UNIT: H02-1 TITLE: The Fire Triangle Part 1- Heat and Fuel

TYPE: Lesson Plan

This activity is based on the US Forest Service's "FireWorks Northern Rocky Mountains & Northern Cascades" Curriculum

Overview

This lesson builds upon the understanding of fire as a chemical change by introducing the fire triangle. The fire triangle can be used to more easily understand the combustion process associated with fire. In this activity, students are introduced to the fire triangle conceptual model. After becoming familiar with the three components of the fire triangle (heat, fuel, and oxygen) students will explore it experimentally. This activity focuses on the necessity of fire to have fuel and an ignition/heat source.

Subjects: Science, Mathematics, Writing, Speaking and Listening, Health and Safety

Duration: 45 minutes

Group Size: Groups of 2-4

Setting: Classroom for introduction, laboratory for activity

Vocabulary: Conceptual Model, Fire Triangle, Heat, Fuel, Oxygen, Chemical Change, Physical Change

Lesson Goals:

Introduce students to a conceptual model so they understand the scientific importance of such models.
Increase students' understanding of fire as a process of chemical change.

Objectives:

- Students can describe the importance of conceptual models.
- Students can describe the chemical change that occurs in combustion.
- Students can explain why combustion is a chemical change.
- Students can list the three components of the fire triangle and can describe the importance of each.

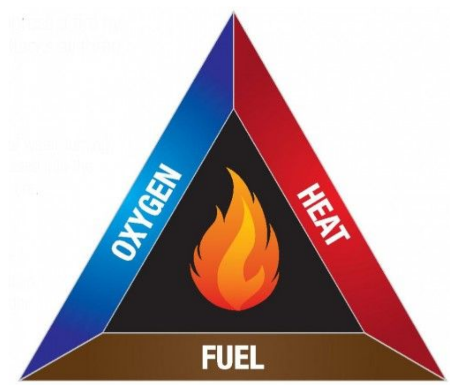
Anchoring Phenomena: Why does the heat plume from a fire have the shape it does?

Academic Standards:

Standards	High School (9-12)

NGSS – Disciplinary Core Ideas	**HS-PS1 Matter and Its Interactions**	• PS1.A, PS1.B
	HS-PS3 Energy	• PS3.D
	HS-LS1 From Molecules to Organisms	• LS1.C
NGSS – Performance Expectations	**HS-PS1 Matter and Its Interactions**	• HS-PS1-7

Teacher Background:



This activity explores the chemistry of combustion as described by a **conceptual model** called the **fire triangle**. A fire cannot start without three things: **fuel**, **oxygen**, and a **heat/ignition** source. If a fire runs out of any of these three, it will stop. The three requirements for fire are conceptualized in the "Fire Triangle." In science, a conceptual model is a simplified representation of a concept or of concepts related to a phenomenon. Often depicted as diagrams, conceptual models show processes or describe the relationships between concepts or factors essential to a phenomenon. The fire triangle is an appealing model because the geometric properties of the triangle are a good analog to the requirements for combustion: triangles are very stable as long as all three sides are present (so stable, in fact, that triangles are used in the construction of buildings, furniture, and many other structures). However, a triangle will collapse if one side is removed. Firefighters use the fire triangle to extinguish fires. To manage tallgrass prairies with fire, this conceptual model is employed to insure fire is possible in a given area usually by focusing on the presence or absence of fuel.

Using a model based on a triangle is appealing because it provides an easy way to introduce students to the **chemical change** of combustion. To review, a **physical change** occurs when a specific molecule/substance/material undergoes a change or changes form without the molecule/substance/material having its unique chemical identity changing. The most well-known physical changes are phase changes such as boiling (vaporization)/condensation and melting/freezing. Physical changes also include transformations such as breaking, crushing, tearing, cutting, and shredding. For a transformation to be a chemical change, the original unique chemical identity of a material/substance must change to a different chemical identity as a result of a chemical reaction. Examples include burning, rusting, cooking, digestion, and photosynthesis. The three sides of the fire triangle actually represent the three chemical equation "inputs" necessary for combustion which can be used as a simple example of a chemical change. One of the simplest combustion reactions is as follows:

$CH_4 + 2O_2$ + Heat → $CO_2 + 2H_2O$ + Heat & Light

In this chemical reaction, chemical changes have occurred. Methane (CH_4) reacts with oxygen (O_2) when there is enough heat present to produce carbon dioxide (CO_2), water vapor (H_2O), and heat and light. The arrow represents the "direction" of the reaction. Notice how the atoms of carbon, hydrogen, and oxygen in the reactants (CH_4 and O_2) are combined and rearranged into completely different products (CO_2 and H_2O). Combustion, therefore, is a chemical change. As part of this activity's introduction, students will use the simple combustion reaction above not only to learn about chemical change but also to review the Law of Conservation of Matter; each element's number of atoms must be the same on "both sides of the arrow." For example, there are a total of four atoms of oxygen on the reactant side of this chemical reaction, and there are a total of four atoms of oxygen on the product side.

$$CH_4 + 2O_2 + \text{Heat} \rightarrow CO_2 + 2H_2O + \text{Heat \& Light}$$

The number of oxygen atoms on both sides of the arrow being equal demonstrates the Law of Conservation of Matter; matter can neither be created nor destroyed. Matter can't disappear from a chemical reaction, and it can't appear from nowhere. Whatever is present "before" must also be present "after."

It is important to recognize the similarity between two of the most important chemical reactions in biology, photosynthesis and cellular respiration.

$6CO_2 + 6H_2O$ + Solar Energy → $C_6H_{12}O_6 + 6O_2$
(photosynthesis)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy
(cellular respiration)

The most obvious difference between photosynthesis and cellular respiration is the direction of the arrow. Furthermore, the combustion of vegetative biomass, composed primarily of cellulose, is very similar to cellular respiration because cellulose is composed of long chains of glucose molecules. This is discussed briefly in the slideshow for this lesson.

Table 5: Key Terms

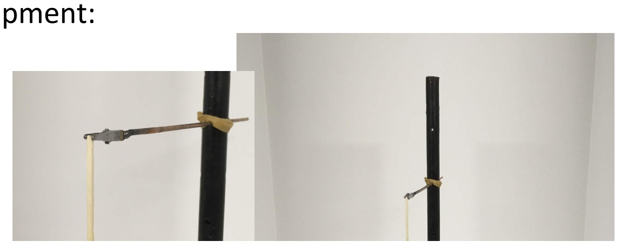
Conceptual Model	In science, a simplified representation of a concept or of concepts related to a phenomenon. Often depicted as diagrams, conceptual models show processes or describe the relationships between concepts or factors essential to a phenomenon.

Fire Triangle	Conceptual model that depicts the relationship between fuel, oxygen, and heat that is necessary for fire to occur.
Heat	In the fire triangle, “heat” is a source of energy that raises the temperature of fuels to the point that they spontaneously react with oxygen through combustion. Typical heat sources that can produce fire include lightning, sparks, and flames.
Fuel	Any material that will react with oxygen through combustion when its temperature reaches the ignition point for that material. Easily recognized fuels include fossil fuels and vegetative biomass (grasses, wood, etc.).
Oxygen	To be involved in combustion, as depicted in the fire triangle, oxygen must be in its gaseous, diatomic form, O_2. About 21% of the gas in Earth’s atmosphere is O_2.
Chemical Change	A process whereby the unique chemical identity of a material/substance is converted into a different chemical identity. Such a process is often referred to as a chemical reaction.
Physical Change	A transformation in which a specific molecule/substance/material undergoes a change or changes form without the molecule/substance/material having its unique chemical identity altered. Phase changes are excellent examples of physical changes.

Materials and Preparation:

This activity can be easily combined with “The Heat Plume of Fire.” Determine the location where this activity will be conducted. Understand that this activity can produce flames that are 10-20 centimeters long. The following considerations should have already been addressed when preparing for “The Heat Plume of Fire:”

- Can this activity been done safely in the area you have chosen?
- Are smoke detectors present? It may be necessary to contact school staff that can address any concerns related to smoke detectors/fire alarms.
- If there are safety issues, a different location will be needed such as a chemistry laboratory with appropriate ventilation or a welding shop.
- It will be very difficult to perform this activity outside since even the slightest wind will blow out a single match and will dramatically influence the behavior of a heat plume.
- To continue,
- Display the FireWorks Safety poster so it is visible in the area where the activity will be conducted.
- The day before doing this activity, remind students to follow the safety guidelines about clothing and hair when they prepare for school.
- Be sure to have a stove lighter and enough matches for all groups for each class.
- Make enough copies of the student worksheet for each student.
- Be sure that the laboratory area has a fire extinguisher that is fully charged.
- Place a metal trash can or bucket without a plastic liner in the laboratory area.
- Set up laboratory stations with the following equipment:
    - Spray bottle, filled with water
    - Box of matches



- Stove lighter
  - Ruler
  - Metal tray
  - Safety goggles/glasses for each student
  - Leather gloves or oven mitt
  - Tree model stand (or ring stand with clamp holder)
  - Cross-piece with alligator clip
  - Rubber band (to "stabilize" cross-piece)
  - Students will use a smartphone as a stopwatch
- Set up the tree model stand and cross piece as shown above. Be sure that the tree model stand is placed on a metal tray.
- To set the system up for the first trial, clip a match to one end with the ignitable tip pointing down as shown above.

Procedure:

- Hand out the student worksheets.
- Present "The Fire Triangle (Part 1) - Heat and Fuel" slideshow.
- Have students complete the investigation according to their worksheets.
- As groups finish the activity, be sure that each station has been cleaned and organized appropriately. The stations should either be ready for the next class/group or "broken down" per teacher instructions.
- Once again, be sure all matches are out before disposing of them. Use the metal bucket in the activity area for match disposal. If in doubt, use the station's spray bottle to wet the matches before putting them in the metal bucket.
- Time permitting, it might be a good idea to quickly go over student worksheet responses by referring to the "Key for Student Worksheet."

Assessment:

Student Worksheet

- **Sample quiz/review questions for the "Fire Triangle"**

1) Which of the following is not one of the three components of the fire triangle?
   a) Heat
   b) Fuel
   c) Hydrogen
   d) Oxygen

   Answer: c

2) A balanced chemical equation reflects which scientific "law?"
   a) Law of Conservation of Energy
   b) Law of Conservation of Matter
   c) Law of Gravity

d) Laws of Thermodynamics

Answer: b

3) Which of the following is the balanced chemical equation for photosynthesis?

a) $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$ + Energy
b) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy
c) $CO_2 + H_2O$ + Solar Energy $\rightarrow C_6H_{12}O_6 + O_2$
d) $6CO_2 + 6H_2O$ + Solar Energy $\rightarrow C_6H_{12}O_6 + 6O_2$
e) $CH_4 + 2O_2$ + Heat $\rightarrow CO_2 + 2H_2O$ + Heat & Light

Answer: d

4) Which of the following is **not** an example of a chemical change?

a) Ice melting
b) Metal rusting
c) Photosynthesis
d) Trees burning
e) Cellular respiration

Answer: a

5) For most terrestrial systems, which of the following is usually the factor that keeps fires from occuring all the time?

a) Availability of a source of heat to produce ignition
b) Availability of oxygen
c) Availability of fuel
d) Availability of a well-trained, prescribed fire crews

Answer: a

Evaluation:

- **Student Worksheet**
  - A key for the student worksheet can be found as a separate document entitled “Key for Student Worksheet.”
- **Sample quiz/review questions for the “Fire Triangle”**
  - Answers provided with the questions in the **Assessment** section.

Extensions:

Collecting data about matches burning at various angles is recommended if the matchstick forest lesson is not planned on being used. Suggested angles would be 90° (match pointing upward), 45°, 0° (horizontal), -45°, and -90° (match pointing downward).

References/Resources:

None for this activity.