

APES “CHEMISTRY REVIEW” NOTES ~ THERMOCHEMISTRY

- I. Energy
- A. HEAT (q)—energy flowing from warmer to cooler objects or areas
- B. THERMOCHEMISTRY
- 1) the study of heat changes in chemical reactions and physical changes
 - 2) the study of heat flow between a system and its surroundings
 - a. SYSTEM—specific part being analyzed
 - b. SURROUNDINGS—everything outside the system (usually the immediate area)
 - c. UNIVERSE—system + surroundings
 - 3) thermochem rxns. are like regular balanced equations except that they specify the heat flow (heat changes) for the rxn.
 - 4) ENTHALPY (H)—heat content of a substance
 - 5) change in enthalpy = ΔH ; heat change for a process at constant pressure; usually measured in kJ (kilojoules)
 - 6) ΔH is used interchangeably with q.

| |
|---|
| ENDOTHERMIC: $+\Delta H$ <i>heat absorbed into system; surroundings cool down</i> $(A + B + \text{ENERGY} \rightarrow C + D)$ $+\Delta H$ |
| EXOTHERMIC: $-\Delta H$ <i>heat released from system; surroundings heat up</i> $(A + B \rightarrow C + D + \text{ENERGY})$ $-\Delta H$ |

- II. Heat Capacity
- A. HEAT CAPACITY—amount of heat required to change a substance’s temperature by exactly 1 °C; common unit: **J / °C**
- B. CALORIE (*calorie with a lower-case c*)—amount of heat required to raise the temp of 1 g of pure water by 1 °C
- C. CALORIE (*Calorie with an upper-case c*)—“diet Calorie” = 1000 calories
- D. JOULE—SI unit of heat and energy; amount of heat required to raise the temp of 1 g of pure water by 0.239 °C.

UNIT CONVERSIONS:

$$1 \text{ Cal (diet Calorie)} = 1000 \text{ cal} = 1 \text{ kcal} = 4.184 \text{ J}$$
$$1 \text{ J} = 0.239 \text{ cal} \qquad 4.184 \text{ J} = 1 \text{ cal}$$

- E. heat changes can be measured with a CALORIMETER, which is a covered cuplike container
- III. Specific Heat Capacity
- A. SPECIFIC HEAT CAPACITY (C or c_p)—amount of heat required to raise the temperature of 1 g of a substance by exactly 1 °C.
- B. C deals with *heat requirements* and *heat retention* :
- 1) low C = low requirements and retention = heats up quickly and cools down quickly
 - 2) high specific heat = high requirements and retention = heat up slowly and cool down slowly
- C. common unit: **J / g °C**
- D. heat changes can be measured with a CALORIMETER
- E. metals have low specific heats
- F. water has the highest specific heat of common substances = 4.184 J/g °C
- G. equation $\Delta = \text{delta} = \text{“change in”}$ $\Delta T = (T \text{ final} - T \text{ initial})$

$$C = \frac{q}{m \Delta T}$$

H. examples

E1) The temperature of an 89.1 g piece of metal rises from 22.0 °C to 51.1 °C when the metal absorbs 794 J of energy. What is the specific heat of the metal?

SOLUTION: $m = 89.1 \text{ g}$ $q = 794 \text{ J}$ $T = 51.1 - 22.0 = 29.1 \text{ }^\circ\text{C}$

$$C = \frac{q}{m \Delta T} = \frac{794 \text{ J}}{(89.1 \text{ g})(29.1 \text{ }^\circ\text{C})} = \boxed{0.306} \frac{\text{J}}{\text{g }^\circ\text{C}}$$

E2) How much heat energy is needed to increase the temperature of 44.7 g of water from 20.0 to 36.3 °C?

SOLUTION:

$m = 44.7 \text{ g}$ $\Delta T = 16.3 \text{ }^\circ\text{C}$ $C = 4.184 \text{ J/g }^\circ\text{C}$ $\Delta T = 36.3 \text{ }^\circ\text{C} - 20.0 \text{ }^\circ\text{C} = 16.3 \text{ }^\circ\text{C}$

$$C = \frac{q}{m \Delta T} \quad q = m \Delta T C \quad q = 44.7 \text{ g} (16.3 \text{ }^\circ\text{C}) 4.184 \frac{\text{J}}{\text{g }^\circ\text{C}} = \boxed{3050 \text{ J or } 3.05 \text{ kJ}}$$

IV. CALORIMETRY—the accurate and precise measurement of the heat change for chemical reactions and physical changes
equation

$$\boxed{q = \Delta H = m C \Delta T} \quad (\text{rearrangement of the specific heat equation})$$

$$q = \Delta H = (\text{mass of water})(\text{specific heat of water})(\text{change in temp})$$

V. Thermochemical Equations

A. THERMOCHEMICAL EQUATIONS—equations that show heat changes

B. ΔH relates to the coefficients of the balanced equation

Chemical change heat transfers:

ΔH_r or ΔH_{rxn} = generic HEAT OF REACTION = heat absorbed or released in a chemical rxn.

ΔH_{comb} = MOLAR HEAT OF COMBUSTION = heat released in combustion of 1 mol of substance

ΔH_f = HEAT OF FORMATION = heat absorbed or released to make 1 mol of a cmpd from its elements

ΔH_f° = STANDARD HEAT OF FORMATION = heat absorbed or released to make 1 mol of a cmpd from its elements in their standard states at 298 K (25 °C)

VI. Heat and Changes of State

A. math problems use ΔH related to coefficients

B. problems discuss melting, freezing, boiling, condensing, dissolving

C. MOLAR HEAT OF FUSION: $q = (\text{mass} / \text{molar mass}) (\Delta H_{fus})$

D. MOLAR HEAT OF VAPORIZATION: $q = (\text{mass} / \text{molar mass}) (\Delta H_{vap})$

Physical change heat transfers:

ΔH_{fus} = MOLAR HEAT OF FUSION = heat energy required to melt 1 mol of substance

ΔH_{solid} = MOLAR HEAT OF SOLIDIFICATION = heat energy released freezing 1 mol of substance

$\Delta H_{fus} = - \Delta H_{solid}$ $\Delta H_{fus} \text{ H}_2\text{O} = 6.01 \text{ kJ/mol}$

ΔH_{vap} = MOLAR HEAT OF VAPORIZATION = heat energy required to boil 1 mol of substance

ΔH_{cond} = MOLAR HEAT OF CONDENSATION = heat energy released condensing 1 mol of substance
 $\Delta H_{\text{vap}} = -\Delta H_{\text{cond}}$ $\Delta H_{\text{vap}} \text{ H}_2\text{O} = 40.7 \text{ kJ/mol}$

ΔH_{soln} = MOLAR HEAT OF SOLUTION = heat energy change due to the dissolving of 1 mol of substance

VII. Hess' Law

- A. HESS' LAW OF HEAT SUMMATION—the overall ΔH for a rxn. equals the sum of all ΔH 's for the individual steps involved
- B. If a chemical equation is written in reverse order, the sign of ΔH must be changed (+ to - OR - to +)

VIII. Gibbs free energy

$$\Delta G = \Delta H - T\Delta S$$

- A. G = free energy
 - 1) Exergonic = spontaneous ($-\Delta G$); favorable
 - 2) Endergonic = nonspontaneous ($+\Delta G$); unfavorable
- B. H = heat energy
 - 1) exothermic = heat given off ($-\Delta H$); favorable
 - 2) endothermic = heat absorbed ($+\Delta H$); unfavorable
- C. T = Kelvin temperature
- D. S = entropy (disorder); an increase is favorable ($+\Delta S$)