Name ________________________________ Chem 161, Section: _______ Group Number: ______

ALE 25. The First Law of Thermodynamics

(Reference: Chapter 6 - *Silberberg 5th edition*)

Important!! For answers that involve a calculation you must show your work neatly using dimensional analysis with correct significant figures and units to receive full credit. No work, no credit. Report numerical answers to the correct number of significant figures. **CIRCLE ALL NUMERICAL RESPONSES**.

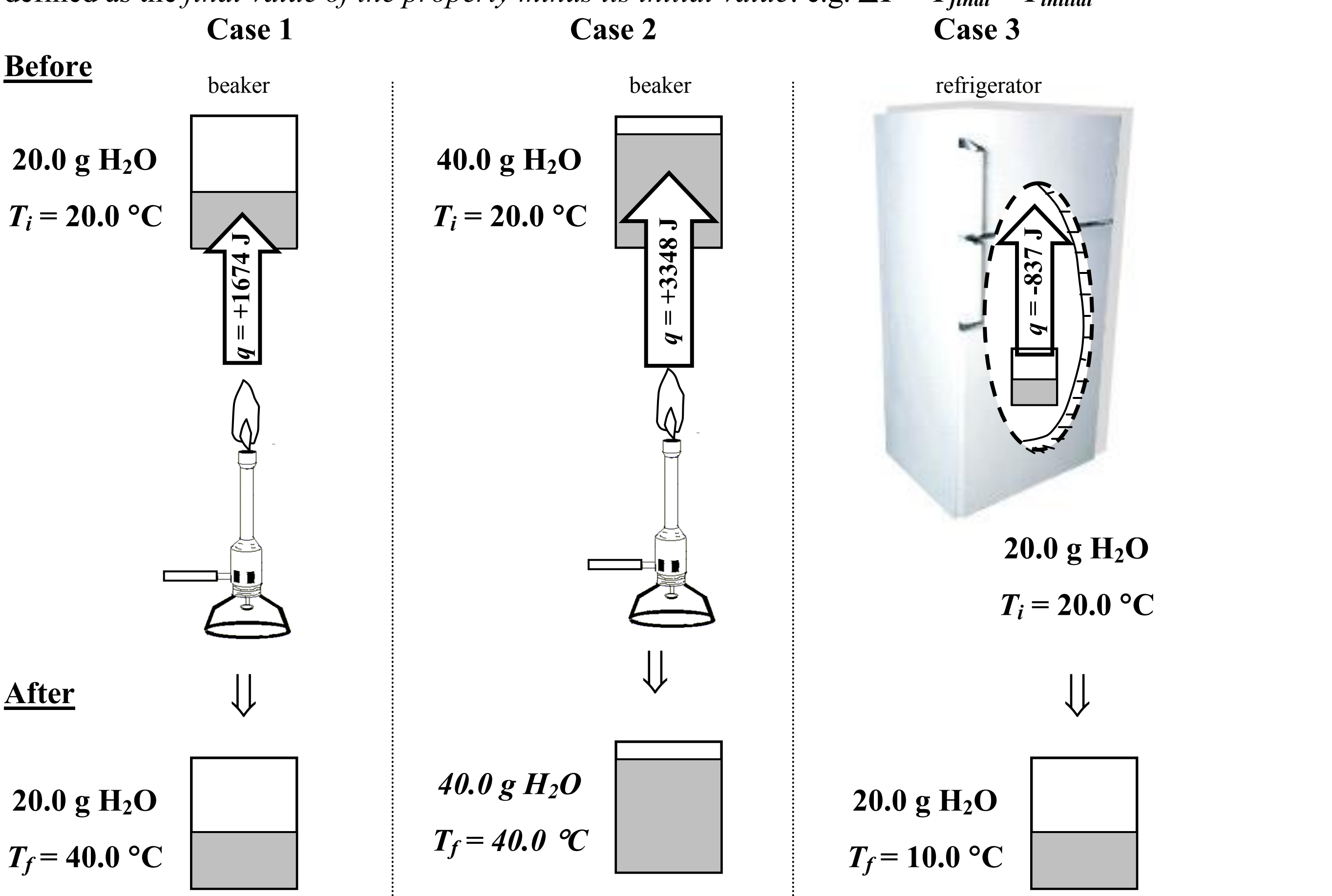
How can the transfer of heat be quantified?

The Model: Heat

Thermodynamics is the study of transformations of energy. The laws of thermodynamics govern, for example, how much mechanical energy could be obtained by combusting a chemical fuel or how much electrical energy could be obtained by completing a circuit thus allowing a battery to function.

You undoubtedly know the **First Law of Thermodynamics** as "Energy cannot be created nor can it be destroyed, but it may be converted from one form into another." The "forms" of energy that thermodynamics is principally concerned with are **heat** and **work**.

The temperature of the substance increases when it absorbs heat energy. There are a number of factors (such as mass of the substance) that affect *how much* the temperature of a substance changes. If you have a substance with mass **m** and you want to increase its temperature by ΔT, you have to add to it an amount of heat q. When you want to cool the substance, heat must be removed. The symbol "Δ", the capitalized Greek letter delta, signifies to the reader a ***change*** in a property. The change in a property is usually defined as the *final value of the property minus its initial value*: e.g. $\Delta T = T_{final} - T_{initial}$



Key Questions

1a. Compare Case 1 and Case 2 in the Model. Is there a <u>direct relationship</u> or an <u>inverse relationship</u> between q and m? (*Hints*: What is the mass of water in Case 1? in Case 2? What is the amount of heat involved in Case 1? in Case 2? As the mass of water increases, does the amount of heat involved increase or decrease?)

There is a ______________________________ relationship between q and m.

b. Compare Case 1 and Case 3 in the Model. Is there a <u>direct relationship</u> or an <u>inverse relationship</u> between q and ΔT? (*Hints*: What is the absolute magnitude of the change in temperature in Case 1? in Case 3? What is the absolute magnitude of heat in Case 1? in Case 3? As the change in temperature increases, does the amount of heat involved increase or decrease?)

There is a ______________________________ relationship between q and ΔT.

c. The proportionality constant that relates q to m and ΔT is symbolized as ***c*** and is called the ***specific heat capacity***. Complete the following formula based on your answers to parts (a) and (b), above, and the following symbols: **ΔT** = temperature change of a substance, ***c*** = specific heat capacity, **m** = mass of the substance, ***q*** = amount of heat energy

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$$q = c$$

d. Use the Model and dimensional analysis (the factor label method) to calculate the value and units of the specific heat of water (to 3 sig figs).

2a. Cases 1 and 2 involve exchanges of heat such that $q > 0$ and Case 3 involves an exchange of heat such that $q < 0$. What does the "sign" of the heat exchange inform the reader about?

b. An **endothermic** process is one for which $q > 0$ and an **exothermic** process is one for which $q < 0$. Based on the Model, and in your own words, what is an endothermic process? What is an exothermic process?

c. How does the sign of ΔT of the system undergoing an exchange of heat compare with the sign of q?

3. a.) Which contains more heat, 100. mL of water at 25 ^oC or a liter (1000. mL) of water at 25 ^oC? Give a quantitative answer—how much more heat?

   b.) Which contains more heat, 100. mL of water at 25 ^oC or 100. mL of water at 50. ^oC? Give a quantitative answer—how much more heat?

   c.) Which contains more heat, 100. mL of water at 80. ^oC or 200. mL of water at 40. ^oC? Give a quantitative answer—how much more heat?

4. a.) Distinguish between heat and temperature.

   b.) In which direction does heat flow?

Exercise

A. Water vapor ("steam") has a specific heat of 1.87 J g^{-1} °C^{-1}. Suppose 1 mol of steam at 100. °C gains 1200. J of heat. What will the final temperature of the steam be?

The Model: Specific Heat Capacity

The magnitude of the temperature change of a substance depends on the mass of the substance, the substances specific heat capacity and the amount of heat added to or removed. You also have probably experienced the fact that different substances heat at different warm up or cool down at different rates Each substance has its own ***specific heat capacity***, or just "specific heat". The specific heat capacity is a measure of the amount of energy needed to change the temperature of the substance. The higher the specific heat, the more energy is required to change the temperature of the substance.

Key Questions

5. Consider 200 Joules (J) of heat energy applied to several objects and fill in the blank: *The higher the specific heat of the object, the* __________________ *the temperature change of the object.*
   lower or higher

6. Which substance has a higher specific heat capacity—water or a metal like the metal in a car hood? *Briefly explain your reasoning*.

Exercises

B. Calculate q when 0.10 g of ice is cooled from 10.0 ^{o}C to -75.0 ^{o}C. Is the process exo- or endothermic? The specific heat of ice = 2.087 J/g ^{o}C.

C. When 165 mL of water at 22.0 ^{o}C is mixed with 85 mL water at 82 ^{o}C, what will be the final temperature? Assume no heat is lost to the surroundings and the density of water is1.00 g/mL and the specific heat of water is 4.184 J/g ^{o}C.

   Hint: Heat lost by the hot water = heat gained by the cold water: $-q_{\text{hot water}} = +q_{\text{cold water}}$

D. Two aircraft rivets, one iron and the other of copper, are placed in a calorimeter (an insulated container that does not allow heat to be lost to or gained from the surroundings) that has an initial temperature of 20.0 ^{o}C. The data for the metals are as follows:

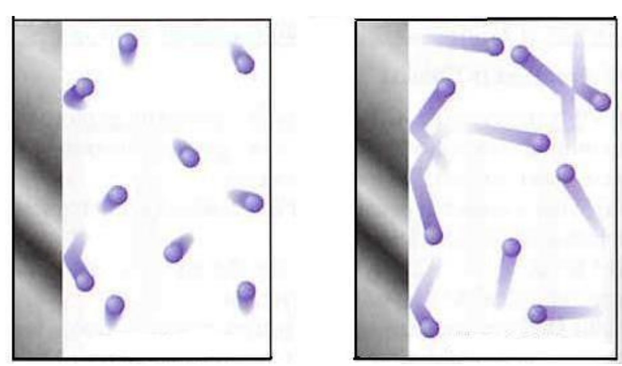
	Iron	**Copper**
Mass (g)	30.0	20.0
Initial T (^{o}C)	0.0	100.0
C (J/g ^{o}C)	0.450	0.387

   a.) Will the heat flow from the Fe to the Cu or from the Cu to the iron. Explain your reasoning.

b.) Assuming the heat capacity of the calorimeter is negligible, calculate the maximum final temperature of the system. Hint: heat gained = heat lost

E. An unknown piece of metal weighing 95.0 g is heated to 98.0 ^{o}C. It is dropped into 250.0 g of water at 23.0 ^{o}C. When equilibrium is reached, the temperature of the water and piece of metal is 29.0 ^{o}C. Determine the specific heat of the metal. Assume the heat capacity of the container, a styrofoam cup, is negligible. Hint: heat gained by water = heat lost by metal

F. A reaction is carried out in a steel vessel within a chamber filled with argon gas, a very inert, unreactive gas. Below are molecular views of the argon adjacent to the surface of the reaction vessel (the dark band on the left in the figure below) before and after the reaction. Was the reaction exothermic or endothermic? Explain your reasoning.



Argon atoms in vessel before reaction **Argon atoms in vessel after reaction**