INTRODUCTION TO CALORIMETRY

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

- understand the concept of heat and joules.
- perform heat-gain and heat-loss calculations.

Procedure Overview

- hot and cold water are mixed. The water masses and temperature changes are used to calculate the heat lost and heat gained.
- ice is melted in water and the heat of fusion is calculated.
- candle is burned under a metal cup containing a known mass of water, and the heat of combustion of the candle is calculated.

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Report Sheet

Heat loss and heat gain

Mass of cold water + cup	_______ g
Mass of cup	_______ g
Mass of cold water	_______ g
Mass of hot water	_______ g
Temperature of cold water	_______ °C
Temperature of hot water	_______ °C
Final mixture temperature	_______ °C
ΔT (hot water)	_______ °C
ΔT (cold water)	_______ °C

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Report Sheet (page 2)

Heat associated with a physical change

	Mass of cup and water	_______ g
	Mass of dry cup	_______ g
	Mass of cup, ice + water	_______ g
	Mass of water	_______ g
	Mass of ice	_______ g
I	initial water temperature	_______ °C
	Final water temperature (after the ice melts)	_______ °C
	ΔT	_______ °C

Heat associated with chemical change

Mass of water + metal cup	__________________ g
Mass of metal cup	__________________ g
Mass of water	__________________ g
Mass of candle before burning	__________________ g
Mass of candle after burning	__________________ g
Mass of candle burned	__________________ g
Initial water temperature	____________ °C
Final water temperature	____________ °C
ΔT	____________ °C

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Report Sheet (page 3)

Calculations
Heat loss and heat gain

1. Calculate the heat gained by the cold water.

2. Calculate the heat lost by the hot water.

3. Compare the results of (1) and (2). What conclusions can you draw?

Heat associated with a physical change

1. Calculate the heat lost by the water. See the example in the experiment description. Remember, this is also the heat gained by the ice.

2. Calculate the heat required to melt one gram of ice. See the example in the experiment description.

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Report Sheet (page 3)

Calculations

Heat associated with a chemical change

1. Calculate the heat absorbed by the water.

2. Calculate the heat released per gram of candle burned.

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Report Sheet (page 3)

Questions/Problems

1. Distinguish between **heat** and **temperature**.

2. Describe what is meant by the **specific heat** of a substance.

3. In this experiment, you measured the heat associated with a burning candle. Does this represent a physical change and/or a chemical change? Describe the change(s) occurring.

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Suggested Answers to Questions/Problems

1. Distinguish between **heat** and **temperature**.

   Heat is a form of energy, manifested by the transfer of energy between two bodies of different temperatures. It is an extensive property, depending on the amount of matter examined.

   Temperature is an intensive property which depends on the intensity of energy present and not on the amount and type of material being measured.

2. Describe what is meant by the **specific heat** of a substance.

   Specific heat is the amount of heat required to raise one gram of a substance by one °C.

3. In this experiment, you measured the heat associated with a burning candle. Does this represent a physical change and/or a chemical change? Describe the change(s) occurring.

   The experiment represents a chemical change. During the combustion of the candle, the candle wax is being converted into carbon dioxide and water with small amounts of other chemicals. The chemical reaction is also generating heat. The incidental melting of wax which accompanies the combustion is a physical change.

Tips and Traps

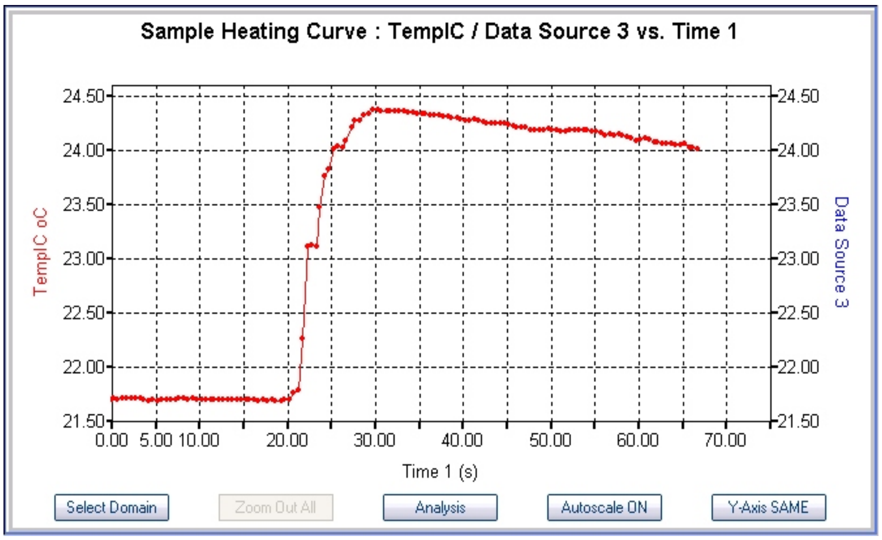
1. It is easy for students to forget to measure some of the masses. Please remind them to read the instructions carefully!

2. Before the lab starts, show your students what approximately 10 grams of ice looks like so no one actually tries to measure it directly on the balance! Remember, the mass of the ice will be measured indirectly by measuring the mass of the water and melted ice at the end.

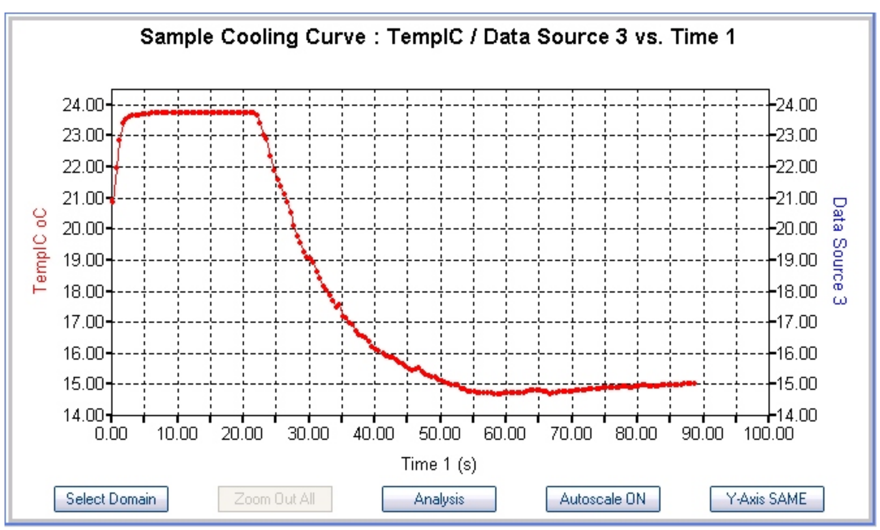
3. The ice can be "dried" by dabbing it with a paper towel.

4. It is important to remind the students to wipe the carbon black off of the bottom of the metal cup after each use! The soot is very messy!

SAMPLE HEATING CURVE



SAMPLE COOLING CURVE



Sample Data

Heat loss and heat gain

Mass of cold water + cup	39.72 g
Mass of cup	1.83 g
Mass of cold water	37.89 g
Mass of hot water	29.82 g
Temperature of cold water	9.72 °C
Temperature of hot water	45.12 °C
Final mixture temperature	23.68 °C
ΔT (hot water)	−21.44 °C
ΔT (cold water)	13.96 °C

Heat associated with a physical change

Mass of cup and water	102.39 g
Mass of dry cup	1.79 g
Mass of cup, ice + water	113.06 g
Mass of water	100.60 g
Mass of ice	10.67 g
Initial water temperature	19.21 °C
Final water temperature (after the ice melts)	11.10 °C
ΔT	8.11 °C

Heat associated with chemical change

Mass of water + metal cup	53.76 g
Mass of metal cup	1.91 g
Mass of water	51.85 g
Mass of candle before burning	17.35 g
Mass of candle after burning	17.13 g
Mass of candle burned	0.22 g
Initial water temperature	18.51 °C
Final water temperature	37.95 °C
ΔT	19.44 °C

Sample Data (page 3)

Calculations

Heat loss and heat gain

1. Calculate the heat gained by the cold water.

   $$(4.184\ J/g\ {}^{\circ}C)\ (37.89\ g)\ (13.96\ {}^{\circ}C) \;=\; 2213\ J$$

2. Calculate the heat lost by the hot water.

   $$(4.184\ J/g\ {}^{\circ}C)\ (29.82\ g)\ (21.44\ {}^{\circ}C) \;=\; 2675\ J$$

3. Compare the results of (1) and (2). What conclusions can you draw?

   The ratio of the heat gained to heat lost is 2213 J/2675 J, or 0.827. This value should theoretically be "1"; however, we should certainly expect some error. There seems to be an unaccounted for heat loss in the transfer of heat from the hot water to the cold water.

Heat associated with a physical change

1. Calculate the heat lost by the water. See the example in the experiment description. Remember, this is also the heat gained by the ice.

   $$(4.184\ J/g\ {}^{\circ}C)\ (100.60\ g)\ (8.11\ {}^{\circ}C) \;=\; 3.41 \times 10^{3}\ J$$

2. Calculate the heat required to melt one gram of ice. See the example in the experiment description.

   heat loss = heat gained

   $$3.41 \times 10^{3}\ J \;=\; (10.67\ g)\ (\Delta H_{fusion}) \;+\; (4.184\ J/g\ {}^{\circ}C)\ (10.67\ g)\ (11.10\ {}^{\circ}C)$$

   $$\Delta H_{fusion} \;=\; 273\ J/g$$

Heat associated with a chemical change

1. Calculate the heat absorbed by the water.

   $$(4.184\ J/g\ {}^{\circ}C)\ (51.85\ g)\ (19.44\ {}^{\circ}C) \;=\; 4217\ J$$

2. Calculate the heat released per gram of candle burned.

   $$4217\ J/0.22\ g \;=\; 1.9 \times 10^{4}\ J/g$$

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Laboratory Preparation (per student station)

Equipment

- ***MicroLAB*** interface and temperature probe
- ring stand, iron ring
- utility clamp
- two foam cups
- cover for foam cup
- clay triangle
- small metal cup (like a Vienna sausage can)
- 100 mL graduated cylinder

Supplies

- candle
- paper towel
- matches

Chemicals

- water
- ice

Safety and Disposal

There are no disposal problems in this experiment. All waste can go in the trash can or down the drain.