Mr. Bracken
AP Chemistry

Name ___________________________
Period ____

Thermochemistry Notes #3

From Notes #1:

Reversing a chemical equation will change the sign of the ΔH

$Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(l)$ $\Delta H^o_{rxn} = +37.1$ kJ

$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$ $\Delta H^o_{rxn} = -37.1$ kJ

If we multiply both sides of an equation, we must also multiply the ΔH value.

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$ $\Delta H = -802.4$ kJ

$\frac{1}{2}\ CH_4(g) + O_2(g) \rightarrow \frac{1}{2}\ CO_2(g) + H_2O(g)$ $\Delta H = (\frac{1}{2})(-802.4) = -401.2$ kJ

$2\ CH_4(g) + 4\ O_2(g) \rightarrow 2\ CO_2(g) + 4\ H_2O(g)$ $\Delta H = (2)(-802.4) = -1604.8$ kJ

Hess's Law: If a reaction is carried out in a series of steps, the ΔH for the reaction will equal the sum of the enthalpy changes for the individual steps.

Example #1:
Consider the following overall chemical reaction:

$\mathbf{CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)}$ $\mathbf{\Delta H_{rxn} = ?}$

We can treat this overall reaction as resulting from two separate reactions:

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$ $\Delta H = -802$ kJ

$2\ H_2O(g) \rightarrow 2\ H_2O(l)$ $\Delta H = -88$ kJ

Add together: $\mathbf{\Delta H_{rxn} =}$

Example #2:

Use Hess's Law to calculate the ΔH for the overall reaction: **$2\ Al(s) + Fe_2O_3(s) \rightarrow 2\ Fe(s) + Al_2O_3(s)$**

$2\ Al(s) + {}^3/_2\ O_2(g) \rightarrow Al_2O_3(s)$	ΔH = – 1601 kJ
$2\ Fe(s) + {}^3/_2\ O_2(g) \rightarrow Fe_2O_3(s)$	ΔH = – 821 kJ

Answer = – 780 kJ

Example #3:

Use Hess's Law to calculate the ΔH for the overall reaction: **$NO(g) + O(g) \rightarrow NO_2(g)$**

$NO\ (g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g)$	ΔH = – 198.9 kJ
$O_3\ (g) \rightarrow {}^3/_2\ O_2\ (g)$	ΔH = – 142.3 kJ
$O_2\ (g) \rightarrow 2\ O\ (g)$	ΔH = 495.0 kJ

Answer = –304.1 kJ

Example #4:

Use Hess's Law to calculate the ΔH for the overall reaction: **$2\ C(s) + H_2(g) \rightarrow C_2H_2(g)$**

$C_2H_2(g) + {}^5/_2\ O_2(g) \rightarrow 2\ CO_2(g) + H_2O(l)$	ΔH = – 1299.6 kJ
$C(s) + O_2(g) \rightarrow CO_2(g)$	ΔH = – 393.5 kJ
$H_2(g) + ½\ O_2(g) \rightarrow H_2O(l)$	ΔH = – 285.8 kJ

Answer = 226.8 kJ

Calorimetry Calculations

$$Q = mC\Delta T$$

Q = heat energy (Joules)
m = mass (grams)
C = specific heat capacity (Joules/g^{o}C)
ΔT = change in temperature….$T_{final} - T_{initial}$ (^{o}C)

Example #5:
How many Joules of energy is required to increase the temperature of 3.40 grams of olive oil from 21.0^{o}C to 85.0^{o}C? The specific heat capacity of olive oil is 2.00 Joules/g^{o}C.

Answer = 435 Joules

Example #6:
A certain mass of liquid water was heated from 23.4^{o}C to 37.6^{o}C. This heating process required 2415 Joules of heat energy. If the specific heat capacity of liquid water is 4.18 Joules/g^{o}C, what was the mass of the water?

Answer = 40.7grams

The equation above works great UNLESS A PHASE CHANGE OCCURS! We must use different math equations to calculate heat energy associated with melting or vaporizing.

MELTING ENERGY
$Q_{fusion} = (\text{mass})(\Delta H_{fusion})$

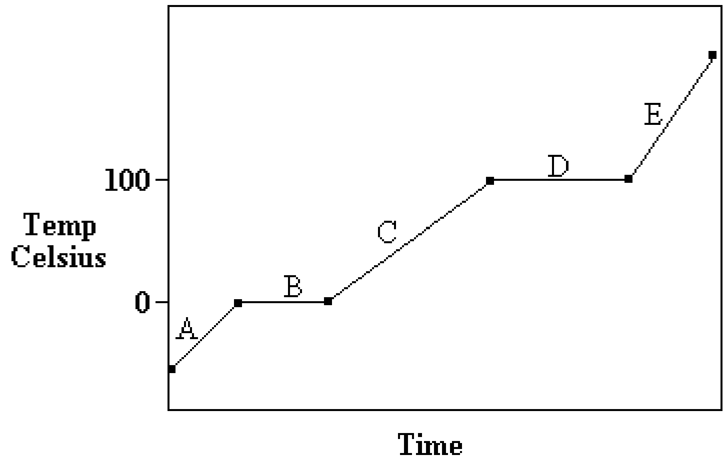
For H_2O:
ΔH_{fusion} = 334 Joules/gram

VAPORIZATION ENERGY
$Q_{vaporization} = (\text{mass})(\Delta H_{vap})$

For H_2O:
ΔH_{vap} = 2260 Joules/gram

When water is <u>melting</u> at 0^{o}C, this is the amount of energy that must <u>enter</u> the system to melt it.
When water is <u>freezing</u> at 0^{o}C, this is the amount of energy that must <u>exit</u> the system to freeze it.

Enthalpy Calculations Involving Phase Changes



Substance	Specific Heat Capacities (J/g-K)
H_2O (s)	2.09
H_2O (l)	4.18
H_2O (g)	1.84

ΔH_{fusion}	334 Joules/gram
ΔH_{vap}	2260 Joules/gram

Calculate the enthalpy change when 27.0 grams of ice is heated from –25.0^{o}C to vapor at 155.0^{o}C.

A. <u>Heat Ice to Melting Point</u> 1,410 Joules (1.6%)

B. <u>Melt Ice</u> *(Phase Change)* 9,020 Joules (10.6%)

C. <u>Heat Melted Liquid to Boiling Point</u> 11,300 Joules (13.2%)

D. <u>Vaporize Liquid</u> *(Phase Change)* 61,020 Joules **(71.4%)**

E. <u>Heat Vapor to Final Temperature</u> 2,730 Joules (3.2%)

TOTAL ENERGY REQUIRED FOR STEPS A → E =_______________ 85,480 Joules (100%)