Food Science –
Chemical Reactions:
Laboratory for Secondary Level Students
Teacher Manual

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Mission Statement

This laboratory will teach chemical reactions to a target audience of middle and high school/secondary-aged students (ages ~12-18) through experiments related to food ripening and spoilage.

Contents

1. Introduction to WS2 Laboratories

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

1.2. Using this Guide

This manual is to be used by the teacher of the laboratory, and it is similar in content to the student manual but contains additional material, namely: Overview, Fundamental Physics and Materials Science Concepts Covered, Practical Skills, Background on Main Topics, Summary of Experiments, Results, Teacher Pre-Lab, Troubleshooting. These additional sections are intended to provide the teacher with the background and foundation critical for successfully implementing this laboratory kit in the classroom. It is recommended that the teachers of this laboratory go through the guide from beginning to end to familiarize themselves with the laboratory content prior to teaching the laboratory to students. Questions about the laboratory content can be directed at any time to ws2global.org@gmail.com, using the subject line "Question about Lab Kit Content".

IMPORTANT NOTES:

- This laboratory is intended for use with secondary-level students (ages ~12-18), but depending on the specific students' educational background, the content may need to be modified by the teacher to be made simpler or more complex. The teacher is encouraged to also cover the laboratory content at the pace that works best for the students; some younger students may need more time and attention from the teacher and/or facilitator to go through the questions and experiments, while older students may be more independent and require less attention from the teacher and/or facilitator. Thus, the content covered, depth of coverage, and pacing are left to the teacher's and/or facilitator's discretion.
- The content in this lab manual may not fit into the specific curriculum of the school in which it is being taught. It is up to the facilitator(s) and teacher(s) whether they would like to introduce new content or skip certain sections that are not applicable to their classrooms.
- In certain areas, modifications to the supply list may need to be made depending on the availability of the supplies in the specific area in which the lab is being taught. We have attempted to list some alternatives in the supply list, but we understand this list of alternatives is not exhaustive.
- In the experiments, the students are split into groups of two to four, but if supplies allow, students may instead work on the experiments alone.

1.3. Key Vocabulary

- Chemical reaction: a change when the final components are chemically distinct from the starting components; clues that a chemical reaction has taken place include the release of light or heat, a color change, gas production, an odor, a sound, or the formation of solids
- Reactants: the starting components of a chemical reaction
- Products: the final components of a chemical reaction
- Conservation of mass: the principle that during chemical reactions no mass is created or destroyed
- Oxidation: The process by which matter reacts with oxygen
- Acid: A type of chemical that produces hydrogen ions (H^+) when dissolved in water and has a value below seven on the pH scale
- Base: A type of chemical that produces hydroxide ions (OH^-) when dissolved in water and has a value above seven on the pH scale

1.4. Key Questions

- What are different chemical reactions that food can undergo?
  - Answer: There are many examples: milk can spoil; fruit can ripen; cooking and baking can cause charring or grilling; digestion breaks down food.
- What are clues that a chemical reaction has taken place?
  - Answer: There may be clues that a chemical reaction has taken place, such as the release of light or heat, a color change, gas production, an odor, a sound, or the formation of solids.
- How does fruit ripen?
  - Answer: Fruits ripen by oxidation (exposure to oxygen) and by exposure to ethylene gas (given off by other fruits that are ripening).

1.5. Purpose

In this lab, students will learn about several chemical reactions that are responsible for food ripening and spoilage including spoiling by acids, ripening by ethylene gas, and oxidation. They will also learn about factors that can enhance these chemical reactions, including heat, light, and environment.

1.6. Overview

Through this laboratory, middle and high school/secondary-aged students (ages ~12-18 years) are going to be taught about chemical reactions using food and food spoilage.

1.7. Fundamental Physics and Materials Science Concepts Covered

This laboratory highlights several important subjects related to Chemistry and Food Science for middle and high school/secondary-aged students including chemical reactions, acids and bases, and oxidation. These lab experiments encourage students to think critically about chemical changes with respect to food ripening and spoilage. The lab culminates in designing a method to ripen fruit and deliberately curdle milk. Finally, an extension experiment is provided that allows students to test a vessel for composting food.

1.8. Practical Skills

- Students will cut and handle food safely.
- Students will preserve food from spoilage.
- Students will connect chemistry concepts to everyday food experiences.

2. Background on Main Topics

2.1. Chemical Reaction

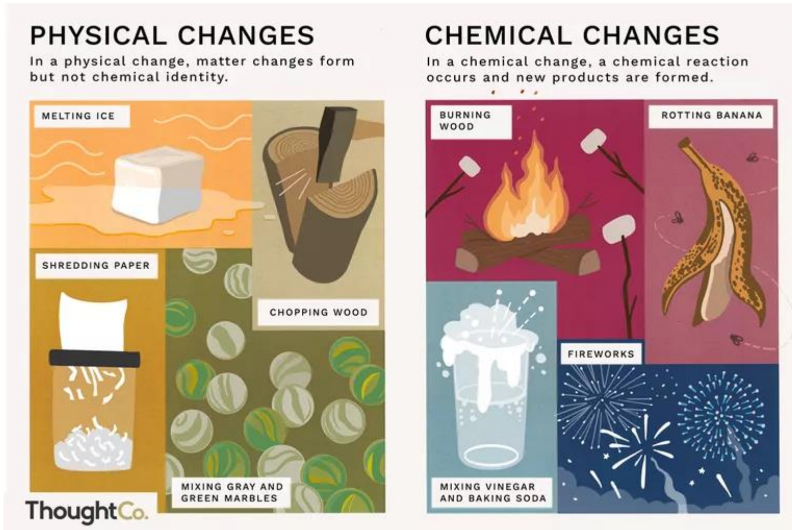


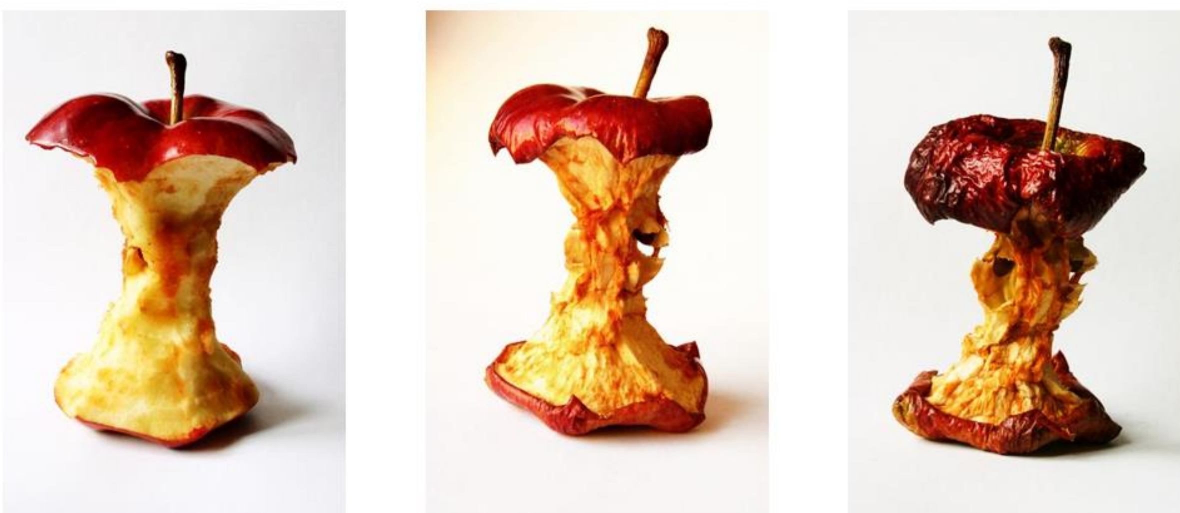
Figure 1. Examples of physical changes on left – melting ice, chopping wood, shredding paper, mixing marbles – and chemical changes on right – burning wood, rotting banana, mixing vinegar and baking soda, fireworks. Source: ThoughtCo.

Physical and chemical changes are readily noted in the preparation, storage, and consumption of food. Recall that physical changes occur when matter changes form, but not chemical identity. Cutting produce (here, produce means many types of farm-produced crops like fruits and vegetables), crumbling a piece of paper, or dissolving sugar in water are examples of physical changes. Chemical identity does not change; therefore, physical change is usually reversible (can return to its original form). For example, dissolved sugar in water can be reversed by evaporating the water from the solution. Once the water evaporates, sugar crystals will be left behind. Examples of physical changes are shown in Figure 1 (left).

A chemical change occurs when chemical reactions form new products with new chemical identities. Baking a cake, leaves changing color on trees, and food digesting in your stomach are examples of chemical changes (others shown in Figure 1 (right)). Chemical reactions have two components: the matter that is present at the start of the reaction, known as the reactants, and the matter that is present at the end of the reaction, known as the products. There may be clues that a chemical reaction has taken place, such as the release of light or heat, a color change, gas production, an odor, a sound, or the formation of solids. Since chemical reactions make new products, they are usually irreversible. Irreversible means the change cannot be undone. For example, when you burn wood, you cannot really turn the heat and gases back into a log very easily.

It is important to know that, during chemical reactions, no matter is created or destroyed in the formation of the products. This is known as conservation of mass. Consider the burning wood example: the wood (reactant) in the presence of oxygen in air (reactant) is consumed by fire, and the products are ash and gasses like water vapor and carbon dioxide. If we were to carefully measure the masses of the reactants and products, they would be equal because of the conversation of mass principle.

Chemical reactions are especially critical in the ripening and spoiling of food. For example, when the flesh of the apple turns brown after a bite is taken, it undergoes a chemical reaction called oxidation, which occurs when oxygen reacts with enzymes in the flesh of the apple and results in the browning of the apple over time (see Figure 2). Another example of oxidation is rusting, which occurs when iron changes to iron oxide when exposed to water and oxygen. If an apple is oxidized long enough that the



"red apple core" by roger.karlsson is licensed under CC BY 2.0

"red apple core two days" by roger.karlsson is licensed under CC BY 2.0

"Red apple core nine days" by roger.karlsson is licensed under CC BY 2.0

Figure 2. Example of a chemical change as an apple core sits out over several days. Notice how the core browns over time.
Source: Roger Karlsson

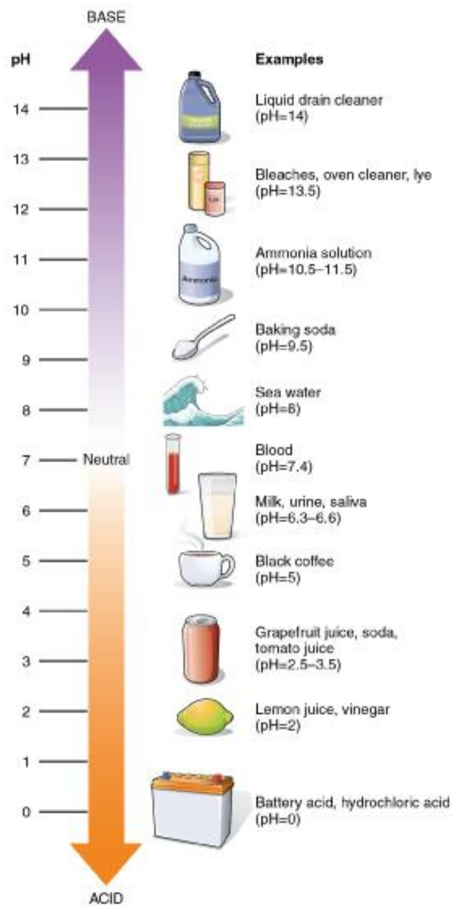


Figure 3. The pH scale with examples of common items that are basic (pH >7), neutral (pH = 7) and acidic (pH < 7).
Source: OpenStax College | commons.wikimedia.org

apple browns significantly, the apple is likely spoiled. Spoiled food can look, feel, taste, and smell unpleasant and can also make you sick if you eat it.

Milk spoiling is another example of a chemical reaction. Fresh milk is a mixture of fat and proteins distributed evenly and suspended in a water-based solution. There are also bacteria present in milk that over time (or in the presence of heat) produce enough acid that cause the solid components, like the proteins, to separate from the liquid components. An acid is a type of chemical that produces hydrogen ions (H^+) when dissolved in water and has a value smaller than seven on the pH scale. An acid can be involved in a chemical reaction, like in the case of spoiling milk or when added to a base. A base is a type of chemical that produces hydroxide ions (OH^-) when dissolved in water and has a value higher than seven on the pH scale. Examples of common acids, bases, and neutral items are shown on the pH scale in Figure 3. In the case of milk, once spoiled, the solids left over are known as curds and the liquid is known as whey as seen in Figure 4. Once milk has spoiled, or curdled, the process cannot be undone, and the milk will taste sour. This sour taste is notable with respect to acids. Interestingly, cheese is made by deliberately curdling milk, but in other cases, curdled milk may be unsafe to drink, depending on how long it has been spoiled.

Chemical reactions that ripen and spoil food, possibly making it unsuitable for consumption, are impacted by various factors such as light, oxygen, heat, humidity, temperature, bacteria, and fungi. Food may be more likely to spoil when exposed to one or more of these factors over time.

Figure 4. Curdled milk with solid components (curds) and liquid components (whey).
Source: Unknown author, CC BY-NC-ND.

2.2. Sources

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3. Summary of Experiments

In this food science laboratory, students will investigate chemical reactions that ripen and spoil food. By the end of the laboratory, students should be able to explain the components of chemical reactions, understand some factors that affect chemical reactions in food, and design a method for composting leftover food. The laboratory is split into three experimental parts: Part I investigates the byproducts of a chemical reaction, Part II separates milk into curds and whey using acids, and Part III probes the effect of the number of bananas on the ripening of a banana. The specific background for Part III is shown in that section. Students can then extend their knowledge with a design challenge and final compost vs. landfill extension experiment.

3.1. Supplies List

- Bananas (alternatives: apples, plantains)
- Lemons (alternatives: limes, grapefruits) and oranges
- Milk
- Vinegar (alternatives: lemon, lime, or grapefruit juice)
- Baking soda
- Water
- Balloon
- Small clear cups (glass or plastic)
- Cotton fabric pieces (large enough to cover the opening of the small clear cups)
- Rubber bands
- Plastic bags
- Empty clear bottle (glass or plastic)
- Pen/pencils
- Marker
- Knife for cutting produce (optional)

3.2. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Demonstrate to the students how to safely hold a knife and cut produce to avoid injuries. You may also pre-cut the produce to avoid any safety concerns.
- Lemon and vinegar are acidic and may sting open cuts and wounds as well if they get into students' eyes.
- While tasting food is part of the food preparation process, please do not taste the food in this lab because the spoiled food may cause the taster to get sick.
- Modern balloons and rubber bands may contain latex. If there are students with latex allergies, they should avoid these supplies. Latex-free substitutes like plastic wrap for balloons and string for rubber bands may be used.

3.3. Teacher Pre-Lab

The teacher can pre-cut the lemons and oranges to be used in Part II. These slices should be roughly equal size for both the lemons and the oranges. Teachers can also organize the supplies for the experiments ahead of time. For each student or each group of 2-4 students, the materials needed are: 1 empty clear bottle, 1 balloon, 4 empty clear cups, 1 cotton fabric piece, 1 rubber band, 1 slice lemon, 1 slice orange, 4 bananas, 2 plastic bags large enough to hold bananas, and pens/pencils for each group. There should be enough milk (about 3 Tablespoons (T) per group (~45 mL)), vinegar (about 4 T per group (~60 mL)), water (about 1 teaspoon (t) per group (~5 mL)), baking soda (about 1 T per group), and 1 marker that the classroom can share. If not already at room temperature, teachers should let the milk warm up (close to room temperature) for Part II.

For Part II, the study of acidic liquids can be further enhanced by using a homemade pH scale to determine the acidity of the liquids that are used to separate the curds and whey in the milk. For students to test the acidity of the liquids, the teacher can prepare pH indicator liquid by boiling roughly chopped red cabbage for a few minutes and then straining the liquid and allowing it to cool. This liquid should be purple in color. The students may add small quantities of the acids they wish to test to this pH indicator, and depending on the color that results, the students can record the pH value of their liquid. For more information, please see Appendix A.

4. Experiments

4.1. Part I. Capturing Reaction Products

4.1.1. *Pre-Experiment Questions*

1. In your life, how can you tell that a chemical reaction has occurred?
    a. Answer: There may be a release of light or heat, a color change, gas production, an odor, a sound, or the formation of solids. If the products are chemically different than the reactants, it is likely a chemical reaction has occurred.
2. What are some examples of chemical reactions while preparing a meal?
    a. Answer:
        i. Chemical reaction examples: baking, grilling, burning, charring
3. What are acids and bases?
    a. Answer: An acid is a type of chemical that produces hydrogen ions (H+) when dissolved in water and has a value smaller than seven on the pH scale. A base is a type of chemical that produces hydroxide ions (OH-) when dissolved in water and has a value larger than seven in the pH scale.
4. Though you may not have a way to measure pH of materials, if you were told that vinegar is an acid (pH<7) and baking soda is a base (pH>7), what do you predict will happen if the two are mixed?
    a. Answer: Acids and bases react with each other when mixed. In this chemical reaction, there may be a release of gas or temperature change.
    b. Extension question: Based on what acids and bases produce when dissolved in water, can you predict what is one product that would form from a reaction?
        i. Answer: Acids and bases react to form water, H_2O. We can see this if we combine H^+ and OH^-.
    c. Extension question: Based on your answer above, try writing out these reactants and products as a chemical reaction (_____ + _____ →

______). Note these are generalized for acid and base reactions; actual acid and base reactions will be more complicated.

i. Answer: $H^+ + OH^- \rightarrow H_2O$

4.1.2. Materials

- Vinegar
- Baking soda
- Clear bottle (glass or plastic)
- Balloon

4.1.3. Procedure (work in groups of 2-4)

1. Gently pour 60 mL (~4 Tablespoons) of vinegar into the clear bottle. You can use a large spoon (filled 4 times) if you do not have another way to measure the vinegar.
2. Gently pour 1 Tablespoon (one large spoonful) of baking soda into the balloon. You may need to work together as a group to hold open the mouth/neck of the balloon as one student pours in the baking soda.
3. Without tipping the balloon upside down and pouring the baking soda out, stretch the mouth of the balloon over the mouth of the bottle.
4. Now, tip up the balloon to allow the baking soda to fall into the vinegar and watch what happens.

4.1.4. Post-Experiment Questions

1. What did you observe once you tipped the baking soda into the vinegar?
   a. Answer: The two chemicals reacted. Bubbling was seen at the bottom of the bottle and then the balloon started to inflate.
2. What was the chemical reaction you observed? Answer using the words "reactant", "product", "acid", and "base".
   a. Answer: The reactants baking soda and vinegar reacted to form the products of water and gas that filled the balloon. The baking soda is a base, and the vinegar is an acid.

3. What do you know about the mass of the reactants compared to the mass of the products?
    a. Answer: The two masses should be the same based on the conservation of mass principle.
4. If you could repeat this experiment, what could you do to make the balloon inflate more? Less?
    a. Answer: Adding more reactants will lead to more products, based on the conservation of mass principle. So, if we use more baking soda and vinegar, we should get more gas, and if we use less baking soda and vinegar, we should get less gas. We could also add heat to the experiment, which may make the gas expand and inflate the balloon further.

4.2. Part II. Curdling Milk

4.2.1. Pre-Experiment Questions

1. How do you store milk after it is opened? How can you tell when it is spoiled?
    a. Answer: Milk is often stored in the refrigerator after opening to decrease the growth of bacteria. When milk is spoiled, it may look less uniform and have solids floating in it. Spoiled milk also tastes sour. Various answers are acceptable. Encourage students to share and listen to one another.
2. What happens when milk is spoiled? Answer using the word "acid".
    a. Answer: As milk ages, the bacteria in the milk produce more acid. This extra acid leads to the proteins separating from the liquid portion of the milk and causes milk to taste sour. If students are stuck, encourage them to go back to the background section and read it more carefully.
3. Instead of waiting for bacteria in the milk to produce acid, let's consider adding acid ourselves. Which liquid will cause milk to curdle the most, lemon juice (pH ~ 2), orange juice (pH ~ 4) or water (pH ~ 7)?
    a. Answer: Likely the strongest acid will cause the milk to curdle the most. Water is not an acid because its pH is 7, so this added liquid will likely not cause the milk to curdle. Since lemon juice has a lower pH than orange juice, it is a stronger acid so it will likely curdle the milk the most.

4.2.2. Materials

- Milk (should not be too cold)
- Slice of lemon
- Slice of orange
- Water
- 4 small clear cups
- Cotton fabric piece
- Rubber band

4.2.3. Procedure (work in groups of 2-4)

1. Pour 15 mL (~1 Tablespoon or one large spoonful) of milk each into three of your small cups. Label these cups “1”, “2”, and “3”. Swirl the milk in these cups and make observations about the milk before adding any other liquids.
2. Place the cotton fabric piece over the top of the fourth cup and secure it into place with the rubber band. Label this cup “4”.
3. Add 5 mL (~1 teaspoon or one small spoonful) of water to cup “1”. Gently rotate the cup to allow the water to mix with the milk. Swirl the cup several times. Record your observations immediately after adding the liquid.
4. Wait 5 minutes and again record your observations. Look especially close for any solids that are stuck on the walls of the cup after swirling.
5. Pour the liquid from cup “1” over the cotton fabric on cup “4”. Record your observations of any solids left behind, and then remove any solids from the cotton and discard them.
6. Repeat steps 3, 4, & 5 with cup “2” and orange juice instead of water. To get orange juice, squeeze the slice of orange over cup “2”.
7. Repeat steps 3, 4, & 5 with cup “3” and lemon juice instead of water. To get lemon juice, squeeze the slice of lemon over cup “3”.

Results are shown in Appendix B.

4.2.4. Results

Cup #	Added liquid	pH of added liquid	Observations immediately after adding liquid	Observations 5 minutes after adding liquid	Amount of solids (curds) collected – rank 1, 2, 3 (1 is the most curds, 3 is the least)
1	Water	7			
2	Orange juice	4			
3	Lemon juice	2			
Milk before adding any other liquid (do not fill out sections with the X)	X	X		X	X

4.2.5. Post-Experiment Questions

1. Which added liquid curdled the milk the most? How do you know?
    a. Answer: Lemon juice curdled the milk the most. This was clear based on the appearance of the milk after adding the lemon juice and the solids that separated from the liquid (not including any pulp from the orange and lemon). After pouring the mixture through the cotton fabric, this was the liquid that led to the most curds left behind.

   b. Extension question: Why do you think this liquid curdled the milk the most?
      i. Answer: Lemon juice curdled the milk the most because it is the most acidic of the liquids that were used. Since acid in the milk leads to the separation of the proteins (solids), the most acidic liquid performed the best at curdling the milk.
2. Which added liquid curdled the milk the least? Why do you think this was?
   a. Answer: Water curdled the milk the least. This is because water is not an acid, and so it did not cause the proteins to separate from the liquid. Water is a neutral substance.
3. What are ways to make the milk curdle faster?
   a. Answer: Heating the milk while adding acid should make the milk curdle faster. Lemon juice acidity is not affected by heat.
   b. Extension question: There is an enzyme called bromelain found in fresh pineapple juice that causes milk to curdle, but the enzyme is deactivated when it is heated. This enzyme also takes some time to activate upon being added to a mixture. What steps would you take to use bromelain to curdle milk effectively?
      i. Answer: Do not heat the pineapple juice before adding it to the milk. Wait extra time to let the enzyme activate. Add extra pineapple juice to make milk curdle more.
4. What are other liquids that you think could make milk curdle?
   a. Answer: Various answers are acceptable - citrus juices, like lime, grapefruit, and lemon; hot coffee; liquids with enzymes that make the solids in milk separate. Encourage the class to share their answers.

4.3. Part III. Bananas Ripening Bananas

4.3.1. Additional Background Information

When fruit ripens, the starch in the fleshy part of the fruit is broken down into sugar. This process sweetens the fruit and makes it more edible. For example, green bananas do not taste sweet and the riper they become, the sweeter they taste! One of the chemicals that starts this reaction is ethylene gas. Fruit ripening is a chemical reaction during which starch is converted to sugar.

Ethylene is produced and released by fast growing plant tissues, such as tips of fruits, flowers, damaged tissues, and reopening fruit. Some fruits such as bananas, tomatoes, apples, avocados, and mangos produce lots of ethylene. While ethylene gas can ripen fruit, it can also spoil food. You may have heard the saying, "One bad apple spoils the whole bushel." This is because the bruised, damaged, or overripe fruit gives off ethylene that makes the other fruit ripen faster.

This experiment examines how the number of bananas affects the process of banana ripening and spoiling. Here, we are assuming that an increase in the number of bananas in a bag means an increase in ethylene gas production.

4.3.2. Sources

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4.3.3. Materials

- 2 plastic bags
- 4 bananas (preferably from the same 'bunch' in order to have the same starting conditions for the 4 bananas)

4.3.4. Pre-Experiment Questions

1. What are some foods you do not store next to one another? Why not?
   a. Answer: Various answers are acceptable. For example, some may not store meat next to produce because the bacteria from the meat can

transfer to the produce. Encourage students to share their experiences and listen to one another.

2. One of the reasons why you may not store many bananas next to each other is because it affects the ripening/spoiling process. Which banana in a bag do you think will ripen first: the one by itself, the one in a bag, or the one with another banana in the bag? Or will they all ripen the same amount? Why did you make this prediction?
    a. Answer: Various answers are acceptable because this is a prediction. The teacher can also make a chart of students' predictions and reasonings.

4.3.5. Procedure (work in groups of 2-4)

1. Label the bags #1 and #2 with a marker.
2. Take 1 banana from the bunch. Make observations about the banana and set this banana aside.
3. Take 1 banana from the bunch. Make observations about the banana and place this banana in bag #1. Seal the bag.
4. Make observations about the final 2 bananas and place both bananas in bag #2. Seal the bag.
5. Store the bags in similar locations. Check on the bags once a day for 5 days and observe any changes with the bananas.
6. Record all observations in the table below.

Below is a picture of the general set-up.

Results are shown in Appendix C.

4.3.6. Results

	Day 1 Date ____ Time ____	**Day 2** Date ____ Time ____	**Day 3** Date ____ Time ____	**Day 4** Date ____ Time ____	**Day 5** Date ____ Time ____
No Bag Banana	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**
Bag #1 **Banana**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**
Bag #2 **2 Bananas Separated**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**	**Drawing:** **Observations:**

4.3.7. Post-Experiment Questions

1. Is fruit ripening a physical change or a chemical change? How do you know?
    a. Answer: Fruit ripening is a chemical change. Even though the fruit is still a fruit, the flesh of the fruit changes from mostly inedible food to edible food, and thus the matter changes. Specifically, when the fruit ripens, the starch in the fleshy part of the fruit is converted to sugar. With this experiment, the green banana is inedible and/or does not taste good. When the banana turns yellow, it becomes different matter that allows it to be edible. Ripening happens due to the ethylene gas.
2. Why did we keep one banana out of the bag and left to sit in the air?
    a. Answer: This banana served as the control. You want to see how quickly a banana ripens by itself, without any external variables. It is a basis for comparing.
3. Which environment made the banana(s) ripen/spoil first? Explain your answer with your observations and results.
    a. Answer: The banana not placed in the bag ripened and spoiled first because it turned yellow first, by day 3, and also browned by day 5. (Number of days may vary.)
    b. Extension Question: Why did this happen?
        i. Answer: This probably happened because it reacted with the oxygen in the air. Oxidation seems to have a bigger effect than ethylene gas - Interesting!
4. Which banana ripened/spoiled last? Explain your answer with your observations and results.
    a. Answer: The banana ripened/spoiled last in Bag #1. It still had green around its stem.
    b. Extension Question: Why did this happen?
        i. Answer: This probably happened because Bag #1 had the least number of bananas, which we are assuming had the least amount of ethylene gas. It also had less exposure to oxygen gas, thus also preventing produce from oxidizing.
5. Did the sealed plastic bag make a difference in the speed of ripening? Why or why not?
    a. Answer: Yes. Even though the bag contained the ethylene gas, it did not allow for the passage of oxygen, which would have sped up the ripening process.

5. Design Challenge

<u>The Challenge:</u> You have been tasked with making a complicated dish that involves ricotta cheese (basically the curds from milk) and fresh, ripened pears. The problem is that you only have the following supplies: milk, vinegar, under-ripe pears, lemons, oranges, paper bags, and plastic bags. You also have access to a stove top for heating ingredients and other kitchen supplies. What is your strategy using the supplies you have to make the dish in the least amount of time possible?

5.1. Pre-Design Questions

1. What results will you use from the experiments to design your solution to making the ricotta cheese and ripening the pears quickly?
    a. <u>Answer:</u> Answers will vary. From Part II we know that to curdle milk, we need to add an acid to the milk. We could choose the vinegar or any of the citrus fruits. To make the process faster, we may want to choose the more acidic ingredients like vinegar or lemon and heat the milk on the stovetop before adding the acidic ingredient. From Part III we know that to ripen fruit we can leave the pears out exposed to air (oxidation) or place the pears into a bag with other pears to expose them to ethylene gas. For the pears to ripen the fastest, they should be exposed to both oxidation and ethylene gas, so we should use an air permeable bag, like a paper bag, with multiple pears in it. We should also consider putting the bag in a warm area and not in a very cold area, which will slow the ripening process.
2. What other information do you need to know in order to design your solution?
    a. <u>Answer:</u> Answers will vary. How much time do you have to make the dish? What is the current state of the food? How much ricotta cheese do you need to make?
3. Are there other variables you may want to test during the design process? Recall that a variable is something you change during the test.
    a. <u>Answer:</u> We may want to test the paper versus plastic bag for ripening speed, the number of pears in the bag, the amount of acid needed to curdle the milk, the type of acid to curdle the milk. We may also want to learn if the different types of acid (all edible acids) make the cheese taste

different and if one produces the best flavor. Various answers are acceptable.

b. Extension question: What are the benefits and risks of testing variables during your design process?
    i. Answer: The benefits are we may find a really fast way to curdle the milk or ripen the pears. The risks are that by changing more than one variable at a time, we may not know which exact factor influenced the curdling or ripening. Another risk is that we could slow down the process of curdling or ripening.

5.2. The Design

Draw your design for ripening the pears and making the ricotta cheese in the box below.

5.3. Post-Design Questions

Answers are personal and will vary. There are no wrong answers. Teachers can encourage classmates to share their answers and to listen to others.

1. Explain your method to ripen the pears and make the ricotta cheese the fastest.
2. How do you feel about the results of your design process?
3. How would you change your method for next time after viewing yours and your classmates' results?
4. What was challenging about completing the design challenge? How did you work through those moments of confusion or frustration?
5. What did you enjoy most about completing this design challenge?
6. What advice would you give a group about completing this design challenge?

6. Extension Experiment: Compost vs Landfill

6.1. Background Information

One can recycle spoiled food and food scraps through composting. A compost is prepared by decomposing plant and food waste with recycled organic material. Some benefits of composting include fertilizing and enriching the soil, reducing the need for chemical fertilizers, encouraging the production of beneficial bacteria and fungi, and reducing food waste. Composting is an example of a chemical reaction because new matter is created as the organic material decomposes.

Besides composting, one might also throw food waste into the trash, which ends up in a landfill. A landfill is typically sealed off to prevent bad smells from leaking into surrounding communities and to keep hungry animals out. Since it is sealed off, a landfill does not have as much air compared to a compost pile.

This extension lesson will demonstrate the difference between throwing our food waste into a compost pile versus into a landfill. It also reinforces the concepts of chemical reactions in food contexts. The time frame of this extension activity is 8 weeks.

6.2. Sources

https://www.epa.gov/recycle/composting-home

https://pathways.mste.illinois.edu/curriculum/food-waste

http://www.islandgrownschools.org/media/documents/Landfills-v.-Compost.pdf

https://helpingninjas.com/kids-compost-jar-experiment/

6.3. Materials

- 1 recycled glass jar without a lid
- 1 recycled glass jar WITH a lid
- Soil
- Bulking agents such as: Newspaper, wood shavings/chips, straw, dead leaves
- Food scraps and skins such: the food scraps above, banana peels, grass clippings, lettuce scraps, bread crusts, eggshells, *No dairy or meat*
- Water/Rain water

6.4. Pre-Experiment Questions

These questions can be asked as an informal class discussion if many students are unfamiliar with composting in general.

1. What can we do with all our spoiled food?
   a. <u>Answer:</u> Answers may vary. Hopefully, a student will mention composting.
2. What is composting?
   a. <u>Answer:</u> Mixing plant and food waste with organic material in order to make the soil better – richer and more nutritious to plants.
3. How is a compost pile different from a landfill?
   a. <u>Answer:</u> Compost pile is exposed to the air whereas a landfill is not.
4. What are the benefits of composting?
   a. <u>Answer:</u> It reduces food waste, enriches and fertilizes the soil, reduces the need for chemical fertilizers, and encourages the production of beneficial bacteria and fungi.
5. Predict how a compost jar will look different from a landfill jar after 8 weeks. Explain your reasoning for your predictions.

a. <u>Answer:</u> Answers may vary.

6.5. Procedure (work in groups of 2-4)

Student 1: One student will add a handful of soil into BOTH glass jars.

Student 2: Another student will add a handful of bulking agents into BOTH jars.

Student 3: The third student will add a handful of food scraps and skins into BOTH jars.

Students 2 and 3 repeat their steps until they run out of material or until BOTH jars are full to the top, whichever happens first.

Student 4: The last student will add a cup of water (or collect a cup of rainwater) and add to BOTH jars. One jar will not have a lid on - this is the compost jar. Student 4 will put the lid on the other glass jar and shake. The jar with the lid on is the landfill jar. Keep the lid on. Set the glass on the windowsill, exposing it to sunlight.

Make observations. Record your observations with the Compost vs. Landfill Observation Chart in Appendix D.

Shake the landfill jar and stir the compost jar once a week, for 8 weeks. Observe changes to both jars every week for 8 weeks and mark a line with a permanent marker to show where the 'new' top is.

<u>After answering the post-experiment questions, add the compost to your garden or farm.</u>

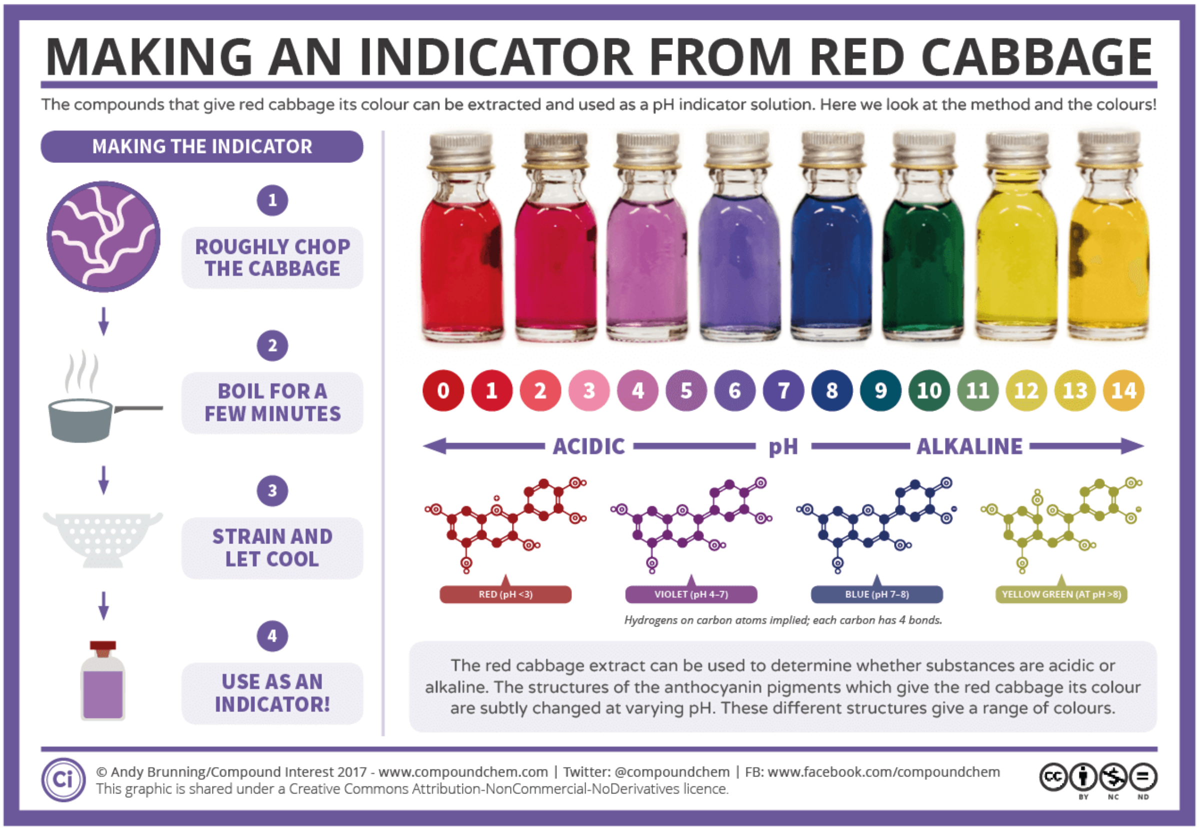
For pictures of results, teachers are directed to others who have taken pictures of this experiment at the sources linked above.

6.6. Post-Experiment Questions

1. How is the compost jar different from the landfill jar?
    a. Answer: The landfill jar had a lid whereas the compost jar did not have a lid. This means that the compost jar was exposed to the air whereas the landfill jar was not. In the compost jar, the food scraps disappeared, turning into compost soil. In the landfill jar with the lid, the food will not decompose completely. Also the bulking agents, such as newspaper and dead leaves, did not decompose. The landfill jar probably stinks more compared to the compost jar.
2. Is the compost jar an example of a physical change or a chemical change? How do you know?
    a. Answer: The compost jar is an example of a chemical change because the material in the jar decomposed into new matter. Also, the level of the compost jar dramatically decreased over 8 weeks compared to the landfill jar.
3. Is the landfill jar an example of a physical change or a chemical change? How do you know?
    a. Answer: There are examples of both physical and chemical changes in the landfill jar. There is a chemical change because some of the food scraps decomposed into new matter. However, there may be some materials, such as newspapers, that remain the same. The materials that remained the same are examples of physical changes.

7. Appendices

7.1. Appendix A - Making a pH indicator out of red cabbage & additional experiment



If there are adequate supplies, interest, and time allows, the following experiment may be conducted using the red cabbage indicator.

<u>Procedure</u>

1. Create red cabbage indicator (see above).
2. Locate the household items for pH testing (items could include: lemon juice, orange juice, clear soda, coffee, vinegar, antacid tablet, bleach, shampoo, glass cleaner, dish soap, hand soap, salt, ammonia, sugar water, baking soda, washing soda, lye, muriatic acid, cream of tartar, laundry detergent).

3. Choose at least ten of the items and put a small amount of each of the ten in separate cups/containers.
4. Drop a few (or more) drops of the red cabbage juice into each of the cups/containers.

<u>Follow-Up Questions</u>

1. What colors do you see after adding the indicator to your household items?
    a. <u>Answer:</u> Red/Pink, Purple, Blue/Green
2. List the household items by color. What do those household items have in common?
    a. <u>Answer:</u> Red/Pink - lemon juice, orange juice, vinegar - sour by taste, stings with an open wound, acids; Purple - milk, salt, sugar (assuming water is neutral)- neutral; Blue/Green - bases - baking soda, lye, glass cleaner, laundry detergent, ammonia - bitter taste, cleaning supplies, slippery to touch
3. Are there any items that do not seem to follow the patterns you observe in question 2?
    a. <u>Answer:</u> Answers may vary (dye from household items might affect results)
4. Think of three other items at home and write down your hypothesis about what you may see if you added indicator to them.
    a. <u>Answer:</u> Answers will vary
5. Predict what happens when you mix vinegar (acid) and baking soda (base) and then add indicator. What color will you observe and why?
    a. <u>Answer:</u> Purple because acid mixed with base can neutralize the solution

<u>Sources</u>

https://stevespangler.com/experiments/red-cabbage-chemistry/#:~:text=Fill%20each%20glass%20three%2Dfourths,when%20mixed%20with%20cabbage%20juice.

https://www.thoughtco.com/making-red-cabbage-ph-indicator-603650

7.2. Appendix B – Results for Part II

Added liquid: water
No solids collected.

Added liquid: orange
A few solids on sides of cup.
Very few solids collected (do not include the orange pulp as a solid collected).

Added liquid: lemon
Many solids on sides of cup.
Many solids collected.

7.3. Appendix C – Results for Part III

After 3 days

Observations: The banana not in the bag is ripening the fastest - lots of brown spots! The banana in Bag #1 is the greenest. The bananas in Bags #2 and #3 are more yellow than the banana in Bag #1.

After 5 days

Note: Bananas taken out of the bags to get better observations and pictures

Observations: The banana not in the bag is spoiling - lots of brown spots! The banana in Bag #1 is still the greenest, especially near the stem. The bananas in Bag #2 are more yellow compared to the banana in Bag #1. The bananas in Bag #3 are browner compared to the bananas in Bag #2.

7.4. Appendix D – Table for Extension Activity

COMPOST VS. LANDFILL OBSERVATIONS

Week #	**Compost Jar (No Lid)** *What do you see? What do you notice? How does it smell? What do the food scraps look like? Draw what you see.*	**Landfill Jar (With Lid)** *What do you see? What do you notice? How does it smell? What do the food scraps look like? Draw what you see.*
Week #0 (Start) *Date* _____ *Time* _____		
Week #1 *Date* _____ *Time* _____		
Week #2 *Date* _____ *Time* _____		
Week #3 *Date* _____ *Time* _____		
Week #4 *Date* _____ *Time* _____		
Week #5 *Date* _____ *Time* _____		
Week #6 *Date* _____ *Time* _____		
Week #7 *Date* _____ *Time* _____		
Week #8 *Date* _____ *Time* _____		