SUMMARY Q-STATEMENTS:

1) Adding a metal (solid) to water and it does not dissolve:

$q_{metal} + q_{water} = 0$ Solve for i) $C_{p\ (metal)}$

ii) final temp

$q_{metal} + (q_{water} + q_{cal}) = 0$ iii) initial temp

iv) mass of water

2) Adding a solid to water and it dissolves:

$q_{solid} + q_{solution} = 0$ Solve for q_{solid}

$q_{solid} + (q_{solution} + q_{cal}) = 0$

3) Mixing two solutions causing a chemical reaction:

$q_{rxn} + q_{solution(mixture)} = 0$ Solve for q_{rxn} (ΔH)

$q_{rxn} + (q_{solution(mixture)} + q_{cal}) = 0$

4) Mixing hot and cold water:

$q_{hot} + (q_{cold} + q_{cal}) = 0$ Solve for q_{cal}

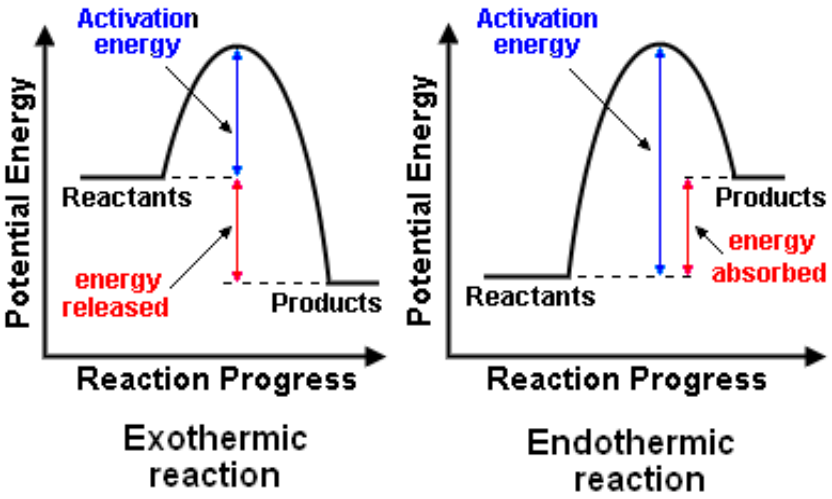
5) Combustion:(bomb calorimeter)

$q_{comb} + q_{cal} = 0$ Solve for q_{comb} usually in kJ/mol

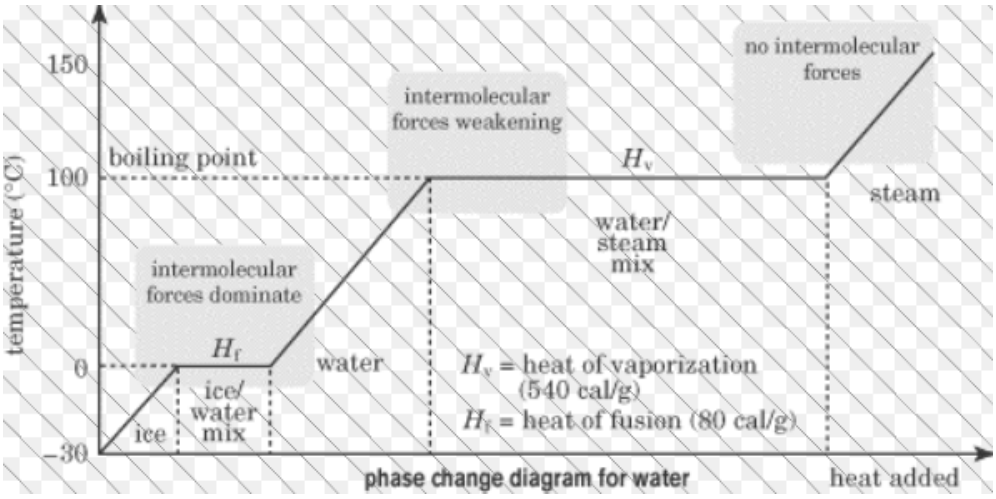
$q_{comb} + (q_{cal} + q_{water}) = 0$

6) Energy diagram calculations: specific heat or phase change

Potential Energy vs Reaction Coordinate:



Energy of Phase change diagram



STOICHIOMETRY OF THERMOCHEMICAL EQUATIONS:

1) The heat of reaction of a forward reaction is identical in magnitude but opposite in sign of the heat of reaction of the reverse reaction.

$S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = -296.8 \text{ kJ}$

$SO_2(g) \rightarrow S(s) + O_2(g) \quad \Delta H = +296.8 \text{ kJ}$

2) The enthalpy of a reaction can be treated as a reactant (if endothermic) or as a product (if exothermic)

$S(s) + O_2(g) \rightarrow SO_2(g) + 296.8 \text{ kJ}$

$296.8 \text{ kJ} + SO_2(g) \rightarrow S(s) + O_2(g)$

3)The major source of aluminum in the world is bauxite (mostly aluminum oxide). Its thermal decomposition can be represented by

$$2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2 \qquad \Delta H_{rxn} = 3252kJ$$

If aluminum were produced this way, how many grams of aluminum could be formed when 1000.kJ of heat was utilized?

THERMODYNAMICS:

1) Energy: the capacity to do work

2) Kinetic Energy: energy associated with motion
ex: thermal, mechanical, electrical, sound

3) Potential Energy: energy that results from an object's position
ex. chemical, nuclear, gravitational

4) 3 Laws of Thermodynamics:
A) 1st: The Law of Conservation of Energy
B) 2nd: In a spontaneous process, the entropy of the universe increases
C) 3rd: There is no disorder in a perfect crystal at 0 K.

5) Heat vs temperature
a) the more thermal energy a substance has, the greater the motion of its atoms or molecules
b) temperature measures the hotness or coldness of a substance.

6) System: the object, or collection of objects, being studied
Surroundings: everything outside the system that can exchange energy with the system

7) Endothermic: heat is transferred from the surroundings to the system

Exothermic: heat is transferred from the system to the surroundings

Determine which are endothermic and which are exothermic:

A) water evaporating
B) striking a match
C) boiling water
D) water freezing
E) solution getting colder when NH_4NO_3 is dissolved
F) steam condensing
G) solution getting hotter when NaOH is dissolved
H) a lit bunsen burner
I) 2 solutions are mixed and a gas is produced and the temperature of the mixture increases

8) Heat Capacity: the amount of heat it takes for a substance to change 1^{o}C (1K)

Specific Heat Capacity: amount of heat required to raise the temperature of one gram of substance 1 ^{o}C (1K)

Molar Heat Capacity: quantity of heat required to raise the temperature of 1 mole of substance 1 ^{o}C (1K)

11/1/13 homework:

Determine which is endothermic and which is exothermic:

1) boiling alcohol
2) water going from 20°C to 10°C
3) adding ammonium chloride to water and the temperature goes from 20°C to 10°C
4) adding HCl to NaOH and the temperature goes from 10°C to 25°C
5) acetone evaporating
6) melting iron
7) water going from 55°C to 75°C
8) steam condensing
9) ethanol freezing
10) adding barium hydroxide to ammonium thiocyanate and the temperature goes from 25°C to 0°C
11) a piece of aluminum goes from 79°C to 35°C.

Example 1: A 5.00-g sample of a substance was heated from 25.2 ^{o}C to 55.1 ^{o}C, requiring 133 J to do so. Calculate its specific heat.

Calculate the amount of heat released when 50.0-g of water at 60.0^{o}C is cooled to 20.0^{o}C.

Calculate the specific heat constant of a substance if 5.00-g of it at 55.1^{o}C releases 133J of heat when cooled to 25.2^{o}C.

CALORIMETRY:

- the science of measuring heat
- based on observing the temperature change when a body absorbs or discharges energy as heat

Coffee-cup Calorimeter: constant pressure calorimetry

ex. a) add a heat solid (metal) to water
b) dissolving a solid compound into water
c) mix 2 solutions and a chemical reaction occurs

(There may be a correction for the calorimeter or not)

CALORIMETRY:

1) 15.0-g of sodium hydroxide is added to 150-g of water at 23.56°C. The temperature increased to 26.75°C. What is the molar heat of solution? Assume that the specific heat and the density of the solution is that of water.

2) A student wishes to determine the heat capacity of a coffee-cup calorimeter. After she mixes 100.0-g of water at 58.5 ^{o}C with 100.0-g of water, already in the calorimeter, at 22.8 ^{o}C, the final temperature of the water is 39.7 ^{o}C. Find the heat capacity of the calorimeter.

3) When we add 30.00-mL of 0.500M NaOH at 21.40 ^{o}C to 30.00-mL of 0.500M $HC_2H_3O_2$ already in the calorimeter at the same temperature, the resulting temperature is observed to be 24.35 ^{o}C. The heat capacity of the calorimeter has previously been determined to be 27.8 J/ ^{o}C. Assume that the specific heat of the mixture is the same as that of water and that the density of the mixture is 1.02 g/mL. Calculate the molar heat of reaction.

4) When 0.500-L of 1.00M $Ba(NO_3)_2$ solution at 25.0°C is mixed with 0.300-L of 1.00M Na_2SO_4 solution at 25.0°C in a calorimeter, solid white $BaSO_4$ forms and the temperature of the mixture increases to 28.1°C. Neglecting any heat that the calorimeter absorbs, the C_p of the solution at 4.18 J/(g*K), and the density of the solution is 1.00 g/mL, calculate the enthalpy change per mol of $BaSO_4$.

BOMB CALORIMETER - constant volume
- may or may not contain water

1) A 2.20-g sample of quinone, $C_6H_4O_2$, is burned in a bomb calorimeter whose total heat capacity is 7.854 kJ/^{o}C. The temperature of the calorimeter increases from 23.44^{o}C to 30.57^{o}C. What is the heat of combustion per gram of quinone? Per mole of quinone?

2) In a bomb calorimeter compartment surrounded by 945-g of water, the combustion of 1.048-g of benzene, C_6H_6, raises the temperature of the water from 23.640°C to 32.692°C. The heat capacity of the calorimeter is 891 J/°C. Calculate the molar heat of combustion of benzene.

ENERGY DIAGRAM:

Values for water: $C_{p(ice)} = 2.03$ J/(g*K)

$C_{p(liquid)} = 4.18$ J/(g*K)

$C_{p(steam)} = 2.06$ J/(g*K)

$\Delta H_{fus} = 6.02$ kJ/mol or 333 J/g

$\Delta H_{vap} = 40.7$ kJ/mol or 2256 J/g

EX. 1:

How much energy does it take to convert 0.500-kg ice at - 20.0°C to steam at 250.°C?

EX. 2: Calculate the amount of heat needed to change 50.0-g of ice at 0◦C to 95.0◦C.

EX. 3:

Consider a 75.0-g sample of steam at 125 °C. What phase or phases are present when 215-kJ of energy is removed from the sample?

EX. 4:

A substance, X, has the following properties:

ΔH_{vap} = 20.0 kJ/mol

ΔH_{fus} = 5.00 kJ/mol

mpt = -15.0 ^{o}C

bpt = 75.0 ^{o}C

C(s) = 3.00 J/(g*^{o}C)

C(l) = 2.50 J/(g* ^{o}C)

C(g) = 1.00 J/(g*^{o}C)

Calculate the energy that must be removed to convert 250.g of substance X from 100. ^{o}C to -50.0 ^{o}C. Assume X has a molar mass of 75.0 g/mol.

EX. 5:

11.0-g of ice at 0°C is added to 50.0-ml H_2O at 29.0°C. After the ice melts, the temperature of the water is 9.7°C. Calculate the heat of fusion of ice.

EX. 6:

If 3 ice cubes at 35.0-g each and -10.0 ^{o}C are added to glass of 300.-mL of water at 68.0 ^{o}C, what will be the final temperature of the water?

4) From the following enthalpies of reaction,

$4HCl(g) + O_2(g) \rightarrow 2H_2O(l) + 2Cl_2(g) \quad \Delta H = -202.4\ kJ$

$1/2H_2(g) + 1/2F_2(g) \rightarrow HF(l) \quad \Delta H = -600.kJ$

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l) \quad \Delta H = -285.8\ kJ$

find the ΔH_{rxn} for $2HCl(g) + F_2(g) \rightarrow 2HF(l) + Cl_2(g)$

5) Determine the molar heat of formation of liquid hydrogen peroxide at 25°C from the following thermochemical equations:

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(g)$ $\Delta H = -241.82$ kJ

$2H(g) + O(g) \rightarrow H_2O(g)$ $\Delta H = -926.92$ kJ

$2H(g) + 2O(g) \rightarrow H_2O_2(g)$ $\Delta H = -1070.60$ kJ

$2O(g) \rightarrow O_2(g)$ $\Delta H = -498.34$ kJ

$H_2O_2(l) \rightarrow H_2O_2(g)$ $\Delta H = 51.46$ kJ

6) If the heat of combustion for cyclohexane, C_6H_{12}, is -3920 kJ/mol, what is the standard heat of formation of cyclohexane?
($H_2O(l)$ is produced)