EXAM I Material

<u>**Part I GASES-**</u>

Chapter 5 (pages 178-216)

I. Properties of gases

II. Measurements-Review

   A. <u>Pressure</u> = $\frac{force}{Unit\ area}$

    1. Conversions:

    `   1 atm= 760 mm Hg = 760 torr (exactly)

    1.013 x 10^5 Pa= 1 atm = 14.68 psi

    2. Barometer

    3. Manometer

   B. <u>Temperature</u> - Kelvin

    K = ^{o}C + 273

   C. <u>Volume</u>

    1. The volume of a gas is the volume of the container it occupies.

    2. Units: liters or milliliters

III. RELATIONSHIP BETWEEN ^{o}T, VOLUME, AND PRESSURE.-Review

    <u>A. Boyle's law</u>   P & V

    As the pressure increases the volume decreases in the same proportion.

    <u>B Charles's law</u> ^{o}T & V
    As the temperature (Kelvin) is increased the volume is increased proportionally.

    <u>C Gay-Lussac's Law</u>
    When temperature (K) increases pressure increases proportionally.

    <u>D Avogadro's Law: Volume and Amount (in moles, n)</u>
    When the amount (moles,n) increases volumne increases proportionally.

    <u>E. COMBINATION OF THE GAS LAWS-Review:</u>
    P, V, and ^{o}T varying. Assume that the mass is constant.
    Prob: A certain mass of gas occupies 5.50 L at 34°C and 655 mm Hg.
    What will its volume in liters be if it is cooled to 10.0^{o}C and its pressure remains the same?

    <u>E. GAY-LUSSAC'S LAW OF COMBINING VOLUMES-Review:</u>
At the same ^{o}T and Pressure, the volumes of gases that combine in a chemical reaction are in the ratio of small whole numbers.

F. IDEAL GAS EQUATION-Review:
Derivation:

KNOW: $PV=nRT$ Where: n = moles of gas

$$R = \frac{0.0821 \text{ L-atm}}{\text{mole-K}}$$

1. What volume in liters will be occupied by 6.00 mol carbon dioxide gas at 105 mm Hg and 28^{0}C?

G MOLAR VOLUME at Standard Temperature and Pressure-Review:
At the same temperature and pressure the same number of moles of different gases have the same volume. The
Molar Volume is the volume of one mole of any gas at a given ^{0}T & P. [STP]
 Standard Temperature and Pressure = $[STP]$:

$$\frac{22.4 \text{ L}}{1 \text{ mole of gas}}$$ At: 273 K and 1 atm (760 torr)

The density of an unknown gas is 1.43 g/L at 0^{0}C and 760 torr. What is the molar mass of the unknown gas?
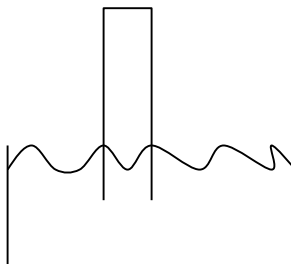
WHEN TO USE:

1. PV = nRT

2. $\frac{22.4 \text{ L}}{\text{mole}}$ at STP

3. $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

4. $P_{Total} = P_1 + P_2 + P_3 + \ldots$

5. $X_1 = \frac{n_1}{n_{Total}} = \frac{P_1}{P_{Total}}$

H. MIXTURES OF GASES AND PARTIAL PRESSURES (DALTON'S LAW OF PARTIAL PRESSURES) a mixture of gases is equal to the sum of the partial pressures exerted by each gas.

$P_{total} = P_1 + P_2 + P_3 + ...$

Collecting Gases over Water

Example: The total pressure in a 1.00 liter container is 725 mm Hg. The container contains water vapor and nitrogen gas.
If the partial pressure of the water vapor is 225 mm Hg, what is the partial pressure of the nitrogen gas.

$P_{total} = P_{N_2} + P_{H_2O}$

I. MOLE FRACTIONS; Mixtures of gases
The mole fraction of a component is the fraction of moles of that component of the total moles of the gas mixture.

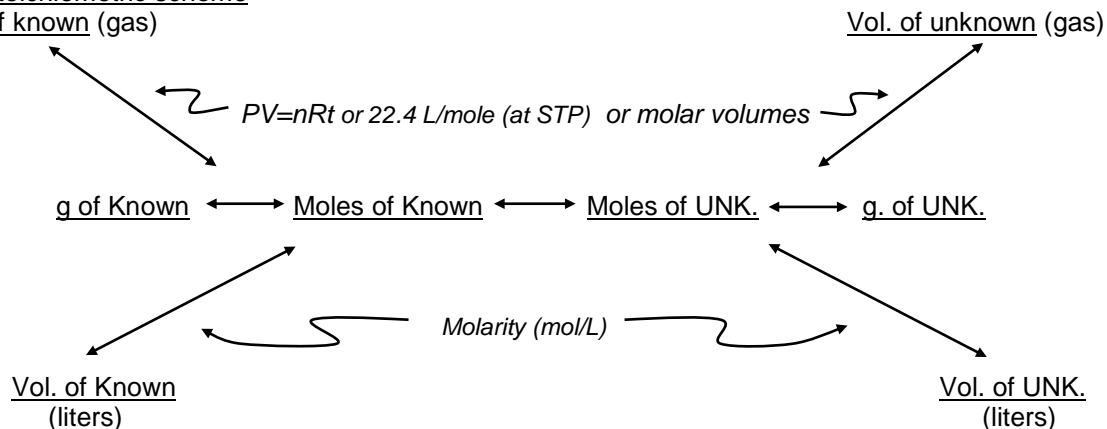## IV GASES IN CHEMICAL REACTIONS: STOICHIOMETRY--Review:

Certain chemical reactions involve gas as a reactant or product. For these types of reactions, the stoichiometric calculations involve the use of: 1) PV=nRT

2) $22.4 \dfrac{L}{mole}$ at STP

3) Molar volumes

The general stoichiometric scheme

Vol. of known (gas)   Vol. of unknown (gas)

PV=nRt or 22.4 L/mole (at STP) or molar volumes

g of Known ⟷ Moles of Known ⟷ Moles of UNK. ⟷ g. of UNK.

Molarity (mol/L)

Vol. of Known   Vol. of UNK.
(liters)   (liters)

Problems:

1. How many liters of ammonia gas can be produced by the reaction of 735 ml hydrogen gas with an excess nitrogen gas at 425 ^{o}C and 135 atm?   Nitrogen + hydrogen --> ammonia
Ans.=0.490 L

2. How many liters of carbon dioxide gas at 0 ^{O}C and 1 atm are produced by the complete combustion of 60.0 mol of liquid glucose, $C_6H_{12}O_6$?

Ans. = 9.10 x 10^3 CO_2

3. How many liters of the air pollutant NO(g) could be produced at 985 ^{O}C and a pressure of 30.0 atm by the reaction of oxygen gas with 455 g of nitrogen gas.

Ans. = 112 L NO

V GAS PROBLEMS--Review:

1. A 655 ml gas cylinder filled with oxygen gas at a pressure of 95 atm and at 26.0 °C was used by a scuba diver. The pressure after it was used was 85 atm. How many moles of oxygen gas were used by the diver?
    Ans = 0.2 mol O_2

2. A flask contained 1.017 mol of carbon dioxide. The gas exerted a pressure of 925 mm Hg at a temperature of 28 °C. When an additional 0.250 mole of Carbon dioxide was added to the flask the temperature increased to 35°C. What is the new pressure in the flask?
    Ans.= 1.56 atm CO_2

3. A sample of an unknown gaseous hydrocarbon had a density of 1.56 g/L at 25.0 °C AND 1.33 atm. Calculate the molar mass of the gas.
    Ans. = 28.7 g/mol

4. A container with only He had a pressure of 544 torr at a temperature of 35 °C. When 0.810 g of Ne is added to this container, the pressure increases to 959 torr. Calculate the grams of He in the container.
    Ans. = 0.212 g He

5 A mixture containing 1.22 g Xe and 0.675 g NO_2 exerts a pressure of 1.44 atm. What is the partial pressure of NO_2?
    Ans. = 0.883 atm NO_2

6.. The complete combustion of 0.500 g of hydrocarbon, containing only C and H, produced 0.771 L of CO_2 at STP and 0.755 g of water. In another experiment, 0.218 g of sample occupied 185 ml at 23 °C and 374 mm Hg. What is the molecular formula of the compound?

Ans. = C_4H_{10}

VI. KINETIC MOLECULAR THEORY-Review

   A. Gases are composed of such extremely tiny atoms or molecules that are widely separated by empty space.

   B. Gas particles move in a random,rapid, and continuous motion, thus has kinetic energy.

   C. Gas particles moves so rapidly and are so far apart the there is essentially no force of attraction between the particles.

   D. Particles collide frequently wtih each other and with the walls of the container, the collisions are perfectly "elastic" - (No net loss of energy as a result of a collision)

VII. TEMPERATURE AND MOLECULAR VELOCITIES: AVERAGE KINETIC ENERGY
The average kinetic energy (energy of motion) of the gas particles are directly proportional to its absolute T^0 (Kelvin)

VIII MOLECULAR SPEEDS; DIFFUSION AND EFFUSION

A. MOLECULAR SPEEDS

of
molecules

molecular speed
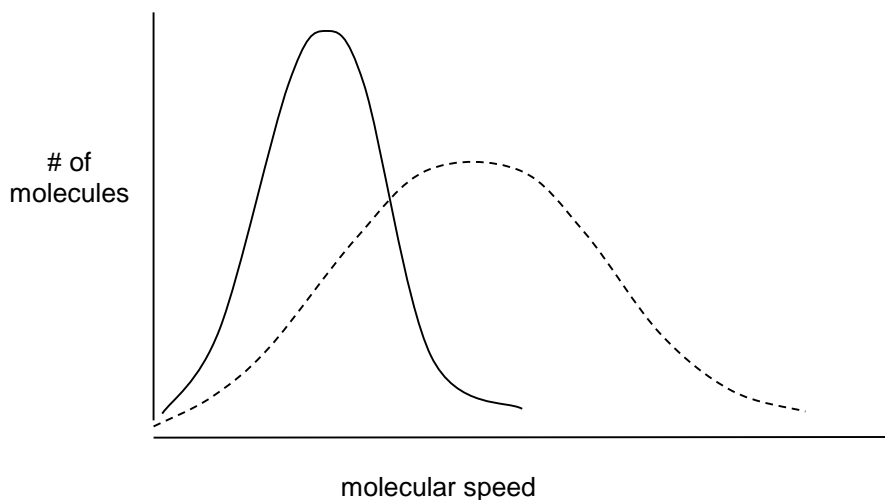
B. DIFFUSION AND EFFUSION

Diffusion is the ability of two or more gases to spontaneously mix until it becomes a uniform,
homogeneous mixture.

Effusion is the process by which gas particles flows thru a very small hole from a container of high
pressure to a lower pressure.

Graham's Law of Effusion - The rate of effusion of a gas is inversely proportional to
it's size [$\sqrt{\text{Molar Mass}}$] at constant temperature and pressure.

$$\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$$

Problem #1: What is the rate of effusion for H_2 if 15.00 ml carbon dioxide of CO_2 takes 4.55 sec to effuse out of a container?

Problem #2: What is the molar mass of gas X if it effuses 0.876 times as rapidly as $N_2(g)$?

IX REAL GASES

Gas laws describe the behavior of an ideal or "perfect" gas - a gas described by the kinetic molecular theory.

Under normal conditions of typical pressure and temperature, gases follow the ideal gas laws fairly closely.

At low temperature and/or high pressures gases deviate from the ideal gas laws.

A. Intermolecular forces of attraction

B. Molecular volume

Chapter 6

Thermochemistry is the study of heat released or absorbed during chemical reactions.

I. Energy

$$\text{Internal Energy} = \Delta E = E_{final} - E_{initial}$$

II. Heat and Work

Heat, q, is the heat transferred to or from a system during a reaction. It is the energy that flows to or from a system due to the difference of °T

Work,w, is the energy exchange when a force ,F, moves an object a certain distance.

Internal Energy = $\Delta E = q + w$

III. Units of Energy
Joule,J

Calorie,Cal

IV. State Functions
State Functions are properties that on dependant upon its present state and not dependant upon the pathway to the present state.

V. First Law of Thermodynamics
Energy can neither be created or destroyed

VI. Enthalpy: The Heat Evolved in a Chemical Reaction at Constant Pressure

Enthalpy, H (Heat content of a substance)

Change of Enthalpy,ΔH, is the heat given off or absorbed by a system at constant pressure. For reactions, the change of enthalpy is the

Heat of Reaction:

$$\textbf{Heat of Reaction} = \Delta H_{rxn} = H_{final} - H_{initial}$$

Mechanics of reactions:

VII. Calorimetry

The **Heat Capacity** of a substance is the amount of heat required to change its temperature 1 °

The **Specific Heat** of a substance is the amount of heat required to change 1 gram of the substance its temperature 1 K

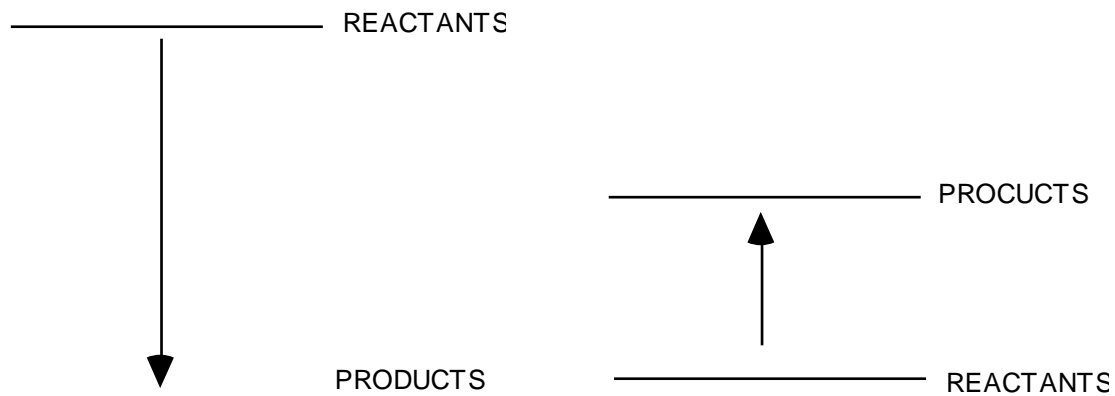Problem: Calculate the amount of heat required to heat 35.0 g of Al from 55.0°C to 75.0°C.

Specific Heat of Al = 0.908 $\dfrac{J}{g\,K}$

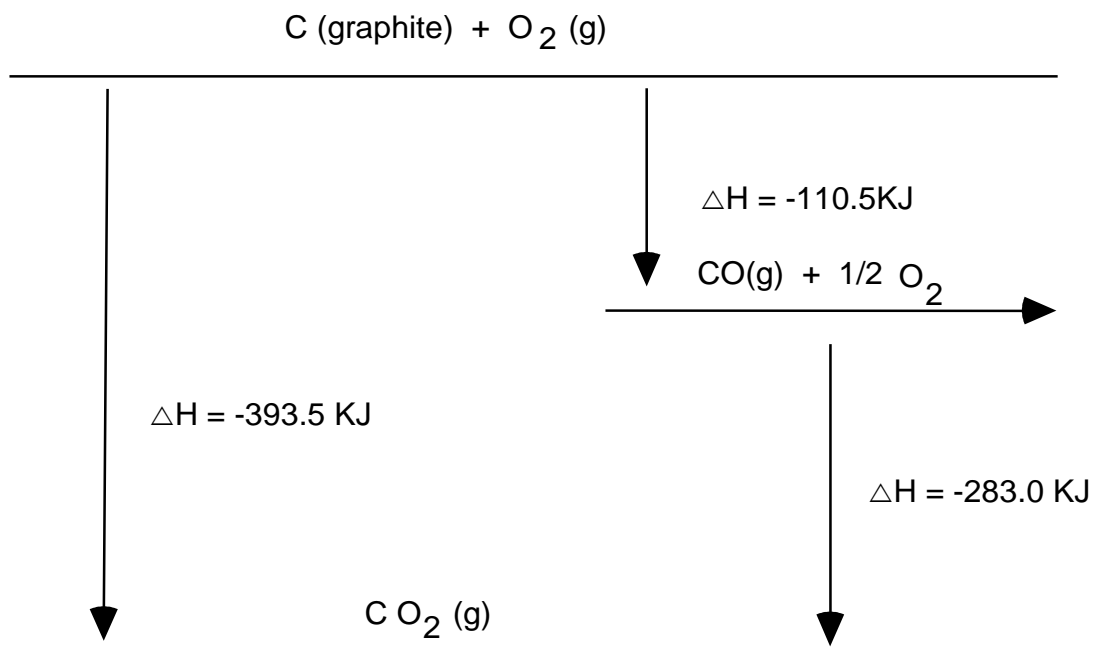The **Heat Capacity** of a substance is the amount of heat required to change its temperature 1 °

VII. Law of Hess-Law of constant heat summation

A. Enthalphy, $\triangle H$ $\triangle H_{rxn} = \triangle H_{products} - \triangle H_{reactants}$

```
                          ———————— REACTANTS
 |
 |
 |
                                        ———————— PROCUCTS
                                        ↑
                                        |
 |                                      |
 ↓                                      |
 ———— PRODUCTS        ———————————— REACTANTS
```

B. Energy diagram

$$C \text{ (graphite)} + O_2 \text{ (g)}$$

```
————————————————————————————————————————————
 |                         |
 |                         |
 |                         ↓   △H = -110.5KJ
 |                         CO(g) + 1/2 O_2
 |                         —————————————————→
 |                         |
 △H = -393.5 KJ            |
 |                         |   △H = -283.0 KJ
 |                         |
 ↓         C O_2 (g)       ↓
————————————————————————————————————————————
```

C. Energy Equations:

  1. Additon of equations

      $C \text{ (graphite)} + O_2(g) \rightarrow$ $CO(g) + 1/2\, O_2$ $\triangle H = -110.5 \text{ KJ}$

      $CO \text{ (g)} + 1/2\, O_2 \text{ (g)} \rightarrow$ CO_2 $\triangle H = -283.0 \text{ KJ}$

2. Multiplying:

   HI(g) $\rightarrow$ 1/2 H_2(g) + 1/2 I_2(s) $\triangle H$ = -25.9 KJ

3. Reversing:

   1/2 H_2(g) + 1/2 I_2(s) $\rightarrow$ HI(g) $\triangle H$ = +25.9 KJ

4. Problem:

   Find $\triangle H$ for 2 NH_3 (g) + 3/2 O_2(g) $\rightleftarrows$ N_2O (g) + 2 H_2O (l) + H_2 (g)
   Given:

   4 NH_3 (g) + 3 O_2(g) $\rightarrow$ 2 N_2(g) + 6 H_2O (l) $\triangle H$ = -1531 KJ

   N_2O(g) + H_2(g) $\rightarrow$ N_2(g) + H_2O (l) $\triangle H$ = -367.4 KJ
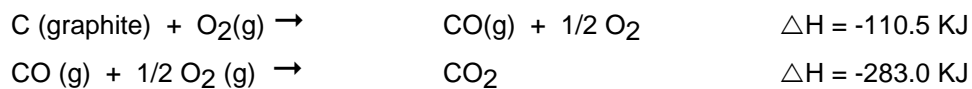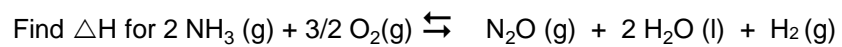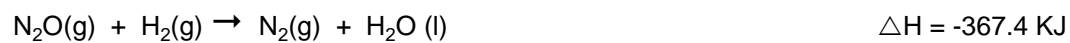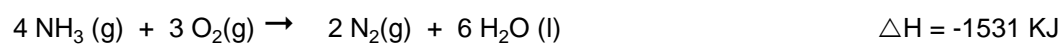
VIII. Standard Heats of Reactions
Calculate the the ΔH for the following reactions: $\Delta H_{RXN} = \sum \Delta H_{Products} - \sum \Delta H_{Reactants}$

1. $C_2H_4 + H_2 \leftrightarrows C_2H_6$

2. $2\,CH_3OH + 3\,O_2 \leftrightarrows 4\,H_2O + 2\,CO_2$
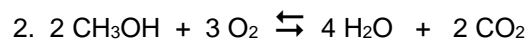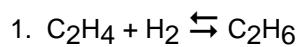
Chapter 8

A. <u>**Electron Configuration and orbital diagrams (review)**</u>

<u>Electron configuration</u>   <u>Orbital diagram</u>

B. <u>**Sublevel Energy Splitting in Multielectron Atoms**</u>
   <u>**->Shielding**</u>

C.   <u>**Electron Configurations, Valence electrons, and the Periodic Table (review)**</u>

D. **Periodic Trends in the Size of Atoms and Effective Nuclear Charge**

    1.   Atomic Radius [Atom Size]
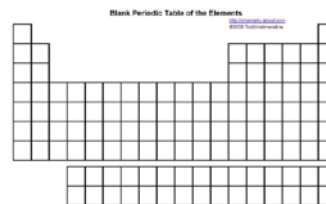
        a. As the number of shells increases, the radius size increases

        b. As you go left to right across a period, the radius size decreases

2. Ion Size - is the measure of the electron cloud around the nucleus.
        a. Cations
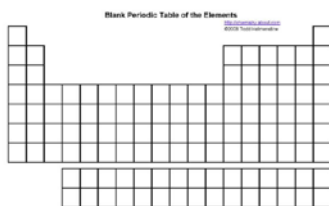
        b. Anions

3. Ionization Energy
   The energy required to remove an electron from a neutral atom (in gas phase).

Blank Periodic Table of the Elements
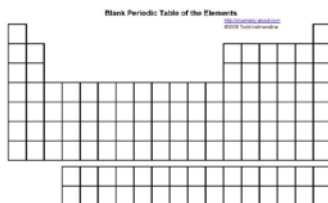
   a. As you go left to right across a period, the ionization energy increases.

   b. As you go down a group (top to bottom), the ionization energy decreases.

4. 1st , 2nd, and 3rd, Ionization Energies

5. Electron Affinity The amount of energy released or absorbed when an electron is added to an atom to form a (-) ion [anion], in gas phase.

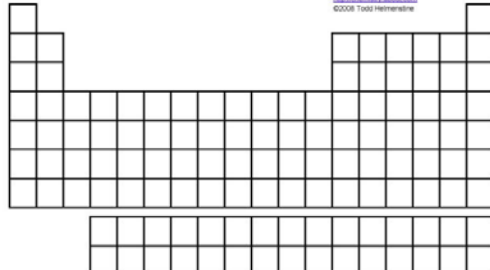Blank Periodic Table of the Elements

   a. As you go left to right across a period, the electron affinity increases.

   b. As you go down a group (top to bottom), the electron affinity decreases.

5. Metalic Character
   a. As you go left to right across a period, metallic decreases.

   b. As you go down a group (top to bottom), the ionization energy increases.

Blank Periodic Table of the Elements
http://chemistry.about.com
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B. Isoelectronic particles - species with the same number of electrons

Problem: Arrange the ions Se^{2-}, Br^-, Rb^+, and Sr^{+2} in decreasing size

Chapter 9

→ The attractive interaction between two atoms or ions

I. Types: -

      1. **Ionic Bond**- Cations (+ charged) and Anions (- charged) are held together by the attractive force of their (+) and (-) charges ⇢ Electrostatic force.

      2. Metallic Bonds

      3. Macro molecular crystals

      4. **Covalent Bonds**- Results from the sharing of a pair of electrons between two atoms.

II. Valence electrons (High energy electrons)-Review

The electrons in the outermost shell (energy level). Valence electrons are involved in reactions.

(Rem: # valence e^- = the group number for the "A" subgroup elements)

ex.

III. Ionic Bonds- The attractive force between a cation (+ ion) and anion (- ion).-Review

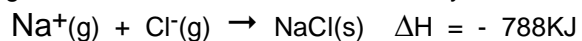Atoms lose or/ gain electrons to obtain an octet.

IV BORN-HARBER CYCLE DIAGRAM

BACKGROUND:

The Born- Haber cycle uses the law of Hess to determine the _Lattice Energy._ The lattice energy is the enthalphy change, ΔH, associated when gaseous cations and anions from a crystal:

$$Na^+(g) + Cl^-(g) \rightarrow NaCl(s) \quad \Delta H = -788KJ$$

Since heat is always evolved in these processes, all lattice energies have a negative sign (Energy is lost). Lattice enrgies cannot be determined directly; therefore, the law of Hess is applied to indirectly determine the lattice energy:

V BORN-HABER CYCLE

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To prepare 1 mole of NaCl, for example, the following steps must be taken:

A. Crystalline Na metal is sublimed into gaseous Na:

$\Delta H_{sublimation} = +108$ KJ

B. Gaseous sodium atoms are ionized into gaseous sodium ions. The amount of energy required for 1 mole of Na is the first ionization energy of sodium

$\Delta H_{ionization} = +496$ KJ

*Note some cations will require the second ionization energy step:

C. Gaseous Cl_2 molecules are dissociated. (Bonds are broken). This the enthalpy change when 1 mole of Cl_2 molecules are dissociated.

$\Delta H_{dissociation} = +243$ KJ

D. Electrons are added to the gaseous chlorine atoms. The enthalpy change per mole of Cl(g) is the first electron affinity of chlorine
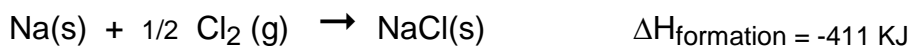
$\Delta H_{electron\ affinity} = -349$ KJ

*Note some anions will require the second electron affinity energy step:

E. In this step, gaseous Na^+ and Cl^- condense into one mole of crystalline sodium chloride. The lattice energy is the amount of energy released per mole of NaCl.

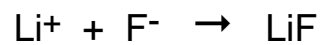$\Delta H_{lattice\ energy} = -788$ KJ

F. Once steps A-E are added, the sum will give you the $\Delta H_{formation}$:

$$Na(s) + 1/2\ Cl_2\ (g) \rightarrow NaCl(s) \qquad \Delta H_{formation} = -411\ KJ$$

Comparision between Lattice energy and $\Delta H_{formation}$:

Problem: Calculate the Lattice energy for:

$$Li^+ \; + \; F^- \; \rightarrow \; LiF \qquad \Delta H_{lattice\ energy} = \;?$$

Given:

$\Delta H_{sublimation} = +155.2$ KJ

$\Delta H_{ionization} = +520.$ KJ

$\Delta H_{dissociation} = +150.6$ KJ (Bond energy)

$\Delta H_{electron\ affinity} = -333$ KJ

$\Delta H_{formation} = -594.1$ KJ

Problem: Calculate the Mg sublimation energy for:

$$Mg^{2+} + 2Cl^- \rightarrow MgCl_2 \qquad \Delta H_{lattice\ energy} = ?$$
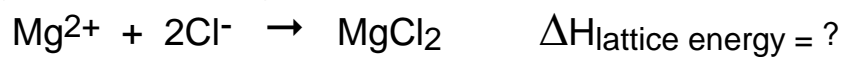
Given:

$\Delta H_{ionization}$: the first and second ionization energy of Mg is: 756 KJ/mole and 1490. KJ/mole, respectively.

$\Delta H_{dissociation}$ = +248 KJ (Bond energy)

$\Delta H_{electron\ affinity}$ = -368 KJ

$\Delta H_{Lattice\ Energy}$ = -2576 KJ

$\Delta H_{formation}$ = -698 KJ

VI. Electronegativity and Bond Polarity

A. Electronegativity - The measure of the attractive force that an atom for its shared electrons. In general, electronegativity increases left to right and bottom to top on the periodic table.

B. Electronegativities and bond polarity

  1. Covalent Bonds

  a. Non polar covalent bonds - differences in the electronegativities is $\leq$ 0.4

  b. Polar covalent bonds - differences in the electronegativities is between 0.5 -1.7

  2. Ionic bonds

   Differences in electronegativities is $>$ 1.7

Examples:

1.

2.

3.

4.

5.

6

7

IV. Covalent Bonds
A. Bond Energy - The average energy required for the dissociation of a bond

B. Bond Length - The average distance between the two nuclei of covalently bonded atoms.

C. Drawing LEWIS STRUCTURES - Electron dot structures-Review

HOW TO:

1.   Write e- dot structure for the individual atoms.

2.   a) Add together the number of valence electrons for all the atoms
(If it is an ion, you must add or subtract electrons accordingly)

b) Divide the total number of e⁻ by 2: This will give you the number of e⁻ pairs available
for bonding.

3.   Determine which is the central atom   a. The least represented atom that is **not H**

b.   Usually, the **first** atom in the chemical

formula that is **not H**.

4.   Arrange atoms symmetrically around the central atom.

5.   Draw a single line (or 2 dots) between the central and outer atoms.

6.   From the total number of valence electrons subtract 2 electron for each bond made.

7.   Attempt to place the remaining electron pairs around the outer atoms to make an octet

or duet (for H)

8.   Additional electrons are placed on the central atom

9.   If the central atom still has less than an octet ; then, a double or triple bond must be formed.
Warning: Do not use a double or triple bond unless you have to!

HONC, a general rule(a help)

Examples.

B. Specific Electron Dot Cases-Review:

1. Ions:

2. Oxy Acids

3. Carbon chains

D. Exceptions to the Octet Rule
  1. <u>Electron deficient molecules:</u> Molecules where the central atom does not have an octet. Usually a group IIIA atom
     Example: BCl_3

2. Expanded valence shell: Molecules where the central atom has more than 8 valence around the central atom. The central atom would belong to the 3rd, 4th, 5th, 6th, or 7th period.
      Example: SF_6

3. Molecules with an odd number of electrons: There are an odd number of valece electrons in the molecule

      Example: NO_2

Practice:
   SO_2

   IF_5

   NO_3^-

   $HBrO$

   CH_3COCH_3

   PF_5