Ageless Apples

Section **CHEMICAL REACTIONS** *Topic* **REACTION RATES & CATALYSTS**

Estimated Time Setup: 5-10 minutes; Procedure: 1 day

OVERVIEW

Students explore the chemistry of browning apples and a simple acid-base reaction that affects this process.

In this activity, students place apple slices into solutions that are acids, bases, or neutral. A day later, they examine the apples and can see dramatic differences in how much each of the slices browned or decayed. Students can explore how acidity changes reaction rates and the chemistry of food preservation.

INQUIRY QUESTIONS

Getting Started:
- How do we know if a chemical or physical change has occurred?

Learning More:
- What is an acid and a base, and how do they affect the rate at which an apple browns?

Diving Deeper:
- What chemical reaction causes apples to brown and how can we slow this process using our knowledge of acids and bases?

CONTENT TOPICS

This activity covers the following content topics: acids, bases, pH scale, enzymes, chemical change, chemical reaction, catalysts

This activity can be extended to discuss: enzyme, protein, amino acids, food preservation

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:
- **5-PS1-4:** Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MATERIALS

For one setup:
- ¼ cup lemon juice
- 1 tbsp. baking soda
- ½ cup water (distilled, if possible)
- 1 apple
- 3 sealable sandwich bags (or small bowls with lids)
- Permanent marker
- ¼ and ½ cup measurer, tablespoon
- Knife or apple slicer

ACTIVITY NOTES

This activity is good for:
- Individual
- Pairs
- Small group
- Large group
- Demonstration

Safety Tips & Reminders:
- An adult should cut the apple for students.
- Although household acids and bases are diluted, they can still pose risks. Follow proper safety procedures like wearing a lab coat, safety goggles, and gloves for protection.
- There is no eating or drinking in the lab, even when we are working with normally edible materials.
- Review the Safety First section in the Resource Guide for additional information

Fun Fact **#1**

Will an apple float or sink in water? (Hint: think of bobbing for apples!) An apple is actually 25% air by volume and easily floats in water.

ENGAGE

Use the following ideas to engage your students in learning about chemical reactions:

- Start by having students observe fruits – cut and whole – over time (or show videos and pictures if you cannot have samples in the room). What do students observe happens over time? Why do they think this might be? Do they have any ideas about what might be causing this and how to slow or stop the process?
- Ask students to brainstorm ways in which humans preserve their food. What do we add to food to keep it fresh? How do we store food to keep it from going bad? Do they know why food goes bad over time?
- If you test out the experiment in advance, start by showing them the three samples but do not label which solution they were put in. Can students guess what happened and why some samples browned while others did not? Turn this into a "20 Questions" game where students can only ask questions that can be answered with "yes" or "no," and see if they can figure out what you did!

See more ideas for engagement in the Reaction Rates & Catalysts Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #2

There are over 2,500 varieties of apples, ranging in size, taste, color, and appearance. But the only apple native to the US is the crabapple.

EXPLORE

Procedure:

1. Using the marker, add one of the following labels to each plastic bag: "lemon juice," "baking soda," and "water."
2. Pour ¼ cup lemon juice into the bag labeled "lemon juice."
3. Mix ¼ cup water with 1 tbsp. baking soda in the bag labeled "baking soda."
4. Pour ¼ cup water into the plastic bag labeled "water."
5. Have an adult cut an apple into 6-12 evenly-sliced pieces.
6. Place 2-4 apple slices into each bag, seal, and gently shake to ensure the apple slice is completely coated in the liquid.
7. Carefully remove the apple slices from each bag and place them on top of the sealed bag they came out of, or on a labeled plate or bowl.
8. Observe immediately and check in over the next few hours or day and note any changes between the apple samples.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- At the start of the experiment, describe each liquid being used: water, lemon juice, baking soda solution. What are the physical properties? How are they similar or different?
- Draw and label of diagram of an apple slice at the start.
- Make a hypothesis: what effect do you think each of the liquids will have on the apple? Draw what you think each sample will look like tomorrow.
- Describe and draw any changes you notice between the three samples over time. This can be every hour, every few hours, or over the course of a few days. What differences can you observe?
- Do you think this is an example of a chemical or physical change? What is your evidence?
- Which of the liquids used could help keep apples fresh for longer? Why?

EXPLAIN

What's happening in this Activity?

First review the Reaction Rates & Catalysts Background section to gain a deeper understanding of the scientific principles behind this activity.

During a chemical reaction the reactants change into the completely new substances called the products, and bonds between atoms are broken or formed. Chemical reactions occur all around us—even in our food! Apples that we eat ripen because of chemical reactions. When an apple is cut open and turns brown, that is also because of a chemical reaction.

When an apple is cut open, it releases a molecule called polyphenol oxidase (PPO). Once PPO is released, the apple reacts with oxygen in the air and turns brown. The brown color of the apple is a defense mechanism, meant to make the plant less appealing so it is less likely to be eaten by other animals.

This change in color is due to an oxidation reaction. **Oxidation reactions** are chemical reaction that involve the transfer of electrons. The brown rust that forms on metal is also the result of an oxidation reaction (see the Cleaning Pennies activities for more!).

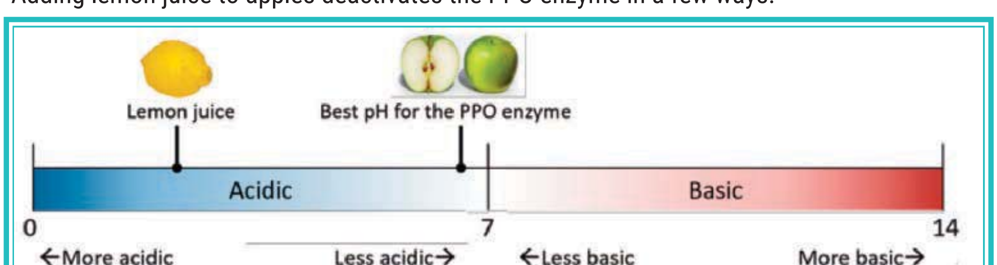
PPO is actually a catalyst. A **catalyst** is a substance that changes the rate of a reaction, but is not used up during the reaction. In this case, PPO makes other compounds in the apple react with oxygen in the air faster, so the apple turns brown faster. PPO itself does not react with anything. PPO is also the enzyme that makes guacamole turn brown over time, and is found in apples and other plants like mushrooms and lettuce. Catalysts make a reaction happen more quickly by decreasing the activation energy. **Activation energy** is the amount of energy needed to start a reaction, or the size of the "energy hill" the reaction has to climb. Since catalysts make it easier for the reaction to occur, it happens more quickly.

Enzymes are catalyst in living things that help to speed up biological reactions. In humans, enzymes help us with things like digesting food, generating energy, and staying healthy. The slowest known biological reaction, which is part of creating our DNA, would like 1 trillion years without a catalyst. With an enzyme, this reaction happens in just 10 milliseconds!

One way to change the rate of a reaction is to add or remove a catalyst. Another way is to change how a catalyst behaves. Whether or not a catalyst is active depends on a number of conditions, like temperature, acidity, and concentration. One of the reasons enzymes work in our bodies is our temperature. Most enzymes in the human body work best at normal body temperature (about 98 °F).

Another thing that can affect a catalyst is pH. The **pH scale** measures how acidic or basic something is. What this depends on is the concentration of hydrogen ions, H^+. pH can range from 0 to 14. **Acids** are substances with a pH less than 7. **Bases** are substances with a pH greater than 7.

Every enzyme has an ideal pH, or balance between acidic and basic, where it works best. PPO works best when the pH is around 6.5. When the pH drops below 2.5, PPO stops working at all. If the PPO in an apple becomes inactive, the oxidation reaction that turns apples brown happens much slower (barely at all!).
Adding lemon juice to apples deactivates the PPO enzyme in a few ways.



Notes

EXPLAIN continued

Vitamin C: Lemons are a great source of vitamin C, also known as ascorbic acid. When ascorbic acid is on an apple, oxygen in the air reacts with ascorbic acid before it reacts with the apple. Instead of the apple being oxidized, the ascorbic acid is oxidized. But this doesn't work forever—once the ascorbic acid has all reacted, the apple with start to oxidize and turn brown.

Low pH: Lemons are very acidic because they contain compounds like citric acid. The pH of lemon juice is 2.0, which is low enough to make the PPO enzyme inactive. Unlike ascorbic acid, the acidity doesn't "run out," so it prevents browning for longer.

Because lemon juice makes the PPO less active, the apple slices that were in lemon juice solution will turn brown slower than th apple slices that were in either baking sod solution or water.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for student of different grade levels by focusing on th concepts outlined below.

GETTING STARTED

For younger students, emphasize the following concepts:

- There are different types of chemical reactions
- Catalysts change the rate of a chemical reaction without being used up
- Enzymes are catalysts in living things

DIVING DEEPER

For more advanced students, emphasize the following concepts:

- Catalysts behave differently depending on conditions like temperature and pH
- pH measures the concentration of hydrogen ions, H+, which determines whether something is an acid or a base

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- Add another control: keep a few apple slices out and compare with the other samples. Students might see that even dipping the apple in water slowed the browning slightly. Why do they think that is? (Hint: with water covering the sample, can oxygen reach the fruit as easily?
- Try this experiment again, but use a variety of acids, bases, and neutral substances, such as vinegar, milk, soda, saltwater, seltzer, orange or cranberry juice, milk of magnesia, tonic water, and more. Which works the best? Why?
- For students who are learning more about acids and bases, get some pH paper and measure the pH of each liquid used in the experiment. Graph the pH versus the level or browning. What is the relation? Now ask students to test the pH of other unknown liquids and make an informed guess of where it will fall on the graph. Test it out and see if they are correct!
- Students can graph their results and run multiple trials to determine which household preservative works the best. On the y-axis they can create a scale for brownness, and on the x-axis they can write what type of treatment they used. With a keen eye, close observation, and a stopwatch, they can also graph the time at which the apple started to brown on the y-axis instead.
- How does storage method affect browning? In this experiment, students learned that oxygen is what causes the enzymes to react. Can they design a way to store apples that limits the amount of oxygen? Or try the experiment again but keep each trial in a different storage container: out in the open, in a Tupperware, in a clean plastic bag. Which worked best?
- Does this work for other fruits or vegetables? Students can run the experiment again with bananas, pears, avocados, potatoes, peaches – whichever other produce items they can think of that brown like apples.
- If you are doing the experiment in the summer or fall in an area where there are apple orchards, pair this activity with a field trip. Learn about how apples are grown, the life cycle, farming, distribution, and the properties of each type of apple. Have students interview the farmers and orchard workers. How do they keep their produce fresh? What processes and products do they use to grow fresh, delicious apples? After students return to the classroom, do this experiment as part of a discussion about how food is produced and ends up in local grocery stores, restaurants, and in their homes. Why might experiments like these be important for the farming industry?
- Do different types of apples brown at different rates? Depending on the type of apple and the maturity, different levels of polyphenol oxidase (PPO) will be present, resulting in different levels of browning. Test it out!
- There are many theories to the evolutionary advantage of browning: perhaps the unappealing appearance keeps animals away from damaged fruit on a tree, or maybe it is a signal to them that the fruit is rotten and should be avoided. What do students think might be the evolutionary advantage to a fruit that can brown when open or damaged?
- Does temperature affect the rate of browning? Try putting one apple in the freezer, one in the refrigerator, one at room temperature, and one in a warm or sunny spot for a few hours. Cut a slice from each and observe. Did they brown at the same rate?

EVALUATE

- Provide groups of students with a mystery sample that is an acid, base, or neutral. Ask them to write a list of the physical properties. If pH paper is available, have them test the pH of their sample, or provide the estimated pH to each group. Using what they learned in this experiment, do they think this will be effective in preventing browning in an apple? Have them test it out, then make a guess as to what their mystery liquid could have been. Provide them with a bank of options (either samples they can look at and test the pH, or a chart) and guess which substance they had. They can then explain the evidence for their answer to their peers and see if everyone correctly guessed their samples.
- Ask students to visit a local grocery store or look at their food at home. What preservation techniques are applied on produce? You can provide scaffolding with various prompts: how are they displayed? Are they in packaging? Do you notice anything that could have been done to the produce to keep it fresh (i.e. think of the wax on apples!)? When reading labels on prepared or packaged produce, can they find the names of any preservatives? The next day, students can share out their findings and make a list of the ways we ensure our food stays fresh and edible.
- Genetically modified foods – like the non-browning Artic Apple – have caused lots of debate in recent years. For older learners, set up a debate using the Artic Apple as the case study. Students should be assigned one side of the debate (pro-genetically modified foods or against – or add in other stakeholders like perhaps a group that wants to treat conventional fruit with acidic solutions instead), conduct research and compile evidence for their argument, then hold a debate in class. Encourage students to think about the pros and cons from the point of view of scientists, farmers, grocers, consumers, the government, and more. What did they learn? Which side was more convincing? What is the role of a scientist in these types of debates?

Notes

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Some grocery stores and fast food locations regularly sell bags of sliced apples – but how do they keep them looking and tasting fresh? This is made possible thanks to chemist Attila Pavlath, who developed a formula of salts and vitamin C (the same acid found in lemon juice!) that can keep a sliced apple as good as new for 21 days!

There are a number of methods used to preserve fruit and prevent it from rotting. One method explored in this experiment is dipping or spraying fruit with an acidic solution. Fruit is sometimes dried to remove moisture, which preserves its shelf life, or dipped in sulfur or honey solutions, which can act as a preservative. Cooking or blanching – dipping in boiling water – also destroys the enzyme that causes fruit to brown, but this changes the taste and texture it might not be a desirable option.

Careers in Chemistry

- Americans waste around 50% of their produce, which equates to around 60 million tons or $160,000,000,000 annually (which is around $1,600 per four-person household)! A big reason for this is that produce that is bruised, browned, or deemed 'damaged' in some way is thrown away – even if it is perfectly edible! This waste has spurred on a number of careers: commercial composting, marketing campaigns for 'ugly fruit,' repurposing slightly damaged produce to solve food insecurity issues, developing more scientific protocol for determining accurate expiration dates, and big business in finding safe, efficient, and effective ways to grow, harvest, package, and transport produce around the world.