Lesson 4 For Book 1

Review Question --- Calculation of Free Energy

At 298K, solid potassium nitrate dissociates when heated to produce solid potassium nitrile and gaseous oxygen,

with the standard enthaply change of reaction = +124 **kJmol-1**

The standard entropies , for the formation of each species, are shown below:

Species	$S^{\ominus}$ (**JK-1 mol-1**)
KNO3 (s)	133
KNO2 (s)	152
O2(g)	205

a) Write the chemical equation involving.

b) Calculate the standard entropy change for the reaction.

c) Calculate the standard free energy change for the reaction.

d) Calculate the temperature at which this reaction becomes spontaneous.

Hint = Free energy change = $\Delta H - T\Delta S$

(+243 JK-1 mol-1, 51.6 kJ mol-1, T=510K)

Chemical Bondings → Ionic bond , Covalent Bond , Metallic Bond

- Ionic Bond exists in ________ compounds. It is **non-directional**. Actually, this kind of force/bond is due to the **columbic a**_________ between cations and ________ .

→ Factors affecting the strength:

1) C_______ of the ions (_____ charges, stronger bond)
2) S____ of the ions (If the size of the ions are comparable → better attraction → _______ bond)

- Covalent Bond exists in __________ compounds, especially in o_______ compounds. They are due to the sharing of electrons between atom's n_______.

→ More Accurately, it is formed by the overlapping of **atmoic o**_______.

- Metallic Bond exists in m___________ compounds (no matter metal, semi-metal, transition metal) → Electron-sea model :

  1) Inside the lattice of metal, metal atoms loses their v______ electrons to form cations and the electron sea.

  2) There exists ionic attractions between the m_______ electrons and the metal c________. → Metallic Bond

→ Factors affecting the strength:

1) no of valence electrons available (group 3> 2 > 1)
2) size of the metal cations (go down the group, the strength will red_______)

→ More formal --- charge to radius ratio

<u>Ionic Compound (ONLY)</u>

- Standard Enthalpy change of **Formation =** $\Delta H^{\ominus}_{f}$ **the enthalpy change** when **one mole** of the ionic compound is formed from its constituent elements (in their standard states) under standard conditions.

→ Please write down the equation for the formation of NaF (s)

- Recall that an ionic compound is formed by the "**Combination**" of a cation and anion. What are the enthalpy changes representing the formation of the cation (From m________) and the anion (From halogen)

*<u>Formation of **Cation (Metal(s) → Metal (g) → Cation(g))**</u>*

→ Standard enthalpy change of **atomization** = $\Delta H^{\ominus}$atom is the enthalpy change when ____ mole of **gaseous** atoms is formed from an element in the standard state under standard conditions.

→ Standard enthalpy change of **ionization** = $\Delta H^{\ominus}$I.E. is the **energy** required to remove / enthalpy change when **one mole of electron** is re________ from one mole of atoms or ions in the g_________

State.

→ Please write down the equation for the $\Delta H^{\ominus}$ 2^{nd} I.E. of Ca(____)

→ REMEMBER＝ It is more difficult to remove electrons from a positively charged species than from a neutral species → $\Delta H^{\ominus}$1st I.E. $\Delta H^{\ominus}$ 2^{nd} I.E. ……

*<u>Formation of **Anion** (Non metal e.g. oxides and halides)</u>*

→ **Electron Affinity =** $\Delta H^{\ominus}$E.A. is the enthalpy change when **one mole of electrons** is a_______ to one mole of atoms or ions in the gaseous state.

e.g. O () + e- → O- ()

Factors affecting the sign / magnitude of the $\Delta H^{\ominus}$E.A.

1) The electronegativity of the species (the strength of nuclear attraction)
2) The electronic configuration → the attraction of electron is more exo_________ if a ______/ full filled electronic configuration can be attained.

*<u>Formation of an **IONIC COMPOUND**</u>*

→ Lattice enthalpy = $\Delta H^{\ominus}$lattice is the enthalpy change when ____ mole of an ionic c________ (better than salt) is formed from its constituent ions in the gaseous state under standard conditions.

→ Physical meaning = a measure of **ionic bond strength**,

i.e. more negative the $\Delta H^{\ominus}$lattice, more strong is the electrostatic attraction between the ions.

✗ a measure of ~~**thermal stability**~~

→ In HKAL, finding $\Delta H^{\ominus}$lattice of an ionic crystal is typical.

Exercise 1

Calculate the **experimental lattice enthalpy** of NaCl(s) using the following thermochemical data and the Born Haber Cycle, in which $\Delta H^{\ominus}6$ represents the lattice enthalpy.

	$\Delta H^{\ominus}$(kJmol-1)
$\Delta H^{\ominus}$atom of Na(s)	108
$\Delta H^{\ominus}$1st IE of Na (g)	495
Bond dissociation enthalpy of Cl_2(g)	239
$\Delta H^{\ominus}$EA of Cl (g)	-349
$\Delta H^{\ominus}$f of NaCl(s)	-411

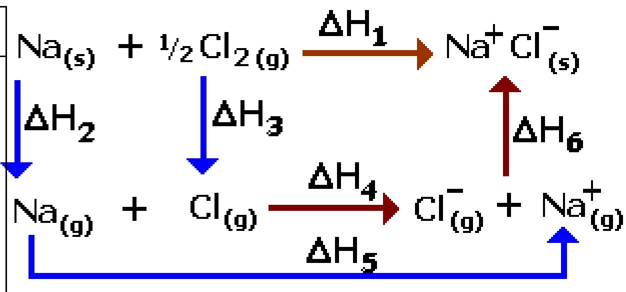


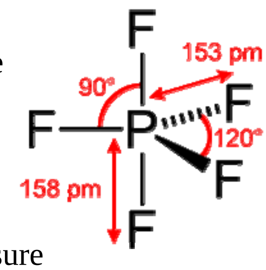
Fig 1.

(c) doc brown at www.docbrown.info

(-784.5 kJmol-1)

→ The theoretical lattice enthalpy of NaCl(s) is -770kJmol-1. If the ionic crystal is in a good agreement with the **Perfect ionic model**, these two values should be close to each other.

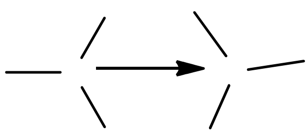
Covalent Compound (only)



- Recall that a covalent bond, which is directional, is formed by the overlapping of atomic o______. **For elements in period 3 or above, octet can be extended** as they have **low l______ vacant d o**______ , ie, the atoms can form more than four covalent bonds. E.g. **PF_5** , a colourless gas at room temperature and pressure
- As for the covalent bond, there is a type called **dative covalent bond**.

→ It is formed by the o_________ of an empty orbital of an atom with an orbital occupied by a l______ pair of electrons of another atom.

→ it is important for you to know that, in later chapter about the formation of **metal complex**, the bond between the metal centre and the **ligand** is dative covalent in nature.



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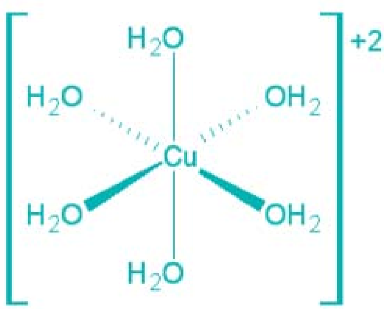


- **Bond dissociation enthalpy**, $\Delta H^{\ominus}$B.E. , for convalent compound (especially for organic compound), is the enthalpy change when **one mole of a particular bond** in a particular environment is broken under standard conditions.

→ the data given for you to do calculation are just an **average** value only.

- The enthalpy change of **atomization** of an organic compound = $\Delta H^{\ominus}$atom is the enthalpy change of the breaking down of one _____ of the gaseous compound into its cinstituent atoms in the g______ state.

e.g. $H_2C=CH_2$ (g) → 2C (g) + 4H (g)

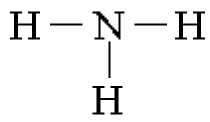
- ** Δ **H**$^{\ominus}$**reaction** = sum of average bond enthalpies of reactants – sum of average bond enthalpies of products (not frequently used)

<u>Drawing of covalent compounds --- Lewis Structure</u>

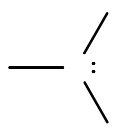
<u>Illustration e.g. NH3</u>

1) Allocate the central atom , i.e. the least **electronegative** atom
2) Count the total no of valence electrons , i.e., it is equal to the no of group of the atoms . That is, N has ____ ; H has <u>one</u> .
3) Then, draw the brief lewis structure without considering the actual shape of the compoound.

Now, there is only ____ valence electrons



4) Since **Two** valence electrons remain unused, we add them to the central N atom and hence there is one lone pair electron of N atom.



p.s. → **Negative Ion**: **Add** the number of electrons equal to the negative charge on the ion. E.g. no of valence electron of NH_2^- = 8+1 = 9

→ **Positive Ion**: **Subtract** the number of electrons equal to the positive charge on the ion. E.g. no of valence electron of NH_4^+ = 8 – 1 = 7

→ If the central atom can extent its octet, double bond or even triple bond can be formed

→ When **resonance is possible,** more than one Lewis structure can be drawn **REMEMBER** = more Lewis structure / Resonance structure, more stable is the compound.

1) Draw Lewis structures for the following molecules or polyatomic ions.

a) H_2O

b) BF_3

c) PCl_5

d) H_2S

e) $SOCl_2$
(S is the central atom, O and Cl are both bonded to S)

f) IO_3^-

g) CH_3CH_2OH

h) CH_3OCH_3

2. Draw Lewis structures for the following molecules or polyatomic ions:

a. N_2

b. CH_3COOH (acetic acid)
(Be sure to use the correct skeletal arrangement for the –COOH group. It is **NOT** straight chain C–O–O–H.)

c. HNO_3 (nitric acid)

d. H_2SO_4

e. CO_2

f. N_2H_2

g. CO

h. O_3 (Structure is not a ring, it is a chain.)