XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

STUDENT

INVESTIGATION 3: ENERGY AND COMBUSTION

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

YOUR NAME

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 from 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 investigations is:

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

SUMMARY OF LAB

Using a video of our UL fire expert in the fire research lab, you will make observations of the timing, behavior, and smoke of different fuels as they burn. Then, build a calorimeter or continue with the video as one is built in the lab to measure the heat and energy stored in common household materials.

eXPLORING THE ISSUE

In previous Fire Forensics investigations, we learned that only gases burn because fire is a gas-phase chemical reaction. Solids do not burn in solid form. 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 the wood is in. This is called the **surface-to-mass ratio.**

In this investigation, 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. 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).

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 woods 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 (this is what we learned in Investigation 2, part B).

Part A. eXPLORATION

Testable question:
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 = 50 g)
- ◯ 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

(LIST FUELS SELECTED FOR YOUR LAB HERE):

- o ______________________
- o ______________________
- o ______________________
- o ______________________
- o ______________________

○ OR Assortment of food items

(LIST FOODS SELECTED FOR YOUR LAB HERE):

- o _____________________
- o _____________________
- o _____________________
- o _____________________
- o _____________________

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

Prepare materials by weighing each material – record starting mass of each material/fuel.

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

1. Pour 50 mL of water into soda can or beaker. (**Table 1** 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 fuel/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 burn including flame spread, smoke, and speed of combustion. Record observations in the data table.

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 HoC of Sample 1, first calculate the heat absorbed by water. You will use this result in the HoC equation in Table 2. 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) * specific heat of water (cal/g C) * 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 calorie/gram °C or 4.186 joule/gram °C*

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,
- mass loss found by caluclating 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

*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 into 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.

Table 1. Heat released

Object burned (Sample #)	Starting mass of object (g)	Mass of water in can (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 in can * change in temperature (C)
Example: Marshmallow	1 g	50 g	28 C	37.2 C	9.2 C	460 cal
1.						
2.						
3.						
4.						

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)
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1.					
2.					
3.					
4.					

CLAIMS / EVIDENCE / REASONING

Does material effect the heat of combustion (HoC)?
Based on our measurements in this investigation, what can we claim about the effect of material types on the amount of heat energy released during combustion?

What is our evidence for these claims?

What is our reasoning for the evidence?

Why is this important for fire investigators to understand?