

PROPOSED MARKING GUIDE

P525/2
Chemistry
Paper 2
July - August 2023
2 ½ hours

[Signature]



UGANDA MUSLIM TEACHERS' ASSOCIATION
UMTA JOINT MOCK EXAMINATIONS 2023

UGANDA ADVANCED CERTIFICATE OF EDUCATION
Chemistry
Paper 2
2 hours 30minutes

INSTRUCTIONS TO THE CANDIDATES

This paper consists of two sections A and B.

Attempt any three questions from section A and any two from section B on the answer sheets provided.

Illustrate your answers with equations where possible.

Molar volume $R=8.314 \text{ J mol}^{-1} \text{ K}^{-1}$.

Molar volume at s.t.p = 22.4 dm^3 .

Begin each question on a fresh page.

Non-programmable scientific electronic calculators may be used.

Illustrate your answers with equations where applicable.

Indicate the questions in the grid below.

Where necessary use, Pb=207; Br = 80; Ag = 108; Na = 23; C = 12; O = 16; H = 1; P=31; Cl = 35.5

Question						Total
Marks						

SECTION A (60 MARKS)

Answer three questions from this section

1. (a) (i) Define the term colligative property. (01 mark)
(ii) State any two colligative properties other than boiling point elevation. (01 mark)

(b) Describe an experiment to determine the relative formula mass of glucose by boiling point elevation. No diagram is required (09 marks)

(c) An aqueous solution containing 9.0g of glucose ($C_6H_{12}O_6$) in 250 cm³ of water boils at same temperature as an aqueous solution containing 1.46g of sodium chloride in 250 cm³ of water. (K_b for water is 0.52°C per mole per 1000kgs).

- (i) Calculate the relative molecular mass sodium chloride in water (04 marks)
(ii) State any two assumptions made in (c)(ii) above (01 mark)

(d) Compare your results in (c)(i) above with the theoretical R.F.M of sodium chloride. Explain the differences between the two values (04 marks)

2. Chromium (Atomic number 24) is not only a transition but also a d-block element.

(a) Write the electronic configuration of chromium ($\frac{1}{2}$ mark)

(b) State the reason why chromium is a:

- (i) transition element (01 mark)
(ii) d-block element (01 mark)

(c) Both chromium and calcium belong to period 4 of the periodic table but chromium has a higher melting point than calcium. Explain this observation. (02 marks)

(d) (i) State the most common oxidation states of chromium exhibited in its compounds (01 mark)

(ii) Write the formulae of the oxides of chromium formed in each of the oxidation states in d(i) above (02 marks)

(e) Ammonium dichromate is an orange solid. When heated strongly, it decomposes to form a green solid Q. Q, when fused with potassium hydroxide in presence of oxygen form a yellow solid W. W dissolves in water to form a yellow solution when dilute sulphuric acid is added to the yellow solution, it turns orange.

(i) Name solid Q ($\frac{1}{2}$ mark)

(ii) Write equation(s) leading to the formation of solid Q from ammonium dichromate, solid W and the orange solution (4 $\frac{1}{2}$ marks)

(f) When potassium nitrite is added to the acidified orange solution in (e), a green solution was formed. Explain. (3 $\frac{1}{2}$ mark)

(g) State what would be the observed and write equation between an aqueous solution of W and

(i) acidified hydrogen peroxide in presence of the ether. (02 marks)

(ii) Silver nitrate (02 marks)

3. Write equation and outline a mechanism for the reaction when:

(a) 2-iodo-2-methylbutane is added to aqueous sodium hydroxide and the mixture heated (03 marks)

(b) benzene is reacted with propene in presence of concentrated arthophosphoric acid (3 $\frac{1}{2}$ mark)

(c) hydrogen chloride gas is bubbled through a boiling mixture of ethanol and benzoic acid (05 marks)

(d) cyclohexanone is converted to cyclohexanone hydrazone (05 marks)

(e) Methyl ethanoate is reacted with alcoholic ammonia solution (3 $\frac{1}{2}$ marks)

4. Phosphorus(V) chloride decomposes at high temperature according to the following equation



(a) Write an expression for the equilibrium constant, K_e for the reaction.

(b) Calculate the enthalpy change for the forward reaction above. (The bond energies for CL -CL and P -CL bonds are -242 and -276.6 $kJmol^{-1}$ respectively) (03 marks)

(c) State and explain the effect on the equilibrium position and values of the equilibrium constant for the reaction when

(i) pressure was increased (03 marks)

(ii) temperature was increased (03 marks)

(iii) inert gas was added at constant volume (02 marks)

(d) 82.5g of phosphorus(V) chloride was sealed in a 8.950 cm^3 glass tube and heated up to 450°C until equilibrium was attained. The tube was quickly broken into an ice-cold excess potassium iodide solution 25.0 cm^3 of solution required 38.50 cm^3 of 0.025 M sodium thiosulphate for complete reaction using starch indicator.

(i) State why the tube was quickly broken into an ice-cold potassium iodide solution. (01 mark)

(ii) Write equation(s) for the reaction(s) that took place (02 marks)

(iii) Calculate the equilibrium constant, K_e for the reaction at 450°C (04 marks)

SECTION B: (40 MARKS)

Answer any two questions from the section

5. The Elements beryllium, magnesium, calcium, strontium and barium belong to group II of the periodic Table.

(a) Write the general outermost electronic configuration of the elements above

($\frac{1}{2}$ mark)

(b) State and explain the trend in variation of the first ionization energy amongst the elements

(3 $\frac{1}{2}$ mark)

(c) (i) Describe the reactions of the elements with hydrochloric acid. (04 marks)

(ii) Write equation(s) for the reaction(s) of beryllium and magnesium with nitric acid under different conditions (03 marks)

(d) The table below shows solubility in water of 20°C and decomposition temperatures at 1 atmosphere of the hydroxides and carbonates of some of the elements respectively

Hydroxide	Mg(OH)_2	Ca(OH)_2	Sr(OH)_2	Ba(OH)_2
Solubility (g/100g at 20°C)	0.002	0.15	0.9	4.0
Carbonate	MgCO_3	CaCO_3	SrCO_3	BaCO_3
Decomposition temperature($^{\circ}\text{C}$)	540	900	1290	1360

Explain the trend in variation of:

(i) solubility of the hydroxides in water. (03 marks)

(ii) thermal stability of the carbonates. (03 marks)

(e) Write equation(s) for the reaction(s), if possible for the:

(i) hydroxides of the elements with potassium hydroxides (1 $\frac{1}{2}$ marks)

(ii) carbonates in (d) above with dilute sulphuric acid (1 $\frac{1}{2}$ marks)

6. With the help of the equations and giving necessary conditions, show how each of the following conversions could be effected.

(a) Chlorobenzene to benzamide (5 $\frac{1}{2}$ marks)

(b) But-2-ene to nitrobenzene (5 $\frac{1}{2}$ marks)

(c) 2-methylpropan-2-ol from ethene (5 $\frac{1}{2}$ marks)

(d) Propanoylchloride to propylamine (5 $\frac{1}{2}$ marks)

(e) Methylbenzoate to benzene (02 marks)

7. Explain each of the following observations.

(a) An aqueous solution of potassium nitrate has pH 7 whereas an aqueous solution of potassium nitrite has pH above 7 (04 marks)

- (b) A mixture of water and carbon tetrachloride boils at a temperature considerably below the boiling point of either liquids (3 $\frac{1}{2}$ marks)
- (c) The basic strength of the following compounds id in the order



- (d) When an aqueous solution of sodium chlorate(I) and lead (II) nitrate was heated, a brown precipitate was formed (3 $\frac{1}{2}$ marks)
- (e) Calcium phosphate is less soluble in calcium nitrate solution but more soluble in dilute hydrochloric acid. (04 marks)

- HCC
8. (a) What is meant by the terms:
(i) order of reaction (01 mark)
(ii) half-life of a reaction (01 mark)

(b) The equation for the acid catalyzed reaction between propanone and iodine is:



The rate equation for the reaction is Rate = $k[\text{CH}_3\text{C}(=\text{O})\text{CH}_3][\text{H}^+]$

Describe an experiment to determine the order of reaction with respect to iodine in the laboratory.

(c) The table below shows the results for the hydrolysis of a bromoalkene, $\text{C}_4\text{H}_9\text{Br}$.
The enthalpy for the reaction is -160 kJ mol^{-1}

Experiment	$[\text{C}_4\text{H}_9\text{Br}] (\text{mol dm}^{-3})$	$[\text{H}_2\text{O}] (\text{mol dm}^{-3})$	Initial rate ($\text{mol dm}^{-3} \text{s}^{-1}$)
1	0.05	0.10	1.0×10^{-5}
2	0.20	0.10	4.0×10^{-5}
3	0.20	0.05	4.0×10^{-5}

- (i) Determine the order of the reaction with reasons to explain your answer (04 marks)
(ii) Write the structural formula and name of the alkylhalide. (1 $\frac{1}{2}$ marks)
(iii) Draw a well labelled energy diagram for the reaction. (2 $\frac{1}{2}$ marks)

END

No. 1

(a) It is a physical property of a dilute solution which depends on the number of solute particles dissolved in a fixed amount of a solvent but independent of their chemical nature.

i) Lowering of vapour pressure of pure solvent
Osmotic pressure of solution

(01)

b) A known mass x g of pure solvent is put into a glass tube having a side arm and fitted with a thermometer and a Cottrell pump.

The solvent is heated and the constant temperature T_0 °C at which the it boils is read and noted.

A known mass y g of glucose is added to the solvent through the sidearm and the tube is shaken to dissolve the mixture into a solution.

The solution is heated and the constant temperature T_1 °C at which it boils is read and noted.

Assumption of results

Let the ebullioscopic constant of the solvent be K_b °C/mol/kg⁻¹

Boiling point elevation $\Delta T_b = (T_1 - T_0)$ °C

x g of solvent dissolve y g of glucose

1000 g of solvent dissolve $\left(\frac{1000}{x}\right)$ g of glucose

(09)

ΔT_b is the boiling point elevation caused by $(1000/x)$ g of glucose.

K_b is the boiling point elevation caused by $\left(\frac{1000 \cdot K_b}{1000/x}\right)$ g of glucose

∴ The relative formula mass of glucose is $\left(\frac{1000 \cdot K_b}{\Delta T_b \cdot x}\right)$

c) (250x1)g of water dissolve 9g of glucose

(1×10^6) g of water dissolve $\left(\frac{9 \times 10^6}{200}\right)$ g of glucose

= 36000 g of glucose

$[(12 \times 6) + 12 + (16 \times 6)]$ g of glucose elevate the boiling point by 0.52 °C

36000 g of glucose elevate the boiling point $\left(\frac{0.52 \times 36000}{180}\right)$ °C

= 104 °C

(02)

$$\frac{(250 \times 1)}{1 \times 10^6} \text{ g of water dissolve } 1.46 \text{ g of NaCl}$$
$$\frac{1.46 \times 10^6}{250} \text{ g of NaCl}$$
$$= 5840 \text{ g}$$

104°C is the boiling point elevation caused by 5840 g of NaCl

0.52°C is the boiling point elevation caused by $\frac{5840 \times 0.52}{404}$ g of NaCl

∴ Relative molecular mass of NaCl in water = 29.2

ii) The solution is very dilute
~~(Sodium chloride does not react with water)~~

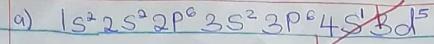
Rej: must be
should be

d) Theoretical Mr (NaCl) = 23 + 35.5 = 58.5

The calculated relative molecular mass of sodium chloride is lower than the actual one.
Therefore, sodium chloride dissociates in water forming sodium ion and chloride ion. This increases the boiling point elevation but molecular mass. Accept: The calculated Mr is half the decreases since colligative property is inversely proportional to molecular mass.

Total marks = 20

No 2



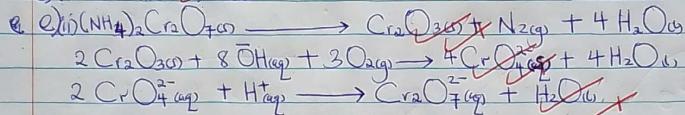
- b) i) It forms ions with partially filled d-orbitals.
ii) The outermost electrons of Chromium are in the d-subenergy levels.

c) Chromium has a stronger metallic bond than calcium. This is because chromium contributes a greater number of electrons from 4s and 3d-subenergy level towards metallic bond formation than calcium. Chromium also has a smaller atomic radius than calcium.

d) i) +3, +6

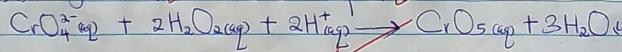
ii) Cr_2O_3 , CrO_3

iii) Chromium(II) oxide

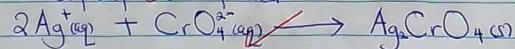


f) The nitrite ion in potassium nitrite reduces dichromate(VI) ion to chromium(III) ion
 $\text{Cr}_2\text{O}_7^{2-} + 3\text{NO}_2^{-} + 8\text{H}_2\text{O}_l \rightarrow 3\text{NO}_3^{-} + 3\text{Cr}^{3+} + 4\text{H}_2\text{O}_l$

g) i) A yellow solution turns to a deep blue solution

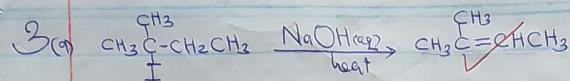


ii) A red precipitate is formed

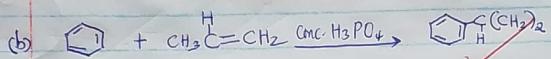
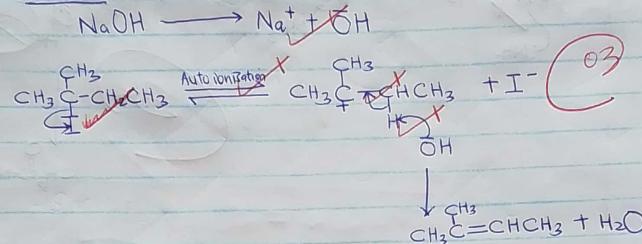


Total marks=20

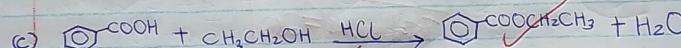
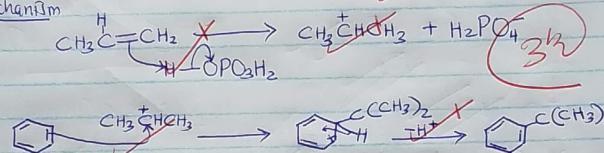
No 3



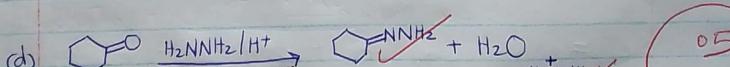
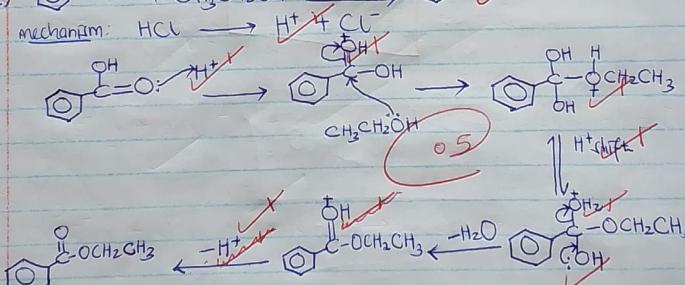
Mechanism



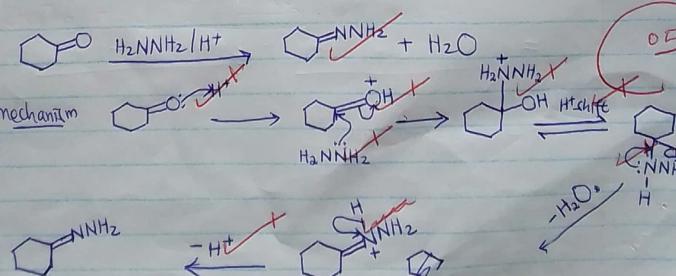
Mechanism

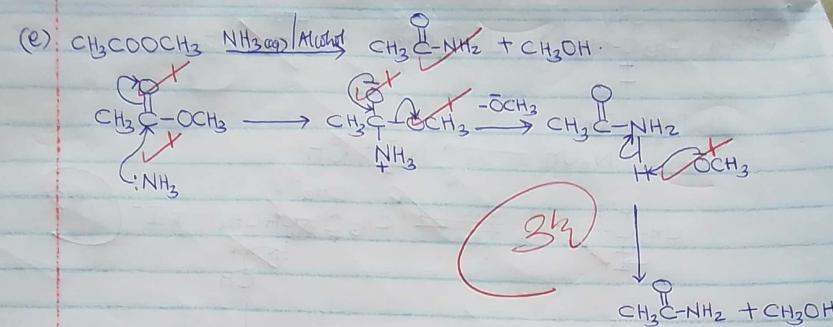


Mechanism:



Mechanism





Total marks = 20

No 4

a) $K_c = \frac{[\text{PCl}_2][\text{Cl}_2]}{[\text{PCl}_5]}$ (02)

b) $\Delta H_r = \sum \text{B.E. (bonds broken)} + \sum \text{B.E. (bonds formed)}$

$$\begin{aligned} &= 5(\text{P-Cl}) + 3(\text{P-Cl}) + (\text{Cl-Cl}) \\ &= 5(276.6) + 3(276.6) + -242 \\ &= +311.2 \text{ kJmol}^{-1} \end{aligned}$$

OR $\Delta H_r = \sum \text{B.E. (bonds formed)} - \sum \text{B.E. (bonds broken)}$

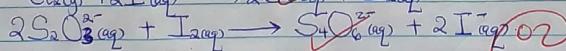
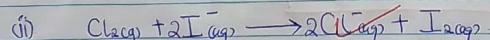
$$\begin{aligned} &= 3(\text{P-Cl}) + (\text{Cl-Cl}) - 5(\text{P-Cl}) \\ &= 3(-276.6) + -242 - 5(-276.6) \\ &= +311.2 \text{ kJmol}^{-1} \end{aligned}$$

(i) The equilibrium position shifts to the left since the backward reaction occurs with decrease in volume (number of moles) but equilibrium constant value remains unchanged (03)

(ii) The equilibrium position since the forward reaction is endothermic thus favoured by increase in temperature. The value of equilibrium constant increases (03) since more phosphorus dichloride dissociates into phosphorus trichloride and chlorine.

(iii) The equilibrium position and value of equilibrium constant remain unchanged since inert gases don't appear in the expression for the equilibrium constant (02)

d) i) To stop the reaction, fix the equilibrium and to dissolve the chlorine formed.



iii) Mr (PCl₅) = 81 + 5(35.5) = 208.5

Initial Moles of PCl₅ = $\left(\frac{32.5}{208.5}\right)$

1000 cm³ of solution contain 0.025 moles of S₂O₃²⁻

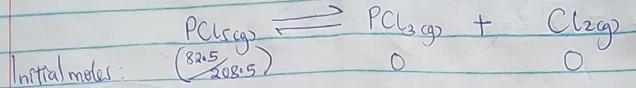
38.5 cm³ of solution contain $\left(\frac{0.025 \times 38.5}{1000}\right) = 9.625 \times 10^{-4}$ moles

Mole ratio of I₂ : S₂O₃²⁻ = 1 : 2

\Rightarrow moles of I₂ = $\frac{1}{2} \times 9.625 \times 10^{-4} = 4.8125 \times 10^{-4}$ mole (01)

Mole ratio of $I_2 : Cl_2 = 1 : 1$

\Rightarrow Moles of Cl_2 at equilibrium = 4.8125×10^{-4} moles



$$\text{If } \alpha \text{ dissociated: } -(\frac{82.5}{208.5})\alpha \quad +(\frac{82.5}{208.5})\alpha \quad +(\frac{82.5}{208.5})\alpha$$

$$\text{Equilibrium moles: } \frac{82.5}{208.5} (1-\alpha) \quad (\frac{82.5}{208.5})\alpha \quad (\frac{82.5}{208.5})\alpha$$

$$\text{Equilibrium concentration: } \frac{82.5 \times 1000 (1-\alpha)}{208.5 \times 8950} \quad \frac{82.5 \times 1000 \alpha}{208.5 \times 8950} \quad \frac{82.5 \times 1000 \alpha}{208.5 \times 8950} \quad 0.3$$

$$\text{But } \frac{82.5}{208.5} \alpha = 4.8125 \times 10^{-4}$$

$$\alpha = \frac{4.8125 \times 10^{-4} \times 208.5}{82.5} = 1.21625 \times 10^{-3}$$

$$K_c = \left(\frac{82.5 \times 1000 \times 1.21625 \times 10^{-3}}{208.5 \times 8950} \right)^2 \div \left(\frac{82.5 \times 1000 (1 - 1.21625 \times 10^{-3})}{208.5 \times 8950} \right)$$

$$= 6.548 \times 10^{-8} \text{ mol dm}^{-3}$$

Total marks = 20

5s² ✓No 5
03

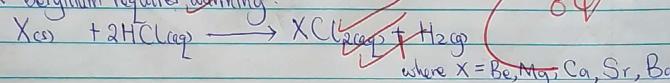
(b) The first ionisation energy decreases from beryllium to barium.

As atomic number increases, both nuclear charge and screening effect increase but since from one element to the next an extra energy level full of electrons is added, the increase in screening effect is greater than the increase in nuclear charge.

As a result, the effective nuclear charge decreases which decreases the nuclear attraction towards the outermost electrons. This decreases the energy needed to remove an electron.

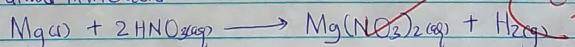
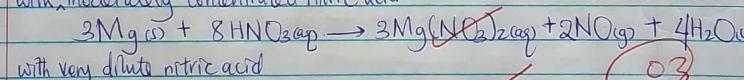
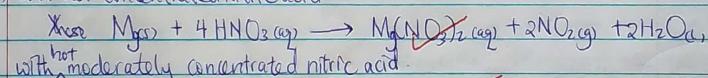
312

(c) i) Beryllium, magnesium, calcium, strontium and barium react with both dilute and concentrated hydrochloric acid forming beryllium chloride, magnesium chloride, calcium chloride, strontium chloride and barium chloride respectively with liberation of hydrogen gas. However, the reaction with beryllium requires warming.



04

ii) with hot concentrated nitric acid.



03

(d) i) Solubility increases from magnesium hydroxide to barium hydroxide.

From magnesium hydroxide to barium hydroxide, both hydration energy and lattice energy decrease but since the hydroxide ion is small, the decrease in lattice energy is greater than the decrease in hydration energy.

This makes the enthalpy of solution to become more negative from magnesium hydroxide to barium hydroxide.

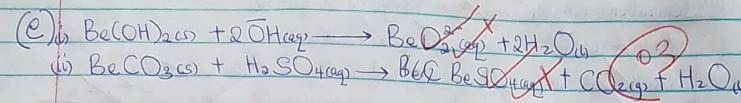
03

ii) Thermal stability increases from magnesium carbonate to barium carbonate.

This is because the ionic radius of the cations increases from magnesium ion to barium ion which decreases the charge density and polarizing power of the cation.

24

As a result ionic character increases from magnesium carbonate to barium carbonate hence thermal stability increases in the same order.

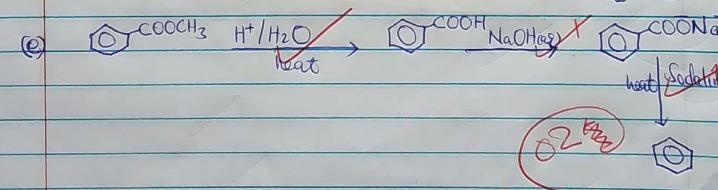
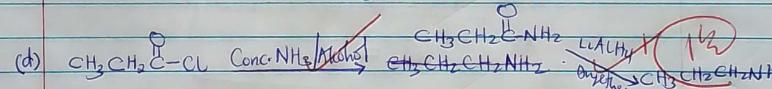
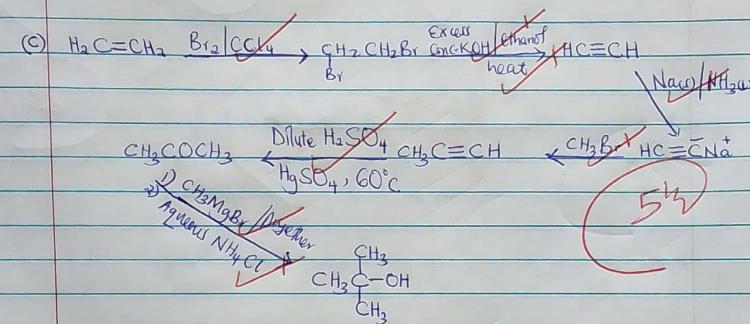
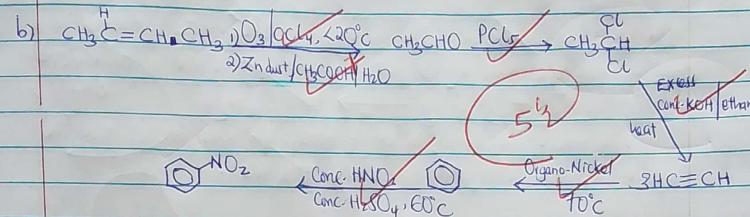
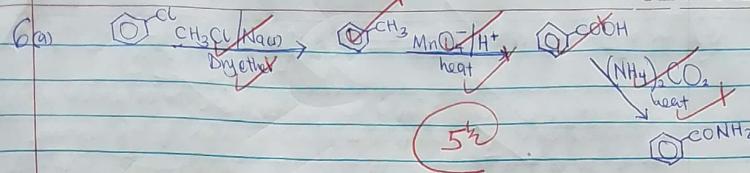


Total marks = 20marks

No. 6

PAGE NO:

/ /

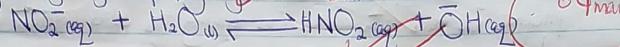


Total marks = 20 marks

No. 7

(a) Potassium nitrate is a salt of a strong acid and a strong base thus it does not undergo hydrolysis.

Potassium nitrate is a salt of a weak acid and a strong base thus it undergoes hydrolysis forming hydroxide ion in solution



(b) Pure molecules of water interact via intermolecular hydrogen bonds while pure molecules of carbon tetrachloride interact via Van der Waal's forces of attraction. On mixing, weaker intermolecular forces are formed between molecules in solution. This increases the escaping tendency of molecules from solution into vapour phase, raising the vapour pressure of solution above that of pure components. Therefore, the solution boils at a lower temperature than that of pure components. $\frac{3}{4}$ mark

(c) The basic strength of amines depends on the availability of lone pair of electrons on the nitrogen atom.

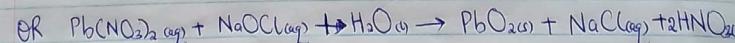
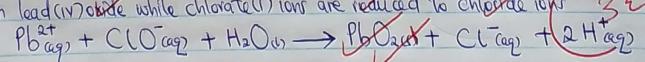
Phenylamine
Basic strength increase from ammonia to dimethylamine

Dimethylamine has two methyl groups with positive inductive effect attached to its nitrogen atom which donate bonding electrons to nitrogen hence the most strong base.

The lone pair of electrons on the nitrogen atom of phenylamine interact with the delocalized electrons of the benzene ring thus unavailable for protonation hence phenylamine is the weakest base.

The nitrogen atom of ammonia lacks alkyl groups thus it weaker base than dimethylamine but stronger than phenylamine.

(d) Chlorate(1) ions in sodium chlorate(1) oxidise lead(2+) ions in lead(II) nitrate to form lead(IV) oxide while chlorate(1) ions are reduced to chloride ions.

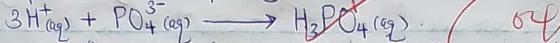


(e) The equilibrium mixture of calcium phosphate in a saturated solution is



Calcium nitrate solution contains a common ion, Calcium ion which increases the concentration of Calcium ions in solution. To restore the equilibrium, phosphate ions react with calcium ions forming the solid Calcium phosphate.

In dilute hydrochloric acid, the hydrogen ions react with phosphate ions forming phosphoric acid which partially ionizes since it's a weak acid.



This decreases the concentration of phosphate ions in solution to restore it, more solid calcium phosphate dissociates.

Total marks = 20 marks

No 8

(a) Is the sum of powers to which the molar concentration terms of reactants are raised in a rate equation.

⑦

(ii) Is the time taken for the concentration of a substance to reduce by half the original.

⑧

b) A known volume of standard iodine solution is added to excess propanone in a flask.

A known volume of dilute sulphuric acid is added and the stop watch is immediately started. The mixture is shaken and left to settle.

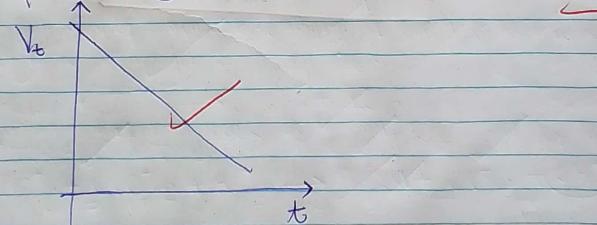
At regular intervals of time, a known volume of the reaction mixture is pipetted into a small flask containing sodiumhydrogen carbonate solution to stop the reaction by neutralizing the acid.

The resultant solution is titrated with a standard solution of sodiumthiosulphate using starch indicator and the volume, V_t , of sodiumthiosulphate required to reach the end point corresponds to the amount of iodine remaining at a given time, t .

The initial (concentration) of the iodine solution is obtained by directly titrating an original flask of equal volume with sodiumthiosulphate solution and the volume of sodiumthiosulphate used, V_0 is the initial amount of iodine solution.

A plot of V_t against t gives a straightline graph with a negative slope which is typical of zero order reaction

⑩



The reaction is therefore zero order with respect to iodine.

(c) Let the order of reaction with respect to $\text{C}_4\text{H}_9\text{Br}$ be x and to H_2O be y .

$$\text{Expt 1} \div \text{Expt 2}$$

$$\left(\frac{0.05}{0.02}\right)^x \left(\frac{0.1}{0.01}\right)^y = \left(\frac{1.0 \times 10^{-5}}{4.0 \times 10^{-5}}\right)$$

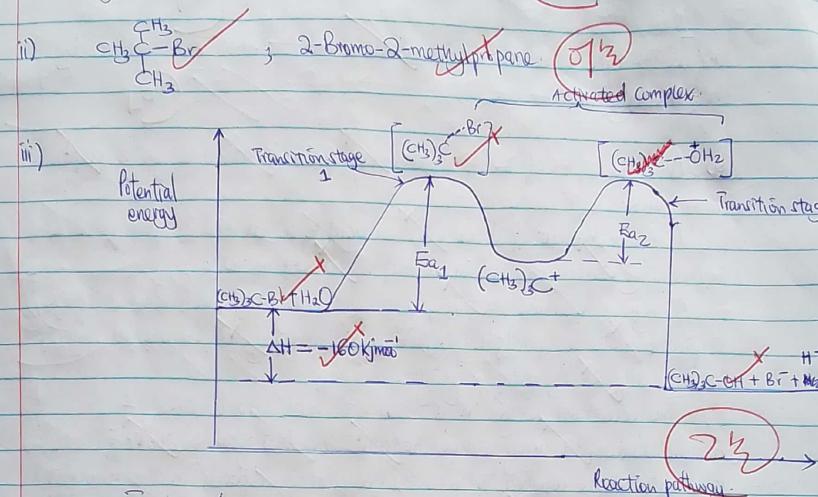
$$\left(\frac{1}{4}\right)^x = \frac{1}{4} \Rightarrow x = 1$$

$$\text{Expt 2} \div \text{Expt 3}$$

$$\left(\frac{0.2}{0.1}\right)^x \left(\frac{0.1}{0.05}\right)^y = \left(\frac{4 \times 10^{-5}}{4 \times 10^{-5}}\right)$$

$$2^y = 2^0 \Rightarrow y = 0$$

The reaction is first order overall. This is because water does not
is in large excess thus its concentration remains constant.



where $E_{\text{A}1}$ Activation energy for the reaction 1
 $E_{\text{A}2}$ Activation energy for reaction 2

Total marks = 20 marks