets. Set aside.
3. Mix the cheeses and herbs in a mixing bowl.
4. Spoon the cheese mixture into the pita pockets.
5. Arrange your vegetables in the pita pocket so they bulge out of the pocket like a bouquet of flowers.
6. Wrap pita in aluminum foil.
7. Place the pita sandwich in the oven and bake for 10 minutes.
8. Carefully tear open the foil and remove the sandwich. Be careful, it may be hot. Cool for several minutes, and then transfer to a lunch plate.
9. Enjoy!