###### Thermochemistry Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*AP Chemistry Lecture Outline*

thermodynamics: the study of energy and its transformations

 -- thermochemistry: the subdiscipline involving chemical reactions and energy changes

**Energy**

kinetic energy: energy of motion; KE = ½ mv2

 -- all particles have KE

 -- Thermal energy is due to the KE of particles.

 We measure the **average** KE of a collection of particles as...

potential energy: stored energy

 Chemical potential energy is due to electrostatic forces between charged particles.

 -- related to the specific arrangement of atoms in the substance

Energy is defined as the capacity to do work or transfer heat.

Units of energy are joules (J), kilojoules (kJ), calories (cal), or nutritional calories (Cal or kcal)

 -- conversions:

system: the part of the universe we are studying

surroundings: everything else

 -- In chemistry, a closed system can exchange energy but not matter w/its surroundings.

 -- Energy is transferred to... (1)

 ...or... (2)

 Work (w) is done when a force moves through a distance.

 Heat (q) is an amount of energy transferred from a hotter object to a colder one.

EX. Find the kinetic energy of a single dinitrogen monoxide molecule moving at 650 m/s.

**First Law of Thermodynamics =**

 -- Energy morphs between its various forms, but the total amount remains the same.

internal energy (E) of a system: the sum of all the KE and PE of the components of a system

 -- The change in the internal energy of a system would be found by:

 And for chemistry, this equation would become:

 E is + if Efinal Einitial (i.e., system... ) 🡪

 E is – if Efinal Einitial (i.e., system... ) 🡪

But we ARE able to find E by measuring two types of “energy” quantities:

 \*\* KEY: Sign conventions are based on the *system’s* point of view.

 In endothermic processes, heat is \_\_\_\_\_\_\_\_\_\_\_\_\_ by the system.

 e.g.,

 In exothermic processes, heat is \_\_\_\_\_\_\_\_\_\_\_\_\_ by the system.

 e.g.,

To go further, we must introduce the concept of enthalpy (H).

-- Enthalpy (H) is defined as... H = E + PV where E = system’s internal energy

 P = pressure of the system

 V = volume of the system

 -- There is much that could be said about enthalpy, but what you need to know is:

 i.e., P indicates constant pressure conditions.

 When H is +, the system...

 When H is –, the system...

 Enthalpy is an extensive property, meaning that…

 enthalpy of reaction:

For exothermic rxns, the heat content of the reactants is \_\_\_\_\_\_ than that of the products.

EX. 2 H2(g) + O2(g) 2 H2O(g) H = –483.6 kJ

 What is the enthalpy change when 178 g of H2O are produced?

H for a reaction and its reverse are the opposites of each other.

 2 H2(g) + O2(g) 2 H2O(g) (H = )

 2 H2O(g) 2 H2(g) + O2(g) (H = )

Enthalpy change depends on the states of reactants and products.

 2 H2(g) + O2(g) 2 H2O(g) (H = –483.6 kJ)

 2 H2(g) + O2(g) 2 H2O(l)

**Calorimetry**: the measurement of heat flow

 -- device used is called a...

 heat capacity of an object: amount of heat needed to raise object’s temp. 1 K = 1oC

 molar heat capacity: amt. of heat needed to raise temp. of 1 mol of a substance 1 K

 specific heat (capacity): amt. of heat needed to raise temp. of 1 g of a substance 1 K

 i.e., molar heat capacity = molar mass X specific heat

We calculate the heat a substance loses or gains using:

 where q = heat

 m = amount of substance

 cP = substance’s heat capacity

 T = temperature change

 cX = heat of fusion (s/l) or heat of vaporization (l/g)

 Typical Heating Curve

EX. What is the enthalpy change when 679 g of water at 27.4oC are converted into

 water vapor at 121.2oC?

cf = 333 J/g

cv = 40.61 kJ/mol

cP,l = 4.18 J/g-K

cP,s = 2.077 J/g-K

cP,g = 36.76 J/mol-K

With a coffee-cup calorimeter, a reaction is carried out under constant pressure conditions.

 -- Why is the pressure constant?

-- If we assume that no heat is exchanged between the system and the surroundings,

 then the solution must absorb any heat given off by the reaction.

 i.e.,

 -- For dilute aqueous solutions, it is a safe assumption that cP =

EX. When 50.0 mL of 0.100 M AgNO3 and 50.0 mL of 0.100 M HCl are mixed in a coffee-cup calorimeter, the mixture’s temperature increases from 22.30oC to 23.11oC. Calculate the enthalpy change for the reaction, per mole of AgNO3.

Combustion reactions are studied using constant-volume calorimetry.

This technique requires a bomb calorimeter.

 -- The heat capacity of the bomb calorimeter (Ccal) must be known.

 -- Again, we assume that no energy escapes into the surroundings, so that the heat

 absorbed by the bomb calorimeter equals the heat given off by the reaction.

EX. A 0.343-g sample of propane, C3H8, is burned in a bomb calorimeter with a heat

 capacity of 3.75 kJ/oC. The temperature of the material in the calorimeter increases

 from 23.22oC to 27.83oC. Calculate the molar heat of combustion of propane.

**Hess’s Law**

The Hrxns have been calculated and tabulated for many basic reactions. Hess’s law allows us to put these simple reactions together like puzzle pieces such that they add up to a more complicated reaction that we are interested in. By adding or subtracting the Hrxns as appropriate, we can determine the Hrxn of the more complicated reaction.

EX. Calclulate the heat of reaction for the combustion of sulfur to form sulfur dioxide.

 2 SO2(g) + O2(g) 2 SO3(g) (H = –198.2 kJ)

 S8(s) + 12 O2(g) 8 SO3(g) (H = –3161.6 kJ)

EX. Calculate H for the reaction… 5 C + 6 H2 C5H12

 given the following: C5H12 + 8 O2 5 CO2 + 6 H2O (H = –3535.6 kJ)

 C + O2 CO2 (H = –393.5 kJ)

 H2 + ½ O2 H2O (H = –285.8 kJ)

enthalpy of formation (Hf): the enthalpy change associated with the formation of a

 compound from its constituent elements

 -- also called…

When finding the standard enthalpy of formation (Hfo), all substances must be in their standard states. The “standard state” of a substance has arbitrarily been chosen to be the state of the substance at 25oC (298 K). If more than one form of the element exists at 298 K, then the standard state is the most stable form, e.g.,

 -- By definition, Hfo for the most stable form of any element in its standard state is zero.

 e.g.,

-- Hf values are for 1 mol of substance, so the units are typically kJ/mol.

 -- Many Hf values have been tabulated.

standard enthalpy of a reaction (Horxn):

 -- Using Hess’s law, we can easily calculate Horxn from the Hfo of all R and P.

 -- equation:

where n and m are the coefficients in the balanced equation

EX. Approximate the enthalpy change for the combustion of 246 g of liquid methanol.

**Food and Fuel**

fuel value: the energy released when 1 g of a material is combusted

 -- measured by calorimetry

***Food***

The body runs on glucose, C6H12O6.

 -- When it is in the blood stream, glucose is called…

 -- Our bodies produce glucose out of the foods that we consume.

carbs: 4 kcal/g; quickly broken down into glucose; not much can be stored ***as carbs***

fats: 9 kcal/g; broken down slowly; insoluble in water; easily stored for future use

proteins: 4 kcal/g; contain nitrogen which ends up as urea, (NH2)2CO after digestion

***Fuel***

fossil fuels: coal, petroleum, natural gas

 -- products of what used to be living things; nonrenewable

coal gasification: coal is treated with superheated steam to make the gases CH4, H2, and CO

 -- most impurities (e.g., sulfur compounds) are easily removed in this process

 -- the fuel gases can be easily transported by pipeline and then burned for fuel

Nuclear energy, from the splitting or fusing of atoms, also is nonrenewable.

 -- a lot of bang for your buck, but there is the problem of hazardous waste disposal

Renewable energy sources include:

 solar wind geothermal hydroelectric biomass

 Solar heating can be used to generate CO and H2 gases, which could be burned...

 Solar (or photovoltaic) cells directly convert solar energy into electricity.

 Problems with solar energy: