Heat, Heat capacities, and Specific heat capacities

Heat is defined as the energy that is transferred between objects due to a temperature difference. Heat 'moves' from objects with a higher temperature to objects with a lower temperature because the two systems want to come to a common temperature-thermal equilibrium. The unit for heat is the joule (J).

Heat capacity is related to the amount of heat some matter can absorb before a temperature change occurs. Heat capacity is dependent on the amount of material. This is often called thermal mass. It takes more energy to heat a tub of water than a teacup of water to the same temperature. Heat is an extensive property, but temperature is intensive because it is independent of the amount of material. The units for heat capacity is J/°C, We assume that the material being measured is homogeneous. Heat capacity is an extensive property because it depends on the amount of the material available.

When we specify the amount of material absorbing the energy to induce a temperature change of 1°C, we are referring to specific heat. Every type of matter has a unique specific heat, therefore, different materials warm and cool at different rates. Materials with a high specific heat resist changes in temperature, which means they can absorb more energy and not change temperature. Materials with low specific heat change temperature more quickly. Specific heat is dependent on mass or moles and is considered an intensive property. The unit for specific heat is J/g°C.

We see this phenomenon when we cook food and eat food. Pizza is a great example. Bread, cheese, oil, and sauce comprise most pizza. When you eat pizza, you probably noticed that the cheese and sauce seem much hotter than the bread. They are actually all at the same temperature, but the cheese and the sauce are able to hold more heat than the bread (which cools quicker) and are better conductors of heat than the crust, so the cheesy goo, and the watery sauce heat up your mouth more because they are more efficient at transferring energy.   Bread has a lower heat capacity than water and a craggy, dry surface, which allows for heat to be dispersed easier and deliver less burn. Melted cheese is contiguous goo with a smooth surface. This means it has more "stick-ablity" and will keep heat in one area-your tongue and the roof of your mouth. The same is true for sauce, which is a tomato/water paste, and the oil. The sauce, you scamp!, has a huge specific heat compared to any other component of pizza. It holds more heat per gram of pizza and releases heat that heat in your mouth. Ouch-that's some burn there! This is also the reason pie filling is warm, while the crust is cool to the touch and why it is most efficient (and healthier) to cook an unstuffed turkey instead of a stuffed turkey.[1]

There are two other properties that we don't discuss in a General Chemistry class, but are important when considering how metals behave when heated. The first is **thermal conductivity.** Thermal conductivity refers to how efficiently a metal or other material conducts heat. A high thermal conductivity value means the material warms faster and can

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[1] http://www.education.com/science-fair/article/effect-salt-concentration-specific-heat/

distribute the energy more evenly. This is not a thermodynamic value. Materials with low specific heats tend to have high thermal conductivities. The second term of interest is **thermal diffusivity.** Thermal diffusivity is a combination of the density of the material, the thermal conductivity, and the specific heat.

Heating substances in the sun: The following table shows the temperature of four different substances after the substances have been in direct sunlight for a period of up to 60 minutes. All the substances have a mass of 10.00 g.

time	Air	Water	Sand	metal
0.0 min	25.0 °C	25.0 °C	25.0 °C	25.0 °C
15.0 min	28.9 °C	26.2 °C	30.0 °C	35.0 °C
30.0 min	32.5 °C	27.5 °C	35.0 °C	45.0 °C
45.0 min	36.2 °C	28.5 °C	40.0 °C	55.0 °C
60.0 min	40.0 °C	30.0 °C	45.0 °C	65.0 °C

The temperature changes of 10.00-g of four different substances after warming for up to 60 minutes in sunlight
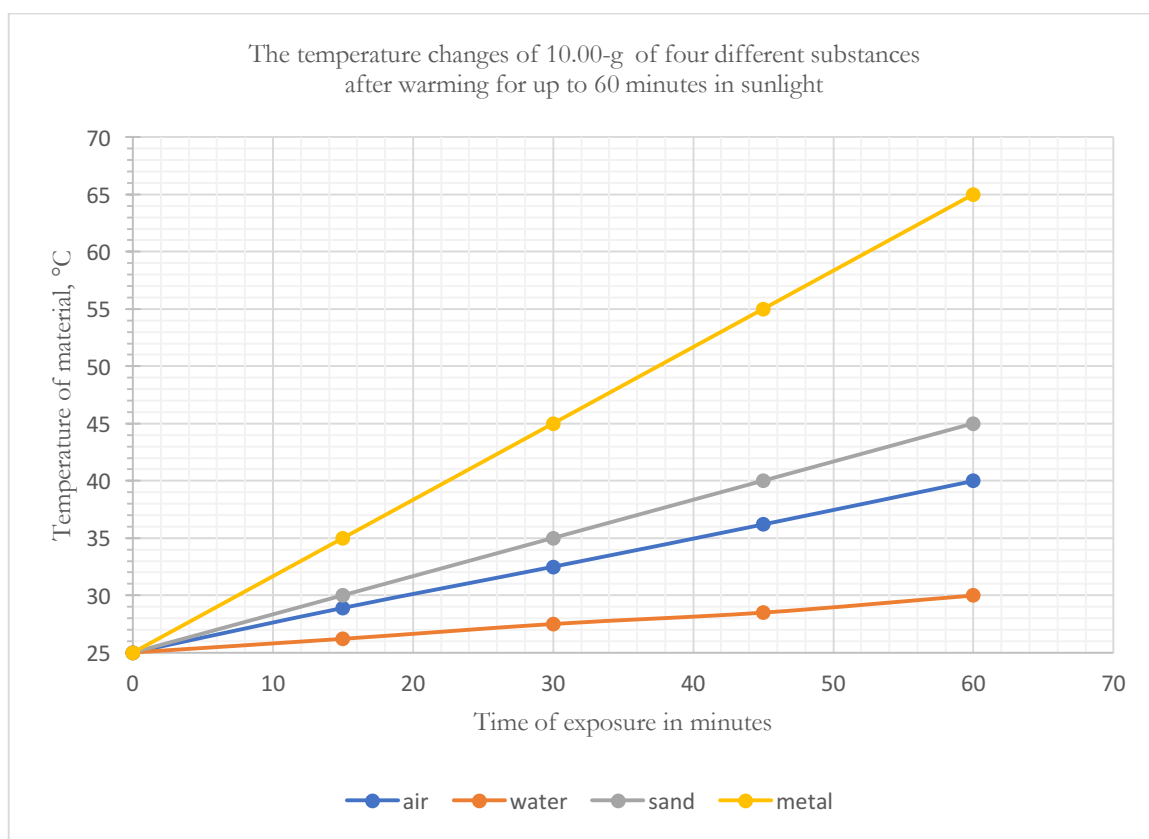
Part One: Using the graph, answer the following questions with complete sentences. Please write your answers such that I can read them. Type your answers if there is any question. These will go in your lab book.

1. Order the substances based on the time required to heat them from slowest to fastest. Explain your choice
2. Based on the definition of specific heat and heat capacity, which of the four substances do you think has the highest specific heat capacity, and which one has the lowest heat capacity?

3. Here are the specific heat capacities of the four substances: 4.18J/g°C, 1.00J/g°C, 0.80 J/g°C, and 0.60 J/g°C. Match these specific heats to its respective substances.
4. Which of these materials conducts heat most efficiently? Explain your choice based on the graph, specific heat, thermal conductivity, etc.

Part Two: Using the graph, the textbook, and other reputable sources, answer the following questions with complete sentences. Please type any explanation answers using good gate keeping and tape the answers into your lab book.

1. When you boil water in a pot on the stove, which heats faster, the metal or the water? Explain.
2. If something has a high specific heat capacity will it take a lot of heat or a little heat to change its temperature? Explain
3. Assuming they both start at the same temperature, which will heat up faster, a swimming pool or a bathtub? Explain.
5. It was a cold, dark night in Finland. I was staying at an inn in Utsjoki. My host brought me a bottle filled with hot water to keep the evening chill off. I'm so glad she did not give me a bottle filled with hot air. Why?
6. In the old days, before electronic flash bulbs, photogs used flashbulbs. These bulbs contained a metal filament such as magnesium and oxygen. When the flash button is pressed, the oxygen is ignited and the metal burns white hot. The bulb is a rigid container. This is a real-life example of constant volume calorimetry. Do you think work was done in this system? Explain.
7. In many parts of the world, people perform the feat of fire-walking-walking on hot coals with bare feet. Can you give a reason how someone can walk on burning coals using thermochemistry principles?

Part Three: Solve the following problems in calorimetry. There are four general types of processes that are measured in calorimeters: phase changes, worming and cooling, reactions, and combustion reactions in bomb calorimeters. Answer the questions and show your work clearly. Put your final answers in the report sheet provided on the website. Attach the pages showing your calculations and answers to questions to the sheet.

Phase changes

1. A bag of ice was placed on a patient's head. The ice bag contained 220.0g of ice at 0.00°C. When the ice bag was removed, all of the ice inside had melted and the liquid had a temperature of 21.00°C. How many joules of heat were added? ΔHfus= 6.01 kJ/mol or 333 J/g, ΔHvap= 40.67 kJ/mol or 2257 J/g; Specific heat of water = 4.184 J/g°C.
2. How many joules are required to convert 10.0g of solid ethyl alcohol at -180.3°C to the vapor state at the boiling point of 78.3°C?
   a. $C_{[solid\ EtOH]}$ = 0.971J/g°C
   b. $C_{[liquid\ EtOH]}$ = 2.30J/g°C
   c. The melting point of alcohol is -117.3°C
   d. ΔH_{fus}= 218J/g
   e. ΔH_{vap}= 854 J/g.} [15.8 kJ]

Warming or cooling material

1. An insulated cup contains 75.0g of water at 24.00°C. A 26.00g sample of metal at 82.25°C is added. The final temperature of the water and metal is 28.34°C. What is the specific heat of the metal?
2. A 70.0 g sample of water at $95.00°$C is mixed with 50.0 g of water at $135.0°$C. Calculate the final temperature of the mixture assuming no heat loss to the surroundings. Remember that the heat gained by the cooler water is equal to the heat lost by the warmer water

Reactions in Calorimeters

1. In a calorimeter, 50.0 mL of a 0.100 M $AgNO_3$ and 50.0 mL of 0.100 M HCl are mixed to yield the following reaction: $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
   The two solutions were initially at $22.60°$C, and the final temperature is $23.40°$C. Calculate the heat that accompanies this reaction in kJ/mol of AgCl formed. Assume that the combined solution has a mass of 100.0 g and has a specific heat capacity of 4.18 J/$°$C·g.

2. Consider the reaction: $2 HCl_{(aq)} + Ba(OH)_{2(aq)} \rightarrow BaCl_{2(aq)} + 2 H_2O_{(l)}$ $\Delta H = -118$ kJ.
a) Calculate the heat (released or needed) when 100.0 mL of 0.500 M HCl is mixed with 300.0 mL of 0.500 M $Ba(OH)_2$. Remember to find the limiting reactant. The limiting reactant will determine how much heat is evolved in the reaction.
b) If the temperature of both solutions was initially $25.0°$C and that the final mixture has a mass of 400.0 g and a specific heat capacity of 4.18 J/g$°$C, calculate the final temperature of the mixture.

Bomb Calorimeter

1. Camphor ($C_{10}H_{16}O$) has energy of combustion of -5903.6 kJ/mol. When a sample of camphor with mass 0.1204 g is burned in a calorimeter, the temperature increases by $2.28°$C. Calculate the heat capacity of the calorimeter.
2. A 0.1964 g sample of quinone ($C_6H_4O_2$) is burned in a bomb calorimeter that has a capacity of 1.56 kJ/$°$ C. The temperature of the calorimeter increases by $3.2°$C. Calculate the energy of combustion in kJ/g and kJ/mol.
3. The combustion of 0.1584 g benzoic acid increases the temperature of a bomb calorimeter by $2.54°$C. Calculate the heat capacity of the calorimeter. The energy released by the combustion of benzoic acid is 26.42 kJ per gram. A 0.2130 g sample of the vanillin is been burned in the same calorimeter, and the temperature increases by $3.25°$C. What is the energy of combustion of vanillin in kJ/g?