ANSWERKEY

Heat, Heat capacities, and Specific heat capacities

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
    - *The metal shows the largest rise in temperature for the same amount of time. The order its water, air, sand, metal*
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?
    - *The highest specific heat would be the material that took the longest to heat because that material is better at absorbing energy without undergoing a large KE change, therefore a temperature change for the same amounts of material. Water would have the largest specific heat and metal would have the smallest specific heat.*
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.
    - *The specific heats would follow then water: 4.18, air: 1.00, sand: 0.80, metal: 0.60J/g°C respectively.*
4. Which of these materials conducts heat most efficiently? Explain your choice based on the graph, specific heat, thermal conductivity, etc.
    - *The material that conducts heat most efficiently would be the metal. It has the lowest specific heat. Compounds with low specific heat are more efficient at dispersing energy, and get hot faster.*

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.
    - *The metal heats faster than the water because it has a lower specific heat than the water, as seen from the graph.*
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
    - *We know that the more heat is added to materials, the more the temperature rises for that material. From the graph, compounds with high heat capacities will need more energy to undergo a temperature change because the material absorbs heat such that the temperature does not rapidly change, like the difference between water and metal.*

3. Assuming they both start at the same temperature, which will heat up faster, a swimming pool or a bathtub? Explain.
    - *Temperature changes are also based on the amount of material. The more material, the more energy needs to be added to invoke a temperature change. Since the swimming pool contains more molecules, and there for more mass, more energy needs to be added to have the same temperature change as that of a bathtub. The bathtub will heat faster.*
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?
    - *The specific heat of water is higher than the specific heat of air. There are more molecules of water for the same volume of air. The water is more efficient at maintaining the temperature of the water bottle, and will disperse the heat slower to keep you warmer over a longer period of time.*
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.
    - *Work is not done in this system. The bulb is a rigid container. This means no $P\Delta V$ work can be done, because the gases can't expand against constant pressure. There are other reactions that do no work; systems that don't involve gases (precipitation), reactions where the moles of gases don't change, and reactions where q_p is larger than $P\Delta V$.*
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?
    - *Fire walking is about skin, speed and heat conductivity. Take toast in a toaster oven, for example. You put your hand in the toaster oven and pull out the toast. The toast and the air in the oven are the same temperature. The brown part is hot, and your fingers can get burned IF you hold the toast for a long period of time. Also, the air in the oven is hot, but it doesn't feel as hot as the toast because they conduct heat in different ways. The dead skin on the soles of your feet and your fingertips act as an insulator. Back to fire. Fire burns! Coals are hot, but it turns out that carbon is really awful as a conductor of heat. So red hot coals, which are mostly carbon, covered by fluffy ash (which has air in it) are a really poor conductor of heat. Walk calmly, not to fast, not to slow, and you won't get burned. The dead skin on your feet, the poor conductivity of ashy coals, and get off the coals quickly. You will not get burned.*

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.

The answers to these problems are posted separately.

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. $C_{[\text{solid EtOH}]}$ = 0.971J/g°C
   b. $C_{[\text{liquid EtOH}]}$ = 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: $2\ HCl_{(aq)} + Ba(OH)_{2(aq)} \rightarrow BaCl_{2(aq)} + 2\ H_2O_{(l)}$ $\quad \Delta H = -118$ 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?