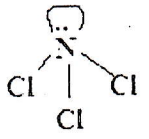
hence polarizing power decreases.
Decrease in polarizing power increases ionic character. The ions are therefore more strongly held, hence increase in their thermal stability.

c) $2KNO_3 \rightarrow 2KNO_2 + O_2$
Decomposition of $Ca(NO_3)_2$ is different from that of KNO_3 due to their products formed for KNO_3, there is formation of nitride which is not in decomposition of $Ca(NO_3)_2$.

14. Draw the expected shape of nitrogen trichloride, NCl_3. State the bond angle in NCl_3. [Atomic Numbers = N: 7, Cl =17) **2 marks**

Answer:



the bond angle is about 107^0

15. The double bond in C_2H_4 consists of two different covalent Bonds. Explain the main difference in their formation. **2 marks**

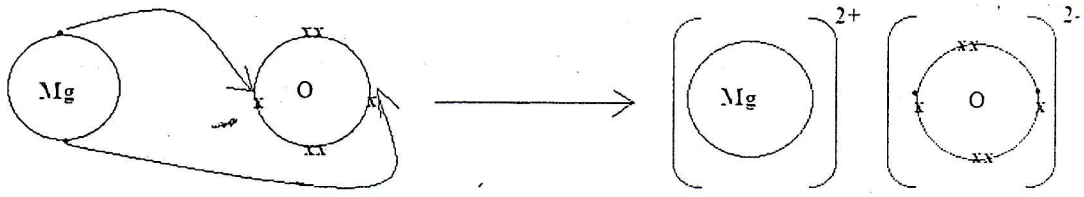
Answer:
Sigma bond is formed by overlapping of two atomic orbitals head to head while the pi bond is formed by overlapping of two p-orbitals side by side.

Section B: Choose three questions from this section. (30 marks)

17. Magnesium oxide, MgO, is a white solid of high melting point.
   a) State one use of Magnesium oxide which depends on its high melting point. **1 mark**
   b) Describe two ways in which magnesium oxide can be prepared. Use a balanced equation in each case. **4 marks**
   c) By drawing a suitable dot-and-cross diagram, show the bonding in magnesium oxide. Use dots and crosses to show electrons in the outer shell only.
   (Atomic numbers =Mg (12), 0(8)) **2 marks**
   d) One method used to obtain magnesium in industry is to heat magnesium oxide with silicon at a high temperature in the absence of air. The equation for the reaction is :
   $2MgO + Si \rightarrow 2Mg + SiO_2$.
   i) What type of reaction is this ? **1 mark**
   ii) Why must the process be carried out in the absence of air? **1 mark**
   iii) State the structure present in SiO_2. **1 mark**

Answer:

a) **MgO is used for the manufacture of glasses**
b) **Preparation**
   i) By heating a metal (Mg) in air or oxygen
   $2Mg(s) + O_2(g) \xrightarrow{heat} 2MgO(s)$
   ii) By heating of carbonates or nitrates
   $MgCO_3(s) \xrightarrow{heat} MgO(s) + CO_2(g)$
   $2Mg(NO_3)_2(s) \xrightarrow{heat} 2MgO(s) + 4NO_2(g) + O_2(g)$
c) **MgO**

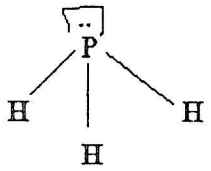


d) **i) Reduction reaction**
ii) To avoid oxidation
iii) Giant covalent structure

19. Nitrogen and phosphorus are the first two elements in group V of the periodic table. Their hydrides are ammonia (NH_3) and phosphine (PH3).
   a) Sketch and explain the shape of phosphine. Show the expected bond angle in the molecule (Atomic numbers: P (15), (H=1)) **4 marks**
   b) the boiling point of NH_3 and PH_3 are -33°C and - 88° C respectively. Suggest reasons for the difference in their boiling points. **2 marks**
   c) P_2O_5 and PCl_5 represent the oxide and chloride of phosphorus in the higher oxide state of phosphorus.
      i) Give the oxidation state of P in P_2O_5 **1 mark**
      ii) Write a balanced equation for the reaction of PCl_5 with water. **2 marks**
      iii) Give the name of the molecular shape of PCl_5. **1 mark**

Answer:

a)



Bond angle: is about 107^0 (actual bond angle is 93.2^0)
The shape is trigonal pyramidal

b) **Nitrogen is more electronegative atom than phosphorus. NH_3 molecules are held together by stronger hydrogen bonds while PH_3 molecules are held together by weak van der waals forces which require less energy to break resulting lower boiling point than NH_3.**

c) **i) The oxidation state of P in P_2O_5 is +5.**
ii) $PCl_5(s) + 4H_2O\ (l) \longrightarrow H_3PO_4(aq) + 5HCl(aq)$
iii) Molecular shape is trigonal bipyramidal.

Section C: Answer one question from this section. (15 marks)

22. A solution of chromate (CrO_4^{2-}) was prepared as follows. Sodium hydroxide solution was added to aqueous Cr^{3+} to give a grey green precipitate. Excess sodium hydroxide was added to dissolve the green precipitate to give a green solution- Aqueous hydrogen peroxide was added and the mixture was warmed to give a yellow solution containing CrO_4^{2-}
   a) Calculate the oxidation number of Cr in CrO_4^{2-} **1 mark**
   b) Write balanced ionic equations to show:
      i) the reaction of Cr^{3+} to give a grey green precipitate. **2 marks**
      ii) the reaction of the green precipitate to form a green solution. **2 marks**
   c) What is the role of hydrogen peroxide in the above preparation? **1 mark**

d) When an acid is added to CrO_4^{2-} it changes to $Cr_2O_7^{2-}$.
i) State the colour of aqueous $Cr_2O_7^{2-}$. **1 mark**
ii) Write an equation for the reaction of CrO_4^{2-} with H^+ ions to form $Cr_2O_7^{2-}$.Is this a redox reaction? Give a reason for your answer. **3 marks**

e) Acidified $Cr_2O_7^{2-}$solution is commonly used as an oxidizing agent. The relevant half-equation is:
$Cr_2O_7^{2-}$.+ $14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$.
Write a balanced equation for the reaction between acidified $Cr_2O_7^{2-}$ and Fe^{2+}. ($Fe^{2+} \rightarrow Fe^{3+} + e^-$) **2 marks**

f) Chromium is used to manufacture steel alloys. One such alloy is stainless steel.
i) what is an alloy? **1 mark**
ii) Give one major property of stainless steel **1 mark**

g) Give the electronic configuration of chromium (Cr). (Atomic Number of Cr : 24) **1 mark**

Answer:

a) **Let oxidation state of Cr in CrO_4^{2-} be x:**
X + 4(-2) = -2
X = +6

b) **i) $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ grey green precipitate**
ii) $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$ green solution

c) **Hydrogen peroxide acts as an oxidizing agent.**

d) **i) It is orange**
ii) IN the presence of an acid chromates are converted to orange solution of dichromate.
$2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow 2Cr_2O_7^{2-}(aq) + H_2O(l)$
Yellow orange
No because the oxidation state of chromium is the same.

e) $2Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$

f) **i) An alloy is a combination of two or more elements of which at least one is a metal. (or an alloy is a combination of two or more metals)**
ii) It does not rust

g) **Cr: 24 = $1s^22s^22p^63s^23p^63d^54s^1$**

ADVENCED LEVEL CHEMISTRY NATIONAL EXAMINATION PAPER 2008

(Biology-Chemistry)

Section A: Answer all questions. (55 marks)

01. An element X has the electronic configuration:
$1s^22s^22p^63s^23p^64s^23d^{10}4p^5$

a) What is the atomic number of X? **1 mark**
b) T0 which group of the Periodic Table does X belong? **1 mark**
c) To which period of the periodic Table does X belong? **1 mark**
d) In terms of Mg and X, Write the formula of the compound formed between Mg and X. **1 mark**

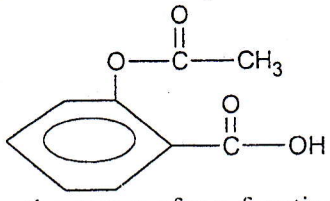
Answer:

a) **Atomic number is 35**
b) **X belongs to group VII, since last orbital contains $4s^2 4p^5$. Thus 2+5 = 7**
c) **X has 4shells, therefore it is in period 4.**
d) **MgX_2**

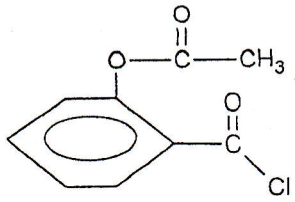
02. Chlorofluorocarbons, CFCs, are widely used commercially.
a) Give one use of CFCs. **1 mark**
b) Explain one environmental problem caused by CFCs. **2 marks**
c) One CFC has a molecular formula $C_2H_2F_3Cl$. Give the structural formulae of two isomers of this CFC. **2 marks**

Answer:
a) **Used as refrigerant e.g: dichloro difluoro methane**
Used as propellants in pressured cans
Used in fire extinguishers.
b) **CFCs are very light and move to the stratosphere and form free radicals which breakdown of the ozone layer.**
$O_3 + Cl^{\cdot} \longrightarrow O_2 + ClO^{\cdot}$
Ultraviolet radiations from the sun then reach the earth hence causing
- skin cancer
- Green house effect (global warming)
c)

03. An organic commercial product has the following structure



a) Give the names of two functional groups present in the above structure.**2 marks**
b) Give the structure of a reagent used to prepare the above compound from



1 mark

Answer:
a) **– Carboxylic acid**
- ester
b) **The reagent used is H_2O**

04. Write balanced ionic equations to represent the reactions described below :
a) the reaction between Br_2 and Kl (aq). **1 mark**
b) the reaction between Fe3* and potassium hydroxide solution **1 mark**

c) the reaction between chromate (VI) ions, CrO_4^{2-}, and H^+ ions. **1 mark**

Answer:

a) $Br_2(aq) + 2I^-(aq) \rightarrow 2Br^-(aq) + I_2(aq)$

b) $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

c) $2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

05. This question concerns sulphur dioxide, SO_2, and carbon dioxide, CO_2 (Atomic numbers : C: 6, S :16).

a) Draw the shapes of the two molecules, showing lone pairs of electrons, if any, on the central atom. **2 marks**

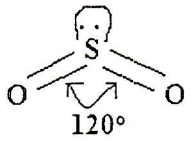
b) Explain why CO_2 is non-polar whereas SO_2 is polar. **2 marks**

Answer:

a) CO_2 is O=C=O, linear shape

180^0

SO_2 is:



b) **Carbon dioxide is linear, O=C=O, so that the polarity in one side cancels with the polarity on opposite side resulting in a zero net dipole moment thus it is non polar.**

06. The table below gives some properties of oxides of period 3 in the periodic table.

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_3
Melting Point(°C)	1275	2827	2017	1607	580	33

a) In terms of bonding and structure, explain the difference in the melting points of MgO and SO_3. **2 marks**

b) Write equations to show the reaction of

i) P_4O_{10} with water

ii) Na_2O with water. **2 marks**

Answer:

a) **MgO forms giant ionic structure with a stronger ionic bond which requires a lot of energy to be broken, thus high melting point.**

SO_3 is simple molecular structure and consists of weak Van Der Waal's forces of attraction, hence lower melting point.

b) **i) $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$**

ii) $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

07. Cobalt (II) ion forms two complex ions with H_2O and Cl^- which are interchangeable.

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftarrows [CoCl_2]^{2-} + 6H_2O$

Pink Blue

a) What is the electronic configuration of Cobalt in the complex ion ? (Atomic number of cobalt = 27) **2 marks**

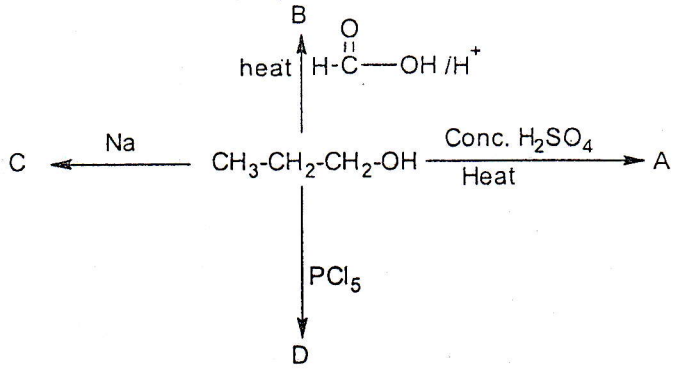
b) Briefly explain the cause of colour in complex ions of transition metals. **2 marks**

Answer:

a) Considering $[Co(H_2O)_6]^{2+}$, the oxidation number of Co is:
$X + 6x0 = 2$
$X = 2$
Its oxidation number is +2
Considering $[CoCl_4]^{2+}$, the oxidation number of Co is $X + 4(-1) = -2$
$X = +2$
If the atomic number of cobalt = 27, Co^{2+} is 25, thus the electronic configuration of Co^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

b) Complexes are coloured because of the partially filled d-orbitals which permits electron transitions from lower energy level to high energy level after absorption of the visible light.

08. Some reactions of propan-1-ol are shown in the scheme below:



Give the structural formulae of the organic products, A, B, C and D. **4 marks**

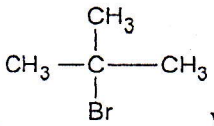
Answer:

a) A is $CH_3CH{=}CH_2$

B is $H\text{-}\overset{\overset{\large O}{\|}}{C}\text{-}O\text{-}CH_2CH_2CH_3$

C is $CH_3CH_2CH_2O^-Na^+$

D is $CH_3CH_2CH_2Cl$

09. The mechanism for the reaction between  with aqueous NaOH is described as S_N1.

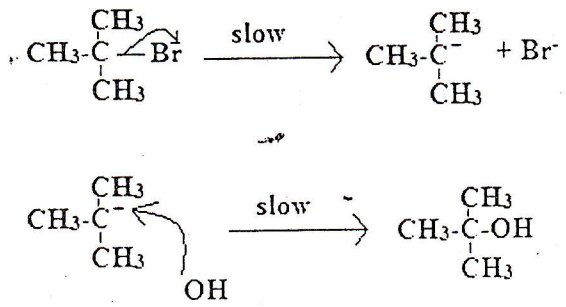
a) What does the term S_N1 represent? **1 mark**

b) Give the full mechanism for the above reaction. **2 marks**

Answer:

a) SN^1 – Substitution nucleophilic unimolecular or substitution nucleophilic first order.

b) $NaOH \rightarrow Na^+ + OH^-$



$Na^+ + Br^- \rightarrow NaBr$

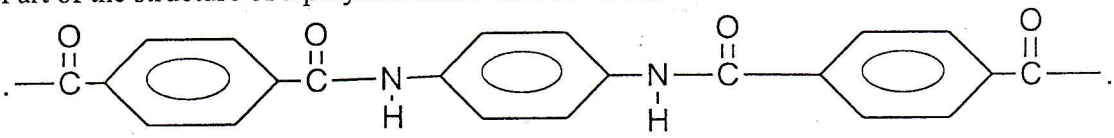
10. a) State the meaning of the term lattice enthalpy or lattice energy. **2 marks**
b) Briefly explain which of the two oxides Na_2O and MgO has a greater magnitude of lattice energy. **2 marks**

Answer:

a) **Lattice energy is the enthalpy change when one mole of an ionic compound is formed from gaseous ions. i.e: $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$**
Or Lattice energy is the enthalpy change when one mole of crystal lattice solid dissociates into its gaseous ions. i.e: $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

b) **MgO has greater lattice energy than Na_2O because of the greater charge and smaller ionic size of Mg^{2+} than Na^+.**

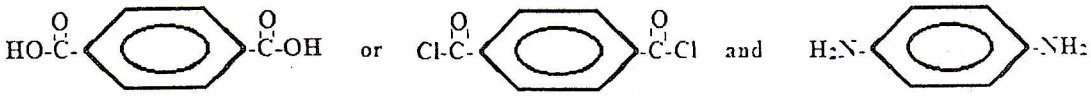
11. Part of the structure of a polymer called 'Kevlar' is shown below:



a) Give the structural formulae of the monomers of the above Polymer. **2 marks**
b) What type of polymer is 'Kevlar'? **1 mark**

Answer:

a)



b) **Condensation polymer or polyamide or Aramid**

12. a) What is meant by the term half-life of a radioactive isotope? **1 mark**
b) The half-life of carbon-14 is 5600 years. Analysis of a fossil from a historical site showed that 6.25% of carbon-14 was present compared to living material. Calculate the age in years of the fossil. **3 marks**

Answer:

a) **Half-life is the time taken for half of the radioactive element to decay.**

b) $\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{5600} = 1.2375 \times 10^{-4} years^{-1}$

$\lambda t = 2.303 \log \left(\frac{No}{Nt}\right)$

$t = \frac{2.303}{1.2375 \times 10^{-4}} \log \frac{100}{6.25} = 22\ 408.8$ years

13. Explain the following observations briefly, using the valence shell electron pair repulsion

theory :

a) the shape of PH_3 is pyramidal while that of H_2S is bent. **3 marks**

b) When H_2O is converted into H_3O^+ the bond angle also changes. **2 marks**
(Atomic Numbers : P: 15, S : 16, O:8, H : 1)

Answer:

a) **Strong electrolyte is fully ionized/ dissociated in aqueous solution whereas weak electrolyte is partially ionized in aqueous solution.**

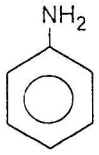
b) **Because ionization increases with dilution due to the decrease in the resistance which results in an increase of mobility of conducting ions.**

c) **Zn is a stronger reducing agent than tin (Sn). Zn will be more rapidly oxidized than Sn hence offering the sacrificial protection to Fe.**

14. This question concerns the chemistry of amines.

a) Using CH_3-CH_2-NH_2 as an example explain with an equation how amines behave as bases. **2 marks**

b) Explain briefly which of the two amines CH_3-CH_2-NH_2 and



is a stronger base **2marks**

Answer:

a) $CH_3CH_2NH_2 + H^+(aq) \rightleftarrows CH_3CH_2{}^+NH_3(aq)$
Or $CH_3CH_2NH_2 + H_2O\ (l) \rightleftarrows CH_3CH_2{}^+NH_3(aq) + OH^-(aq)$

b) **Ethylamine is a stronger base than phenylamine. In phenylamine the lone pair of electrons on the nitrogen atom interacts with the delocalized pi-electrons in benzene ring making the lone pair less available.**

$CH_3CH_2NH_2$ has a methyl group which has a positive inductive effect releasing electrons to nitrogen atom which increases the availability of the lone pair of electrons on nitrogen atom thus a stronger base it is a stronger base than amino benzene.

15. a) How does the relative stability of +2 or +4 in group 4 of the periodic table change down the group? **1 mark**

b) Use oxides of C and Pb to illustrate your answer in (a) above. **1 mark**

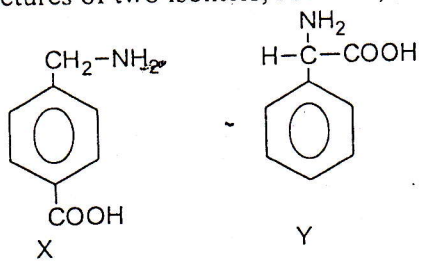
Answer:

a) **There is a steady increase of +2 oxidation state as you move down the group. The relative stability of +4 oxidation state decreases as the group descends.**

b) **In carbon the +4 oxidation state is very stable relative to +2 for example CO is less stable than CO_2. In lead the +2 is more stable than +4 oxidation state due to the inert pair effect. PbO is more stable than PbO_2**

Section B: Choose three questions from this section. (30 marks)

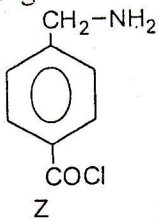
16. a) The structures of two isomers, X and Y, are shown below:



i) Give the names of two functional groups present in each isomer. **2 marks**

ii) State which of the two isomers is chiral / shows optical isomerism. What physical property can be used to distinguish between them? **2 marks**

iii) What reagent would be used to convert X into Z below?



1 marks

b) Molecules of Z (shown in (iii) above) can undergo polymerization. Draw a structure of the polymer formed showing two repeat units and any other product formed. **3 marks**

c) Compound Y can exist as a zwitterion. Draw the structure of the zwitterion of Y at a pH close to 7. What would be the structure of the zwitterion at a pH of 2? **2 marks**

Answer:

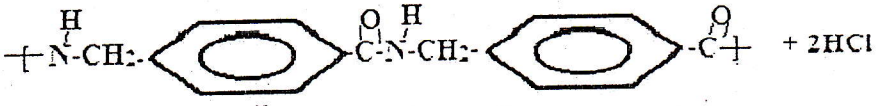
a) **i) - Carboxylic acid group**

- Amine group

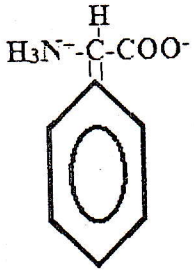
ii) Y is chiral because it has a carbon atom bonded to four different groups and it rotates the plane of polarized light.

iii) PCl_5 or $SOCl_2$ or PCl_3.

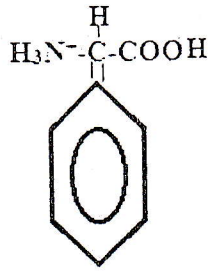
b)



c) **Zwitterion of Y at P^H close to 7 (neutral)**



At P^H of 2



17. a) The reaction between oxygen and nitrogen monoxide:

$$O_2(g) + 2NO(g) \rightarrow 2NO_2(g)$$

is known to be first order with respect to oxygen and second order with respect to nitrogen monoxide.

i) Write an expression for the rate equation for the reaction. **1 mark**

ii) What are the units of the rate constant? **2 marks**

iii) When the initial $[O_2] = 1.0 \times 10^{-2}$ mol dm^{-3} and $[NO] = 3.0 \times 10^{-2}$ mol dm^{-3}, the initial rate is 6.3×10^{-4} mol dm^{-3} s^{-1}. Calculate the numerical value of the rate constant- **2 marks**

b) Nitrogen monoxide reacts with carbon monoxide and oxygen to form nitrogen dioxide and carbon dioxide.

$$NO(g) + CO(g) + O_2(g) \rightarrow NO_2(g) + CO_2(g)$$

The results from a series experiments for this reaction are shown below:

Experiment	[NO]/ mol dm^{-3}	[CO]/ mol dm^{-3}	[O_2]/ mol dm^{-3}	Initial rate/ mol dm^{-3}s^{-1}
1	1.00×10^{-3}	1.00×10^{-3}	1.00×10^{-1}	4.40×10^{-4}
2	2.00×10^{-3}	1.00×10^{-3}	1.00×10^{-1}	1.76×10^{-3}
3	2.00×10^{-3}	2.00×10^{-3}	1.00×10^{-1}	1.76×10^{-3}
4	4.00×10^{-3}	1.00×10^{-3}	2.00×10^{-1}	1.76×10^{-3}

Use the above results to deduce the order with respect to:

i) NO

ii) CO

iii) O_2

Give reasons in each case. Write an expression for the rate equation. **5 marks**

Answer:

a) i) Rate = $k[O_2][NO]^2$

ii) $K = \frac{Rate}{[O_2][NO_2]^2}$

Units of k = $\frac{moldm^{-3}s^{-1}}{(moldm^{-3})(moldm^{-3})^2}$ = mol^{-2}dm^{6}s^{-1}

iii) $K = \frac{6.3 \times 10^{-4} s}{(1.0 \times 10^{-2})(3.0 \times 10^{-2})^2}$ = 70mol^{-2}dm^{6}s^{-1}

K = 70mol^{-2}dm^{6}s^{-1}

b) i) Using results of experiments 1 and 2

[CO] and [O_2] are constant, [NO] is doubled and rate quadrupled (4times).

$\frac{1.7 \times 10^{-3}}{4.4 \times 10^{-4}}$ = 4, the order is 2 with respect to NO.

ii) Using experiments 2 and 3; when [CO] is doubled, keeping [NO] and[O_2]

constant no change in rate, the order is zero with respect to CO.

iii) Using experiments 2 and 4

When [NO] is doubled, $[O_2]$ is doubled and rate is quadrupled (4times) but order with respect to NO is 2, changing $[O_2]$ has no effect on rate thus the order is zero with respect to O_2.

Rate = $k[NO]^2[CO]^0[O_2]^0 = k[NO_2]^2$.

18. a) The standard enthalpy change of formation of phenol, C_6H_5OH, can be determined indirectly from enthalpies of combustion using Hess's law.

i) State Hess's Law of constant heat summation. **2 marks**

ii) Write a balanced equation to show the formation of phenol from its elements.

iii) Calculate the standard enthalpy change of formation of phenol from the data below:

$\Delta H_f^\theta (CO_2) = -394\ kJmol^{-1}$

$\Delta H_f^\theta (H_2O) = -286\ kJmol^{-1}$

$\Delta H_f^\theta (C_6H_5OH) = -3050\ kJmol^{-1}$ **4 marks**

b) Phenol can react as an acid and can also undergo electrophilic substitution.

i) Write an equation to show how phenol reacts as an acid. **1 mark**

ii) Write an equation to show how phenol undergoes electrophilic substitution. **2 marks**

Answer:

a) **i) Hess's law states that for any chemical reaction at constant temperature and pressure the enthalpy change from reactants to products is the same independent of route taken.**

ii) $6C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_6H_5OH\ (l)$ I

iii) $C(s) + O_2(g) \rightarrow CO_2(g)$ -394kJ/mol.....II

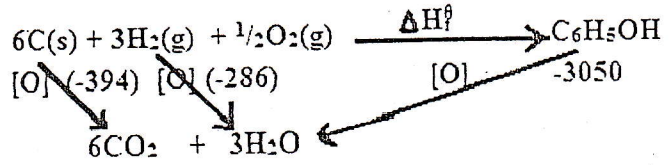
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O$ -286 kJ/mol.....III

$C_6H_5OH\ (l) + 7O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$ -3050kJ/mol....IV

From data above I = 6(II) + 3(III) –(IV)

$\Delta H_f^\theta\ C_6H_5OH = 6(-394) + 3(-286) - (-3050) = -172$ kJ/mol

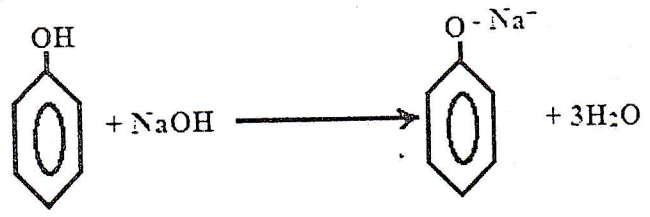
Or **use: Haber cycle process**



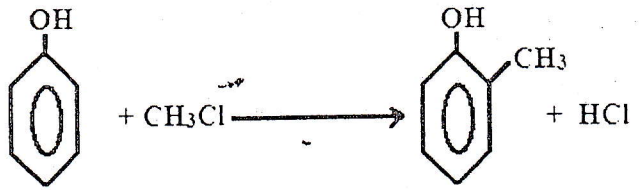
$\Delta H_f^\theta - 3050 = 6(-394) + 3(-286)$

$\Delta H_f^\theta\ C_6H_5OH = -172$kJ/mol

b) i)



ii)



19. a) Methane gas reacts with steam according to the equation given below:

$CH_4(g) + H_2O(g) \rightleftarrows 3H_2(g) + CO_2(g)$ $\Delta H^{\theta} = +210$ kJmol^{-1}

i) How does an increase in pressure affect the equilibrium position? Explain your answer. **2 marks**

ii) Write an expression for the equilibrium constant, Kc, and state its units. **2 marks**

b) Ethanoic acid has a pKa value of 4.77 at 25°C.

i) What is meant by pKa of an acid? **1 mark**

ii) Calculate the pH of 0. 1mol dm^{-3} ethanoic acid (CH_3COOH) solution at 25°C. **3 marks**

c) A mixture of ethanoic acid and sodium ethanoate acts as a buffer solution.

i) What is a buffer solution? **1 mark**

ii) Use an equation to explain how such a buffer solution reacts to an addition of a small amount of acid (H^+ ions).

Answer:

a) **i) There is increase in moles of gas (volume) in the forward reaction. Increase in pressure favours the backward reaction or shifts equilibrium position to the left where there are a few moles of gas.**

ii) $Kc = \frac{[H_2]^3[CO_2]}{[CH_4][H_2O]}$ **units mol^{2}dm^{-6}**

b) **i) Pka = -logka**

ii) Pka = 4.77

ka = -log^{-1}[-4.77] = 1.69 x 10^{-5}moldm^{-3}

$CH_3COOH(aq) \rightleftarrows CH_3COO^-(aq) + H^+(aq)$

Ka = $\frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

At equilibrium $[CH_3COO^-] = [H^+]$

$[H^+] = \sqrt{ka\ x(CH_3COOH)} = \sqrt{1.69\ x\ 10^{-5} x\ 0.1} = 1.3 \times 10^{-3}$

$P^H = -\log[H^+] = -\log(1.3 \times 10^{-3}) = 2.88$

c) **i) Buffer solution is a solution which resists change in P^H when a small amount of acid or base is added.**

ii) The mixture contains a large amount of CH_3COO^- (from the salt and acid) when a small amount of acid is added:

$CH_3COO^- + H^+ \longrightarrow CH_3COOH$

This prevents an increase in $[H^+]$: hence P^H remains almost constant.

When a small amount of base is added:

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

Hence the $[OH^-]$ does not increase and P^H is kept constant.

20. Electrolysis is used in a variety of industrial processes.

a) Describe in detail how impure copper is purified by electrolysis, explaining what

happens at each of the electrodes. **4 marks**

b) In an experiment to electroplate a metal with copper, a current of 0.5A was passed through copper sulphate solution for 30 minutes.

i) Calculate the quantity of electricity passed. **1 mark**

ii) Calculate the mass of copper deposited on the metal. **3 marks**

(Cu = 63.5, F = 96 500 C mol^{-1})

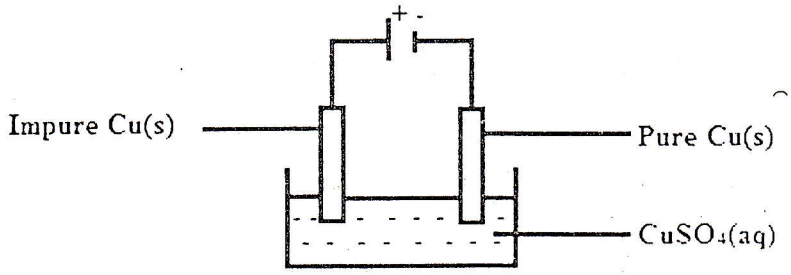
c) Sodium is extracted from molten sodium chloride by electrolysis.

i) Why does the sodium chloride have to be in molten state? **1 mark**

ii) Why would an aqueous solution of sodium chloride be unsuitable for this process? **1 mark**

Answer:

a) **Electrolysis of aq. $CuSO_4$ using impure copper as anode and pure copper as cathode.**



Anode dissolves and impurities drop to the bottom

$$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$$

Pure copper deposits on the cathode

$$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$$

b) **i) Q = It = 0.5 x 30 x 60 = 900C**

ii) $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

2 faradays deposited 63.5 g of Cu

2x96 500 C deposited 63.5 g of Cu

1C doposits $\frac{63.5\ g\ x\ 900C}{96\ 500C}$ **of cu**

900C doposits $\frac{63.5\ g\ x\ 900C}{2x\ 96\ 500C}$ **= 0.296g of Cu**

c) **i) To make ions free to move**

ii) In aqueous solution, H^+ would be discharged in preference to Na^+, hence no sodium would be formed.

Section C: Answer one question from this section. (15 marks)

21. In each of the following investigations you are required to determine the percentage of the specified element or compound.

a) A 2.0g sample of iron was reacted with excess dilute acid. The resulting solution containing Fe^{2+} ions was diluted to 250 cm^3 with distilled water. 25 cm^3 of the solution was titrated with acidified manganate (VII) (MnO_4^-) solution. 26.50 cm^3 of 0.02 mol dm^{-3} MnO_4^- solution was needed to react with 25 cm^3 of the Fe^{2+} solution. The relevant half-equations for the titration are:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

i) Write a balanced equation for the reaction between Fe^{2+} and acidified MnO_4^-. 2 marks

ii) Calculate the amount in mol of Fe^{2+} in 250 cm^3 of the solution. 2 marks

iii) Calculate the percentage of iron in the original sample of iron to 1 decimal place (Fe = 56). 2 marks

b) A Commercial product is known to contain aluminium sulphate, $Al_2(SO_4)_3$. A 5.000g sample of the product was dissolved in Water and an excess of aqueous barium chloride was added. The precipitate of barium sulphate was dried and weighed. The mass of barium sulphate was found to be 2.33g.

i) Write an ionic equation for the reaction between Ba^{2+} and SO_4^{2-} ions. 1 mark

ii) Use the data provided to calculate the mass of aluminium sulphate in the sample and hence its percentage by mass in the commercial product. [Ba = 137, S = 32, O = 16, Al = 27) 4 marks

c) 1 g of an impure sample of ammonium sulphate was boiled with aqueous sodium hydroxide. The ammonia gas evolved was neutralized by 30 cm^3 of 0.1 mol dm^{-3} hydrochloric acid.

i) Write a balanced equation for the reaction between ammonium sulphate and sodium hydroxide. 1 mark

ii) Calculate the number of moles of ammonia gas which was evolved. 1mark

iii) Calculate the percentage by mass of nitrogen in the sample of the salt. (N = 14) 2 marks

Answer:

a) i) $5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \longrightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

ii) 1000cm^3 of MnO_4^- contain 0.02 mol

26.50cm^3 of MnO_4^- contain $\frac{0.02 \times 26.50}{1000} = 5.3 \times 10^{-4}$ moles

Number of moles of $Fe^{2+} = \frac{5 \times 5.3 \times 10^{-4}}{1} = 2.65 \times 10^{-3}$ mol

25 cm^3 of Fe^{2+} contain 2.65×10^{-3} moles of Fe^{2+}

250cm^3 of Fe^{2+} contain $\frac{2.65 \times 10^{-3} \times 250}{25} = 2.65 \times 10^{-2}$ moles of Fe^{2+}

iii) Actual mass of Iron (Fe) = $2.65 \times 10^{-2} \times 56$g in dm^3 = 1.484 g

% of Fe in the original sample of Iron = $\frac{actual\ mass \times 100}{sample\ mass} = \frac{1.484 \times 100}{2}$ =74.2%

b) i) $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

ii) $Al_2(SO_4)_3(aq) + 3BaCl_2(aq) \longrightarrow BaSO_4(s) + 2AlCl_3(aq)$

Number of moles of $BaSO_4$ produced $\frac{2.33}{233}$ = 0.01 mole of $BaSO_4$

$Al_2(SO_4)_3(s) \longrightarrow 2Al^{3+}(aq) + 3SO_4^{2-}(aq)$

Using mole ratio 1:3

3 moles of $SO_4^{2-}(aq) \longrightarrow$ 1 mole of $Al_2(SO_4)_3(s)$

0.01 moles of $SO_4^{2-}(aq) \longrightarrow \frac{1 \times 0.01}{3} = 3.33 \times 10^{-3}$ moles of $Al_2(SO_4)_3$

Actual mass = $3.33 \times 10^{-3} \times 342 = 1.13886$g

% age mass = $\frac{1.13886 \times 100}{5}$ = 22.8%

c) i) $(NH_4)_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2NH_3 + 2H_2O$

ii) Number of moles of HCl $\longrightarrow 3.0 \times 10^{-3}$ moles

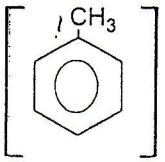
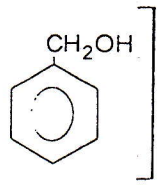
Therefore the number of moles of $NH_3 = 3.0 \times 10^{-3}$ moles due to mole ratio.

iii) Number of moles $(NH_4)_2SO_4$ = (1/2 x 3.0 x 10^{-3}) = 1.5 x 10^{-3} moles of $(NH_4)_2SO_4$

Therefore number of moles of nitrogen = 2x1.5 x 10^{-3} moles = 3.0x10^{-3} moles

Mass of nitrogen = 3.0 x 10^{-3} x 14 = 0.042g

% age mass = $\frac{0.042 \times 100}{1.0}$ = 4.2%

22. By stating the reagents, conditions, observations and relevant equations, describe briefly how the following conversions can be made.
    a) Zinc into zinc carbonate. **4 marks**
    b) Propan-1-ol into ethyl propanoate. **4 marks**
    c) Methylbenzene  into phenylmethanol  1 mark
    d) Hydrochloric acid into sodium chlorate (I) (NaOCl). **3 marks**

Answer:

a) $Zn(s) + HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

Observation: Bubbles of a gas/ effervescence with a ''pop sound''.

$ZnCl_2(aq) + Na_2CO_3(aq) \longrightarrow ZnCO_3(s) + 2NaCl(aq)$

Observation: White precipitate

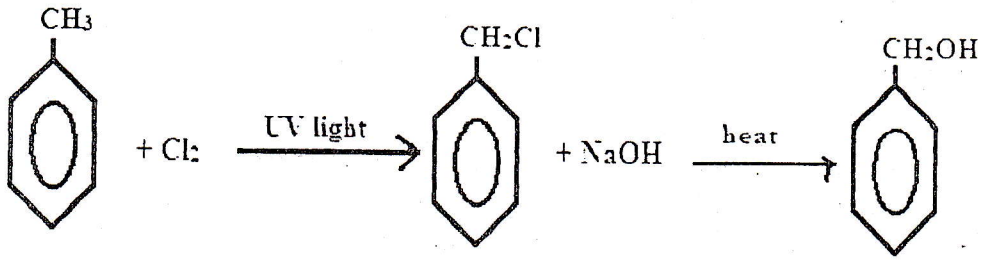
b) $CH_3CH_2CH_2OH \xrightarrow[\text{heat}]{Cr_2O_7^{-2}/H^+} CH_3CH_2COOH$

Observation: The orange solution of potassium dichromate turns green.

$$CH_3CH_2COOH + CH_3CH_2OH \overset{H^+}{\rightleftharpoons} CH_3CH_2C(=O)OCH_2CH_3 + H_2O$$

Observation: Fruity smell of an ester.

c)



d) $4HCl(aq) + MnO_2(s \xrightarrow{heat} Cl_2(g) + 2H_2O(l) + MnCl_2(aq)$

Observation: Greenish yellow gas with chocking smell that bleaches litmus paper.

$Cl_2(g) + 2NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l) + NaOCl(aq)$

ADVENCED LEVEL CHEMISTRY NATIONAL EXAMINATION PAPER 2008

(Math-Physics)

Questions and their answers which are not in here, check from 2008-Biology chemistry questions and answers because they are the same.

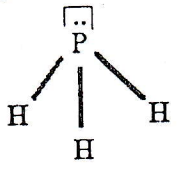
Section A : Answer all questions. (55 marks)

13. Explain the following observations briefly, using the valence shell electron pair repulsion theory :
    a) the shape of PH_3 is pyramidal while that of H_2S is bent. 3 marks
    b) When H_2O is converted into H_3O^+ the bond angle also changes. 2 marks

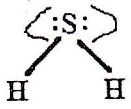
    (Atomic Numbers : P: 15, S : 16, O:8, H : 1)

    Answer:

    a) **PH_3 has one lone pair of electrons on p which does not exert greater repulsion force between three hydrogen bond electrons equally and hence a pyramidal shape.**



H_2S has a bent shape due to two lone pairs of electrons on sulphur atom which exerts the greater repulsion force between two bond pair electrons making V-shape.



    b) **The bond angle decreases from H_2O to H_3O^+**
    Water has two lone pairs of electrons while H_3O^+ has one lone pair of electrons and the more the lone pairs of electrons the greater the repulsion hence smaller bond angle. Therefore H_2O will have smaller bond angle than H_3O^+.

Section B: Choose three questions from this section. (30 marks)

17. Briefly account for the trends shown below:
    a) the volatility of Group VII elements decreases down the group. 2 marks
    b) the acid strength of hydrogen halides increases down the group. 2 marks
    c) a solution of aluminium chloride is acidic but that of sodium chloride is neutral.3 marks
    d) propan- 1-ol is miscible with water but propane does not dissolve in water. 3 marks

    Answer:

    a) **Group VII elements exist as non-polar diatomic molecules held together by weak Van Der Waal's forces.**
    As you move down the group, the size of the atoms increase hence increase in the magnitude of Van Der Waal's forces holding them. This lowers the volatility down the group.

b) The acid strength of hydrogen halides depends on the ease to release a proton which depends on the bond strength. The bond strength decreases from HF to HI due to decrease in electronegativity from F to I, hence increase in the ease of release of a proton.

c) Aluminium (III) Chloride is hydrolyzed by water. The Al^{3+} has small size with big charge hence high polarizing power. Al^{3+} hence has high attraction for oxygen atom in water molecules. This weakens the O-H bond hence releasing hydrogen ions in solution.

$AlCl_3 \rightarrow Al^{3+} + 3Cl^-$

$Al^{3+}(aq) + 6H_2O(l) \rightleftarrows [Al(H_2O)_6]^{3+}(aq)$

$[Al(H_2O)_6]^{3+}(aq) \rightleftarrows [Al(H_2O)_3OH]^{3+}(aq) + 3H^-(aq)$

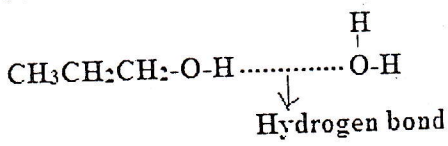
The acidity is due to the release of H^+ in solution.

NaCl dissolves is water to form a neutral solution.

$NaCl \xrightarrow{aq} Na^+ + Cl^-$

The Na^+ has a small size and cannot polarize water and hence no release of H^+ ions therefore the solution remains neutral.

d) In propan-1-ol is miscible with water because it is polar and forms hydrogen bonds with water molecules.



In propane $CH_3CH_2CH_3$, the bonds are non-polar, thus cannot dissolve in a polar solvent such as water.

19. a) Briefly outline the chemical reactions which occur during the extractionof its ore (Fe_2O_3). 3 marks

b) What is an alloy? Give one example of an alloy of iron and state its use. 3 marks

c) One of the characteristics of transition metals is their ability to form complex ions. Explain the following observations in terms of the complex ions which are formed.

i) When excess ammonia solution is added to $Cu^{2+}(aq)$, a dark blue solution is observed. 2 marks

ii) Addition of NaOH(aq) to $Cr^{3+}(aq)$ gives a grey green precipitate which dissolves in excess reagent to give a green solution. 2 marks

Answer:

a) Haematite, limestone and coke are added from the top of blast furnace, hot air is fed from the bottom. The energy and reducing agent are obtained by combustion of coke.

$C(s) + O_2(g) \longrightarrow CO_2(g)$

$CO_2(g) + C(s) \longrightarrow CO(g)$

CO reduces haematite to spongy iron.

$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe + 3CO_2(g)$

Limestone then decomposes to calcium oxide which reacts with sandy impurities.

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

$CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(s)$

The molten slag and iron trickle down the blast furnace and the slag slots on top of molten iron preventing oxidation of Iron by hot air.

b). An alloy is a combination of two or more elements of which at least one is a metal.
- Steel is an example of an alloy of iron.
- Steel is used for making sheets and wires
- Steel is used in building and general engineering.

c) i) A dark blue solution is due to the formation of tetra amino copper (II) ion.

$Cu^{2+}(aq) + 4NH_3(aq) \rightarrow [Cu(NH_3)_4]^{2+}(aq)$

Dark blue solution

ii) $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ – grey-green precipitate

$Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_4]^-$

Green solution

20. a) How does a sigma bond differ from a Pi bond?

b) State the number of sigma and Pi bonds which are present in the molecules below:

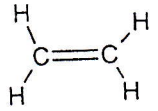
i) C_2H_6

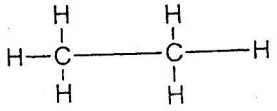
ii) C_2H_2

iii) C_2H_4 **3 marks**

c) Hybridization of atomic orbital of the carbon atom may be used to explain shapes of molecules containing carbon. The carbon atom can show three types of hybridization: sp^3, sp^2 and sp. State the type of hybridization shown by carbon in the following molecules:

i) H—C≡C—H

ii) 

iii) 

d) i) How does a dative covalent bond differ from the usual covalent bond? **1 mark**

ii) Draw a structure of the following species to show the types of bonds present:

Al_2Cl_6 **1 mark**

Answer:

a) **Differences between sigma and pi bonds**

Sigma bond	Pi-bond
It is the end to end overlapping of atomic orbitals	It is formed by sidewise overlapping of atomic orbitals
Stronger	Weaker
It is formed alone	It exists in association with sigma bond.
S and P atomic orbitals participate in bonding	Only P atomic orbitals participate in bonding

b) **i) 7 sigma bonds and no pi bonds**

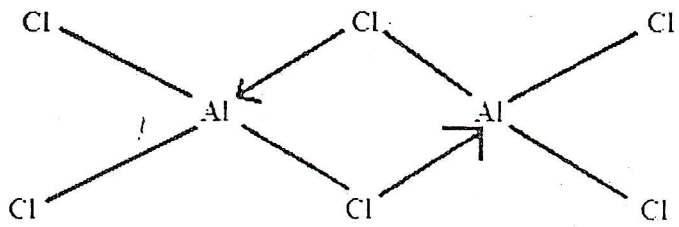
ii) 3 sigma bonds and 2 pi bonds

iii) 5 sigma bonds and 1 pi bond

c) **i) sp**

ii) sp^2
iii) sp^3

d) i) A dative bond is formed when the shared electrons comes from only one atom while in the usual covalent bond the shared electrons come from both atoms.
ii)



Section C: Answer one question from this section. (15 marks)

21. In each of the following investigations you are required to identify the respective ions or compounds explaining clearly how you arrive at your answer.

a) A colourless solution containing three cations was divided into three portions. To one portion, sodium hydroxide was added dropwise, followed by excess reagent. A white precipitate was formed which later dissolved in excess reagent to form a colourless solution. To the second portion, aqueous ammonia was added dropwise, followed by excess reagent. A white precipitate was observed but part of the precipitate dissolved in excess ammonia. To the third portion, aqueous potassium iodide was added. A yellow precipitate was observed.
i) Suggest the possible identities of the three cations, explaining your reasoning. **3 marks**
ii) What is the yellow precipitate? **1 mark**
iii) Write an equation for the formation of the yellow precipitate. **1 mark**

b) A organic compound A of molecular formula $C_5H_{10}O_2$ was boiled with aqueous NaOH. The mixture was distilled to give a distillate of compound B of molecular formula C_2H_6O. The solution remaining in the distillation flask was acidified with hydrochloric acid to give compound C of molecular formula $C_3H_6O_2$. Compound B reacted with PCl_5 to give off fumes of HCl. When an aqueous solution of compound C was mixed with sodium carbonate, bubbles of a colourless gas were observed.
i) Identify the organic compounds A, B and C by writing their structural formulae. **4 marks**
ii) Write an equation for the reaction of compound B with PCl_5. **1 mark**

c) A green solid X was dissolved in water and the solution divided into two portions. One portion was mixed with aqueous NaOH and gave a green precipitate which turned brown after about one hour's exposure to air. A second portion was mixed with hydrochloric acid and warmed. It gave off gas Y which turned acidified dichromate (VI) solution from orange to green.
i) Identify gas Y. **1 mark**
ii) Identify one cation and one anion in solid X. **2 marks**
iii) Identify the green precipitate and the brown solid which were formed. **2 marks**

Answer:

a) i) For white precipitate soluble in excess ammonia. The soluble cation is Zn^{2+} confirmed.
Insoluble cations are: Pb^{2+}, Al^{3+} (Sn^{2+} or Sn^{4+} suspected)
On addition of KI, a yellow precipitate is observed, Pb^{2+} confirmed.
The three cations are Zn^{2+}, Pb^{2+}, Al^{3+}(Sn^{2+} or Sn^{4+} suspected).
ii) $Pb^{2+}+2I^{-}(aq) \rightarrow PbI_2(s)$, yellow precipitate
iii) $PbI_2(s)$

b)
i)

A is $CH_3CH_2\overset{O}{\overset{//}{C}}-OCH_2CH_3$

B is CH_3CH_2OH

C is $CH_3CH_2\overset{O}{\overset{//}{C}}-OH$

ii) $CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2Cl + HCl + POCl_3$

c) i) Gas y is SO_2
ii) Cation is Fe^{2+} and anion SO_3^{2-}
iii) Green precipitate is $Fe(OH)_2$
Brown precipitate is $Fe(OH)_3$.
$Fe(OH)_2+O_2+2H_2O \rightarrow 4Fe(OH)_3(s)$

ADVENCED LEVEL CHEMISTRY NATIONAL EXAMINATION PAPER 2009

SECTION A: Attempt all questions. (70 marks)

01. An element X represented as $^{232}_{90}X$ emits two alpha-particles and three beta-particles to form element Y.
a) Calculate the number of neutrons in the nucleus of X. **1 mark**
b) Write the mass number and atomic number of Y. **2 marks**
c) Assuming that the half-life of element X is 400 years, how long does it take 50 g of X to change to 3,125g? **2 marks**

Answer:
a) **Neutrons in X are 232 – 90 = 142**
b) **Mass number of Y is 224**
Atomic number of Y is 89
c) **Simple method:**
$50g \xrightarrow{400\ years} 25g \xrightarrow{400\ years} 12.5g \xrightarrow{400\ years} 6.25g \xrightarrow{400\ years} 3.125g$
t = 4 x 400years = 1600years

02. Explain the following trends in atomic or ionic size:
a) The size of Mg^{2+} is less than that of Mg. **2 marks**
b) The size of O^{2-} is larger than that of O. **2 marks**

Answer:
a) **The electronic configuration of Mg is $1s^22s^22p^63s^2$ whereas that of Mg^{2+} is $1s^22s^22p^6$. Mg loses two electrons to form Mg^{2+} resulting into an increase in**

effective nuclear charge and a decrease in shielding effect thus the valence electrons in Mg^{2+} are strongly attracted resulting into a smaller size for Mg^{2+} than Mg.

b) The electronic configuration of O is $1s^2 2s^2 2p^4$ whereas that of $1s^2 2s^2 2p^6$. O gains two electrons to form O^{2-} resulting into a decrease in effective nuclear charge thus valence electrons in O^{2-} are weakly attracted resulting into a larger size of O^{2-} than O.

03. The atomic number of manganese (Mn) is 25.

a) Write the electronic configuration of Mn, using the s, p, ...notation **1 mark**

b) In terms of electronic structure, explain which of the ions Mn^{2-} or Mn^{3-} is more stable. **2 marks**

c) State one property of Mn which is typical of transition elements. **1 mark**

Answer:

a) Mn = 25: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$ or $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

b) The electronic configuration of Mn^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$. While that of Mn^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$. The 3d sub-energy level in Mn^{2+} is half-filled, thus thermodynamically stable whereas in Mn^{3+}, the 3d sub-energy is neither half-filled nor fully-filled hence less stable.

c) - Partially filled d sub-energy level
- Variable oxidation states

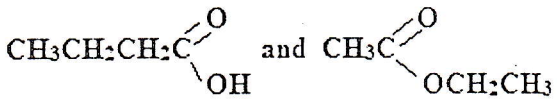
04. An organic compound has a molecular formula of $C_4H_8O_2$.

a) Give the structural formulae of its two people isomers with different functional groups. **2 marks**

b) What chemical test would you use to distinguish between the two isomers? Describe the expected observations. **2 marks**

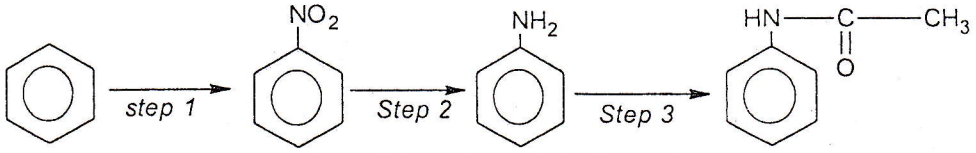
Answer:

a)



b) **By adding sodium carbonate or Sodium hydrogen carbonate solution.**
Observations:
For $CH_3CH_2CH_2COOH$, a colourless gas which turns lime water milky, is observed.
$CH_3COOCH_2CH_3$ - No observable change.

05. A reaction scheme is shown below:

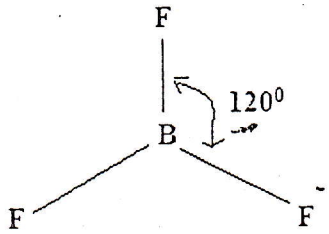


a) State the reagents and conditions for step 1. **2 marks**

b) What type of reaction is involved in step 2? **1 mark**

c) Give the structural formula of the reagent used in step 3. **1 mark**

Answer:



b) **The bond angle increases when H_2O forms H_3O^+. H_2O has a v-shape and there are two lone pairs of electrons on oxygen atom which strongly repel with the two bonding electrons decreasing the bond angle whereas in H_3O^+ has a trigonal pyramidal shape with only one lone pair of electrons on the oxygen atom which weakly repel the three bonding electrons hence increasing the bonding angle.**

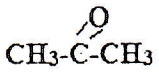
09. Some organic reactions are shown in the diagram below:

$$CH_3CH{=}CH_2 \xrightarrow[\text{Step 1}]{} CH_3CHBrCH_3 \xrightarrow[\text{Step 2}]{} CH_3CH(OH)CH_3 \xrightarrow[\text{Heat}]{K_2Cr_2O_7/H^+} X$$

a) State the name or formula of the reagent used in step 1. **1 mark**
b) What type of reaction is involved in step 2? **1 mark**
c) Give the structural formula of the compound x. **1 mark**

Answer:

a) **Hydrobromic acid (HBr)**
b) **Nucleophilic substitution reaction or SN_1**
c)



10. a) What is meant by the standard enthalpy change of combustion? **2 marks**
b) Given that the standard enthalpy change of combustion of butane is $-2877 kJmol^{-1}$, calculate the amount of heat produced by burning 5g of butane (C=12, H=1). **2 marks**

Answer:

a) **This is the enthalpy change that occurs when one mole of a compound is completely burnt in oxygen under standard conditions (temperature of 298°K and 1 atm pressure)**
b) **Molar mass of butane = 4 x 12 + 10 = 58g/mol**

$$\text{Moles} = \frac{mass}{Molar\ mass} = \frac{5}{58}$$

1 mole of butane produces -2877kJ

$\frac{5}{58}$ **moles of butane will produce** $\left(\frac{-2877 \times 5}{58}\right)$ **= -248.01 kJ/mol**

11. A complex ion has the formula $[Co(NH_3)_4Cl_2]^-$.

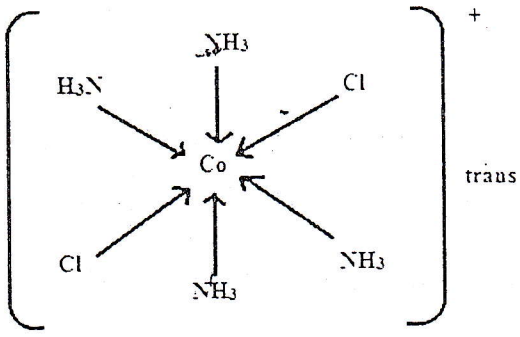
a) Calculate the oxidation number of Co in the complex ion. **1mark**
b) The complex ion exists as two isomers. Draw the shapes of two isomers. **2 marks**
c) Given that the atomic number of Co= 27, write the full electronic configuration of Co. **1 mark**

Answer:

a) **Let the oxidation number of Co be y:**
y + (4x0) + (2x-1) = 1

y = +3

b)



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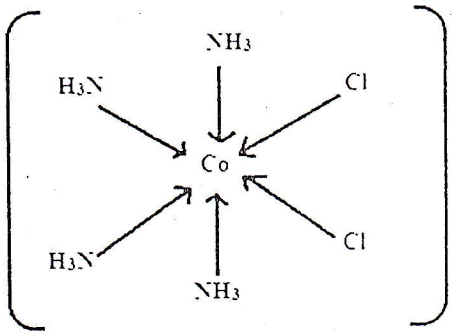
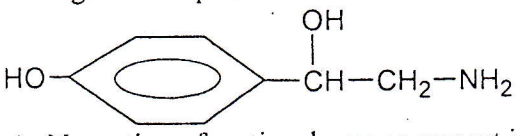


Cis

c) Co is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$

12. An organic compound has the structure.



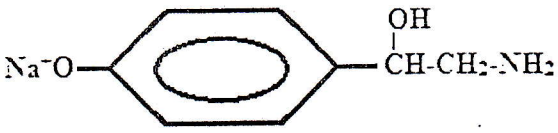
a) Name three functional groups present in the compound. **3 marks**

b) Write the structural formula of the organic product when the above compound reacts with sodium hydroxide. **1 mark**

Answer:

a) **– Phenol group**
- Alcohols
- Amino group

b)



13. a) What is meant by the term "first ionisation energy"? **2 marks**

b) Why is the third ionisation energy of Mg much higher than the second ionisation energy? (Atomic Number of Mg =12). **2 marks**

Answer:

a) **First ionization energy is the minimum enthalpy change required to remove the outermost electron from a gaseous atom to form one of a positive charged gaseous ion with unit charge.**
$X(g) \rightarrow X(g) + e^-$

b) **For third ionization energy of magnesium, an electron is removed from Mg^{2+}, $1s^2 2s^2 2p^6$ which has a higher effective nuclear charge hence stronger attraction of outermost electron resulting into very high third ionization energy.**
$Mg^{2+}(g) \rightarrow Mg^{3+} + e^-$
For second ionization energy, an electron is removed from Mg^+, $1s^2 2s^2 2p^6 3s^1$ with higher screening effect and less effective nuclear charge, hence low second ionization energy. $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$

14. Explain the following observations in terms of bonding:
    a). $SiCl_4$ is a volatile liquid at room temperature whereas SiO_2 is a solid with a high melting point. **2 marks**
    b) Diamond is a poor conductor of electricity. **1 mark**

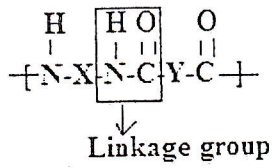
    Answer:
    a) **SiO_2 forms a giant covalent structure held by strong covalent bond hence a solid while $SiCl_4$ forms a simple covalent structure held by weak intermolecular bonds hence a volatile liquid.**
    b) **All electrons in diamond are bonded and thus it has no delocalized electrons which are mobile to conduct electricity.**

15. a) With the help of an equation, explain the meaning of the term "lattice energy" of sodium bromide. **2 marks**
    b) Explain why the lattice energy of sodium bromide is more exothermic than that of potassium bromide. **2 marks**

    Answer:
    a) **Lattice energy is the enthalpy change when one mole of crystal lattice energy is formed from its constituent gaseous ions.**
    $Na^+(g) + Br^-(g) \rightarrow NaBr(s)$
    Or Lattice energy is the enthalpy change when one mole of a solid crystal lattice is broken into its constituent gaseous ions.
    $NaBr(s) \rightarrow Na^+(g) + Br^-(g)$
    b) **Na^+ has a smaller ionic radius compared to K^+. This resulting into stronger electrostatic attraction between Na^+ and Br^- hence lattice energy for NaBr is more exothermic. Since K^+ has a big ionic radius, there is weak electrostatic attraction between K^+ and Br^- hence low lattice energy for KBr.**

16. Nylon is a condensation polymer. It is formed from two monomers represented as NH_2-X-NH_2 and HOOC-Y-COOH.
    a) What is a condensation polymer? **1 mark**
    b) Draw a structure to represent the repeat unit of the nylon polymer from two monomers. Draw a ring around the linkage group. **2 marks**
    c) What name is given to the linkage group in nylon polymer? **1 mark**

    Answer:
    a) **A condensation polymer is a polymer formed from the combination of two or more monomers with different functional groups followed by loss of small molecules such as water.**
    b)



    c) **Amide group**

17. a) Write a balanced equation to show the thermal decomposition of magnesium nitrate. **2 marks**
    b) In terms of products formed, how is the thermal decomposition of sodium nitrate

different from that of magnesium nitrate. **1 mark**

c) Why are nitrates often used as fertilizers? **1 mark**

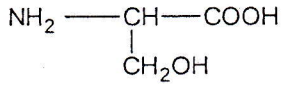
Answer:

a) $2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$

b) $2NaNO_3(s) \rightarrow 2NaNO_2(s) + O_2(g)$

c) **Nitrates contain nitrogen with is one of the main nutrients required by plants.**

18. The amino acid "serine" has the structure :



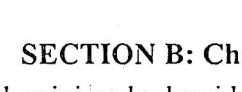
a) Show the structure of the zwitterion of the above amino acid. **1 mark**

b) What name is given to the polymers formed by amino acids? **1 mark**

c) Show the structure formed when the above amino acid is dissolved an acidic solution. **1 mark**

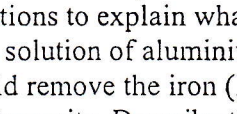
Answer:

a)



b) **Condensation polymers**

c)



SECTION B: Choose three questions from this section. (30 marks)

19. a) Aluminium hydroxide is described as "amphoteric". Use two relevant balanced equations to explain what is meant by the term "amphoteric". **3 marks**

b) A solution of aluminium ions was contaminated with iron (III) ions Outline how you would remove the iron (III) ions to leave a solution containing aluminium ions free from this impurity. Describe the expected observations at each stage. **4 marks**

c) Explain why the melting point of Al is higher than that of Mg. (Atomic Numbers of Al and Mg are 13 and 12 respectively). **3 marks**

Answer:

a) **An amphoteric compound is substance which has both acidic and basic properties. E.g:**

$Al(OH)_3(aq) + OH^-(aq) \rightleftarrows Al(OH)_4^-(aq)$

$Al(OH)_3(aq) + 3H^+(aq) \longrightarrow Al^{3+}(aq) + 3H_2O(l)$

b) **By addition of excess sodium hydroxide solution: a brown precipitate of Iron (II) hydroxide and a colourless solution of the aluminate complex will be formed. The mixture is then liberated and the brown precipitate removed as a residue.**

c) **Aluminium and magnesium are both metals thus they form metallic bonds. However aluminium atom contributes 3 electrons in the metallic bond while magnesium atom contributes 2 electrons. Therefore aluminium forms a stronger metallic bond hence higher boiling point than magnesium.**

20. a) Compound A undergoes the following reactions:

$$A \xrightarrow[\text{I}]{\text{Bromine}} CH_3CHBrCHBrCH_3 \xrightarrow[\text{II}]{} CH_3CH(OH)CH(OH)CH_3$$

i. Suggest the structural formula of A. **1mark**
ii. What type of reaction is step 1?
iii. Suggest the reagents and conditions necessary to carry it out. Step II **3 marks**

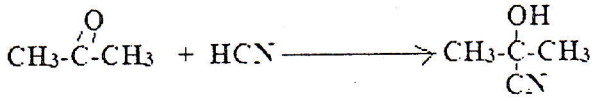
b) Using suitable examples, choose one reaction to illustrate each mechanism below:
i. Nucleophilic addition,
ii. Electrophilic addition.

For each reaction, give the full mechanism. **6 marks**

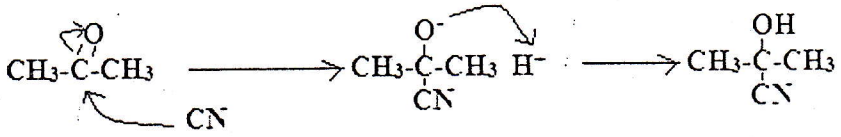
Answer:

a) **i) $CH_3CH{=}CHCH_3$**
ii) Electrophilic addition
iii) Sodium hydroxide and heat

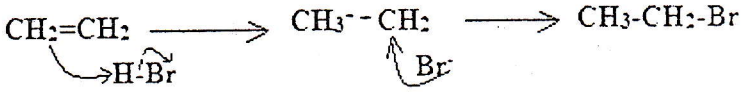
b) **i) Nucleophilic addition reaction. Occurs in aldehydes and ketones to give a single product.**



Mechanism:
$HCN \rightarrow H^+ + CN^-$



ii) Electrophilic addition reaction occurs in alkenes and alkynes to form single (saturated products).
$CH_2{=}CH_2 + HBr \longrightarrow CH_3CH_2Br$
Mechanism:



21. This question concerns the chemistry of Group VII elements.

a) Describe and explain the trend in the volatility of halogens down the group from chlorine to iodine. **2 marks**

b) Describe what is observed when aqueous silver nitrate is added to
i. Cl^- ions
ii. I^- ions
Write ionic equations for the reactions which occur. **4 marks**

c) How does the oxidising power of halogens change down the group? Predict which of the reactions below is likely to occur and give its products.
$Br_2 + KCl \rightarrow$
$Cl_2 + KBr \rightarrow$
$Br_2 + KI \rightarrow$ **4 marks**

Answer:

a) **Trend: Volatility of Group VII elements (halogens)**

Reason: Down the group the sizes of molecules increase hence increase in Van Der Waal's forces holding the molecules, hence decrease in volatility.

b) i) White precipitate of silver chloride

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

ii) Yellow precipitate of silver iodide

$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$

c) The oxidizing power of halogens decreases down the group because electronegativity decreases down the group.

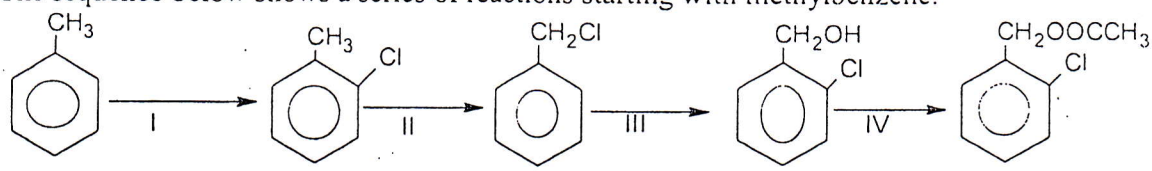
$Br_2 + KCl \rightarrow$ No reaction

$Cl_2 + 2KBr \rightarrow Br_2 + 2KCl$

$Br_2 + 2KI \rightarrow KBr + I_2$

22. a) What reagents and conditions are used to convert benzene into methylbenzene? **2 marks**

b) The sequence below shows a series of reactions starting with methylbenzene:



For each of the reaction steps I to IV, give the reagents and conditions. **8 marks**

Answer:

a) **CH_3Cl in the presence of $FeCl_3$ or $AlCl_3$**
Or CH_3Br in the presence of $FeBr_3$ or $AlBr_3$.

b) **Step I reagent is Cl_2 in the presence of $FeCl_3$ (or $AlCl_3$ or Fe or $FeCl_3$) at room temperature.**
Step II reagent is Cl_2 in the presence of U.V light (or sun light)
Step III reagent is NaOH in presence of heat.
Step IV reagent is CH_3COOH in the presence of an acid catalyst (sulphuric acid) and heat.

23. a) By means of balanced equations, outline the steps involved in manufacture of sulphuric acid from sulphur in the Contact process. **4 marks**

b) Briefly explain how the manufacture of sulphuric acid may affect environment. **2 marks**

c) How would you distinguish by chemical tests between magnesium sulphate and magnesium sulphite? Describe the expected observations. **2 marks**

d) Using "dot and cross" diagrams, show the type of bonding present in sodium sulphide. Show electrons in the outer shell only. (Atomic numbers of Na and S are 11 and 16 respectively). **2 marks**

Answer:

a) **Sulphur is burnt into oxygen to produce sulphur trioxide.**

$S(s) + O_2(g) \rightarrow SO_2(g)$

Sulphur dioxide is then burnt into oxygen to produce SO_3 in presence of V_2O_5 catalyst.

$SO_2(g) + \frac{1}{2} O_2(g) \rightarrow SO_3(g)$

Sulphur trioxide is the reacted with concentrated sulphuric acid to produce

oleum.

$SO_3(g) + H_2SO_4(aq) \longrightarrow H_2S_2O_7(l)$

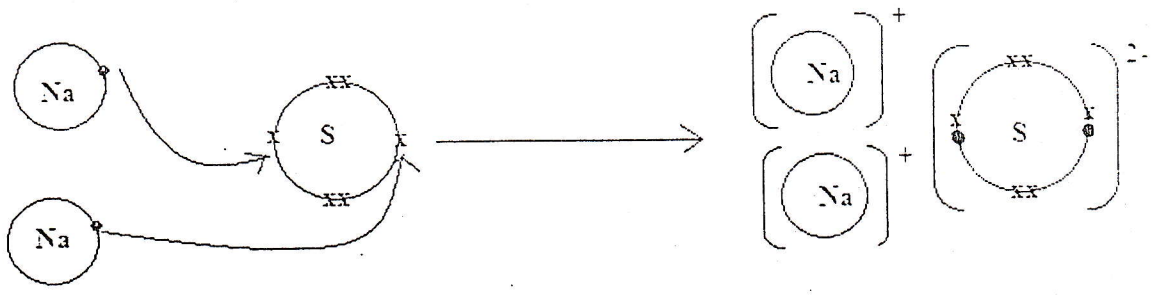
Oleum is then dissolved in water to give sulphuric acid.

$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(aq)$

b) Manufacture of sulphuric acid produces greenhouse gases such as sulphur dioxide which can destroy the ozone layer leading to global warming hence greenhouse effect.

c) By using barium nitrate and nitric acid (or barium chloride and hydrochloric acid). For magnesium sulphate a white precipitate insoluble in the acid is observed. Magnesium sulphite, white precipitate soluble in the acid.

d)



ADVENCED LEVEL CHEMISTRY NATIONAL EXAMINATION PAPER 2010

SECTION A: Attempt all questions. (70 marks)

01. The electronic configuration of manganese (Mn) is: $1s^22s^22p^63s^23p^63d^54s^2$.

a) What is the maximum oxidation state of manganese? **1 mark**

b) Explain how the electronic configuration shows that Mn is a transition element. **1 mark**

c) Briefly explain why Mn^{2+} is more stable than Mn^{3+}. **2 marks**

Answer:

a) +7

b) It has partially filled d-sub-energy level.

c) The electronic configuration

Mn^{2+}: $1s^22s^22p^63s^23p^63d^5$

Mn^{3+}: $1s^22s^22p^63s^23p^63d^4$

The 3d sub-energy level in Mn^{2+} is half-filled thus thermodynamically more stable where as in Mn^{3+} the 3d sub-energy level is neither half-filled nor fully-filled hence less stable.

02. An organic compound A of molecular formula $C_4H_{10}O$ was oxidized by heating it with acidified potassium dichromate to produce compound B of molecular formula C_4H_8O. B could not undergo further oxidation. When A was heated with concentrated H_2SO_4, it produced two isomeric compounds C and D of molecular formula C_4H_8.

a) Give the structural formula of compound A. **1 mark**

b) Give the name or the structural of functional group in B. **1 mark**

c) Give the names of the two. organic compounds C and D. **2 marks**

Answer:

a)

CH_3-CH_2-CH(OH)-CH_3

b) – C=O or ketone

c) **1-butene and 2- butane**

Or but-1-ene and but-2-ene

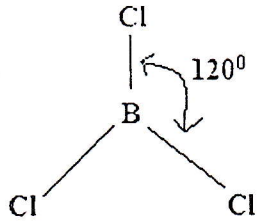
03. a) Name the shape of BCl_3 and give its bond angle (atomic number of B=5). **2 marks**

b) Explain why a molecule of BCl_3 is able to form a bond with a molecule of NH_3 and name the type of bond formed. (Atomic number of N=7) **2 marks**

c) Write a balanced equation for the reaction of $SiCl_4$ and water. **2 marks**

Answer:

a)



b) **BCl_3 is able to form a bond with NH_3 because the lone pair of electrons on NH_3 is donated into vacant orbital of BCl_3. The type of bond formed is coordinate bond or dative covalent bond.**

c) **$SiCl_4(l) + 2H_2O\ (l) \longrightarrow SiO_2(s) + 4HCl(aq)$**

04. a) Give a mathematical definition of pH. **1 mark**

b) Calculate the pH of 0.1mol dm^{-3} ethanoic acid (CH_3COOH) given that its Ka=1.8x10^{-5} mol dm^{-3}. **3 marks**

Answer:

a) **$P^H = -\log[OH^-]$**

b) **$CH_3COOH(aq) \rightleftarrows CH_3COO^-(aq) + H^+(aq)$**

c) **$Kc = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]} =$**

At equilibrium $[CH_3COO^-] \simeq [H^+]$

$1.8 \times 10^{-5} = \frac{[H^+]^2}{[CH_3COOH]} \Rightarrow 1.8 \times 10^{-5} = \frac{[H^+]^2}{0.1} \Rightarrow [H^+]^2 = 1.8 \times 10^{-6}$

$[H^+] = \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3}$ mol dm^{-3}

$P^H = -\log[H^+] = -\log(1.34 \times 10^{-3}) = 2.872$

05. The standard enthalpy change of combustion of phenol, $C_6H_5OH(s)$ is-3050KJmol^{-1}at 298K.

a) Write a balanced equation to show the complete combustion of phenol. **2 marks**

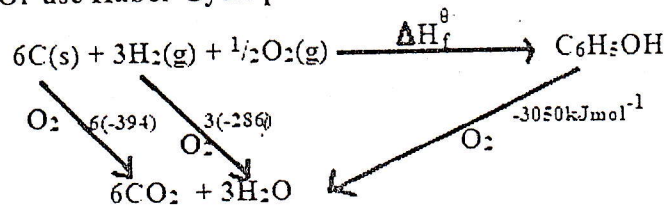
b) Given that the standard enthalpy changes of formation of carbon dioxide, $CO_2(g)$ and water, $H_2O(l)$ are -394KJmol^{-1} and -286KJmol^{-1} respectively, calculate the standard enthalpy change of formation of phenol $C_6H_5OH(s)$. **3 marks**

Answer:

a) **$C_5H_4OH(s) + 7O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$**

b) **$C(s) + O_2(g) \rightarrow CO_2(g)$ -394 KJ mol^{-1}.....i**

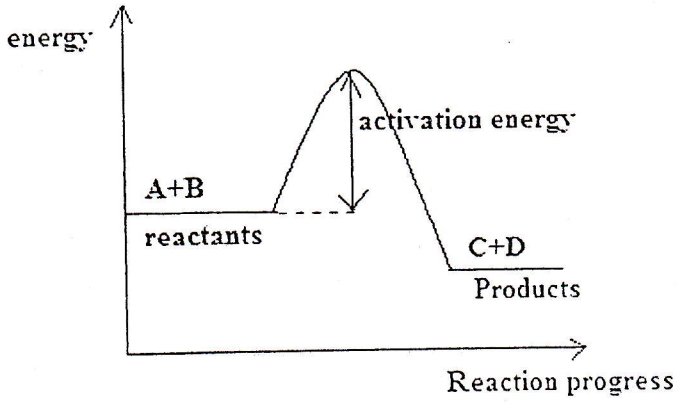
$H_2(g) + ½ O_2(g) \rightarrow H_2O$ -286 KJ mol^{-1} ii
$C_6H_5OH(l) + 7O_2(g) \rightarrow 6CO_2(g) + 3H_2O(l)$ ...iii
$6C(s) + 3H_2(g) + ½ O_2(l) \rightarrow C_6H_5OH(l)$ iv
From data above eq.(iv) = 6(i) + 3(ii) – iii
$\Delta H = 6(-394) + 3(-286) - (-3050)$
$\Delta H = -3222 + 3050 = -172$ KJ mol^{-1}
Or use Haber Cycle process:



$\Delta H_f^\theta - 3050 = 6(-394) + 3(-286)$
$\Delta H_f^\theta = -172$ KJ mol^{-1}

06. The equation below represents an exothermic reaction which is reversible.
$A + B \rightleftarrows C + D$ $\Delta H = -x$ $KJmol^{-1}$.
a) How would an increase in temperature affect the amount of C and D in the equilibrium mixture? Give a reason for your answer. **2 marks**
b) Draw a labeled diagram for the energy profile for this reaction showing: the reactants, products, activation energy and ΔH. **3 marks**

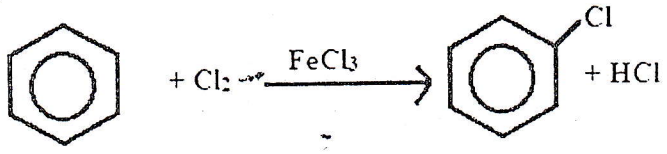
Answer:
a) **Amount of C and D would decrease. This is because the reaction is exothermic hence increase in temperature favours the backwards reaction.**
b) **A labeled diagram showing the energy profile diagram for the given reaction (exothermic)**



07. Benzene undergoes a reaction with chlorine in the presence of iron (III) chloride.
a) Write an equation for the reaction. **2 marks**
b) What is the role of iron (III) chloride? **1 mark**
c) Give the mechanism for the reaction of benzene with chlorine in the presence of $FeCl_3$. **3 marks**

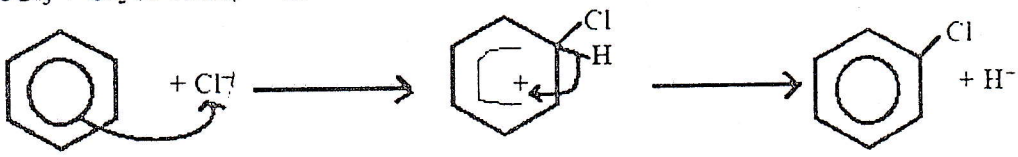
Answer:

a)



b) Catalyst or halogen carrier

c) $FeCl_3 + Cl_2 \rightleftarrows FeCl_4^- + Cl^+$



$H^+ + FeCl_4^- \longrightarrow HCl + FeCl_3$

08. a) State two factors which affect lattice energy. **2 marks**

b) Briefly explain which of the two compounds KBr and NaF has a greater lattice energy. **2 marks**

Answer:

a) **- Ionic radius**

- Charge on the ion

b) **NaF has a greater lattice energy than KBr. This is because of ionic radius of Na^+ and F^- are small than K^+ and Br^- respectively.**

Due to the smaller ionic sizes of Na^+ and F^-, it results into stronger electrostatic force of attraction between Na^+ and F^- resulting into stronger bond hence higher lattice energy for NaF than KBr.

09. Dinitrogen tetroxide, $N_2O_4(g)$, decomposes according to the equation

$N_2O_4\ (g) \rightleftarrows 2NO_2\ (g)$.

a) Write an expression for the equilibrium constant, Kc, for the above reaction. **1 mark**

b) Explain the effect on the composition of the equilibrium mixture when the pressure doubled. **2 marks**

Answer:

a) $Kc = \frac{[NO_2]^2}{[N_2O_4]}$

b) **From boyles law and Avogadro's law, increase in pressure favours side with less number of moles therefore if the pressure is doubled, the backwards reaction will favoured. NO_2 will decompose into N_2O_4.**

10. a) Explain what is meant by the term 'base' according to the Bronsted-Lowry theory of acids and bases. **1 mark**

b) Identify the acid-base conjugate pair in the reaction:

$CH3COO^- + H_20 \rightleftarrows 1\ CH_3COOH + OH^-$ **2 marks**

Answer:

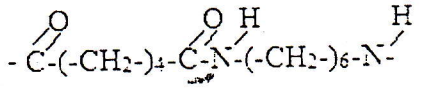
a) **According to Bronsted-Lowry theory, a base is a proton acceptor.**

b) **Acid- base conjugate pair is**

$\left.\begin{matrix} H_2O \\ OH^- \end{matrix}\right\}$

Or CH_3COOH/ CH_3COO^-: acid-base conjugate pair.

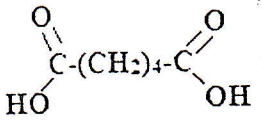
11. Nylon 6,6 has a structure containing the following repeat unit:



a) What type of polymer is this? **1 mark**
b) Give the structural formulae of the monomers of this polymer. **2 marks**
c) What natural polymer has the same linkage group as Nylon 6,6? **1 mark**

Answer:

a) **Condensation polymer or polyamide.**
b)



and $H_2N\text{-}(CH_2)_6\text{-}NH_2$

c) **Proteins**

12. a) What is meant by a "buffer solution"? **1 mark**
b) Calculate the pH of a buffer solution containing 0.10moldm^{-3} propanoic acid (CH_3CH_2COOH) and 0.20 moldm^{-3} sodium propanoate ($CH_3CH_2COO\text{-}Na^+$).
[Ka of $CH_3CH_2COOH = 1.35\times10^{-5}$ mol dm^{-3}].

Answer:

a) **A buffer solution is a solution which is resistant to P^H change when a small amount of acid or base is added.**
b) $P^H = P^{ka} + \log\frac{[salt]}{[acid]}$

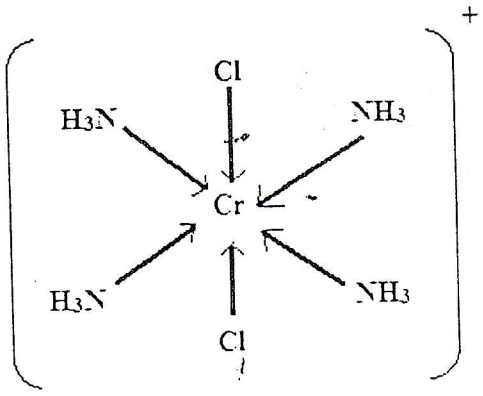
$= -\log(1.35 \times 10^{-5}) + \log\frac{[0.2]}{[0.1]} = 5.17$

13. One of the complex ions formed by chromium is:
$[Cr(NH_3]_4Cl_2]^+$

a) What is the oxidation state/number of Cr in the complex ion? **1 mark**
b) What is the co-ordination number of Cr in the complex ion? **1 mark**
c) State or draw the shape of the above complex ion. **1 mark**

Answer:

a) **Let oxidation state of Cr be x:**
$X+(4x0) + (2x-1) = 1$
$X-2 = 1$
$X = 3$
b) **Coordination number is 6**
c) **Octahedral shape or**



14. Steel is one of the alloys of iron. 1.40g of a sample of steel was dissolved in dilute acid to convert all the iron into Fe^{2+}(aq). The solution was made up to 100 cm^3 using distilled water. 10 cm^3 of this solution were acidified and titrated with 0.0167 mol dm^{-3} potassium dichromate ($K_2Cr_2O_7$) using a suitable indicator. 24.2cm^3 of potassium dichromate were needed to reach the end point. The reduction of dichromate ions is represented by the equation:

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O\ (l)$

a) What is meant by the term "alloy"? **1 mark**
b) Write an equation to show the oxidation of Fe^{2+} to Fe^{3+}. **1 mark**
c) Write the overall balanced equation for the reaction between acidified $Cr_2O_7^{2-}$ and Fe^{2+}. **2 marks**
d) Calculate the number of moles of $Cr_2O_7^{2-}$ in 24.2cm^3 of the dichromate solution. **1 mark**
e) Calculate the number of moles of Fe^{2+} in 100cm^3 of the original solution. **2 marks**
f) Calculate the percentage of iron in the sample of steel (Fe = 56) **2 marks**
g) One way of prevention of rusting is to convert iron into stainless steel.
   i. State two conditions necessary for iron to rust. **2 marks**
   ii. State the name of a transition metal present in stainless steel. **1 mark**
   iii. Describe two other methods of preventing rust. **2 marks**
h) Give the electronic configuration of Fe^{3+} (Atomic number of Fe=26). **1 mark**

Answer:

a) **An alloy is a combination of two or more elements of which at least one is a metal. Or an alloy is a combination of two or more metals.**
b) $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$
c) $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O\ (l) + 6Fe^{3+}(aq)$
d) 1000 cm^3 of solution → 0.0167 moles of $Cr_2O_7^{2-}$

   24.2 cm^3 of solution → $\frac{0.0167 \times 24.2}{1000} = 4.0414 \times 10^{-4}$ moles of $Cr_2O_7^{2-}$
e) From the equation

   1 mole of $Cr_2O_7^{2-}$ reacts with 6 moles of Fe^{2+}

   4.04×10^{-4} moles of $Cr_2O_7^{2-}$ react with $6 \times 4.04 \times 10^{-4} = 2.4284 \times 10^{-3}$ moles of Fe^{2+}

   10 cm^3 of solution → 2.42484×10^{-3} moles of Fe^{2+}

   100cm^3 of solution → $\frac{2.42484 \times 10^{-3} \times 100}{10} = 2.42484 \times 10^{-2}$ moles of Fe^{2+}
f) $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$

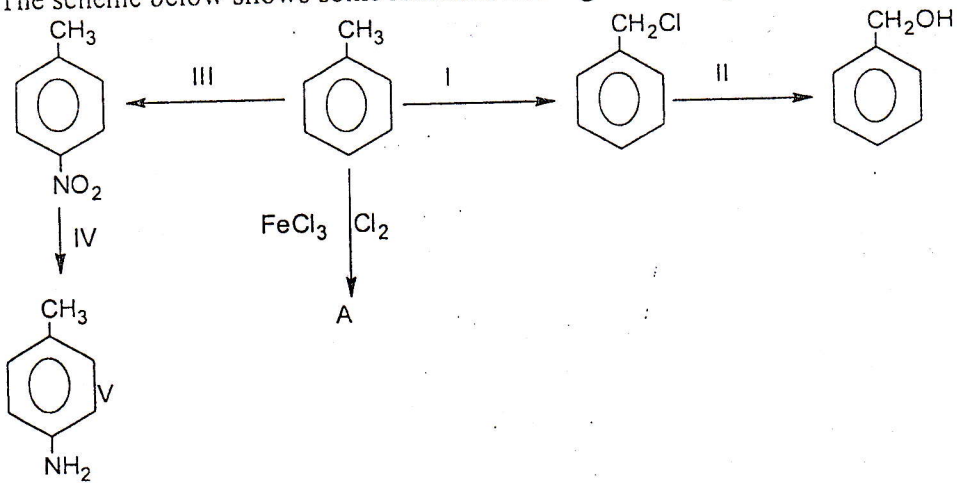
From the equation:
1mole of Fe^{2+} is produced from 1 mole of Fe
2.4284×10^{-2} mole of Fe produced from 2.4284×10^{-2} Fe^{2+}
Mass of Fe = number of moles x atomic mass of Fe = $2.4284 \times 10^{-2} \times 56 = 1.36g$
Percentage purity of Fe = $\frac{Actual\ mass \times 100}{sample\ mass} = \frac{1.36 \times 100}{1.4} = 97.14\%$

g) i) Oxygen
Moisture
ii) Iron
iii) Galvanizing
Tin-plating

h) **The electronic configuration of Fe^{3+} is $1s^2 2s^2 2p^6 3s^2 3p^6\ 3d^5$**

SECTION B: Attempt any three questions. (30 marks)

15. The scheme below shows some reactions starting with methylbenzene.



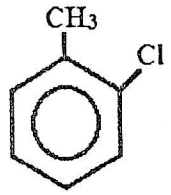
a) Give the reagents and conditions used to carry out reactions in the steps below:
(i) I (ii) II (iii) III **6 marks**
b) What type of reaction is involved in step IV? **1 mark**
c) Give the structural formula of compound A. **1 mark**
d) What is the name of the mechanism involved in
(i) step I ? **1 mark**
(ii) step II? **1 mark**

Answer:

a)

Reagent	Conditions
i. Cl_2 (Chlorine gas)	Sunlight or U.V.
ii. NaOH (sodium hydroxide)	Heat
iii. Conc.HNO_3 in presence of	30^0C and Conc. H_2SO_4

b) **Reduction**
c)



d) **Free radical mechanism**
e) **Nucleophilic substitution bimolecular (SN_2)**

16. This question concerns the chemistry of chlorine and hydrides of Group VII elements of Periodic Table.
    a) Chlorine forms several compounds in which it shows different oxidation states (numbers). Write down the formulae of a chlorine compound in chlorine shows its:
       (i) Lowest oxidation state;
       (ii) Highest oxidation state.
       Show the oxidation state of chlorine in each case. **2 marks**
    b) Chlorine is used to treat water to make it safe for drinking.
       i) Write a balanced (reversible) equation for the reaction of chlorine with water. **2 marks**
       ii) Explain how a lowering of pH affects the position of equilibrium of the reaction in (i). **2 marks**
    c) Briefly explain the following observations concerning the hydides of halogens:
       i) the boiling points increase in the order HCl<HBr<HI **2 marks**
       ii) the acidity of aqueous solutions increase in the order HCl<HBr<HI. **2 marks**

Answer:

a) **i) HCl or (any ionic chloride where Cl has an oxidation state of -1.**
   ii) Cl_2O_7 (dichlorine heptaoxide) or (any perchlorate, ClO_4^-):
   Let oxidation state of Cl be x:
   $2X + 2(-7) = 0$
   $X = +7$
b) **i) $Cl_2(g) + H_2O(l) \rightleftarrows HCl(aq) + HOCl(aq)$**
   ii) Lowering the P^H hinders the forward reaction because the concentration of acid will increase hence equilibrium shifts to the left.
c) **i) The atomic radius of halogens increases in order Cl<Br<I. Thus the molecular size of their corresponding hydrides increase in the order HCl<HBr<HI. The larger the molecular size, the stronger the van Der Waal's forces attraction and hence boiling point increases in the order HCl<HBr<HI.**
   ii) The acid strength of hydrogen halides depends on the ease to release a proton which depends on bond strength.
   The bond strength decreases from HCl to HI due to decrease in electronegativity from Cl to I. Hence increase in the ease of release of a proton.

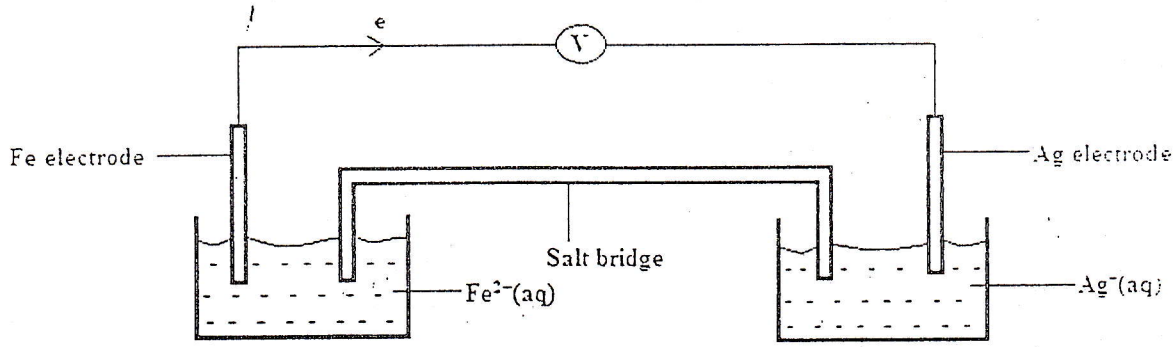
17. Use the data below to answer the questions which follow:
    $Ag^+ + e^- \rightleftarrows Ag \quad E^\theta = +0.80V$
    $Fe^{2+} + 2e^- \rightleftarrows Fe \quad E^\theta = -0.44V$
    a) Draw a labelled diagram to show an electrochemical cell consisting of silver and iron half-cells/ electrodes. In the diagram show: **3 marks**

i) A salt bridge
ii) The direction of electron flow by using an arrow (→)

b) Calculate the standard cell voltage for the above electrochemical cell. **1 mark**
c) Write a balanced equation for the cell reaction. **2 marks**
d) On which electrode does oxidation occur? **1 mark**
e) A constant current was passed through an electrolyte of copper (II) sulphate using copper electrodes. After one hour, the mass of the copper cathode increased by 15.24g. Calculate the current used in amperes. [F=96 500Cmol^{-1}, Cu=63.5] **3 marks**

Answer:

a)



b) **E^0 cell = $E^O_{right} - E^O_{left}$ = 0.80-0.44 = +1.24V**
c) **$Fe(s) + 2Ag^+(aq) \longrightarrow Fe^{2+}(aq) + 2Ag(s)$**
d) **On the Iron electrode (left hand electrode)**
e) **$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$**
1 mole of Cu is deposited by 2F
63.5g of Cu is deposited by 2 x 96500C
15.24g of Cu is deposited by $\frac{2 \times 96500 \times 15.24}{63.5}$ = 46 320C
Using Q = It
46320C = I x 60 x 60
$I = \frac{46\,320}{3600}$ = 12.87A

18. Nitrogen monoxide reacts with bromine as show by equation below:
$2NO(g) + Br_2(g) \longrightarrow 2NOBr(g)$
The variations of concentration of reactants and rate at a constant temperature and pressure are shown in the tablebelow:

Experiment	Initial in [NO] in mol dm^{-3}	Initial in [Br] in mol dm^{-3}	Initial rate in mol dm^{-3}S^{-1}
1	2.00x10^{-2}	2.50x10^{-3}	1.60x10^{-3}
2	2.00x10^{-2}	5.00x10^{-3}	3.20x10^{-3}
3	4.00x10^{-2}	5.00x10^{-3}	1.30x10^{-2}

a) Deduce the order of reaction with respect NO and the order of reaction with respect to Br_2. Give reasons for your answers. **3 marks**
b) Write an expression for the rate equation for the above reaction. **1 mark**

c) Calculate the rate constant using experiment 1 and give its units. **2 marks**
d) Briefly explain the effect of temperature on the rate of a reaction. **2 marks**
e) Using the concept of activation energy briefly explain how a catalyst affects the rate of a reaction. **2 marks**

Answer:

a) Using experiment 1 and 2:
[NO] is constant and [Br] is doubled, rate is also doubled, the order is 1 with respect to Br_2.
Using experiment 2 and 3:
[Br] is constant and [NO] is doubled, rate is increased by a factor of 4, the order is 2 with respect to NO.

Or Let the order of respect to NO and Br_2 be x and y respectively.

Then the Rate = $k[NO]^x[Br_2]^y$

$$\frac{3.2 \times 10^{-3}}{1.6 \times 10^{-3}} = \left[\frac{2.00x10^{-2}}{2.00x10^{-2}}\right]^x \left[\frac{5.00x\ 10^{-3}}{2.50x10^{-3}}\right]^y$$

$2^1 = 1^x . 2^y \Rightarrow 2^1 = 2^y \Rightarrow y = 1$, the order with respect to Br_2 is 1.

Using experiment 2 and 3:

$$\frac{1.3 \times 10^{-3}}{3.2 \times 10^{-3}} = \left[\frac{4.00x10^{-2}}{2.00x10^{-2}}\right]^x \left[\frac{5.00x\ 10^{-3}}{5.00x10^{-3}}\right]^y$$

$4 = 2^x.1^y \Rightarrow 4 = 2^x \Rightarrow 2^2 = 2^x \Rightarrow x = 2$, the order with respect to NO is 2

b) Rate = $k[NO]^2[Br_2]$

c) Using experiment 1, Rate = $k[NO]^2[Br_2]$

$1.60x10^{-3}\ moldm^{-3}s^{-1} = k(2.00x10^{-2}moldm^{-3})^2(2.50x10^{-3}moldm^{-3})$

$$k = \frac{1.60 \times 10^{-3} moldm^{-3}s^{-1}}{1.00x10^{-6} mol^2dm^{-6}} = 1.600mol^{-1}dm^3s^{-1}$$

d) **The rate of endothermic reaction increases with an increase in temperature because the number molecules with activation energy thus increase in effective collisions.**

e) **A catalyst provides an alternative route of low activation energy so that more particles can acquire low activation energy to make effective collision.**

19. Propanal is a liquid at room temperature with a boiling point of 49°C. It is prepared from compound Z as follows:
It is mixed with dilute sulphuric acid and potassium dichromate (VI) and heated to a temperature of 50°C to ensure that propanal vaporises as fast as it formed.

a) Give the name or structural formula of compound Z. **1 mark**
b) Why is propanal distilled off as fast as it is formed? **1 mark**
c) What colour change would you observe in this experiment? **1 mark**
d) What reagent would use to confirm the presence of the functional group in propanal? What is the expected observation for a positive result? **2 marks**
e) Propanal is reacted with hydrogen cyanide (HCN) and the product is hydrolysed by heating with a dilute acid.
i) Name the type of reaction between propanal and HCN and give the structural formula of the product. **2 marks**
ii) What type of isomerism is shown by the product in (i)? Give a reason for your answer. **2 marks**
iii) Give the structural formula of the organic compound by hydrolysis of the

compound in (i). **1 mark**

Answer:

a) Z is propan-1-ol

b) To prevent further oxidation of propanal to propanoic acid.

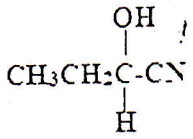
c) Orange acidified potassium dichromate (VI) changes to green.

d) Tollens reagent and heat

Observation: Silver mirror

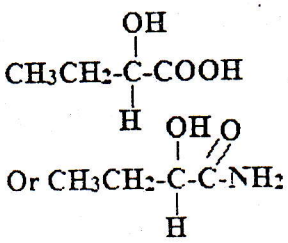
e) i) Nucleophilic addition reaction

The product formed is



ii) Optical isomerism the product contains chiral centre/ asymmetric carbon atom.

iii) By hydrolyzing with a dilute acid (it means H^+/H_2O) the compound formed is:



ADVENCED LEVEL CHEMISTRY NATIONAL EXAMINATION PAPER 2011

SECTION A: Attempt all questions. (70 marks)

01. a) Give the systematic names of three alcohols whose molecular formula is C_4H_9OH. **3 marks**

b) One of the alcohols in (a) can be oxidized to form a ketone.

i) Give the structural formula of the alcohol. **1 mark**

ii) Give the structural formula of the ketone. **1 mark**

Answer:

a) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}OH$ butan-1-ol

$CH_3\text{-}CH(OH)\text{-}CH_2\text{-}CH_3$ butan-2-ol

$CH_3\text{-}C(CH_3)_2\text{-}OH$ 2-methylpropan-2-ol

b) i) $CH_3\text{-}CH\text{-}CH_2\text{-}OH$

$CH_3\text{-}CH(OH)\text{-}CH_2\text{-}CH_3$

ii) $CH_3\text{-}C(=O)\text{-}CH_2\text{-}CH_3$

02. 14.8g of magnesium nitrate were heated until there was no further change in the mass.

a) Write a balanced equation for the reaction. **2 marks**

b) Calculate the mass of magnesium oxide produced. **2 marks**

Answer:

a) $2Mg(NO_3)_2(s) \xrightarrow{heat} 2MgO\ (s) + 4NO_2(g) + O_2(g)$

b) **2 mol of $Mg(NO_3)_2$ produce 2 Mg**

Number of moles MgO $= \frac{mass}{Molar\ mass} = \frac{14.8}{148} = 0.1\ mole$

Mass of MgO = 0.1 x (24+16) = 4.0g

Or

148g of $Mg(NO_3)_2 \longrightarrow$ 40g of MgO

14.8g of $Mg(NO_3)_2 \longrightarrow \frac{14.8 \times 40}{148} = 4.0$g of MgO

03. The atomic number of arsenic [As] is 33.

a) Using s, p, d notation, give the electronic configuration of arsenic. **1 mark**

b) Predict the molecular formulae of two chlorides of arsenic. **2 marks**

c) Deduce the molecular shape and the bond angle of the chloride of arsenic in which arsenic shows a lower oxidation number. **2 marks**

Answer:

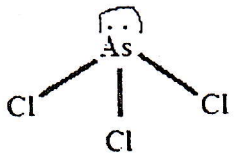
a) **As= 33: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$**

b) **Chloride shows +3 and +5 oxidation states of As**

Hence: $AsCl_3$ and $AsCl_5$

c) **$AsCl_3$**

Shape: Trigonal pyramidal or



Bond angle is about 107^0

04. Aqueous bromide ions are oxidized by hydrogen peroxide in acidic medium according to

the equation below:

$2Br^-(aq] + H_2O(aq] + 2H^+(aq) \rightleftarrows Br_2(aq)+2H_2O(l)$ ΔH = negative

Predict and explain the effect on the equilibrium position when:

a) A small amount of aqueous potassium bromide is added. **2 marks**

b) A small amount of aqueous sodium hydroxide is added. **2 marks**

c) The temperature is increased. **2 marks**

Answer:

a) **KBr(aq) increases concentration of $Br^-(aq)$ hence equilibrium position shifts to the right.**

b) **NaOH(aq) provides OH^- ions which react with H^+ to form H_2O. This decreases concentration of H^+ hence equilibrium position shifts to the left.**

c) **Equilibrium position shifts to the left. Increase in temperature favours an endothermic reaction which is the backward/ reverse reaction since the forward reaction is exothermic.**

05. a) What is meant by the term 'electronegativity'? **2 marks**

b) State and explain the trend in electronegativity across period 3 from Na to Cl. **2 marks**

c) Explain the trend in-polarity of the molecules of Group 7 hydrides from HF to HI. **2 marks**

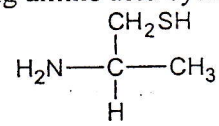
Answer:

a) **Electronegativity is the ability of an atom to attract a pair of electrons in a covalent bond. Or The tendency of an atom to become negatively charged in a covalent bond.**

b) **Electronegativity increases across period 3.**
Explanation: Nuclear charge increases across the period and also atomic radius decreases hence attraction for electrons decreases.

c) **The molecules become less polar. Down the group electronegativity decreases: Hence F has the greatest attraction for electrons and I has the least attraction.**

06. A naturally occurring amino acid cystine has the structure given below:



a) Give the structural formula of a tripeptide formed from cystine molecules. **2 marks**

b) Give the structural formula of the zwitterion formed from cystine. **1 mark**

c) Give the structural formula of the organic product formed when cystine reacts With:

i) Hydrochloric acid solution. **1 mark**

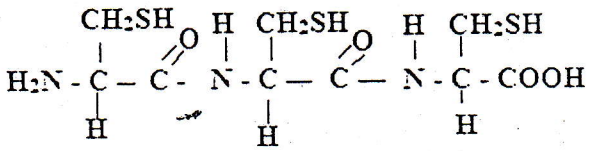
ii) Aqueous sodium carbonate. **1 mark**

iii) Ethanol in the presence of an acid catalyst. **1 mark**

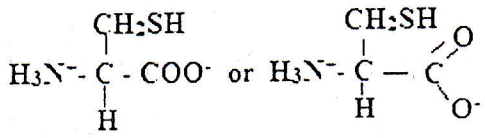
Answer:

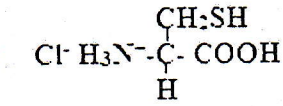
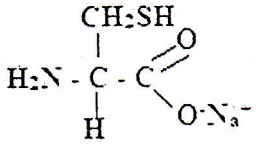
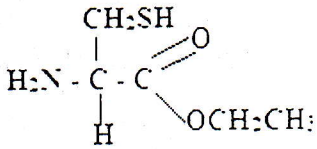
a)

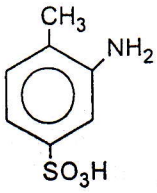
a)

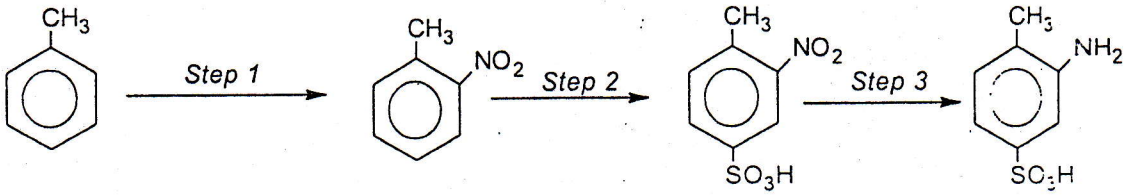


b)



i)  ii)  iii) 

07. A sulphonic acid  can be synthesized from methylbenzene according to the scheme shown below.



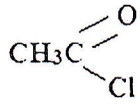
a) What type of reaction is step 2? **1 mark**
b) For each of the steps 1 to 3, state the reagents and conditions needed to carry out the reaction. **6 marks**
c) Outline the mechanism for the reaction in step 2. **3 marks**

Answer:

a) **Electrophilic substitution or sulphonation**
b) **Step 1: Conc. HNO_3 and Conc. H_2SO_4 at 30^0C**
Step 2: Conc. H_2SO_4 or fuming H_2SO_4
Heat or reflux
Step 3: Tin and Conc. HCl
Heat or under reflux

c)

a) **Conc.HNO_3, Conc.H_2SO_4, 55^{0}C/warm**
b) **Reduction**
c)



06. The oxides of period 3 of the Periodic Table show a trend in properties across the period. Using MgO and SO_3 as examples:
   a) Explain using equations, the difference in the acid-base character of the two oxides. 2 **marks**
   b) Which of the two oxides has a higher melting point? Give a reason. **2 marks**

   Answer:
   a) **MgO is a basic oxide and dissolves in water to give a basic solution.**
   $Mg(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$
   SO_3 is an acidic oxide and dissolves in water to an acidic solution.
   $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
   b) **MgO has a higher melting point due to stronger ionic bonding whereas SO_3 forms a simple covalent structure in which molecules are held together by weak Van Der Waals forces of attraction which are easily broken hence low melting point.**

07. Give a brief explanation of each of the trends shown below:
   a) The ionization energy of group II element (Be to Ba) decreases down the group. 2 **marks**
   b) Electronegativity increases across period 3 from Na to Cl. **2 marks**

   Answer:
   a) **Down the group, an extra shell electron is added from one element to another. This increases the screening effect which outweighs the increasing nuclear charge and thus the valence electrons are weakly attracted resulting into a decrease in ionization energy down the group.**
   b) **Across the period an extra proton is added from one element to another. This results into an increase in nuclear charge reducing the screening effect and thus the valence electrons are strongly attracted hence electronegativity increase across the period.**

08. a) Deduce the shape and bond angle of the molecule BF_3
   (Atomic Number of B=3, Atomic Number of F=9) **2 marks**
   b) How does the bond angle change when H_2O forms H_3O^+? Explain your answer (Atomic Number of O=8). **2 marks**

   Answer:
   a)