Learning Heat of Combustion and Specific Heat through Determining the Heat of Combustion of Paraffin

A lesson plan arranged by:

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Standards

HSCES:

1. Performance expectations:
   C1.1B Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions. In the elaborate section, students will analyze the sources of heat loss from burning a paraffin candle. The students must propose two solutions to limit this heat loss.
   C1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision). In the explore section, students will investigate the heat of combustion of paraffin using thermometers, digital balances, and graduated cylinders to measure temperature, mass, and volume, respectively.

2. Content Expectations:
   C3.4c Write chemical equations including the heat term as a part of equation or using delta \( H \) notation. In the engage section, students will write and balance a chemical equation of the combustion of ethyl alcohol with the heat term as a part of the equation. How to write and balance a chemical equation of the combustion of pentane, including thermal energy, will also be modeled in the explain section. I will assess if students correctly wrote and balanced a chemical equation for the combustion of pentane, including thermal energy, in the elaborate section, too.
   C5.2A Balance simple chemical equations applying the conservation of matter. In the engage section, students will write and balance a chemical equation of the combustion of ethyl alcohol with the heat term as a part of the equation. How to write and balance a chemical equation of the combustion of pentane, including thermal energy, will also be modeled in the explain section. I will assess if students correctly wrote and balanced a chemical equation for the combustion of pentane, including thermal energy, in the elaborate section, too.
   C5.4A Compare the energy required to raise the temperature of one gram of aluminum and one gram of water the same number of degrees. In the explain section, I will ask students if it takes more or less energy to raise one gram of aluminum 5 degrees Celsius than it does one gram of water.
   C3.1c Calculate the delta \( H \) for a chemical reaction using simple coffee cup calorimetry. In the explore/explain section, students will calculate the heat of combustion for burning paraffin by measuring the change in temperature in a known amount of water.

NGSS:

1. Science and Engineering Practices
   Planning and carrying out investigations: In the explore section, students will be asked a series of questions used to guide their development of an experimental procedure to determine the heat of combustion of paraffin. The students will carry out their investigation, collecting mass and temperature data.
   Using mathematics and computational thinking: In the explore section, students will use their data from the experiment to calculate the heat of combustion of paraffin. In the explain section, students will convert the heat of combustion of paraffin to a molar heat of combustion to compare the value to propane. In the elaborate section, students will perform various heat of combustion calculations with moles and grams and balanced equations.

2. Disciplinary Core Ideas
   PS3.A: Definitions of Energy
   a. Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS- PS3-1),(HS-PS3-2) In the explain section, heat is described as the total kinetic motion of the molecules.
PS3.B: Conservation of Energy and Energy Transfer
a. Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) In the explore section, students are calculating the heat of combustion of paraffin by stating that the release of energy during combustion equals the energy going to heating the water.
b. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4) In the explain section, students will analyze how heat is 'lost' or transferred between systems. In the explain section, there is a visual to support the idea that energy is converted and therefore often lost.

3. Crosscutting Concepts
Energy and Matter
a. Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS- PS3-3) In the explore section, the change of energy of the water is accounted for by the flow of thermal energy in from the combustion of paraffin.
b. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.(HS-PS3-2) In the explain section, a visual depicted energy 'loss' through conversions will be shown to describe how energy cannot be created or destroyed but converted.

Nature of Science (NOS)
Science is a highly creative endeavor. In the explain section, students will be asked to design an experimental set-up that will limit the heat loss from the burning candle to the water. The students will be asked if they think scientists have to use creative thinking to design experiments.

Objectives
1. A student will be able to explain that scientists use creativity to design effective experiments.
2. A student will be able to state that endothermic is the absorption of energy and exothermic is the release of energy.
3. A student will be able to calculate the heat of combustion of a substance using experimental data.
4. A student will be able to state that specific heat is the amount of energy needed to raise 1 gram of a substance 1 °C.
5. A student will be able to write a balanced chemical equation, including the amount of energy produced, for the combustion of any alkane.
6. A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in moles.
7. A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in grams.
8. A student will be able to describe a simple laboratory procedure used to determine the energy given off by a burning fuel.

Requisite Knowledge
Students should be able to perform simple algebraic calculations. They should be able to identify combustion reactions, balance simple reactions, and use simple dimensional analysis.
Safety Considerations and Precautions

*Teacher Demonstration:* Ethyl alcohol will be burned in a plastic container. Ethyl alcohol is a highly flammable chemical. The reaction should take place behind a large safety shield with considerable distance from the students (about 20 feet). Because the plastic on the bottle may degrade/wear down, resulting in an explosion, keep track of how many times the bottle is used for the demonstration. Do not use the bottle more than twenty times. Remove the ethyl alcohol container from the site of the demonstration after use. To start the reaction, the teacher should hold a burning candle or splint by the opening of the container by taping the candle or splint to the end of a meterstick, keeping considerable distance away from the container. The teacher must wear safety goggles. Ethyl alcohol should be stored in a flammables cabinet. When the demonstration is over, the contents of the bottle can go down the drain. Rinse the bottle out. Rinse the match/splint off and throw it in the trash.

*Experiment:* Students will be working with open flames. Remind students not to play with matches, to throw matches in the sink or rinse with burning water, to tie back loose clothing/hair, and to wear safety goggles at all times. Nothing but the candle should be burned. If glass is broken, tell the students to notify the teacher and not to pick it up. No horseplay or running is allowed. The candles and pop cans can be reused and the water can go down the drain. The matches should be rinsed off and thrown in the trash.

*Elaborate:* Do not really have a student dip her/his hand into the beaker of boiling water. Handle the beaker of water with tongs or heat resistant gloves. Tie back loose hair and clothing when dealing with an open flame.

In the event of a fire, use the fire extinguisher to extinguish flames. Use the safety shower if any person is on fire. If glass is to break, sweep up the glass and place it in the sharps container. If a student is injured, send him/her to the school nurse.

Describe the applicable chemical, electrical, biological, and general safety precautions, disposal procedures, and required safety equipment (goggles, aprons, gloves, etc.) required during your lesson.

Scientific Background

Combustion is the burning of a substance in the presence of oxygen to produce water, carbon dioxide, and heat. Combustion is an exothermic process, and the energy released can be captured and used in other processes, such as driving a car. The heat of combustion of a substance is the quantity of thermal energy given off when a certain amount of a substance burns. It is possible to determine the heat of combustion of a substance indirectly by applying the concept of specific heat. Specific heat is a property of a substance. Specific heat is the amount of heat needed to raise the temperature of one gram of the substance by one degree Celsius. Temperature is the average kinetic energy of the particles while heat is the total amount of thermal energy. Therefore, temperature and heat are not the same.

Misconceptions

According to Alwan (2011), students may hold the misconceptions that temperature is the “intensity” of heat or heat and temperature are the same thing. To address this misconception, I will clearly define the differences between temperature and heat. I will ask students, what has more heat, a match or a campfire? I will tell students that although the two are at the same temperature, the campfire has more heat due to its size. In the elaborate section, I will also boil a beaker of water. I will place a drop of this water on my hand, showing the students that I am not burned. I will then ask for a volunteer to dip his/her hand in the water. I do not expect any student to volunteer and if the student volunteers I will not allow the student to
Students should explain that although the drop of water and the beaker of water are at the same temperature, the beaker of water contains more heat and will burn more than the drop of water. If this misconception exists after instruction, students can calculate the heat of Lake Michigan versus the heat of 8 ounces of water at the same temperature.

According to Boo (1995), students may believe that the candle wax in a burning is not burning but only melting. In the explore section, students will burn a candle. They will write the complete chemical equation for the combustion of the paraffin. They will also collect any melted paraffin on an index card. The students will be asked if the candle underwent a chemical or physical change. Students should answer that the candle underwent both a chemical and a physical change (some melted as seen on the index card from the heat). If this misconception exists after instruction, the teacher can show that a candle undergoes a chemical change by holding a beaker of cold water slightly above and to the side of a flame (to show water vapor). The teacher can show that the candle undergoes a physical change by blowing out the candle and relighting the paraffin gas in the smoke.

**Differentiation**

Tactile: The explore laboratory setup allows students engage in ‘hands on’ chemistry while determining paraffin’s heat of combustion.
Mathematical: Students will use mathematics to apply heat of combustion.
Verbal: I verbally explain the heat, combustion, and temperature concepts during the explain section.
Linguistic: Students have the opportunity to discuss why a beaker of water has more heat than a drop of water. I also provide written notes on the Powerpoint slides.
Visual: The Whoosh! Demonstration (how much heat is released when ethanol burns?) in the engage section provides a visual for students to see combustion.
Inter/Intrapersonal: Students have the opportunity to work in groups during the lab, and in groups or individually when completing worksheets/other assignments.

**Engage (Day 1)**

1. **Overview and objectives:** The teacher will demonstrate the combustion of ethyl alcohol. The demonstration is flashy, designed to catch the students attention. After the demonstration, the students will practice writing complete balanced equations (which they already know how to do) and will learn what molar heat of combustion is. The worksheet also urges students to think about why they should care about the combustion of petroleum products (they rely on this energy everyday!). This demonstration/worksheet targets the following learning objectives: A student will be able to state that endothermic is the absorption of energy and exothermic is the release of energy. A student will be able to write a balanced chemical equation, including the amount of energy produced, for the combustion of any alkane.

2. **Materials and Set-up:**
   - 25mL of ethyl alcohol (supplied by Flinn Scientific, Inc.)
   - Large plastic jug
   - Match
   - Meterstick with candle or splint taped to the end
   - Large safety shield (supplied by Flinn Scientific, Inc.)
   - Safety Goggles (supplied by Flinn Scientific, Inc.)
   - This demonstration should be performed with considerable distance from the students. The plastic jug should be placed behind the safety shield to protect the students from flames/explosions.
3. **Procedure:** Before class, the teacher will gather and set-up all materials. The How much heat is released when ethanol burns? worksheet should be passed out to each student. Tell students that the air inside the bottle has the same composition as the air outside of the bottle. Wearing goggles, the teacher will pour 25 mL of ethyl alcohol into the plastic container, swirling it on the sides to promote vaporization. The teacher will remove the ethyl alcohol bottle far away from the demonstration site, into the ventilation hood. Ask the students to make their predictions as to what will happen. The teacher will light a splint attached to the ruler, and hold the flame around the mouth of the plastic jug. A giant ‘whoosh’ flame should result from the combustion of the ethyl alcohol vapors. The teacher will ask students to identify the products of the reaction by pouring out the liquid water and noting how cloudy the container gets. The teacher will instruct the students to complete the rest of the worksheet. The teacher will rinse out the plastic bottle, rinse off and dispose the splint, and return the ethyl alcohol container to the Flammables cabinet in the stockroom. The teacher will walk around the room as the students complete the worksheet. After 25 minutes or so, the teacher will instruct the kids to pay attention up front. The teacher will define the different types of energy on the PowerPoint. The teacher will ask students what heat of combustion is. They should say that it is the energy released from a combustion reaction. The teacher will then have students come up to the board to complete the balanced chemical equation for the combustion of ethyl alcohol and the total thermal energy released from the reaction. Tell the students to write on the back of the handout if they think that the match or beaker has more heat/temperature. Collect the handout.

4. **Assessment:** The students will complete the How much heat is released when ethanol burns? worksheet. In this worksheet, students will write the complete balanced equation for the combustion of ethyl alcohol and determine how much energy is released in the complete combustion of ethyl alcohol.

**Explore (Day 1/ Day 2)**

1. **Overview and objectives:** Students will determine the heat of combustion (in kJ/g) or paraffin by burning a candle and measuring the temperature change of water and the change in mass of the candle. The concept of specific heat will be applied to determine the thermal energy released from the reaction. The materials and experimental setup will be given to the students, but the students will answer a series of questions to guide them into making a procedure. This demonstration/worksheet targets the following learning objectives: A student will be able to calculate the heat of combustion of a substance using experimental data. A student will be able to state that specific heat is the amount of energy needed to raise 1 gram of a substance 1 °C. A student will be able to describe a simple laboratory procedure used to determine the energy given off by a burning fuel.

2. **Materials and Set-up:**
   - Paraffin Candle
   - Thermometer
   - Ring stand
   - Safety goggles
   - Matches
   - Index Card
   - Water
   - Pop can
   - Calculators
Graduated cylinder
• “How much energy does a candle have” lab handout

3. Procedure: The teacher will pass out the lab handout. On the overhead, the teacher will display the experimental set-up and go through the materials given. The teacher will also define specific heat capacity. The teacher will assign lab partners. The students will be working with their lab partner in answering the pre-lab questions in the lab setting. The teacher will circulate the room as students answer the questions, guiding students to the right answers. The questions and expected answers are below:

1. What does specific heat capacity mean? The quantity of heat needed to raise the temperature of one gram of the substance by 1 degree Celsius.

2. Write the complete balanced equation for the combustion of paraffin, \( C_{25}H_{52} \): \( C_{25}H_{52} + 38 O_2 \rightarrow 25 CO_2 + 26 H_2O + \text{heat} \)

3. In order to calculate the heat of combustion of the candle \((\text{J/g})\), what two pieces of information do you need? HINT: Look at the given units. Mass of the paraffin that burned, the thermal energy released from the combustion of paraffin

4. How will you determine the change in mass of the candle? Melt the bottom of the candle so that it sticks to the index card. Measure the mass of the candle prior to burning. Measure the mass of the candle after the experiment is over.

5. The water will be used to determine the thermal energy given off by the burning of paraffin. What two pieces of data will you need to collect to determine the thermal energy given off by the burning of paraffin? HINT: You will need to use the specific heat capacity in your post-lab calculations. The exact volume of water (used to calculate the mass of the water) and the change in temperature of the water

The students will then write a short lab procedure, which must be approved by the teacher prior to beginning the experiment. The students will run the experiment, collecting and organizing data. The students will then be provided sample notes to guide their post-lab heat of combustion calculations. The teacher will circulate during this explore activity to guide student thinking/answer questions. Before the explain section tomorrow, the students will be given, as a bellwork, experimental data similar to the lab and asked to calculate the heat of combustion of paraffin.

4. Assessment: The lab handout will be collected and graded. The pre-lab questions and procedure will be graded on completion. Data organization, the calculations, and the lab summary will be graded based on accuracy. The bellwork in which the students are given experimental data to calculate the heat of combustion will not be collected, but I will circulate the room and assess student progress, making note of how many students do not complete the bellwork or do so incorrectly.

Explain (Day 3)

1. Overview and objectives: During the explain section, I will describe how heat of combustion is applied to petroleum and why the students should care about heat of combustion. I describe what specific heat capacity means, as well as the difference between temperature and heat. Lastly, I model a couple of heat of combustion calculations. This portion of the lesson is completed with a PowerPoint Presentation. The students will also complete a post-lab worksheet that has them further perform calculations and compare their heat of combustion of paraffin to that of propane. The students will also be asked to design an experimental set-up to limit the heat lost to the air in the experiment. The targets I hope to address in this section include the following: A student will be able to state that specific heat is the amount of energy needed to raise 1 gram of a substance 1 °C. A student will be able to write a balanced
chemical equation, including the amount of energy produced, for the combustion of any alkane. A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in moles. A student will be able to explain that scientists use creativity to design effective experiments. A student will be able to describe a simple laboratory procedure used to determine the energy given off by a burning fuel.

2. **Materials and Set-up:**
   - Powerpoint Presentation
   - Heat of Combustion Post-Lab Worksheet

3. **Procedure:** Using the PowerPoint presentation, the teacher will describe how petroleum is an energy source and that we obtain this energy from combustion. This energy originally came from the sun. The heat of combustion can be converted to other useful energies. As the number of energy conversions increases, the more energy will be ‘lost.’ The teacher will explain how the specific heat of water was used to calculate the heat of combustion of paraffin. The teacher will ask students to compare the specific heat capacity of aluminum and water. The teacher will describe the difference between temperature and heat, using a match versus a campfire as an example. Lastly, heat of combustion calculations will be modeled. The students will complete the Heat of Combustion Post-Lab Worksheet as homework.

4. **Assessment:** The Heat of Combustion post-lab worksheet will be collected and graded. I will note student answers to the analysis of the specific heat of aluminum versus water.

**Elaborate/Extend (Day 3)**

1. **Overview and objectives:** The students will apply the concepts of temperature and heat to explain why a drop of boiling water does not burn as much as a beaker of boiling water. The students will also perform calculations related to heat of combustion and describe what his/her answer value means in a sentence. This will promote the conceptual understanding of the calculations. This will be completed on a handout, which has the students reflect between their answer and the ‘correct’ answer. The objectives addressed in this section are the following: A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in grams. A student will be able to describe a simple laboratory procedure used to determine the energy given off by a burning fuel.

2. **Materials and Set-up**
   - In Class Handout: Heat, Temperature, and Combustion Questions
   - Beaker of water
   - Dropper
   - Ring stand
   - Bunsen Burner
   - Match
   - Wire Gauze
   - Heat resistant gloves or tongs
   - Before class, heat the beaker of water to a boiling temperature using the ring stand and Bunsen burner.

3. **Procedure:** Direct the students’ focus to the boiling beaker of water. Take a drop of the out of the beaker. Ask students if the temperature of the drop of water is the same less than or equal to the water in the beaker. The temperature is the same. Ask students what would burn more, a drop of that water on your hand or putting your hand in a beaker of water? Students should say the beaker of water. Place a drop of
the water on your hand, showing you are not hurt. Ask students if they want to dip their hand in the beaker of water. No one should volunteer, and if a student does volunteer, do not allow them to dip their hand in it. Have students write down on their handout an explanation to the questions. Have students share their explanation with a partner. Have the partners play rock, paper, scissors. The winner of the game will stand up and share an answer. Students should say that the beaker of water will burn more than the drop because it has more mass and therefore more heat even though the temperatures are the same. Instruct the students to complete the heat of combustion calculations on their handout. After students are mostly finished, share the answers on the board and have students reflect on how the ‘right’ answers may be different from their answers.

4. **Assessment:** I will collect the In Class Handout to assess if the students correctly answered the water question and the heat of combustion calculations.

**Evaluate**

- How much heat is released when ethanol burns? Worksheet
  - Engage Section
  - Assesses: A student will be able to state that endothermic is the absorption of energy and exothermic is the release of energy. A student will be able to write a balanced chemical equation, including the amount of energy produced, for the combustion of any alkane.
  - Page 11/12
- “How much energy does a candle have” Lab Report
  - Explore
  - Assesses: A student will be able to calculate the heat of combustion of a substance using experimental data.
  - Page 13
- Bellwork to calculate the heat of combustion using experimental data
  - Explore section
  - Assesses: A student will be able to calculate the heat of combustion of a substance using experimental data.
- Heat of Combustion Post-Lab Worksheet
  - Explain Section
  - Assesses: A student will be able to explain that scientists use creativity to design effective experiments. A student will be able to describe a simple laboratory procedure used to determine the energy given off by a burning fuel.
  - Page 17
- In Class Assignment: Heat, Temperature, and Heat of Combustion Questions
  - Elaborate
  - Assesses: A student will be able to state that specific heat is the amount of energy needed to raise 1 gram of a substance 1 °C. A student will be able to write a balanced chemical equation, including the amount of energy produced, for the combustion of any alkane. A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in moles. A student will be able to use molar heat of combustion to calculate the amount of energy produced when a reactant is burned when given the amount in grams.
  - Page 19
• Petroleum Part B Quiz
  o Assesses all learning objectives. (This also includes material that is not in this lesson plan)
  o Page 21

References


Supporting Materials (See Attached)
How much heat is released when ethanol burns?

1. What were the reactants? Products?

2. Write a complete balanced equation for the combustion of ethanol (C₂H₆O).

3. In the complete combustion of ethanol, how many moles of ethanol was burned? (Look at #2)

4. In an exothermic reaction, energy is released or ‘exits’. In an endothermic reaction, energy is absorbed or goes ‘into’ the reaction. Was this reaction exothermic or endothermic? Explain.

READ: We can calculate the amount of thermal energy given off when a substance burns. This is called the heat of combustion. Molar heat of combustion is the amount of energy given off when one mole of a chemical burns. The molar heat of combustion of ethanol is 1360 kJ/mol. This means that for every one mole of ethanol that is burned, 1360 kJ of thermal energy is released.

Using this information:

5. Determine how much thermal energy is released from the complete combustion of ethanol in the balanced chemical equation in number 2.

6. Circle the correct answer in parentheses: If the reaction was exothermic, meaning heat exited the reaction, we can consider heat as a (product or reactant) in the reaction.

7. Molar heat of combustion can be written as part of the balanced chemical equation. Use the heat of combustion value from number 5, and include it in the full balanced equation of ethanol in number 2. HINT: Recall if you considered heat to be a product or reactant.

8. Like ethanol, the combustion of petroleum products releases energy. How do you use this energy?
How much heat is released when ethanol burns?

1. What were the reactants? Products?

   The reactants were ethyl alcohol and oxygen, and the products were water and carbon dioxide.

2. Write a complete balanced equation for the combustion of ethyl alcohol (C₂H₅OH).

   \[ C₂H₅OH + O₂ \rightarrow 3H₂O + 2CO₂ + 1360 \text{ kJ} \]

3. In the complete combustion of ethanol, how many moles of ethanol was burned? (Look at #2)

   1 mole of ethanol was burned

4. In an exothermic reaction, energy is released or ‘exits’. In an endothermic reaction, energy is absorbed or goes ‘into’ the reaction. Was this reaction exothermic or endothermic? Explain.

   Exothermic, because heat was released.

We can quantify the amount of thermal energy given off when a certain amount of a substance burns. This is called the heat of combustion. Molar heats of combustion, the amount of thermal energy given off when a mole of a substance burns, can be written as part of the balanced chemical equation. The molar heat of combustion of ethyl alcohol is 1360 kJ/mol. This means that for every one mole of ethyl alcohol that is burned, 1360 kJ of thermal energy is released. Using this information:

5. Determine how much thermal energy is released from the complete combustion of ethyl alcohol in the balanced chemical equation in number 3.

   1360 kJ

6. Circle the correct answer in parentheses: If the reaction was exothermic, meaning heat exited the reaction, we can consider heat as a (product or reactant) in the reaction.

   product

7. Molar heat of combustion can be written as part of the balanced chemical equation. Use the heat of combustion value from number 5, and include it in the full balanced equation of ethanol in number 2. HINT: Recall if you considered heat to be a product or reactant.

   See question 2

9. Like ethanol, the combustion of petroleum products releases energy. How do you use this energy?

   This energy is used for fueling cars, electricity, etc.
How much energy does a candle have?

Materials:
- Index card
- 50 mL of water (Specific Heat Capacity = 4.2 J/g°C)
- Candle
- Matches
- Thermometer
- Pop can
- Ring stand

What does specific heat capacity mean?

Write the complete balanced equation for the combustion of paraffin, C_{25}H_{52}.

In order to calculate the heat of combustion of the candle (J/g), what two pieces of information do you need? HINT: Look at the given units.

How will you determine the change in mass of the candle?

In this lab, we are assuming that the energy given off by the candle equals the energy being absorbed by the water. The water will be used to determine the thermal energy given off by the burning of paraffin. What two pieces of data will you need to collect to determine the energy absorbed by the water? HINT: You will need to use the specific heat capacity in your post-lab calculations.

Write a brief procedure below. The only materials you need are listed above. This must be detailed enough so that another classmate could complete the experiment. You may not work in the lab until your procedure is approved by either Ms. McCulloch or Mr. DeWitt.

Teacher Initials ____________
Data: You will neatly organize your data below. All data need units and labels. Think before you write.

Calculations: Show all work!

1. Calculate the mass of water heated. (Remember, the density of water is 1 g/mL)

2. Calculate the temperature change in the water.

3. Calculate the quantity of thermal energy absorbed by the water. See the example problem on your note sheet. (Remember, the specific heat of water is 4.2 J/g°C)

4. Calculate the mass of paraffin that was burned.

5. Calculate paraffin’s heat of combustion in Joules/gram. See the example problem on your note sheet.

6. Convert the heat of combustion from J/g to KJ/g. HINT: 1000 J = 1 KJ

Did the paraffin candle undergo a chemical or physical change? Explain.

Don’t forget to write a Summary. A good summary will restate the purpose of the lab, summarize the procedure, report the experimental findings, and describe what you learned. If you need more room, attach a piece of looseleaf.
How much energy does a candle have?

Materials:
- Index card
- 50 mL of water (Specific Heat Capacity = 4.2 J/g°C)
- Candle
- Matches
- Thermometer
- Pop can
- Ring stand

What does specific heat capacity mean?

*The amount of energy needed to raise one gram of a substance one degree.*

Write the complete balanced equation for the combustion of paraffin, C_{25}H_{52}.

\[
C_{25}H_{52} + 38O_2 \rightarrow 26H_2O + 25CO_2 + \text{heat}
\]

In order to calculate the heat of combustion of the candle (J/g), what two pieces of information do you need? HINT: Look at the given units.

*Mass of the candle burned and the thermal energy given off*

How will you determine the change in mass of the candle?

*Measure the initial mass of the index card + candle and subtract the final mass of the index card + candle + candle droppings*

In this lab, we are assuming that the energy given off by the candle equals the energy being absorbed by the water. The water will be used to determine the thermal energy given off by the burning of paraffin. What two pieces of data will you need to collect to determine the energy absorbed by the water? HINT: You will need to use the specific heat capacity in your post-lab calculations.

*Temperature change of the water and the mass of the water*

Write a brief procedure below. The only materials you need are listed above. This must be detailed enough so that another classmate could complete the experiment. You may not work in the lab until your procedure is approved by either Ms. McCulloch or Mr. DeWitt.

*Procedure describes the data that will be collected*

*Procedure is easy to follow*

Teacher Initials ___________
**Data:** You will *neatly* organize your data below. All data need units and labels. Think before you write.

*Data has units.*
*Data is neatly organized/easy to follow.*
*Data includes initial mass of candle/index card, final mass of candle/index card, temperature change of water, volume of water used*

**Calculations:** Show all work!

1. Calculate the mass of water heated. (Remember, the density of water is 1 g/mL)
   
   \[ 50 \text{ mL} \times 1 \text{ g/mL} = 50 \text{ grams of water} \]

2. Calculate the temperature change in the water.
   
   \[ \text{Final temperature} - \text{initial temperature} = \text{temperature change in degrees Celsius} \]

3. Calculate the quantity of thermal energy absorbed by the water. *See the example problem on your note sheet.*
   (Remember, the specific heat of water is 4.2 J/g°C)
   
   \[ \text{Thermal energy (}J\text{)} = 4.2 \text{ J/g} \cdot \text{°C} \times 50 \text{ grams} \times \text{change in temperature} \]

4. Calculate the mass of paraffin that was burned.
   
   \[ (\text{Initial mass of index card + candle}) - (\text{final mass of index card + candle}) = \text{mass of paraffin burned} \]

8. Calculate paraffin’s heat of combustion in Joules/gram. *See the example problem on your note sheet.*
   
   \[ \text{Thermal energy absorbed by water (Answer to number 3)}/ \text{Mass of paraffin burned (Answer to number 4)} = \text{heat of combustion (J/g)} \]

6. Convert the heat of combustion from J/g to KJ/g. HINT: 1000 J = 1 KJ

   \[ \text{Heat of combustion (J/g)} \times (1 \text{ kJ/1000 J}) = \text{heat of combustion (kJ/g)} \]

Did the paraffin candle undergo a chemical or physical change? Explain.

*The paraffin underwent both a chemical and a physical change. The heat of the flame melts the wax (as evidenced by the wax droppings on the index card) and the paraffin undergoes a combustion reaction.*

Don’t forget to write a **Summary.** A good summary will restate the purpose of the lab, summarize the procedure, report the experimental findings, and describe what you learned. If you need more room, attach a piece of looseleaf.

1 Point each for restate the purpose of the lab, summarize the procedure, report the experimental findings, and describe what you learned (four points total)
Heat of Combustion Post-Lab Worksheet

<table>
<thead>
<tr>
<th>Alkane</th>
<th>Heat of Combustion</th>
<th>Molar Heat of Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>55.6 kJ/g</td>
<td>890 kJ/mol</td>
</tr>
<tr>
<td>ethane</td>
<td>52.0 kJ/g</td>
<td>1560 kJ/mol</td>
</tr>
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<td>4141 kJ/mol</td>
</tr>
<tr>
<td>heptane</td>
<td>48.2 kJ/g</td>
<td>4817 kJ/mol</td>
</tr>
</tbody>
</table>

1. How does your experimental heat of combustion (in kJ/g) for paraffin wax \(\text{C}_{25}\text{H}_{52}\) compare to the accepted heat of combustion for propane, \(\text{C}_3\text{H}_8\)?

2. Calculate the thermal energy released when one mole of paraffin burns. (One mole of paraffin = 352g).

3. How do the molar heats of combustion (in kJ/mol) for paraffin and propane compare?

4. Explain any differences noted between paraffin and propane in your answers to Questions 1 and 3. HINT: Keep in mind the calculation you did in number 2.

5. Which hydrocarbon, paraffin or propane, is the better fuel? Explain.

6. In calculating heats of combustion, you assumed that all thermal energy from the burning fuel went to heating the water.
   a. Is this a good assumption? Explain.

   b. Describe two things that you can include in your experimental design that will decrease the heat loss.

   c. Do you think scientists need to think creatively to design experiments? Explain.
1. How does your experimental heat of combustion (in kJ/g) for paraffin wax (C_{25}H_{52}) compare to the accepted heat of combustion for propane, C_3H_8?

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</table>

*The experimental heat of combustion for paraffin wax should be lower than the heat of combustion for propane (when compared in kJ/g)*

2. Calculate the thermal energy released when one mole of paraffin burns. (One mole of paraffin = 352g).

\[
\text{Heat of Combustion (kJ/g)} \times 352\text{g/mole} = \text{thermal energy released per mole}
\]

3. How do the molar heats of combustion (in kJ/mol) for paraffin and propane compare?

*The molar heat of combustion of paraffin should be higher than the molar heat of combustion of propane.*

4. Explain any differences noted between paraffin and propane in your answers to Questions 1 and 3. HINT: Keep in mind the calculation you did in number 2.

*Although the heat of combustion of propane per gram is higher than paraffin, paraffin has a higher molar mass making its molar heat of combustion higher than the molar heat of combustion of propane.*

5. Which hydrocarbon, paraffin or propane, is the better fuel? Explain.

*The better fuel is propane because you can get more energy per gram burned from propane than from paraffin.*

6. In calculating heats of combustion, you assumed that all thermal energy from the burning fuel went to heating the water.

a. Is this a good assumption? Explain. *No, there will be heat lost from the air or the can will absorb energy.*

b. Describe two things that you can include in your experimental design that will decrease the heat loss. *Answers should attempt to account for the heat lost to the air or the can absorbing some of the energy.*

c. Do you think scientists need to think creatively to design experiments? Explain. *Scientists need to be creative in designing experiments because they need to think about cost effectiveness, accurate/precise measurements, any sources of error and correct for these sources.*
In Class Handout: Heat, Temperature, and Combustion Questions

**Compare a drop of hot water to a beaker of hot water.**

1. Is the temperature of the drop of water the same, less than, or equal to the beaker of water?
   - Your Answer:
   - Right Answer:

2. What would burn more, a drop of that water on your hand or putting your hand in a beaker of water? Explain.
   - Your Answer:
   - Right Answer:

Compare your explanation to the ‘right’ explanation. How was it different?

**Heat of Combustion Calculations**

1. Write a balanced chemical equation, including the amount of thermal energy, for the combustion of butane. Explain what your answer (the number value) means in a sentence.
   - Your Answer:
   - Right Answer:

2. How much thermal energy is given off when 7.4 moles of butane burns? Explain what your answer (the number value) means in a sentence.
   - Your Answer:
   - Right Answer:

3. How much thermal energy is given off when 660 grams of butane burns? Explain what your answer (the number value) means in a sentence.
   - Your Answer:
   - Right Answer:

Compare your answers to the correct answers. How were they different?
In Class Handout: Heat, Temperature, and Combustion Questions

**Compare a drop of hot water to a beaker of hot water.**

3. Is the temperature of the drop of water the same, less than, or equal to the beaker of water?
   Your Answer:

   Right Answer: *The temperatures are equal.*

4. What would burn more, a drop of that water on your hand or putting your hand in a beaker of water?
   Explain.
   Your Answer:

   Right Answer: *The beaker of water would burn more because it has more heat because it has more mass.*

Compare your explanation to the ‘right’ explanation. How was it different?

**Heat of Combustion Calculations**

4. Write a balanced chemical equation, including the amount of thermal energy, for the combustion of butane.
   Your Answer:

   Right Answer: \(2 \text{C}_4\text{H}_{10} + 6 \text{O}_2 \rightarrow 10 \text{H}_2\text{O} + 8 \text{CO}_2 + 5718 \text{kJ}\) *For the complete combustion of butane (2 moles of butane reacting), 5718 Kj of energy is released.*

5. How much thermal energy is given off when 7.4 moles of butane burns?
   Your Answer:

   Right Answer: *7.4 moles x 2859 kJ/mole = 21157 kJ if 7.4 moles of butane burned. 21157 kJ of energy would be released.*

6. How much thermal energy is given off when 660 grams of butane burns?
   Your Answer:

   Right Answer: *660 grams x 49.3 kJ/g = 32,538 KJ for every 660 grams of butane that burned, 32,538 KJ of heat is released.*
1) In a chemical reaction, which of the following will always be true?
   A) The products are always exothermic and the reactants are always endothermic.
   B) The products are always endothermic and the reactants are always exothermic.
   C) Energy is absorbed when bonds are broken and energy is released when bonds are formed.
   D) Energy is released when bonds are broken and energy is absorbed when bonds are formed.

2) What do we call the amount of energy required to raise one gram of a substance one degree celsius?
   A) specific heat capacity
   B) temperature capacity
   C) heat of combustion
   D) molar heat of combustion

3. Assume that, on average:
   a) you drive a car that gets 25 miles/gallon
   b) you drive 235 miles/week
   c) gas costs $2.55 a gallon
   d) your car’s engine is 30% efficient.

   **SHOW ALL WORK FOR FULL CREDIT!!**

<table>
<thead>
<tr>
<th>How many miles do you drive in a year?</th>
<th>How many gallons of gas do you use in a year?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How much do you spend on gasoline each year?</th>
<th>How many gallons are wasted each year as a result of your car’s inefficiency?</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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</table>

4) Use the energy diagram to answer the following questions.

   ____ What region of the diagram shows the products?
   ____ What region of the diagram has the most energy?
   ____ Where in the diagram is energy being released?
   ____ Where in the diagram are bonds being broken?
   Is this reaction exothermic or endothermic? **EXPLAIN**
<table>
<thead>
<tr>
<th>HYDROCARBON</th>
<th>HEAT OF COMBUSTION</th>
<th>MOLAR HEAT OF COMBUSTION</th>
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</table>

5) Write a balanced chemical equation, including the amount of thermal energy, for the combustion of butane.

6) How much thermal energy is given off when 4.3 moles of propane burns? 7) How much thermal energy is given off when 302 grams of hexane burns?

8) Find the heat of combustion for paraffin using the information provided. SHOW WORK.

<table>
<thead>
<tr>
<th>starting mass of candle</th>
<th>10.2 g</th>
<th>heat absorbed by water = (specific heat) (\times) (mass of water) (\times) (change in temp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass of water</td>
<td>98 g</td>
<td>heat absorbed by water = thermal energy released by candle</td>
</tr>
<tr>
<td>starting temperature of water</td>
<td>21 °C</td>
<td>heat of combustion = (\frac{\text{thermal energy released}}{\text{mass of substance burned}})</td>
</tr>
<tr>
<td>final temperature of water</td>
<td>39 °C</td>
<td></td>
</tr>
<tr>
<td>final mass of candle</td>
<td>9.7 g</td>
<td></td>
</tr>
<tr>
<td>specific heat of water</td>
<td>4.2 J/g°C</td>
<td></td>
</tr>
</tbody>
</table>

9) In the combustion lab, why was it inappropriate to assume that the heat absorbed by the water is equal to the heat given off by the candle? Include at least two reasons.
Petroleum Quiz B Answer Key (25 Points Total)

1. C
2. A
3. Miles per year: Gallons per year: Amount spent on gas each year: Gallons wasted:
4. C,B,2,1, Endothermic because it took more energy to break the bonds than it did to form the new bonds
5. \(2 \text{C}_4\text{H}_{10} + 6 \text{O}_2 \rightarrow 10 \text{H}_2\text{O} + 8 \text{CO}_2 + 5718 \text{kJ}\)
6. 4.3 moles x 2200 kJ/mole = 9460 kJ
7. 302 grams x 48.2 kJ/g = 14,556 kJ
8. Mass of paraffin burned = 10.2 g – 9.7 g = 0.5 g
   Heat absorbed by the water = 4.2 J/g C x 98g x (39°C-21°C) = 7408.8 J
   Heat of combustion = 7408.8J/0.5g = 14818 J/g
9. Some of the thermal energy was lost to heat the air and some the energy was absorbed by the can.