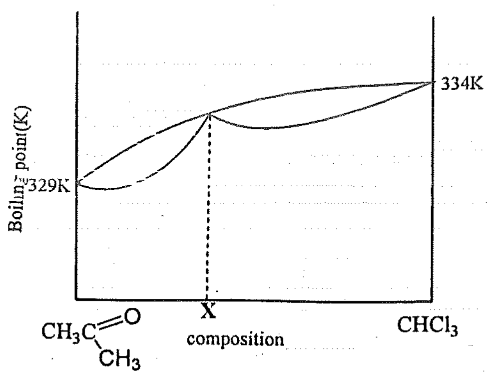
(f) (i) Fractional distillation.

(ii)



X=azeotropic mixture

(iii) No. Because of the presence of constant boiling point mixture with the same composition in the vapour as in the liquid called azeotropic mixture.

3. (a) It states that for a system in equilibrium, at constant temperature, the product of the concentrations of the products divided by the product of the concentrations of the reactants each raised to a power equal to the coefficient in a chemical balanced equation is a constant.

i.e. $aA+bB \rightleftharpoons cC+dD$

$$Kc = \frac{[C]^c_{eqm}[D]^d_{eqm}}{[A]^a_{eqm}[B]^b_{eqm}}$$

(b) (i) The reaction is exothermic since the value of the Kp decreases when the temperature increases from 500°C to 1100°C indicating that the concentration of NH_3 is decreasing as it decomposes to N_2 and H_2.

(ii) (A): The equilibrium will shift to the left since the reaction is exothermic thus more N_2 and H_2 will be produced.

(B) The equilibrium will shift to the right since the number of gaseous molecules (number of moles) of reactants is greater than those of the product. The shift is to minimize the change.

(C) It does not affect the equilibrium position. It increases the rate of the forward and backward reaction at the same rate.

(iii) The equilibrium position will decrease as more NH_3 dissociates to H_2 and N_2 thus reducing the concentration of the product and reducing the equilibrium constant

(c). It is the e.m.f of that half cell measured between a standard hydrogen electrode and the electrode system under standard conditions of 1 molar solution, 25°C (298K) and 1atm.

(d). (i) (A) $S_2O_3^{2-}$

(B) I_2

(ii) $Pt/2S_2O^{2-}_{3(aq)}, S_2O^{2-}_{6(aq)} :: I_{2(aq)}, 2I^-_{(aq)}/Pt$

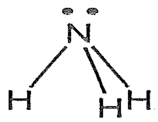
$E.m.f = E_R - E_L = 0.54 - 0.10V = +0.64V$

(e) (i) In H^+, the positive charge nuclei repel each other and are attracted by a single electron in the covalent bond thus H-H$^+$ is weaken while in H_2 the positive charge nuclei repel each other and are attracted by two electrons in the covalent bond which stabilize the H-H bond.

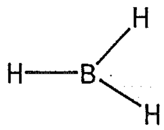
(ii) Aluminium atom are held by metallic bonds when deformed, the metal ions slide past each other and are attracted by the delocalized electrons but carbon is held by a covalent bond which when broken the positive charge nuclei repel each other.

(iii) The presence of hydrogen bonds between ammonia molecules due to high electronegativety of nitrogen than phosphorus

(f). (i)

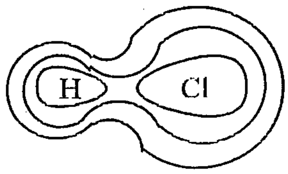


Trigonal pyramidal. The lone pair of electron on nitrogen repels the three bonded pair as far apart as possible than the way bonded pair repel each other



Trigonal planar. These bonded pairs repel each other equally to a maximum bond angle of 120°C

(ii)



SET 6: SECTION A (CGCEB 2014)
Physical chemistry

1) (a) The loss of electron by an atom or any species

(b) (i) $Cr_2O_{7(aq)}^{2-}/H^+_{(aq)}$ this is because the species has the most positive E° value

(ii) $Zn_{(s)}$ It is the species with the most negative E° value

(iii) $Pt/2I^-(aq), I_2(aq) :: Fe^{3+}(aq), Fe^{2+}(aq)/Pt$

$E.m.f = E_R - E_L = 0.77 - 0.54 = +0.23V$ OR $E_{ox} + E_{red}$

c) (i) N^o of moles of $NH_3 = \frac{632.2}{17} = 37.19$ mole

N^o of moles of $CO_2 = \frac{1142}{44} = 25.95$ mole

From equation 2 mol of NH_3 requires 1 mole of CO_2

37.19 mol of NH_3 requires x mole of CO_2

$x \text{ mol} = \frac{37.19 \text{ X } 1}{2} = 18.595$ mole of CO_2

There are 25.95 mol of CO_2. Therefore, CO_2 is excess.

2mol of NH_3(or 34g) → 60g of urea

37.19g of NH_3 → xg of urea

$\Rightarrow x = \frac{60 \times 37.19}{2} = 1115.7g$

OR 34g of NH_3 ⟶ 60g of urea

632.2 ⟶ xg

$\Rightarrow x = \frac{632.2 \text{ X } 60}{34} = 1115.64g$

(ii) 34g of NH_3 ⟶ 44g of CO_2

632.2 g $\longrightarrow$ xg of CO_2

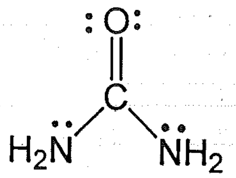
$$x = \frac{632.2 \times 44}{34} = 818.1g$$

excess = 1142 − 818.1 = 323.9g

OR

excess moles of CO_2 = 25.95 − 18.595 = 7.355mol

excess mass of CO_2 = 7.355 X 44 = 323.62g



(iii) % of N$=\frac{14\times2}{60} \times 100 = 46.67\%$

(iv) Yes. Urea is polar due to the difference in electronegativity of O, and N. thus the molecule has a dipole moment.

(v) Use as fertilizers.

(d) ((i) (B): Electron affinity of fluorine

(C) Lattice energy for the formation of LiF

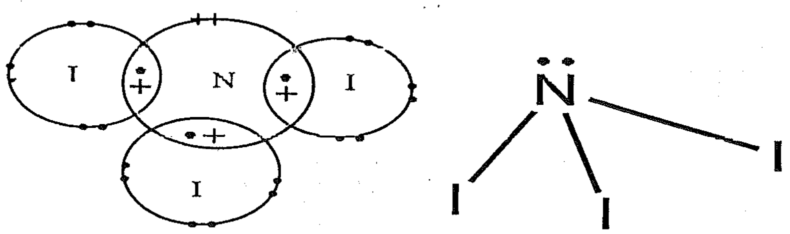
(ii) A+B+C=D

230.5+192-1077=−594.5KJ/mol

2. (a) (i) In covalent bond, each atom in the bond provides an electron to be shared while in dative covalent bond one atom (donor atom) provides these electrons to be shared and the acceptor atom provides an empty orbital to accept the electron pairs

- Covalent bond occurs between non-metals. while dative covalent occur between metals/non-metals or non-metal/non-metals

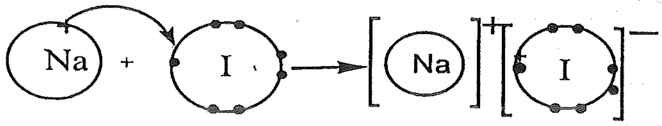
(ii).



Trigonal pyramidal (107°)

(iii). Ionic bond Na losses an electron to form Na^+ and Br gains the electron to form Br^-. The two oppositely charged ions attract each other keeping them together in the ionic bond.

before combination after combination



(b). (i) It states that for a system at equilibrium' at constant temperature, the products of the concentrations of the products divided by the product of the concentrations of the reactants each raised to a power equal to the coefficient in a chemical balanced equation is a constant.

i.e $aA + bB \rightarrow cC + dD$, $Kc = \frac{[C]^c_{eqm}[D]^d_{eqm}}{[A]^a_{eqm}[B]^b_{eqm}}$

(ii) $Kp = \frac{P(I_2)_{eq} \times P(H_2)_{eq}}{P^2(HI)_{eq}}$

(iii) The partial pressure of each component in equilibrium.

(iv) A decrease in pressure has no effect on the equilibrium constant. This is because; Kp is independent of pressure but simply the total pressure. Therefore, increase in total pressure increases the mole fraction term but sum is always 1. Thus equal number of gaseous molecules on both sides.

- Decrease in temperature increases the kp. This is because the reaction is exothermic and this will cause HI to dissociate to H_2 and I_2 thus the partial pressure of I_2 and H_2 will increase Kp.

(c). (i) The maximum pressure which the vapour exerts over its own liquid at equilibrium in a closed system.

(ii) It is a constant boiling point mixture with same composition in the vapour as in the liquid phase.

(d) (i) N^o of mole of $C_6H_{14} = \frac{50}{86} = 0.58mol$

N^o mol of $C_7H_{16} = \frac{70}{100} = 0.7mol$

total number of moles $= 0.58 + 0.7 = 1.28mol$

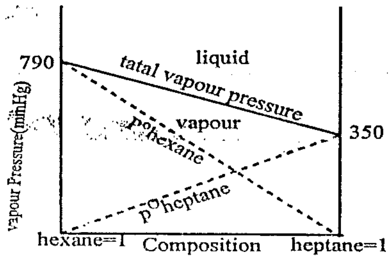
$$X_{hex} = \frac{0.58}{1.28} = 0.45$$

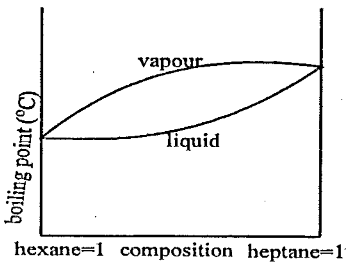
$$X_{hep} = \frac{0.7}{1.28} = 0.55 \text{ OR } 1 - 0.45 = 0.55$$

(ii) $P_{hex} = X_{hex}P^0_{Hex} = 0.45 \times 790 = 355.5mmHg$

$$P_{hep} = X_{hep}P^0_{hep} = 0.55 \times 350 = 192.5mmHg$$

(e)





3. (a) (i) each series presents the transition of electrons from higher energy level to a particular lower energy level

(ii) The energy levels of an atom are specific (quantize) thus the energy radiated due to electron transition is also specific. OR Each transition from different higher levels emits specific frequency.

(iii) By taking the energy difference in electron transition from the lowest energy level and the continuum (convergence limit)

(iv) Electron bombardment method. By plotting the graph of logarithm of ionization energy against the number of electrons removed, it gives the evidence for the existence of shells (energy levels). sub-shells

(b) (i) An acid is a proton donor and a base is a proton acceptor.

(ii) NH_4^+/NH_3 or H_2O/OH^-

(c) (i) $P^H = -\log ka + \log\frac{[salt]}{[acid]}$

$P^H = -\log(6.4 \times 10^{-5}) + \log\frac{[0.05]}{[0.05]}$=4.2

(ii) Adding an acid, protonate the benzoate ion ($C_6H_5COO^-$) to give undessociated benzoic acid (C_6H_5COOH). and the equilibrium will shift to the left but the pH remain almost unchanged

(iii) A buffer solution

(d) (i) An acid which only partially ionizes in solution.

(ii) $pH = 9,\ HA \leftrightarrow H^+ + A^-$

$p^H = -\log ka + \log\frac{[A^-]}{[HA]}$

$$9 = -\log[10^{-9}] + \log\frac{[A^-]}{[HA]}$$

$$9 = 9 + \log\frac{[A^-]}{[HA]} \Rightarrow 0 = \log\frac{[A^-]}{[HA]}$$

$$\Rightarrow 10^0 = \frac{[A^-]}{[HA]} = 1$$

(e) (i) By colorimetry or conductivity method

(ii) By adding the sample withdrawn to $NaHCO_3$ Or Na_2CO_3 or by diluting the sample in cold ice water (NB: this method using ice does not completely quench the reaction but its slows down the reaction).

(iii) (A) In reactions 1 and 2, $[I^-]$ doubles and the rate doubles hence 1st order

Reaction 2 and 3 the $[KIO_3]$ double and the rate quadruples hence 2nd order

(B) rate = $[KIO_3]^2[I^-]^1$

SET 7: SECTION A (CGCEB 2015)

Physical chemistry

1. **(a)** The energy required to remove one mole of electrons from a mole of gaseous atom to give one mole of unipositive gaseous ion.

$X_{(g)} \longrightarrow X^+_{(g)} + e^-$

(b) (i) They represent the energy radiated (emitted) due to electron transitions from higher energy levels to a particular lower energy level,

(ii).

Lymann series	**Balmer series**
Ultraviolet region of EMS	Visible region of the EMS
Electron transition is from higher energy level to n=1	Electron transition is from higher energy level to n=2

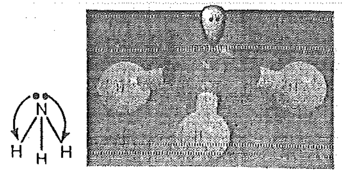
(iii). It shows us that the energy levels in an atom become closer and closer and converges as the principal quantum number (number of shells) increases. OR it gives information that electrons in an atom are located on shells.

(c) (i) ns^2np^2

(ii). Group IV OR group 14.

Explanation: -The first four ionization energies show a steady increase meaning the electrons are removed from the same shell. There is a large jump between the 4th and 5th ionization energy showing that the electron is removed from a new shell which is closer to the nucleus.

(d) The shape of ammonia is trigonal pyramidal (OR pyramidal) because of greater repulsion of the lone pair of electrons on nitrogen on the three bonded pairs.



(c) (i) Covalent bond is an electrostatic force of attraction between atoms in the same molecule while intermolecular force is an electrostatic force of attraction between molecules. OR covalent bond influences both physical and chemical properties of a substance while intermolecular force influences only the physical properties.

(ii). Ethanoic acid when dissolved in benzene or inert solvent will have a molar mass higher due to the presence of H-bond between the acid molecules.

(f) (i) It is the solution of a weak acid and the salt of that weak acid (conjugate base of the acid with a strong base)

(ii). (A)$CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$

OR $CH_3COO^- + H_3O^+ \rightleftharpoons CH_3COOH + H_2O$

(B) $CH_3COOH \rightleftharpoons CH_3COO^- + H_2O$

(iii) $N^o\ of\ moles\ of\ NaOH = \frac{0.04\times50}{1000} = 0.002$

$$CH_3COOH + OH^- \rightleftharpoons CH_3COO^- + H_2O$$

$$N^0\ of\ moles\ of\ CH_3COOH\ left = 0.02 - 0.002 = 0.018mol$$

$$N^o_-\ of\ mol\ of\ CH_3COO^-Na^+ = 0.002 + 0.04 = 0.042\text{mol}$$

Total volume of mixture $1000+50=1050cm^3$

$$\text{conc. of each } CH_3COO^-Na^+ = \frac{0.042\times1050}{1000} = 0.0441\text{M}$$

$$\text{conc. of each } CH_3COOH = \frac{0.018\times1050}{1000} = 0.0189\text{M}$$

$$p^H = -\log(Ka) + \log\frac{[\text{salt}]}{[\text{acid}]} = -\log(1.7\times10^{-5}) + \log\frac{[0.0441]}{[0.0189]} = 4.77 + 0.368 = 5.12$$

---

2. (a) (i) The amount of substance that contains as many elementary particles (atoms, electrons, protons, ions etc) as there are atoms in exactly 12g of carbon-12 isotopes.

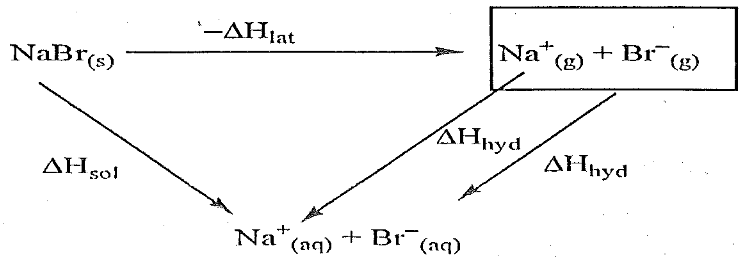
(ii). $number\ of\ mole\ of\ FeCl_3 = \frac{0.1\times250}{1000} = 0.025\ mol$

$1\ mole\ of FeCl_3\ contain\ 56g\ of\ Fe^{3+} = Fe$

$\therefore 0.025g\ contain\ X = 0.025 \times 56 = 1.4\ g$

(b) The lattice energy of NaOH is less than the hydration energy while in NH_4NO_3 the lattice energy is greater than the change in hydration energy.

(c)



$$\Delta H_{sol} = \Delta H_{lat} + \Delta H_{hyd} \Rightarrow -0.06 = \Delta H_{hyd} - 735$$

$\Rightarrow \Delta H_{hyd} = -0.06 - 735 = -735.06kJmol^{-1}$

(d) (i) It is the power to which the concentration of the reactant is raised in the rate law and it is experimentally determined. OR the sum powers to which reactant concentration terms are raised in the rate law.

(ii). A: Exp't. 1 and 2, [A]=constant and [B]=doubles: the rate quadruples hence the reaction is 2[nd] order w.r.t [B]

Exp 1 and 3, [A] =doubles, [B]=constant: the rate remains the same hence the reaction is 0[th] order w.r.t [A].

Overall order=2+0=2. Hence 2[nd] order overall.

B: $Rate = K[B]^2 \Rightarrow$

$$Using\ Exp't\ 1, \quad K = \frac{rate}{[B]^2} = \frac{0.001}{(0.1)^2} = 0.1mol^{-1}dm^3s^{-1}$$

C: $B + B \xrightarrow{slow} B_2$

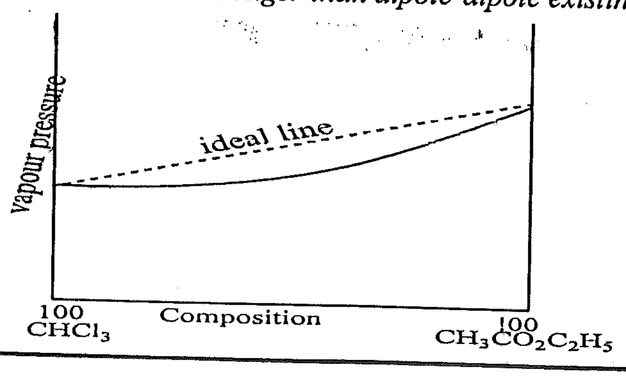
$B_2 + A \xrightarrow{fast} C$

e) (i) The partial pressure of a component in a mixture of miscible liquid is directly proportional to its mole fraction at a given temperature.

➢ OR the partial vapour pressure of any volatile constituent of a solution is equal to the vapour pressure of the pure constituent multiplied by the mole fraction of that constituent in solution over the whole concentration range at all temperature.

(ii). Different molecular structure OR hydrogen bond in the mixture compare to dipole-dipole attraction in the individual components. The forces between the particles (molecules) in solution are different from those between particles in the separate substances.

(iii). *There will be a rise in temperature. This is because the intermolecular hydrogen bond existing in the solution is stronger than dipole-dipole existing in separate components of the mixtures.*

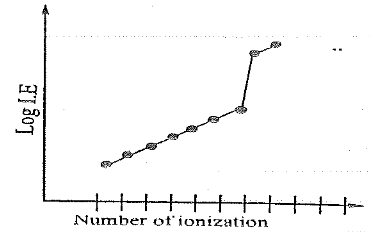


SET 8: SECTION A (CGCEB 2016)
Physical chemistry

1. (a) (i) This is the energy required to remove one mole of electrons from one mole of gaseous uni-positive charge ion of fluorine to give one mole of gaseous doubly positively charged ion of fluorine

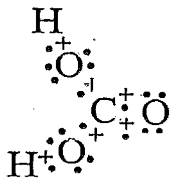
(ii) $F^{+}_{(g)} \longrightarrow F^{2+}_{(g)} + e^{-}$

(iii)

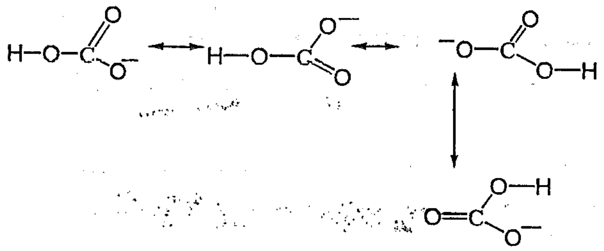


(iv) The first 7 electrons are removed from the same shell (outer shell) which requires lower energy. However, the regular increase is due to increase nuclear charge. The sharp increase from the 8th I.E is due to removal of electron from an inner shell which requires more energy.

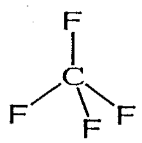
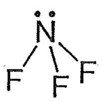
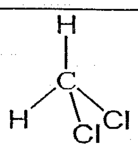
(b) (i)

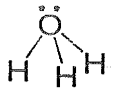


(ii)



(iii)

Species	Molecular shape	Bond angle
CF_4	Tetrahedral 	109.5^0
NF_3	Trigonal pyramidal 	107^0 or 108^0
CH_2Cl_2	 tetrahedral	109.5^0

H_3O^+	Trigonal pyramidal 	107^0 or 108^0

(c) (i) A

From Exp 1 and 3, $\frac{R_3}{R_1} = \left(\frac{C_3}{C_1}\right)^n = \frac{9.3\times10^{-23}}{1.9\times10^{-23}} = \left(\frac{0.0550}{0.0113}\right)^n$

$\Rightarrow (4.9)^n = 4.9 \;\Rightarrow\; n = 1$, hence first order with respect to H_2

B using Exps 2 and 4,

$\frac{R_4}{R_2} = \left(\frac{C_4}{C_2}\right)^n = \frac{1.9\times10^{-22}}{1.1\times10^{-22}} = \left(\frac{0.0056}{0.0033}\right)^n$

$\Rightarrow (1.7)^n = 1.7 \;\Rightarrow\; n = 1$, hence first order with respect to I_2

(ii) $1 + 1 = 2$

reaction is second order overall

(iii) Rate $= K[H_2][I_2]$

(iv)

$$K = \frac{\text{Rate}}{[H_2][I_2]} = \frac{1.9 \times 10^{-23}\,\text{moldm}^{-3}\text{s}^{-1}}{0.0113\text{moldm}^{-3} \times 0.0011\text{moldm}^{-3}} = 1.53 \times 10^{-18}\text{dm}^3\text{mol}^{-1}\text{s}^{-1}$$

---

2. (a) (i)

Negative deviation:

The mixture **forms** **stronger** intermolecular forces than those in the individual components

Positive deviation:

Stronger intermolecular forces that exist in the individual components are broken. Thus the intermolecular forces between the molecules in the mixture are weaker than those in the pure liquids

(ii) Lower boiling point. Because stronger intermolecular forces are broken when the two liquids are mixed

(b) (i) This is the amount of substance that contains the same number of particles as there are atoms in exactly 12g of ^{12}C-isotope

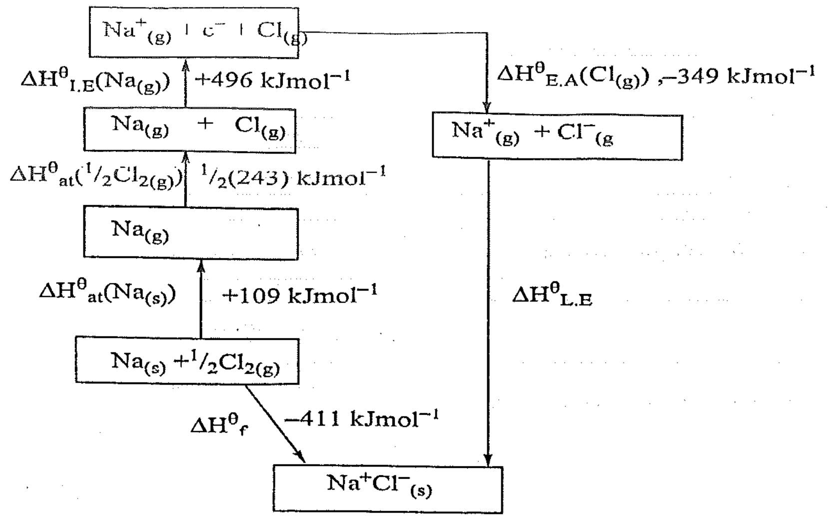
(ii) 12 moles of carbon atoms

1 mole of sucrose contains 12 moles of C-atoms

(iii) Number of atoms $=$ moles x L $= 12 \times 6.022 \times 10^{23} = 7.23 \times 10^{24}$ atoms

(c) (i) This is the energy evolved when one mole of a solid ionic crystal is formed from its constituent gaseous ions.

(ii)



$$\Delta H^\theta_f = \Delta H^\theta_{at}(Na_{(s)}) + \Delta H^\theta at\left(\frac{1}{2}Cl_{2(g)}\right) + \Delta H^\theta_{I.E}\,Na_{(g)} + \Delta H^\theta_{E.A}\,Cl_{(g)} + \Delta H^\theta_{L.E}$$

$$\Delta H^\theta_{L.E} = \Delta H^\theta_f - [\Delta H^\theta_{at}(Na_{(s)}) + \Delta H^\theta at\left(\frac{1}{2}Cl_{2(g)}\right) + \Delta H^\theta_{I.E}\,Na_{(g)} + \Delta H^\theta_{E.A}\,Cl_{(g)}]$$

$$\Delta H^\theta_{L.E} = -411 - \left[109 + \frac{243}{2} + 496 - 349\right] = -788.5\ kJmol^{-1}$$

(d) (i) 1molar H^+ions

(ii) saturated solution of KCl or KNO_3

(iii) $Sn_{(s)}/Sn^{2+}_{(aq)} :: 2H^+_{(aq)}, H_{2(g)}/pt$

SET 9: SECTION A (CGCEB 2017)

Physical chemistry

1a(i) One with a known concentration

(ii) One in which reduction and oxidation occur simultaneously

b(i) $KMnO_4$ is a self-indicator

(ii) Pale pink

(iii) To create a medium for $KMnO_4$ to function as a better oxidizing agent

c(i)

$$\frac{M_{Fe^{2+}}V_{Fe^{2+}}}{M_{KMnO_4}V_{KMnO_4}} = \frac{5}{1} \Rightarrow M_{Fe^{2+}} = \frac{5M_{KMnO_4}V_{KMnO_4}}{V_{Fe^{2+}}}$$

$$= \frac{5 \times 0.018M \times 22.8cm^3}{25cm^3} = 0.082M$$

(ii) Moles = Concentration × Volume(dm^3)

$0.082\ moles/dm^3 \times \frac{250}{1000}dm^3$ = 0.021 moles (1 *mk*)