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Standards

Arizona

> **6.P1U1.1:** Analyze and interpret data to show that changes in states of matter are caused by different rates of movement of atoms in solids, liquids, and gases (Kinetic Theory).

> **6.P1U1.2:** Plan and carry out an investigation to demonstrate that variations in temperature and/or pressure affect changes in state of matter.

NGSS

> **MS-PS1-5:** Matter is conserved because atoms are conserved in physical and chemical processes.

> **MS-PS1-6:** The transfer of energy can be tracked as energy flows through a designed or natural system.

Materials

PowerPoint – Science of Combustion

Combustion Worksheet

Chemical Reaction Decoder

Poster

Poster paper

Colored pencils

Magazines/printed images

Post-It notes

Markers

S'mores Ingredients

Graham crackers

Sticks/wooden skewers

Marshmallows

Chocolate bars (usually milk chocolate)

Wet wipes

Plates/napkins

Fire Pit/Grill Materials

Lighter/matches

Propane source grill/fire pit

Safety glasses/goggles

Tongs

Metal pan

Hot material gloves

Firewood/wood pieces

Water

Combustion Worksheet

Colored pencils

Markers

Overview

In this lesson, students are introduced to the science of combustion. Students will learn the stages of combustion and the characteristics of those stages. The lesson includes hands-on marshmallow toasting and making a combustion poster where students explore the combustion process.

Goals

- Students will learn the stages of combustion and the characteristics of those stages.
- Students will do a marshmallow toasting activity to observe the stages of combustion.
- Students will create combustion posters.

Learning Objectives

- List the three parts of the fire triangle
- Identify types of fuel used for combustion
- Describe the stages of combustion
- Connect the concepts of fire science and fire safety

Vocabulary

Heat: to add energy to make hot or warm

Thermal Energy: energy in the form of heat

Energy Transfer: conversion of one form of energy into another

Combustion: the process of burning

Fuel: material that is burned to produce heat or power

Drying: the process of removing water

Pyrolysis: decomposition caused by heat

Flaming Pyrolysis: decomposition caused by heat that creates a flame

Char: carbon material left after intensive heating or combustion

Ash: the powdery mineral residue left after burning

Aerosols: tiny droplets of liquid in a gas

Vapor: a compound in its gas phase

Soot: tiny black carbon particles produced by incomplete combustion

Extinguish: to put out a fire or stop combustion

Carbon Monoxide (CO): an odorless, colorless gas that is toxic to humans and animals

Carbon Dioxide (CO₂): a colorless, odorless gas produced by burning carbon

Oxidizer: a material that can supply oxygen for a combustion process

Ignite: to cause something to burn or start a fire

Decompose: to break down into smaller components

The Science of Combustion

Set Up

Set up “Science of Combustion” PowerPoint to introduce students to the stages of a combustion process. The activities on the slides are to be done in pairs or groups of three to promote student engagement when answering the questions. After the lesson, set up the marshmallow toasting activity using the guidelines provided in the lesson plan for safety.

For online lesson delivery, follow the notes in the lesson plan and the process outlined on the PowerPoint slides. Synchronous delivery is suggested over providing pre-recorded material. For the S’mores activity, use the marshmallow toasting in an oven demonstration video to make the observations and to do the activity remotely.

Lesson Procedure

Follow the PowerPoint as a guide to the lesson.

1. Present the PowerPoint “The Science of Combustion”.
2. Pose questions to students embedded in the presentation.
3. Have students do the S’mores activity outside with grill/fire pit while adding observations to the Combustion Worksheet.
4. Discuss observations and follow-up questions from the worksheet.
5. Have students make posters of the stages of combustion using vocabulary provided.
6. Have students do a “gallery walk” of the posters to give feedback and reinforce concepts.

Part 1 (45 to 60 minutes): Presentation with discussion, outline posters as pairs or groups of 3

1. Setup Science of Combustion PowerPoint presentation.
2. **Slide 3:** Ask students the warm-up questions.
3. **Slide 4:** After the students have answered the questions, give examples of how fire helps.
4. **Slide 5:** Explain that natural wildfires are a part of the natural ecosystem. Give instances where wildfires could occur. Explain the benefits of natural fires to an ecosystem. (This is the connection of the lesson to arid land regions.)
5. **Slide 6:** Watch video(s) and ask the students to write observations: What would you smell? Hear?
6. **Slide 7:** Ask the ignition question for the students to discuss. This is the introduction to the fire triangle.
7. **Slide 8:** Introduce the fire triangle; ask students to brainstorm ways to prevent a fire from starting.
8. **Slide 9:** Identify the 4 stages of combustion. The discussion of combustion parameters may be a good time to review temperatures scales, with questions like: What is the boiling point of water?
9. **Slides 10-13:** Explain the key differences in each stage of combustion.
10. **Slide 14:** Ask the question: What is left over after a fire?
11. Discuss problems with fire and associated solutions:
 - **Slide 15:** Discuss the challenge of fuel/fire not being hot enough.
 - **Slide 16:** Explore carbon monoxide (CO), the dangers of CO poisoning, and methods to prevent CO. Use the Chemical Reaction Decoder Document to explore the use of formulas with students.
- Slide 17-19:** Smoke: how to use an afterburner to reduce the smoke to a clean stack; explain the difference between aerosols, soot/particulates, and vapors. Chemical equations of incomplete and complete combustion are shown using propane (C₃H₈) as the fuel (which is common in grills and some home heating furnaces). Point out that incomplete combustion produces molecules that we do not want, such as carbon monoxide and soot/carbon. Highlight that less oxygen and less heat (energy) in a combustion can create these undesirable products (the numbers of oxygen molecules are circled to help illustrate the pattern). Emphasize that more heat helps convert the fuel into carbon dioxide (CO₂), the product of complete combustion. Using an afterburner helps enable a “clean stack” (only H₂O and CO₂) from propane by providing more heat and oxygen. Note: for expanded information on chemical reaction equations, please refer to the *Chemical Reaction Decoder* (available to download) for reference.
12. **Slides 20-21:** Introduce biomass as a fuel source for the combustion process and give examples of biomass.
13. **Slide 22-23:** Introduce oxidizers to provide oxygen for combustion in environments which do not have enough oxygen, such as under water or in outer space. Explore how some chemicals decompose to provide oxygen. Example: magnesium nitrate (Mg(NO₃)₂) decomposes in water to give oxygen.

The Science of Combustion

Lesson Procedure (*continued*)

14. **Slide 24:** Introduce fire extinguishers. Ask the question: Using the fire triangle, how does a fire extinguisher stop a fire?
15. **Slide 25:** Ask the students what they can do to limit man-made wildfires using the fire triangle.
16. **Slide 26:** Set-up the activity and handout Combustion Worksheet. Ask students to write down the observations using sight, smell, sound, touching (feeling the heat), and taste (change of flavor of marshmallow).
17. If time is available, begin poster outlines: Set-up fire triangles and/or stages of combustion showing the conversion from chemical to thermal energy.

Part 2 (30 to 60 minutes): S'mores activity with Combustion Worksheet

Note: Be aware of potential food allergies/dietary restrictions: may need gluten-free crackers, vegan marshmallows, or alternative "toast-able" food.

1. S'mores activity
 - Using a fire pit with logs
 - a. Using lighters/matches, start the campfire.
 - b. Supply and explain the worksheet to students.
 - c. Split students into two groups: one group to observe fire and one for toasting marshmallows/eat S'mores.
 - d. Ask students to assemble "S'more site" (plate + graham cracker + chocolate).
 - e. Have students taste uncooked marshmallows and write observations of smell, taste, texture.
 - f. Provide sticks to toast the marshmallows.
 - g. For observing group, add a new log to the fire to observe the 4 stages of combustion on the worksheet.
 - h. For toasting group, have the students carefully toast the marshmallows using the stick over the fire.
 - i. Have students observe the changes to the marshmallow.
 - j. After the marshmallow has been toasted, place the marshmallow in on a piece of graham cracker + chocolate and place the other graham cracker on top, making a "sandwich."
 - k. Let students eat their S'mores.
 - l. Repeat d through k, switching groups so all students make a s'more & record observations.
 - m. Extinguish fire and clean up using wet wipes.
 - Propane/butane grill
 - a. Using lighters/matches, start the grill.
 - b. Supply and explain the worksheet to students.
 - c. Split students into two groups: one group to observe fire and one to eat/toast marshmallows.
 - d. Ask students to assemble "S'more site" (plate + graham crackers + chocolate).
 - e. Have students taste uncooked marshmallows and write observations of smell, taste, texture.
 - f. Provide sticks to toast the marshmallows.
 - g. For observing group, using tongs and hot material gloves, hold a wooden stick over the grill while holding a metal pan under the stick.
 - h. Once the stick has ignited, hold the stick where students can see and allow to burn it until it goes out.
 - i. Repeat with second stick after students have had a minute or two to write observations.
 - j. For toasting group, have the students carefully toast the marshmallows using the stick over the fire.
 - k. Have students observe the changes to the marshmallow.
 - l. After the marshmallow has been toasted, place the marshmallow on a piece of graham cracker + chocolate and place the other graham cracker on top, making a "sandwich."
 - m. Let students eat their S'mores.
 - n. Repeat d through m, switching groups so all students make a s'more and record observations.
 - o. Extinguish fire and clean up using wet wipes.

Lesson Procedure (*continued*)

2. Review observations and compile follow-on questions (This might be a good time to incorporate resources from firefighting/fire safety components or similar topics.)
3. Remind students to complete Combustion Worksheet.

For online delivery, have students to watch the following videos to make observations of the stages of combustion and for the marshmallow toasting activity.

1. Videos for observations:
 - How to roast your marshmallows in your kitchen without fire (6:11)
https://www.youtube.com/watch?v=0yEKP_1GTzI
 - The beautiful combustion that occurs when you build a matchstick log cabin on a stovetop (1:38)
<https://www.youtube.com/watch?v=HCFvZ6YI25M>
2. Video for toasting marshmallow in the oven if this is possible for the student/family:
 - S'mores| In Your Oven at Home S'mores! (1:58)
<https://www.youtube.com/watch?v=PUM19kLDpgg>

Part 3 (50 minutes): Use the worksheet and collected pictures from fire pit/grill to make combustion posters. After completing the posters, conduct a gallery walk for all students.

1. **Make posters:** encourage students to include as many of the combustion vocabulary words as possible on their drawings/diagrams.
 - a. Option A: General combustion poster
 - Posters should include at least 3 vocabulary words from the lesson.
 - b. Option B: What happens when you burn plastic/paper?
 - Students create descriptive illustrative model using imagery and words from activity.
 - c. Option C: Design of a new fire extinguisher or personal protective equipment (PPE) that would be useful when working with fire.
 - Students create descriptive illustrative model using imagery and words from the activity.
 - d. Option D: Online/remote learning
 - Students create informational poster or PowerPoint slide(s) on the connections between of arid lands and combustion.
2. **Do gallery walk of posters:** connect to fire safety/firefighting, and/or allow time for poster revisions:
 - a. Give each poster a number and assign specific poster numbers to each student (as a way to make semi-anonymous.)
 - b. Have each student review 2-3 posters each time making 4 sticky notes:
 - i. Count the number of vocabulary words and check if the words were used correctly.
 - ii. Make one suggestion of how to make labels clearer.
 - iii. List an aspect of the poster that was well-done/helpful.
 - iv. Offer one suggestion to improve the poster.
3. **Closing**
 - For poster revisions, have students add or correct vocabulary based on suggestions they received during gallery walk.
 - If possible, review information learned in this lesson and connect with other curriculum or events such as fires reported to the public.

Author Biographies

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