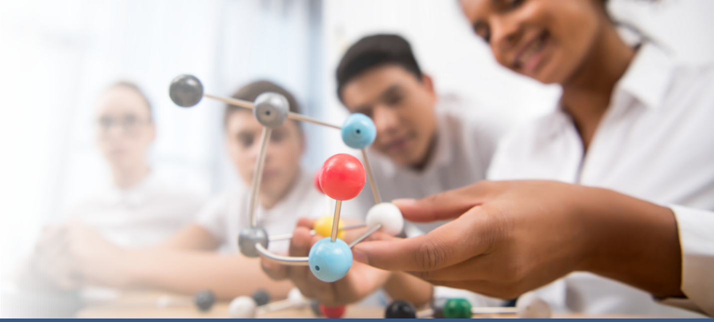
STEM Careers Coalition



CLASSROOM ACTIVITY

Combustion of Hydrocarbons

OBJECTIVES

Students will be able to:

- **Build** reactants and products of several combustion reactions.
- **Calculate** the energy needed for each bond that is broken and formed during the reaction.
- **Determine** if the reaction is exothermic or endothermic.

OVERVIEW

In this activity, students will examine the varying amounts of energy produced by the combustion of different hydrocarbons. They will observe how oxidation plays an important role in how we obtain energy from fossil fuels. They will use common household materials or molecular model kits to build the reactants and products during a combustion reaction. Finally, students will calculate the bond energies for the combustion of various hydrocarbons.

NATIONAL STANDARDS

Next Generation Science Standards

- **HS-PS1-4 Chemical Reaction**
  Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the energy changes in total bond energy.
- **HS-PS1-7 Chemical Reactions**
  Use mathematical representations to support the claims that atoms, and therefore mass, are conserved during a chemical reaction.

BACKGROUND

A hydrocarbon is an organic chemical compound composed exclusively of hydrogen and carbon atoms. They are naturally occurring compounds that are found in fossil fuels like petroleum, coal, and natural gas. Energy is stored in chemical compounds in the bonds that bind atoms to each other. When fossil fuels are burned during combustion, the hydrocarbon molecules are converted to carbon dioxide, water, and released energy. Fossil fuels made it possible for countries to convert from an agricultural economy into an industrial economy during the industrial revolution. The industrial revolution paved the way to our modern society and changed the way humans do everything. Society is driven by the need to produce energy to make products (manufacturing), to move around (transportation), to heat homes and buildings, and to create light (electricity). Fossil fuels have accounted for about 80% of U.S. energy production in the past decade.

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KEY VOCABULARY

- Combustion
- Endothermic
- Exothermic
- Hydrocarbons
- Bond Energy
- Law of Conservation of Matter

MATERIALS

- Molecular model kits
- If model kits are not available—Styrofoam balls, pipe cleaners, candy, or toothpicks could be used

TEACHER PREPARATION

- Select 8 to 10 images of hydrocarbons and create a digital collage of the images
- Copies of *Energy of Combustion* for each student
- Pliers (for the removal of stubborn bonds)

PROCEDURE

1. Explain to students that they will be examining images of several types of molecules. Display the collage and provide 1 minute for students to write a list of observations based on what they see. Have students review their lists, highlighting words that are common to more than one image. Put students into pairs and provide 1 to 3 minutes for partners to compare their lists and discuss potential connections between the images. Invite students to share their observations with the class.
2. Explain that a hydrocarbon is an organic chemical compound composed exclusively of hydrogen and carbon atoms. They are naturally occurring compounds that are found in fossil fuels like petroleum, coal, and natural gas. Energy is stored in chemical compounds in the bonds that bind atoms to each other. When fossil fuels are burned during combustion, the hydrocarbon molecules are converted to carbon dioxide, water, and release energy.
3. Explain to students that different hydrocarbons produce different amounts of energy when combusted or burned. Place students into small groups of 1-3 and explain that they will work together to determine how much energy is produced from the combustion of different hydrocarbons.
4. Share with the students that the combustion of all fossil fuels follows a very similar reaction: fossil fuel (any hydrocarbon) plus oxygen yields carbon dioxide and water and energy. Explain that energy is stored in chemical compounds in the bonds that bind atoms to each other.
5. Demonstrate how to build an oxygen molecule with the molecular model kit. Explain that it takes energy to break the double bond between the two oxygen atoms. It takes 494 kJ to break the double bond. This process is endothermic because energy is required to break the bonds. When energy is required, we express this value as a positive number.

6. Demonstrate how to build carbon dioxide, one of the products of a combustion reaction. Explain that the formation of a new bond is an exothermic process where heat is given off. The formation of carbon dioxide releases 1598 kJ to form the bonds in the molecule. When energy is released, we express this value as a negative number.
7. Distribute the *Energy of Combustion* worksheet to each student and state that they will determine how much energy is produced by the combustion of different hydrocarbons.
8. Explain to students that they will work together to balance each equation and use the molecular model kits to build the total reactants and total products required for the reaction to occur. They will examine each reactant molecule built, identify the bonds in each molecule, and calculate the energy required to break each bond using the *Bond Energy Chart*. Then, they will examine each product built, identify the bonds in each molecule, and calculate the energy released when forming each bond. They will calculate the net energy released from the reaction. All calculations can be placed on the *Energy of Combustion* capture sheet.
9. Methane has been completed on the *Energy of Combustion* capture sheet as an example. Demonstrate how to balance the equation by counting the total number of atoms for each element on the reactant side and the product side. Remind students that equations must be balanced to accurately reflect the law of the conservation of matter.
10. Invite two students to build the molecules for the combustion of methane. One student can build the reactants and the other can build the products.
11. Use the models the students built to demonstrate how to identify each bond and determine the amount of energy required to be broken or the amount of energy released when formed. Demonstrate how to calculate the net energy of the reaction by subtracting the total energy released from the total energy required. State that a negative number indicates an exothermic reaction.
12. The teacher should walk around the room to answer questions that students may have. Students may also need help balancing equations and calculating the energy required or released.
13. To close the activity, explain that this lesson is one of the many topics engineers would study. Share with students that engineers work in a variety of fields to analyze, develop, and evaluate large-scale complex systems. Companies from around the world are making sure that students like you are aware of the opportunities to earn a quality education in various careers.
14. Invite students to explore the oil and gas career guide using the following link. (IN THE NATURAL GAS AND OIL INDUSTRY) Have them review the engineering positions that are available. After they read each engineer's career description and review the education requirements and median salary, have them select the top two that seem the most interesting to them.

EXTENSION

Explore ways we use energy in daily life. Start here with a good overview from the National Academies: http://needtoknow.nas.edu/energy/energy-use.

ENERGY OF COMBUSTION

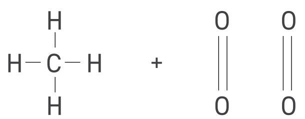
Fuel (any hydrocarbon source) + O_2 → CO_2 + H_2O + energy

Directions: Complete the following steps for each hydrocarbon.

1. Balance the equation.
2. Build the reactants.
3. Use the *Bond Energy Chart* to calculate the energy required to break the bonds of the reactants.
4. Build the products.
5. Use the *Bond Energy Chart* to calculate the energy given off in the formation of new bonds in the products.
6. Calculating the net energy of the reaction.

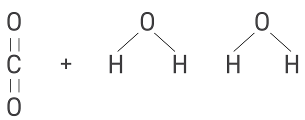
Example: Combustion of Methane: $CH_4 + O_2 \rightarrow CO_2 + H_2O$

1. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

2. 

3. CH_4 C-H 4 x 410 kJ = +1640 kJ

   O_2 O=O 2 x 494 kJ = +988 kJ

4. 

5. CO_2 C=O 2 x 799 kJ = -1598 kJ

   H_2O O-H 4 x 460 kJ = -1840 kJ

6. Energy required = +2628 kJ

   Energy released = -3438 kJ

   Net energy = -810 kJ

Bond Energy Chart	
Bond	**Bond Energy (kJ/mole)**
H-H	432
O=O	494
O-H	460
C-H	410
C-O	360
C=O	799
C-C	347
C=C	611
N=O	623

ENERGY OF COMBUSTION

Combustion of Ethane	$C_2H_6 + O_2 \rightarrow CO_2 + H_2O$
Balanced Equation	
Energy Required	
Energy Released	
Net Energy	

Combustion of Propane	$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
Balanced Equation	
Energy Required	
Energy Released	
Net Energy	

Combustion of Ethanol	$C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
Balanced Equation	
Energy Required	
Energy Released	
Net Energy	

Combustion of Iso-Octane	$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$
Balanced Equation	
Energy Required	
Energy Released	
Net Energy	

Analysis Questions

1. Rank the hydrocarbons from the most amount of energy released to the least.

2. Describe the property of oxygen that allows it to be an oxidizing agent.

3. Why are hydrocarbons good fuel sources?