UL XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

EDUCATOR

INVESTIGATION 3: ENERGY

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

AGE GROUP
Middle School

CATEGORY
Fire Forensics

COMPLETION TIME
2 - 4 Class Periods

Enduring understanding: To investigate a fire, we must first understand ignition and combustion principles. To solve a case, we must understand how to build a claim supported by evidence and reason.

INVESTIGATION 3: ENERGY AND COMBUSTION

Note: Includes video of fire and fire-related data; optional burn of small materials in controlled lab setting.

FIRE INVESTIGATORS MUST UNDERSTAND:

- Heat of combustion of different common household materials.

When fire investigators know how different fuels ignite and combust, they can better understand a burn scene and can build stronger claims based on knowledge of types of evidence and patterns of fuels.

Exploration: What is heat of combustion (HoC) and how is it measured?

The TESTABLE question guiding our investigation is:

- Does the material the fuel is made of effect the amount of energy released during combustion?

Essential knowledge and skills

We will look for students to understand:

- How to analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. (MS-PS1-2)

- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary to MS-PS1-4)

We will look for students to be able to:

- Construct, use and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. (MS-PS3-5)

ASSESSMENT: This understanding looks like:

- Students can make a claim supported by evidence collected through visual observations and supported by reasoning based on understandings of the heat of combustion of different materials.

- Students can apply knowledge and elaborate on reasons that it is important for firefighters and investigators to understand heat released by different materials.

SUMMARY OF LAB

Students watch the interactive video of our UL Fire Experts in the fire research lab to make observations of the timing, behavior and smoke of different fuels as they burn. The video continues with the building of a calorimeter to measure the heat of combustion from common household materials. If your classroom has the proper ventilation and equipment, directions are provided for building a calorimeter for classroom investigation.

Please take all precautions for safety as recommended for middle school lab classrooms. If you do not have the proper equipment or ventilation for fire testing, please use the video as it demonstrates the concepts and allows for students to make predictions and see results.

eXPLORING THE ISSUE: BACKGROUND INFORMATION

In previous Fire Forensics investigations, we learned that only gases burn, solids do not burn. When a solid is heated, it gives off fuel gases, which are flammable. This process is called **pyrolysis**.

We also learned that synthetic materials burn a lot faster than organic materials. We learned that the mass and density of materials may enable them to ignite and burn at different rates – meaning that we can change how easy it is (or how much energy is required) to ignite a material, like wood, based on the shape and size of the wood, or the form that it is in. This is called the **surface-to-mass ratio.**

Now, we want to investigate the heat released when different fuels burn, and measure the heat released by household materials and foods using a process and calculation for the ***heat of combustion.***

HEAT RELEASED AND HEAT OF COMBUSTION

What's the difference between temperature and heat? According to the National Fire Protection Association (NFPA):

- **Temperature:** The degree of sensible heat of a body as measured by a thermometer or similar instrument.
- **Heat:** A form of energy characterized by vibration of molecules and capable of initiating and supporting chemical changes and changes of state.

Heat of combustion is the energy released from a fuel while it is burning with oxygen at standard temperature and pressure. This is a primary difference between heat and temperature. For example, think of a candle flame and a campfire or fire in a fireplace. The flames of different sizes may be the same temperature, but the energy released is different. In addition to the potential energy of the material, the amount of energy released is also based on the oxygen consumed during combustion.

When you eat food, your body burns calories – or the potential energy stored in the food. You breathe in oxygen, then oxidize and digest the food you consumed. Your body moves around and sweats because you are hot, generating heat and burning the calories you consumed. Some foods are more efficient fuel than others.

Fire is a rapid oxygenation process that gives off a relative amount of heat. The ***calorimeter*** is a simple tool used to measure the heat released by burning objects – both food and common objects found in homes and buildings.

To determine the HoC of a fuel (material), we can use a simple calorimeter. A ***calorimeter*** measures the energy released during a chemical reaction (fire) or phase change (in objects like food or a household item).

We will burn objects under a can of water. The temperature change in the water provides a rough measurement of HoC, the heat generated and transferred to the water from the can during combustion. We will record the temperature change in the water.

The material or sample being burned is the fuel. The fuel is releasing energy as it burns under the can. This transfer of energy is mostly due to convection – the energy from the hot gases are transferred to the can via convective heat transfer. The can transfers the energy to the water and we can measure the temperature change of the water. When the flame touches the can, it is a conductive heat transfer. The light energy from the flames to the can is radiation heat transfer.

Everything burned in this investigation is found in homes, including wood and food. Fire investigators need to know how different common household items burn so when they arrive at a fire scene and enter a room where everything is rubble, they can sift through the debris and determine what was on fire, how it burned, and understand the patterns of the burn scene around them. When fire investigators investigate the evidence left behind from different fuels, they have to know how the fuels reacted in the fire, if they were insulators or conductors of heat, and how to use this information to trace back to what the fuel was that burned.

The rate of ignition is the speed and ease that the object catches on fire. Understanding the rate of ignition and combustion of common household items helps make safer spaces. Materials may have a different rate of ignition and burning, depending on if they are organic or synthetic items. Furniture made of wood will be a different kind of fuel source than furniture made of foam plastic or synthetic upholstery.

CALORIMETRY

A calorie is a unit of energy. A calorie equals the amount of energy per unit mass required to raise the temperature of 1 gram of water by 1 degree Celsius. When looking at food labels, a food Calorie is equal to a kilocalorie or 1,000 calories.

Specific heat is the measure of the heat capacity of a material on a unit mass basis. Heat capacity is another way of saying how much heat a material can absorb (store) per gram (or kilogram or pound) before the temperature changes.

- Specific heat is equal to the amount of heat needed to raise the temperature of one kilogram of mass by 1 Kelvin.

In terms of calories -- the Specific Heat of Water is equal to 1 calorie per gram per degree Celsius.

In terms of Joules the specific heat of water is equal to 4.179 joules per gram per degree Celsius.

Setup a simple calorimeter in your classroom for this investigation if you have proper lab ventilation and fire-retardant surface.

Please take all the precautions for safety as recommended for middle school lab classrooms. If your classroom does not have the proper equipment or ventilation for fire testing, please use the Xplorlabs Videos from Investigation 3. The video demonstrates the concepts and allows for students to make prediction and see results.

Part A. eXPLORATION

Does the material the fuel is made of effect the amount of energy released during combustion?

MATERIALS

(one set per group of students or one set for teacher's demonstration)

- Investigation 3 Video
- Student Xplorlab pages
- Beaker or soda can
- Graduated cylinder (to measure water)
- Water (50 mL)
- Small digital thermometer
- Beaker stand (to hold beaker) or ring stand (to hold can)
- Paper clip or straight pin
- Cork

- **Assortment of real fuels found in the interior of a home**
  - **o Wood***
  - **o Foam insulation**
  - **o Carpet**
  - **o Gypsum board**
  - **o Scraps of carpet padding**
  - **o Wood paneling**
  - **o Plastic plumbing pipe**
  - **o Upholstery fabric**
- **OR Assortment of food items**
  - **o Cheese curls***
  - **o Marshmallows***
  - **o Potato chips**
  - **o Hot dog pieces**
  - **o Baloney pieces**

*Materials used in Xplorlabs Video Investigation 3
Caution: Home materials can give off smoke even when burning small samples.

PROCEDURE

Prepare materials by weighing each material – record starting mass of each material in **Table 1**.

Make a prediction about the object's stored energy: will it have a higher heat of combustion (HoC) or a lower HoC than the other objects? Why?

**Helpful tip for teachers: Watching the video before conducting the experiment will be helpful to see the setup of the calorimeter.*

1. Pour 50 mL of water into soda can or beaker. (Your table will ask for the Mass of Water in grams. Hint: 1 mL = 1 g. mL is a unit of measurement for volume; g is a unit of measurement for mass.)

2. Use a paper clip to create a stand for the sample.

3. Record the name of Sample 1 food/material (object burned) and its mass in grams in the data table.

4. Place Sample 1 on the paper clip securely so that the cork balances and isn't easily knocked over. Place this item in the center of a metal jar lid or on a non-flammable surface in case it is knocked over.

5. Place the can into a ring stand or beaker into beaker stand and lower the bottom of the can 1 inch from the Sample 1.

6. Take a starting temperature of the water in the can and record the temperature in **Table 1.**

7. Be sure there is nothing flammable surrounding the set up and check that sleeves are rolled up and hair tied back.

8. Hold the long reach lighter flame to Sample 1 and ignite Sample 1.

9. Observe the rate and type of burn including flame spread, smoke, speed of combustion.

Record observations in Table 1.

Note for teachers: The way these three samples burn are very different. The observations of these samples are an excellent way to do this lab without calculating the equations.

10. Once the sample is completely burned, record the temperature reading in degrees Celsius after it has stopped rising (peak water temperature) and record in Table 1. Use caution! Things will be hot!

11. Weigh the object with consideration for the weight of the paper clip.

12. To calculate the heat of combustion (HoC) of Sample 1, first calculate the heat absorbed by water. You will use this result in the HoC equation in Data Table 1.

Heat absorbed by water (heat released in calories) = mass of water (g) X specific heat of water (cal/g C) X change in temperature (C).

Table 1. Heat absorbed by the water (or heat released)

Object burned (Sample #)	**Starting mass of object (g)**	**Mass of water (g)**	**Starting temp of water (°C)**	**Peak water temp (°C)**	**Temp increase (°C)**	**Heat absorbed by water (cal) = heat released (cal)** heat released (cal) = mass of water (g) * mass of water (g) * change in temperature (C)	**Observations of sample during combustion**
Example: Marshmallow	1 g	50 g	28 C	37.2 C	9.2 C	460 cal	
1.							
2.							
3.							

13. To calculate the heat of combustion, complete Table 2. Enter the values for:

Heat absorbed by water (from Table 1), the beginning mass of the object before burning, the mass of the object after burning, calculate the mass loss by finding the difference between the beginning mass and mass after burning.

Calculate the heat of combustion using the equation: Heat of Combustion HoC = Heat absorbed by water (heat released)(Cal) / mass consumed (g).

Table 2. Heat of Combustion (HoC)

Object burned (Sample #)	**Heat absorbed by water (cal) = heat released (cal)** **From Table 1**	**Beginning mass (g) of sample**	**Mass of sample after burning (g)**	**Mass loss of sample (g) = mass consumed (g)**	**Heat of combustion (cal/g)** **Heat of Combustion HoC = Heat released (Cal) / mass consumed (g)**
Example: Marshmallow	460 cal	6.85 g	6 g	0.85 g	541 cal/g
1.					
2.					
3.					

*Let temp equalize/return to room temp/starting temp between each burn – does not have to be exact as calculating relative temp.

14. Using lab tongs, empty water from can in sink and add another 50 mL of water OR use a new can with 50 mL of fresh water.

15. Repeat entire procedure with samples 2-5.

GROUP ROLES (2-4 students)

THE STUFF SUPERVISOR

Gathers and cleans up materials

THE EXPERIMENT EXEC

Runs the experiment

THE DIRECTOR OF DOCUMENTS

Reads the procedure to the group and helps the group members with data collection

THE PRINCIPAL PRESENTER

Shares the group's work with the rest of the class

PROCEDURE - EDUCATOR

ENGAGE

WHAT TEACHER DOES

Ask students – what has a higher heat of combustion: a cheese curl or a marshmallow? A piece of wood or a piece of carpet?

What material ignites faster/easier – [two samples that seem obvious, but may not be]?

WHAT STUDENTS DO

Respond to prompt – hypothesis/multiple hypotheses and reasoning
A. Food
B. Carpet

EXPLORE

WHAT TEACHER DOES

Prepare materials by weighing approximately 2 grams of each material – record starting mass of each material.

**If using the Student Xplorlab pages, students will need to list the household and food items chosen for the experiment in their materials list.*

1. Make a prediction about the object's stored energy: will it have a higher heat of combustion or a lower one than the other objects? Why?

2. Follow procedure for objects 1-3.

*Let temperature equalize/return to room temp/starting temperature between each burn – does not have to be exact as calculating relative temperature.

WHAT STUDENTS DO

1. Record beginning mass of the object.

2. Predict what will happen with each material burned: will it burn longer? Have a higher HoC (more energy)? Why?

3. As products ignite and combust, make observations about how quickly the item ignites, how the flame looks, physical changes to materials etc.

4. Calculate heat absorbed by water (Table 1: Heat Released) and then the Heat of Combustion (Table 2: HoC) (see Procedure).

EXPLAIN

WHAT TEACHER DOES

Allow students to present findings and facilitate discussion.

WHAT STUDENTS DO

Present and respond:
Claim – X object contains more energy for combustion than Y object
Evidence – What is the evidence to support the claim? How did the calculations of HoC compare with the visual observations?
Reasoning – student's explanations, including if evidence supports or challenges hypothesis

PROCEDURE - EDUCATOR

ELABORATE

WHAT TEACHER DOES

How does knowing this help firefighters?
How does knowing this help fire protection engineers?
How does knowing this help fire investigators?

WHAT STUDENTS DO

Think – Pair – Share ideas on how this applies to fire fighting and fire investigation.

EVALUATE

WHAT TEACHER DOES

Using the C/E/R rubric, assess quality and accuracy of responses and provide feedback to students.

WHAT STUDENTS DO

Question: What types of fuels have higher heat of combustion?
Based on our measurements in this investigation, what can we claim about how different materials release energy as they combust?
What is our evidence for these claims?
Why is this important for fire investigators to understand?

**If time, students use the C/E/R rubric to do self-assessment or peer assessment and provide feedback to one another.*

EXTEND

EXTENSION

Follow procedure above and include other common household items, such as ceramic tile, brick, gypsum board, synthetic carpet, wool fabric, or other common items or materials found in homes.