UL XPLORLABS

FIRE FORENSICS: CLAIMS & EVIDENCE

STUDENT

INVESTIGATION 2: HEAT TRANSFER & IGNITION

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

YOUR NAME

INVESTIGATION 2: HEAT TRANSFER & IGNITION

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

FIRE INVESTIGATORS MUST UNDERSTAND:

- **How fires start**
- **How fires spread**
- **How different amounts and shapes of materials burn differently**

When we know how heat is transferred, we can better understand a fire scene.
Knowing the ignition of different materials helps fire investigators understand and read a burn scene.

Exploration: This investigation is divided into two parts

A. How do fires spread?
B. How do fires start?

The TESTABLE question guiding our investigations is:

A) How does heat transfer between materials?

B) Does shape and size effect ignition (catching fire) and combustion (burning)?
Does the material effect ignition (catching fire) and combustion (burning)?

SUMMARY OF LAB

A) You will make observations about how thermal energy is transferred and how transferred heat starts fires.

B) You will compare the surface to mass ratio of a block of wood and a toothpick, then compare how easily they ignite. Then, you will make observations about how different materials ignite and burn.

SAFETY CONSIDERATIONS

- **Good ventilation**
- **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

HEAT TRANSFER

Solids and liquids do not burn. Gases burn. Solids and liquids are broken down into simpler molecular compounds (a chemical change) by the effects of heat. These gases are the products of decomposition and that is what burns in a fire.

In a candle, how do we go from solid wax to gaseous fuel? The wax isn't burning until we add heat from the lighter or match, and then the heat is consistently applied by the burning wick. The solid wax is fuel, but does not burn until heat is applied.

Many things are fuel and can burn – things around us every day like clothes, hair, carpeting, furniture, etc. If heat comes into contact at a fast-enough rate, solids can turn to gaseous fuel through pyrolysis.

Pyrolysis. A process in which material is decomposed or broken down, into simpler molecular compounds by the effects of heat alone; pyrolysis often proceeds combustion. Pyrolsate. Product of decomposition through heat; a product of a chemical change caused by heating. *National Fire Protection Association*

Knowing that when heat is applied, solids and liquids can turn to gaseous fuels, we need to know how heat is transferred. There are three main methods of heat transfer: 1) conduction, 2) convection, and 3) radiation.

- **Conduction. The transfer of heat within a solid or between two solids.**
- **Convection. Heat transferred due to gasses – either hot gases interacting with each other or a hot gas hitting a cold surface and transferring heat to that surface.**
- **Radiation. Heat transferred by light energy.**

CONDUCTION

Conduction is the transfer of heat within a solid or between two solids. A small, hardened drop of wax on a 6" (15.2cm) length of copper wire and wooden popsicle stick demonstrates conduction. When the copper wire is put in the candle flame, the wax on the other end of the copper wire melts. The heat from the flame is conducted through the wire to melt the wax. Metals are very conductive – they transfer energy or heat. Copper wiring is used in our homes to efficiently transfer energy throughout our home.

The wax on the wood stick, however, does not melt while the wood stick will most likely catch fire (be sure to put the stick into the pan of water). Heat is not conducted through wood; wood is an insulator, which is the opposite of conductor. A good insulator is air; wood is made of cellulose and air is trapped within. In a campfire or fire place, the popping and cracking sounds are the moisture and air bubbles expanding.

A fire investigator needs to understand what conducts heat and what does not to determine if there was a competent energy source, meaning enough energy to the source to turn solids to a gaseous fuel that will burn. If the material in the room does not conduct energy, it may not be a competent ignition source.

CONVECTION

Convection is heat transferred due to gasses – either hot gases interacting with each other or a hot gas hitting a cold surface and transferring heat to that surface.

Holding an index card 1-2" (2.5 – 5cm) over the candle flame will turn the paper black (char) and may ignite. While holding a fresh index card 1-2" (2.5 – 5cm) to the side of the candle flame there are no observable changes to the card. The temperature is higher above the flame than next to it. The thermal plume of the candle is convective heat transfer.

Convection is how most heat energy is transferred in a house or building fire. The hot air rises and spreads out, and this rising hot air draws cooler air to the base. In a house fire, the temperature near the floor is cooler than above. This rising heated air makes the ceiling and walls hotter; when heat is applied at a fast-enough pace, the surfaces will pyrolyze, if all the gases in the room ignite at the same time, it is a phenomenon called *flashover.*

RADIATION

The index card to the side of the candle flame demonstrates radiative heat. If you place your hand to the side of the candle, it is warm while putting your hand over the candle it is hot (be careful!). Radiation is heat transferred by light energy. On a sunny day, sun on skin is sun transferring heat to you via thermal radiation. That's why sunscreen or staying out of the sun avoids burning the skin.

Convection compared to radiation heat transferred is demonstrated by roasting a marshmallow over a fire. Holding the marshmallow to the side will slowly roast the marshmallow (radiation) while holding it directly above the flames ignites the marshmallow (convection).

IGNITION

When heat is transferred to materials, they will ignite and burn differently – most of these differences are observable before any measurements are taken. The same material (same chemistry) will ignite in different ways depending on the surface area and amount of the material, or the surface to mass ratio. Different materials, like organic (naturally occurring) and synthetic (man-made) ignite and burn in different ways. It is important for fire fighters and investigators to know the characteristics of how common materials burn so they can predict the behavior of the fire as it burns and can read a fire scene once the fire is extinguished.

SURFACE TO MASS RATIO

To demonstrate the principle of surface to mass ratio, open flame is applied to different shapes and masses of wood – the same chemistry with different geometry. A 2x4" (5x10cm) block of wood will most likely char and smoke, but not ignite while a popsicle stick/wood stick will ignite quickly and burn. The sawdust in the metal pan ignites, but doesn't burn well.

The 2x4" (5x10cm) block of wood has a lower surface area and higher density, while the sawdust has a higher surface area and lower density. Surface to mass ratio is the amount of energy it takes to ignite a material – higher density materials take more energy to ignite, but burn longer (more fuel), while lower density materials are easily ignited but do not burn well.

INORGANIC VS. ORGANIC VS. SYNTHETIC

Things in our homes and schools and offices are generally made of three different categories of materials. **Inorganic** materials occur naturally but are abiotic, or non-living. Inorganic materials are things like rocks, brick, concrete, and ceramic. **Organic** materials occur naturally, like wood, wool, and cotton. **Synthetic** materials do not occur in nature and are man-made, or synthesized by humans. Two of the categories of materials ignite and burn differently, and leave behind different evidence to read from.

Synthetic materials like, polystyrene (Styrofoam), which is made of synthesized oil by-products, ignites very rapidly when heat is applied. As it burns, it drips hot liquid and gives off a heavy black smoke with a rapid flame spread rate (i.e., how quickly the flame spreads on the material). Similar observations are made of synthetic carpet, furniture upholstery, clothing, etc.

Organic materials, however, ignite less quickly, burn slower, have a slower flame spread rate, and the smoke is considered "cleaner."

Inorganic materials do not ignite or burn. They do not contain carbon. But, when heated, the gases from the inorganic materials will burn – gases from heated surfaces will ignite through the process of pyrolysis.

How materials burn will also provide information on how much potential energy is stored in them in the form of sugars, oils, fats. A marshmallow ignites rapidly and chars as it burns, while a cheese curl also ignites rapidly and burns slowly and at a higher temperature. In this investigation, it is helpful to do visual observations of how these foods burn and compare them to household materials. In Investigation 3: Heat Release Rate, a quantitative measure of this difference will be taken and analyzed.

SAFETY NOTE: When observing these materials burn, it is important to have good ventilation in the classroom and a pan of water to extinguish the burning materials. It is also important to do this over a fire-retardant surface, like a lab table or concrete.

eXPLORATION

MATERIALS

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

- ◯ **Pillar or small candle in center of metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material)**
- ◯ **Beaker of ice water**
- ◯ **2 6" (15cm) lengths of copper wire**
- ◯ **5 popsicle sticks/also known as craft sticks (non-coated, not colored)**
- ◯ **4 index cards**
- ◯ **Tongs to handle materials that are hot or briefly flaming**
- ◯ **Long reach lighter**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) with 1-2" (2.5 – 5cm) of water**

- ◯ **Student Xplorlab pages**
- ◯ **Xplorlabs video: Investigation 2**

***Preparation**
Dip a toothpick into hot wax and place a small drop of wax on one end of one piece of copper wire.
Do the same with a popsicle stick/craft stick.

ROLES

THE STUFF SUPERVISOR	THE EXPERIMENT EXEC	THE DIRECTOR OF DOCUMENTS	THE PRINCIPAL PRESENTER
Gathers and cleans up materials	Runs the experiment	Reads the procedure to the group and helps the group members with data collection	Shares the group's work with the rest of the class

Part A. Testable Question: How does heat transfer between materials?

PROCEDURES

A. Conduction

1. Place one popsicle/wood stick and one copper wire piece (both without the wax bead) in the beaker of ice water.

2. Feel the temperature of each sample and share what you feel.

3. Why is one cold to the touch and the other not?

4. Light the candle in the center of a metal pan or on fire-retardant surface.

5. Using the tongs, place the popsicle/wood stick and copper wire with the dried wax bead, one at a time at the opposite end of the bead in the open flame of the candle.

6. What happens to the dried bead of wax?

OBSERVATIONS - Conduction

eXPLANATION:

Conduction is *the transfer of heat within a solid or between two solids.*
How does this definition explain what you observed?

B. CONVECTION / RADIATION

1. Light the candle in the center of a metal pan or on fire-retardant surface.

2. Hold an index card 1-2” (2.5 – 5cm) directly over the flame.

3. Observe the effects of the flame on the card (if card ignites, place in pan of water).

4. Hold new index card 1-2” (2.5 – 5cm) to the side of the flame.

5. Observe the effects of the flame on the card.

OBSERVATIONS - Convection / Radiation

eXPLANATION:

Convection is *heat transferred due to gases – either hot gases interacting with each other or a hot gas hitting a cold surface and transferring heat to that surface.*

Radiation is *heat transferred by light energy.*

How do these definitions explain what you observed?

CLAIMS / EVIDENCE / REASONING

QUESTION: HOW IS HEAT TRANSFERRED BETWEEN MATERIALS? BASED ON OUR OBSERVATIONS IN THIS INVESTIGATION, WHAT CAN WE CLAIM ABOUT HOW HEAT IS TRANSFERRED?

WHAT IS OUR EVIDENCE FOR THESE CLAIMS?

WHAT IS OUR REASONING FOR THE EVIDENCE?

WHY IS THIS IMPORTANT FOR FIRE INVESTIGATORS TO UNDERSTAND?

PART B. TESTABLE QUESTIONS:

Does shape and size have an impact on ignition (catching fire) and combustion (burning)?

MATERIALS

- ◯ **Pillar or small candle in center of metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material)**
- ◯ **5 popsicle sticks/also known as craft sticks (non-coated, not colored)**
- ◯ **A block of lumber/wood cut in 2x4" (5x10cm) (commonly used in construction, readily available at**
- ◯ **hardware store)**
- ◯ **2 oz. (28g) of sawdust (handful) (also available at hardware store by asking lumber department for sample) – place in center of metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material)**
- ◯ **Strip of carpet (small samples free at carpet stores)**

- ◯ **Polystyrene piece (small) (Styrofoam)**
- ◯ **Brick or ceramic tile**
- ◯ **Tongs to handle materials that are hot or briefly flaming**
- ◯ **Long reach lighter**
- ◯ **Metal/non-flammable pie pan or tray (not! plastic, paper, or wax coated material) with 1-2" (2.5 – 5cm) water**
- ◯ **Student Xplorlabs pages**
- ◯ **Xplorlabs video: Investigation 2**

PROCEDURE

Surface to mass ratio.

1. Light the candle in the center of a metal pan or on fire-retardant surface.

2. Discuss differences/similarities between 2x4" (5x10cm) block of wood, popsicle/wood stick, and sawdust (all same material, but different sizes and shapes, densities and mass).

3. Hold the 2x4" (5x10cm) block of wood over the candle's flame with the wood touching the flame.

4. Observe the 2x4" (5x10cm) block of wood. Identify charring (blackening of wood).

5. Hold popsicle/wood stick in the candle's flame.

6. Observe the popsicle/wood stick (if ignites, place in pan of water).

7. Extinguish candle and replace candle with sawdust in center of metal pan.

8. Hold long reach lighter flame to the sawdust.

9. Observe sawdust in presence of flame.

OBSERVATIONS

Draw with labels or describe:

Based on our observations in this investigation, what claim can we make about what common items have the fastest ignition?

What is our evidence for these claims?

What is our reasoning for the evidence?

Why is this important for fire investigators to understand?

eXPLANATION

BASED ON OUR OBSERVATIONS, WHAT CAN WE SAY ABOUT THE IMPACT OF SHAPE AND SIZE OF A MATERIAL AND HOW IT IGNITES (CATCHES FIRE)?

TESTABLE QUESTION: DOES THE MATERIAL HAVE AN IMPACT ON IGNITION (CATCHING FIRE) AND COMBUSTION (BURNING)?

PROCEDURE

Inorganic vs. organic vs. synthetic

A. Organic – wood

1. Light the candle in the center of a metal pan or on fire-retardant surface.

2. Define organic material.

3. Make predictions about how/if the material will ignite and burn with reasons for predictions (I think...because...)

4. Hold the popsicle/wood stick with tongs and lower the popsicle/wood stick into the candle's flame.

5. Observe and record flame spread, smoke, burning.

6. Extinguish by placing the popsicle/wood stick into the pan of water.

B. Synthetic - polystyrene

1. Define synthetic material.

2. Make predictions about how/if the material will ignite and burn with reasons for predictions (I think...because...)

3. Hold the small piece of polystyrene with tongs and lower the polystyrene into the candle's flame.

4. Observe and record flame spread, smoke, burning.

5. Extinguish by placing the polystyrene into the pan of water.

C. Inorganic – brick/ceramic tile

1. Define inorganic material.

2. Make predictions about how/if the material will ignite and burn with reasons for predictions (I think...because...)

3. Hold the piece of brick/ceramic tile and lower into the candle's flame.

4. Observe and record flame spread, smoke, burning.

5. Extinguish by placing the brick/ceramic tile into the pan of water.

OBSERVATIONS

Draw with labels or describe:

ORGANIC

SYNTHETIC

INORGANIC

eXPLANATION

BASED ON YOUR OBSERVATIONS, WHAT WERE THE DIFFERENCES IN HOW THE MATERIALS IGNITED (CAUGHT FIRE) AND COMBUSTED (BURNED)?

WHAT ARE POSSIBLE EXPLANATIONS OF THOSE DIFFERENCES?

CLAIMS / EVIDENCE / REASONING

CHOOSE one question to answer:

A. What is the impact of the surface to mass ratio to ignition and burning?
Based on our observations in this investigation, what can we claim about the impact of surface to mass on ignition and combustion?

B. How do different types of materials ignite and burn?
Based on our observations, what can we claim about how different materials ignite and burn?