# CHEMISTRY HSSC–I (3rd Set Solution)

**SECTION – A (Marks 12)**

**Time allowed: 20 Minutes**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 15 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | A | C | C | B | D | B | D | A | C | D | B | A | B | C | A | B |

## SECTION – B

**Q.2**

i. $8.7X10^{24}$ $H_2$ molecules are produced by the reaction of zinc and 30%W/W $H_2SO_4$ solution of density 1.25g/ $cm^3$. For the following reaction:

$Zn_{(s)} + H_2SO_{4(aq)} \longrightarrow H_{2(g)} + ZnSO_{4(s)}$

Calculate the volume of sulphuric acid solution used.?

(Zn = 65, O = 16, S = 32, H = 1 g/mol)

**Answer:**

It this reaction 30%W/W $H_2SO_4$ is used, it means 30 g of sulfuric acid is used to make 100 g of solution.

Molecules of $H_2$ produced = $8.7 \times 10^{24}$

Moles of $H_2$ = $8.7 \times 10^{24} / 6.022 \times 10^{23}$

Moles of $H_2$ = 14.45

According to chemical equation:

1 mole of $H_2$ is produced from: 1 mole of $H_2SO_4$

14.45 moles of $H_2$ is produced from : 14.45 mole of $H_2SO_4$

Mass of $H_2SO_4$ = moles x molar mass

Mass of $H_2SO_4$ = 14.45 x 98

Mass of $H_2SO_4$ = 1416.28 g

We can calculate the volume of solution for 30% W/W solution:

Mass of solution: 4720.93 g

d = m/v

By putting the values:

1.25 $g/cm^3$ = 4720 .93g / v

V = 3776.74 $cm^3$

ii. Briefly describe the miscibility of phenol and water system.

**Answer:**

When equal volumes of phenol and water are mixed into each other, two layers are formed. The lower layer consists of small amount of water dissolved in phenol, while the upper layer

consists of small amount of phenol dissolved in water. It is observed that, upper layer is 5% solution of phenol in water and lower layer is 30% water in phenol at 25 $^{o}$C.
So, we conclude that phenol and water are partially miscible liquids in each other. Water is a polar molecule and phenol has –OH group, which is hydrophilic and non-polar benzene ring, which is hydrophobic. The –OH group can interact with water by hydrogen bonding and dissolve but benzene does not. Because of this reason, the phenol water system is a partially miscible solution.

iii. Describe briefly Zeeman and Stark effect on Bohr atomic model.

**Answer:**
Zeeman effect is the splitting of the line of a spectrum when the source of the spectrum is exposed to a magnetic field. Whereas, Stark effect is the splitting of spectral lines observed when the radiating atoms, ions, or molecules are subjected to a strong electric field. The electric analogue of the Zeeman effect (i.e., the magnetic splitting of spectral lines). For example, according to Azimuthal quantum number of value of l=0 there is no effect of magnetic as well as electric field. If l= 1. Then it splits up into three spectral lines i.e. +1 ,0, -1.

iv. List the quantum numbers value of 5p.

**Answer:**
The principal quantum number n = 5,
The azimuthal quantum number l = 1
The magnetic quantum number m = +1 , 0 , -1
The spin quantum number +1/2 and -1/2

v. Interpret the change in the bond energy in the following.

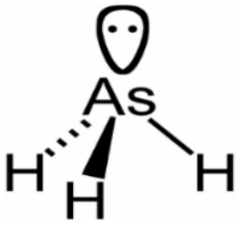
| **Bonds** | C-F | C-Cl | C-Br | C-I |
|---|---|---|---|---|
| **Energy KJ/mol** | 485 | 329 | 276 | 240 |

**Answer**:
The bond energy goes on decreasing from C-F to C-I. The bond energy of C-F bond is highest in the list. The reason is that the highest electronegativity and small size of F. The bond energy of C-Cl is lesser than C-F. The reason is that the low electronegativity and large size of Cl. Similarly, the bond energy is lowest in case of C-I. The reason is that the lowest electronegativity and largest size of I. Hence, in moving from C-F to C-I, electronegativity difference decreases and bond length increases, which will decrease the bond energy.

vi. Demonstrate the values of bond pair, lone pair and total electron pair in $AsH_3$ by VSEPR theory, and draw its structure.

**Answer**:
As has 5 valence electrons. This is $AB_3E$ type structure according to VSEPR.
Total electron pairs = 4.

Bond pairs = 3
Lone pair = 1
Structure of $AsH_3$ according to VSEPR is trigonal pyramidal:

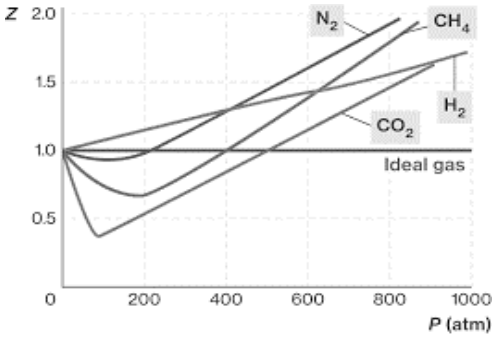



Lone pair bond pair repulsion is greater than bond pair, bond pair repulsion. Hence bond angle will be 107.5°. This is $AB_3E$ type structure according to VSEPR.

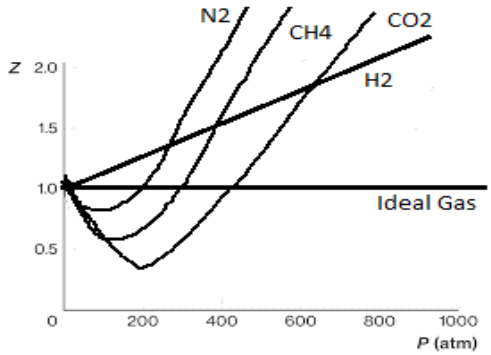
vii. Show by derivation the unit of density in the expression d = $\frac{PM}{RT}$ when R= 0.0821atm $dm^3mol^{-1}k^{-1}$.

**Answer:**
Units of density:
Putting the units of all parameters:
d = atm. $g.mol^{-1}$ / atm $dm^3mol^{-1}K^{-1}$ K
d = g / $dm^3$
So the units of the density according to given equation is:
g / $dm^3$

viii. Deviation from ideal behavior is shown in following graph at 25°C. Sketch the deviation from ideal behavior at 5°C.




**Answer:**
Deviation from ideal behavior at 5°C:



ix. A gas collected over water at $10^0$C and 873 torr. If gas occupies 90cm$^3$, calculate the volume of dry gas at STP when aqueous tension is 9.2torr.

**Answer:**

**Data:**

$V_1 = 90\ cm^3$

From Dalton's law Pg=Pt- $PH_2O$

$P_1 = 873\ torr - 9.2\ torr = 863.8\ torr$

$T_1 = 283\ K$

$P_2 = 760\ torr$

$V_2 = ?$

$T_2 = 273\ K$

According to the general gas equation

$$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

$$V_2 = \frac{V_1P_1T_2}{T_1P_2}$$

$$V_2 = \frac{90cm^3 \text{ x } 863.8 \text{ torr x } 273 \text{ K}}{283\ K \times 760\ torr}$$

$V_2 = 98.7\ cm^3$

x. Describe the surface tension of the given solvents in term of intermolecular forces.

| Solvent | Surface Tension |
|---|---|
| Water ($H_2O$) | $7.275x10^2$ |
| Hexane ($C_6H_{14}$) | $1.84x10^2$ |

**Answer:**

Surface tension of the water is higher as compare to the surface tension of hexane. Water is a polar substance while hexane is a non-polar substance. Water molecules possess hydrogen bonding but in case of hexane, it possesses London dispersion force, it contains more number of carbon atoms i.e. 6, which enhance the LDF. As, LDF is weaker than hydrogen bonding, because of this reason, the surface tension of the water is higher as compared to hexane.

xi. Ice floats at the surface of the water. Tabulate its three advantages.

**Answer:**

| | |
|---|---|
| 1 | Because of this phenomenon, the temperature of water in depth will be maintained. |
| 2 | The life under water can survive because of normal temperature. |
| 3 | Ice on the surface will not allow more heat to dissipate from the water below the surface. |

xii. $CH_3COOH + HCl \longrightarrow CH_3COOH_2^+ + Cl^-$

What is conjugate acid and conjugate base pair, identify conjugate acid and conjugate base.

**Answer:** In the Bronsted–Lowry definition of acids and bases, a conjugate acid–base pair consists of two substances that differ only by the presence of a proton ($H^+$). A conjugate acid

is formed when a proton is added to a base, and a conjugate base is formed when a proton is removed from an acid.
Identification:
Conjugate acid = $CH_3COOH_2^+$
Conjugate base: $Cl^-$

xiii. Calculate pH of $1x10^{-3}$ M $Fe(OH)_3$.

**Answer:**
$Fe(OH)_3$ is a base so first of all we will calculate the $OH^-$.
$Fe(OH)_3 \rightleftharpoons Fe^{+3} + 3\ OH^-$
Upon ionization 3 $OH^-$ ions are produced. So, concentration will become
$3 \times 10^{-3}$ **M**
$pOH = - \log [OH^-]$
$pOH = - \log 3x10^{-3}$
pOH = 2.52
As we know that:
pH + pOH =14
So
pH = 14 – 2.52
pH = 11.48

xiv. Briefly explain buffer action with the help of $CH_3COOH$ and $CH_3COONa$.

**Answer:**
A mixture of a weak acid and its salt with a strong base serves as an acidic buffer.
$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
$CH_3COOH$ is a weak acid, while $CH_3COO^-$ is a strong conjugate base
So, if NaOH is added to the system the following reaction occurs:
$CH_3COOH(aq) + NaOH(aq) \rightleftharpoons CH_3COO^-(aq) + H_2O(l) + Na^+(aq)$
The reaction shows that some acetic acid reacts with the $OH^-$ from the base and converts it to water. Therefore, the pH will not change as drastically as it would have without the buffer. Sodium acetate ionizes completely providing the acetate ion, $CH_3COO^-$.
If HCl is added:
$CH_3COO^- + HCl \rightleftharpoons CH_3COOH$
When HCl is added in the solution $H^+$ will react with acetate ion which results in the formation of acetic acid, thus maintaining the pH of the solution.

xv. Discuss briefly the colligative property of $C_{12}H_{22}O_{11}$ and $CO(NH_2)_2$.
**Answer:**
Sucrose and urea both are non volatile and non electrolyte solutes. When 342 g $C_{12}H_{22}O_{11}$ or 60 g $CO(NH_2)_2$ are dissolved in one kg water (a volatile solvent), there will be following observations in the solution:

1. Elevation of boiling point 100.52$^oC$
2. Depression of freezing point -1.86 $^oC$

Hence colligative properties shown by sucrose and urea do not depend upon mass but depend on number of moles and molecules when they are dissolved in a volatile solvent.

xvi. Prove first law of thermodynamics and show that $\Delta E = q_{v.}$

**Answer:**

**First law of thermodynamics:**

"This law is also called the law of conservation of energy. This law is stated as, "energy of the universe is constant".

OR

"Energy can neither be created nor destroyed but can change from one form to another."

Mathematically.

$\Delta E = q + W$

$\Delta E = q + W$

Where $\Delta E$ = Internal energy changes q =Heat and W= work

Since $W = - P \Delta V$

**At constant volume:**

If the volume of gas does not change, no work is done, ($\Delta V = 0$). By applying the first law of thermodynamics.

$\Delta E = q_v - P \Delta V$

$\Delta E = q_v - 0 \quad (\Delta V = 0)$

$\Delta E = q_v$

So the increase of heat at constant volume ($q_v$) increases only the internal energy ($\Delta E$) of the system and work done is zero.

xvii. Differentiate between exothermic and endothermic reactions with thermochemical equations.

**Answer:**

| Exothermic | Endothermic |
|---|---|
| Chemical reactions that release energy are called exothermic. In exothermic reactions, more energy is released when the bonds are formed in the products than is used to break the bonds in the reactants.<br>Thermochemical equations:<br>$2\,NO_2(g) \longrightarrow N_2O_4(g) \quad \Delta H = -57.6\ kJ$<br>$PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g) \quad \Delta H = -92.5\ kJ$ | Chemical reactions that absorb energy are called endothermic reactions. In endothermic reactions, more energy is absorbed when the bonds in the reactants are broken than is released when new bonds are formed in the products.<br>Thermochemical equations:<br>$N_2(g) + O_2(g) \longrightarrow 2\,NO(g) \quad \Delta H = +181\ kJ$<br>$N_2(g) + O_2(g) \longrightarrow 2\,NO(g) \quad \Delta H = +181\ kJ$ |

xviii. Briefly describe cleavage planes and habit of crystal.

**Answer:**

**Cleavage plane:**

A cleavage plane is the fracture of a crystal or metal by crack propagation across a crystallographic plane or cleavage plane, or the tendency to cleave or split along definite crystallographic planes.

**Habit of crystal:**

Crystal habit is the characteristic external shape of an individual crystal or groups of crystals. A single crystal's habit is a description of its general shape and its crystallographic forms, and how well developed each are.

xix. Complete the reaction on the bases of reduction potentials of $Pb^{+2}/Pb$ = -0.36v and $Fe^{+2}/Fe$ = -0.44v

$PbSO_4 + Fe \longrightarrow$

**Answer:**

Iron is ranked higher in activity series as compared to lead so it can displace lead.

$E_{cell} = E_{cathode} - E_{anode}$

$= - 0.36-(-0.44)$

$=+0.08v$

Feasible reaction is

$PbSO_4 + Fe \longrightarrow FeSO_4 + Pb$

xx. Calculate the energy of ${}_3^7Li^{+2}$ for Balmer series when electron jumps from n=5.

**Answer:**

In Balmer series electron jumps from $n_2 = 5$ to $n_1 = 2$.

So, we will use following formula:

$$\Delta E = \frac{mZ^2e^4}{8\varepsilon_0{}^2h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Z = 3 for $Li^{+2}$.

$n_1 = 2$

$n_2 = 5$

$\Delta E = 2.18 \times 10^{-18} \times (3)^2 (1/2^2 - 1/5^2)$

$\Delta E = 2.18 \times 10^{-18} \times (1/4 - 1/25)$

$\Delta E = 4.57 \times 10^{-19}$ J

## SECTION – C

**Q.3** a. $CH_{4(g)} + 4Cl_{2(g)} \rightleftharpoons CCl_{4(l)} + 4HCl_{(g)}$

Derive Kc expression at equilibrium of given reaction. (06)

**Answer:**

Kc expression:

$$CH_{4(g)} + 4Cl_{2(g)} \rightleftharpoons CCl_{4(l)} + 4HCl_{(g)}$$

| | | | |
|---|---|---|---|
| Initial conc. | a/v | b/v | 0 |
| Eq. Conc. | a-x /v | b-4x/v | 4x/v |

$Kc = [HCl]^4 / [CH_4] [Cl_2]^4$

$Kc = (4x)^4 / v^4 / (a-x)/v (b-4x)^4/v^4$

$Kc = 256(x)^4 v / (a-x) (b-4x)^4$

b. Describe that increase in collision energy by increasing the temperature can improve the collision frequency. (3+2+2)

**Answer:**

According to Arrhenius equation:

$$k = A \cdot e^{-\frac{Ea}{RT}}$$

$k$ - rate constant
$A$ - Arrhenius constant
$Ea$ - activation energy
$R$ - gas constant
$T$ - temperature

According to above equation, A is frequency constant which explains the effect of change in temperature on collision frequency.

We know that a chemical system can be made up of atoms. These particles are moving around in random motion. The collision theory explains why reactions occur between these atoms, ions, and molecules. It also explains how it is possible to speed up or slow down reactions that are occurring.

The rate of reaction can be discussed in terms of three factors: collision frequency, the collision energy, and the geometric orientation. Collision frequency is the number of collisions per second. The collision frequency increases with the increase in temperature of the reaction.

When the temperature is increased, the average velocity of the particles is increased. The average kinetic energy of these particles is also increased. The result is that the particles will collide more frequently, because the particles move around faster and will encounter more reactant particles. Rate is increased just because the particles are, colliding more frequently. The major effect of increasing the temperature is that more of the particles that collide will have the amount of energy needed to have an effective collision. In other words, more particles will have the necessary activation energy.

With an increase in temperature, there is an increase in energy that can be converted into activation energy in a collision.

Hence there is an increase in the number of effective collisions, which will increase the reaction rate

**Q.4** a. Under what conditions synthesis of ammonia will give maximum yield by Haber's process. (2+2+2)

**Answer:**

If we look at the reaction of Ammonia;

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + energy$

It is an exothermic reaction where volume or number of moles are decreasing, so according to Le Chatelier's principle; the favorable conditions for ammonia production are:

1. High Pressure 200 atm (As number of moles are decreasing)
2. Low Temperature 400 $^oC$(As the reaction is exothermic)
3. Removal of Product
4. Addition of reactants

1) **By increasing pressure:** the yield can be maximized. Moles of product are less so by increasing pressure equilibrium will shift forward to increase the production of ammonia. 200 atm pressure is feasible.
2) **At low temperature:** The rate of a reaction increases as the temperature increases, so to increase the temperature until reactants cross the potential barrier.400 $^oC$ is the temperature at which maximum yield is obtained. This is the optimum temperature.
3) **Removal of ammonia**: By removing the product, the equilibrium will shift forward and more product will be formed.
4) **Addition of reactants:** will also favour the formation of product. Increasing the concentration of reactants will shift the equilibrium forward making the conditions more favourable for the formation of more ammonia.

b. Describe dissolution of KCl and $C_6H_{12}O_6$ in water. (4+3)

**Answer:**

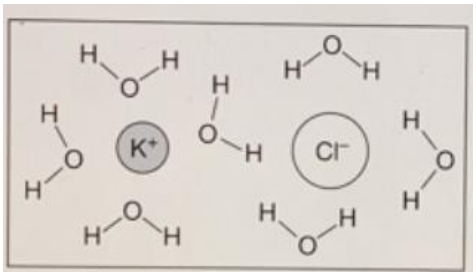
Dissolution of KCl:

When KCl is put in water, it immediately splits in to $K^+$ and $Cl^-$ .

$$KCl \rightleftharpoons K^+ + Cl^-$$

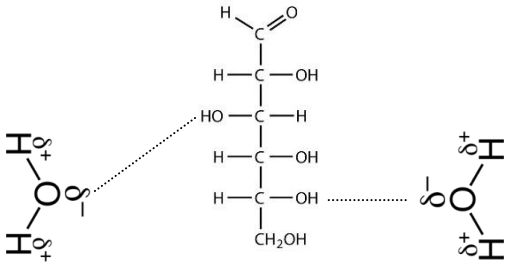
Water, $H_2O$, is a polar molecule, and has partial positive $^+\delta$ and negative charges $^-\delta$. The hydrogens on water are partially positive, and the oxygen on water is partially negative.

Since opposite charges attract each other.So the oxygen of the water molecules are attracted to the $K^+$, and the hydrogens are attracted to the $Cl^-$. The water actually surrounds the $K^+$ and $Cl^-$ so that the opposite charges are allowed to be close together to form hydrate and process is called hydration (solvation). That is why KCl is dissolved in water.




**Dissolution of $C_6H_{12}O_6$**

$C_6H_{12}O_6$ is polar with OH group and water is also polar. Water, $H_2O$ has partial positive $^+\delta$ and negative charges $^-\delta$. The hydrogens on water are partially positive $^+\delta$, and the oxygen on water is partially negative $^-\delta$ .Since opposite charges attract each other. So the oxygen of the water molecules are attracted to hydrogen of glucose to form hydrogen bonding. That is why glucose dissolve in water.



Doted line show hydrogen bonding in between gulocose and water.

**Q.5** a. Demonstrate the reactions that occur in lead storage battery when it is recharged.

**Answer:**

The following half-cell reactions take place inside the cell during recharging:

At the Cathode: $Pb^{+2} + 2e^{-} \rightarrow Pb$

At the Anode: $Pb^{+2} + 2H_2O \rightarrow PbO_2 + 4H^{+} + 2e^{-}$

Overall: $2Pb^{+2} + 2H_2O \rightarrow Pb + PbO_2 + 4H^{+}$

During the charging process, the reactions at each electrode are reversed; the anode becomes the cathode and the cathode becomes the anode.

b. Sulphuric acid can be prepared by contact process using following reactions when one ton (1000kg) sulphur is used then how much $SO_3$ will be produced and how much oxygen is used? (3+4)

$$S + O_2 \longrightarrow SO_2$$

$$2SO_2 + O_2 \longrightarrow 2SO_3 \qquad (S= 32, O=16)$$

**Answer:**

**Data:**

Mass of S = 1000kg = 1000000 g

First we calculate the moles of S.

Moles of S = 1000000 / 32

Moles = 31250

Reaction equation:

$2S + 3O_2 \longrightarrow 2SO_3$

**Amount of $SO_3$ produced:**

According to equation:

2 moles of S is producing : 2 moles of $SO_3$

1 moles of S is producing : 2/2 moles of $SO_3$

31250 moles of S is producing : 2/2 x 31250 moles of $SO_3$

Mass of $SO_3$ = moles of $SO_3$ x molar mass of $SO_3$

Mass of $SO_3$ = 31250 x 80

Mass of $SO_3$ = 2500000 g = **2500 kg**

**Amount of $O_2$ used:**

According to the equation:

2 moles of S reacting with : 3 moles of $O_2$

1 moles of S reacting with : 3/2 moles of $O_2$
31250 moles of S reacting with : 3/2 x 31250 moles of $O_2$
31250 moles of S reacting with : 46875 moles of $O_2$
Mass of oxygen used = 46875 x 32 = 1500000 g = **1500 kg**