UL XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

STUDENT

INVESTIGATION 1: THE FIRE TRIANGLE

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

YOUR NAME

INVESTIGATION 1: THE FIRE TRIANGLE

Note: Involves open flame and burning of small amounts of material in controlled lab setting.

FIRE INVESTIGATORS MUST UNDERSTAND:

- **the three things fire must have to burn**
- **the fire triangle**

Fire fighters and fire investigators need to know basic fire science to both fight fires and to uncover the source of a burn.

Exploration: What are the three things a fire must have to burn?

The TESTABLE question guiding our investigations is:

- **What is the effect of limiting one leg of the fire triangle?**

SUMMARY OF LAB

Using a candle, you will conduct four experiments to limit one side of the fire triangle at a time – oxygen, fuel, and heat - to understand the needs of fire. Then, using a metal screen, you will look at a candle flame to observe combustion.

SAFETY CONSIDERATIONS

- **Hair pulled back and sleeves rolled up**
- **Safety glasses on**
- **Fire retardant surfaces – table tops or go outside in schoolyard on open concrete or asphalt avoiding vegetation and structures overhead**

eXPLORING THE ISSUE

The fire triangle is defined by the three needs of fire – oxygen, fuel, and heat.

A BURNING CANDLE

When we light a candle, the oxygen is provided by what is in the room. The fuel is the solid wax, and the heat is from the burning wick.

LIMITING OXYGEN

Oxygen is supplied by what is available in the atmosphere – 21% of room air is comprised of oxygen. The rest of air is made up of nitrogen, an inert gas that does not burn. When a glass is lowered over the candle flame and a gap is left open between the table and the glass, the smoke pushes out underneath because the hot gases inside the glass expand and create a higher pressure than the atmosphere. The higher pressure will not let the oxygen in even though there is a gap at the bottom of the glass.

LIMITING FUEL

The candle flame's fuel is provided when the wax is heated. Solid wax doesn't provide the fuel, it is only melted wax that is providing flammable gases that burn. To limit fuel to the candle's flame, a flat piece of aluminum foil slid between the wick and the melted wax cuts off the amount of heat that can get back to the wax by closing the gap around the wick. Without heat, the fire's fuel supply is limited and heat can't get back to generate more fuel to the fire.

Another way to explore this is by observing smoke, a product of combustion, as fuel. When we blow out a candle, the wick will produce smoke. When we hold an open flame, like a long reach lighter, to the smoke, the smoke ignites by burning the gases in the combustion product and travelling down to re-light the wick.

LIMITING HEAT

The candle's heat is provided by the burning wick. The metal on a screwdriver is cold, or at least room temperature. Metal absorbs heat. When we hold the screwdriver's metal end to the flame, touching the flame without touching the wick, the metal absorbs the heat taking the heat out of the candle wick (the source energy) and limiting the wax (fuel) getting to the wick.

COMBUSTION

A candle is solid, but solids don't burn. Gases burn. Heat causes pyrolysis, the change of solids to combustible gases. The melted wax is transferring heat to the fire and it's melting the wax.

It is possible to see combustion as it occurs in the case of the candle. When you lower a small, non-flammable screen over a candle flame, the screen limits the energy and quenches the flame above the screen, cutting off the top of the flame. This provides the opportunity to see a cross section of the flame.

When you look at the flame, you can see through it at the bottom because that is where the fuel is, most of the combustion is happening where the candle flame is clear. The yellow in the flame is carbon particles in a high state of energy hitting each other so hard that they are breaking bonds and creating heat and light. Observe that the flame looks hollow in the center. This is because the center is fuel rich, and there is no oxygen to burn. Around the edges of the flame where it looks like a halo, the screen absorbed the heat and broke down into gaseous fuel. Fuel gases are coming through the screen and can be lit but the fire has been made less efficient because it needs another ignition source or more oxygen to allow it to burn.

Where the screen turned black is called soot, these are carbon particles. To see soot in another way, hold a ceramic tile close to the flame. The tile will not ignite (no fuel), but the soot from the candle will make patterns on the tile.

FIRE INVESTIGATION

The fire triangle is critical to fire fighting and fire investigation. Fire professionals must understand what a fire needs to burn and how eliminating one leg of the fire triangle can extinguish a fire. Why do fire fighters use water to put out a fire? What leg of the fire triangle are they eliminating?

Just like a candle flame can leave a soot pattern on a ceramic tile, fire investigators look for these types of patterns on walls, furniture, and other parts of structures to help them determine the point of origin of the fire, or the location where the fire started. Knowing where a fire started helps investigators understand how it was caused.

eXPLORATION

MATERIALS

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

- ◯ **Long reach lighter**
- ◯ **Pillar candle or small candle**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) – place candle in pan**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) with 1-2" (2.5 – 5cm) of water**
- ◯ **Aluminum foil pieces (2) 2 cm x 2 cm with small slit (1 cm) cut in the middle of one side**
- ◯ **Glass jar or drinking glass**
- ◯ **Small (5 cm x 5 cm) metal screen (non-flammable)**
- ◯ **Tongs to handle materials that are hot or briefly flaming – plastic/heat resistant coated handles**
- ◯ **Large screwdriver with plastic (non-heat conducting) handle**
- ◯ **Ceramic tile**
- ◯ **Student Xplorlab pages**
- ◯ **Xplorlabs video: Investigation 1**

ROLES

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

Part A. Testable Question: What is the effect of limiting one leg of the fire triangle?

PROCEDURES

A. Limiting oxygen –

1. Remove the oxygen leg of the fire triangle by placing a glass jar over a lit candle on a non-flammable plate.

2. Lower glass over the candle until the rim of the glass is 1" (2.5 cm) from the table, leaving a gap between the glass and the table.

3. Observe.

B. Limiting fuel –

1. Using the slit cut into the foil piece, slide the lit wick into the slit so that the foil separates the wax from the flame.

2. Observe.

C. Limiting fuel –

1. Remove the fuel leg of the fire triangle by blowing out the candle, then bring an open flame (lit long reach lighter) to smoke as it rises out of the extinguished candle.

2. The flame will travel down the smoke and attach to the wick, relighting the candle

3. Observe.

D. Limiting heat –

1. Remove the fuel leg of the fire triangle by placing the metal end of the screwdriver next to the lit wick of the candle.

2. Observe.

OBSERVATIONS

Limiting oxygen

Limiting fuel

Limiting heat

eXPLANATIONS: Based on our observations, what is the effect of taking away one leg of the fire triangle?

Part B. Testable Question: What will happen when we lower a small metal screen (non-flammable) onto the flame of the candle?

PROCEDURE

1. Lower a small metal screen (non-flammable) onto the flame of the candle and observe. The best place to observe is looking down on the candle. Be careful! It's hot directly above the flame.

OBSERVATIONS

Draw with labels or describe:

eXPLANATION

BASED ON OUR OBSERVATIONS, WHAT HAPPENS WHEN WE LOWER A SCREEN ONTO THE FLAME OF A CANDLE?

CLAIMS / EVIDENCE / REASONING

Question: What is the effect of limiting one leg of the fire triangle?

Based on our observations in this investigation, what can we claim about the fire triangle?

What is our evidence for these claims?

What is our reasoning for the evidence?

Why is this important for fire investigators to understand?