SUGGESTED GUIDE

Candidate's Name: @ THE LAW.

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P525/1
CHEMISTRY
(Theory)
Paper 1
Nov./ Dec. 2022
2¾ hours

UGANDA NATIONAL EXAMINATIONS BOARD
Uganda Advanced Certificate of Education

CHEMISTRY
(THEORY)

Paper 1

2 hours 45 minutes

100/100

INSTRUCTIONS TO CANDIDATES:

Answer **all** *questions in section* **A** *and* **six** *questions from section* **B**.

All your answers **must** *be written in the spaces provided.*

The Periodic Table, with relative atomic masses, is attached at the end of the paper.

Mathematical tables (3-figure tables) are adequate or non-programmable scientific electronic calculators may be used.

Illustrate your answers with equation(s) where applicable.

Where necessary, use the following:

Molar gas constant, R $= 8.31\ JK^{-1}\ mol^{-1}$.
Molar volume of gas at s.t.p is 22.4 litres.
Standard temperature $= 273\ K$.
Standard pressure $= 101325\ Nm^{-2}$.

For Examiners' Use Only																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
04	04½	06	04½	06	05	05	05	06	09	09	09	09	09	09	09	09	

SECTION A (46 MARKS)

Answer **all** *questions in this section.*

1. Complete the following nuclear reaction equations:

(a) $^{30}_{15}P \longrightarrow {}^{30}_{16}S + \ldots {}^{0}_{-1}e$ ✓ *(01 mark)*

(b) $^{56}_{26}Fe + {}^{2}_{1}H \longrightarrow \ldots {}^{57}_{27}Co$ ✓ $+ {}^{1}_{0}n$. *(01 mark)*

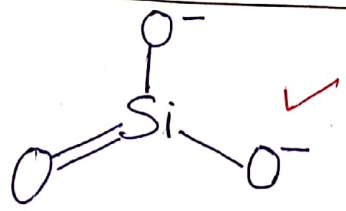
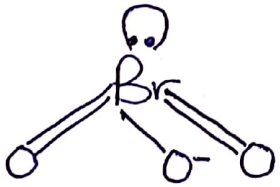
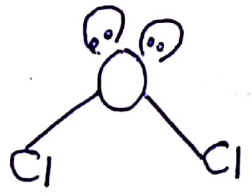
(c) $^{1}_{1}H + {}^{7}_{3}Li \longrightarrow \ldots {}^{8}_{4}Be$ ✓ *(01 mark)*

(d) $^{234}_{90}Th \longrightarrow \ldots {}^{234}_{91}Pa$ ✓ $+ {}^{0}_{-1}e$. *(01 mark)*

04

2. Draw the structure and state the shape of each of the following species in table 1.

Table 1 *(4½ marks)*

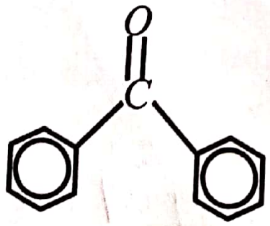
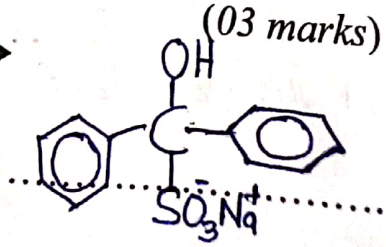
Species	Structure	Shape
SiO_3^{2-}	 ✓	Trigonal planar ✓+
BrO_3^-	 ✓	Trigonal pyramidal ✓+
Cl_2O	 ✓	Bent ✓+

4½

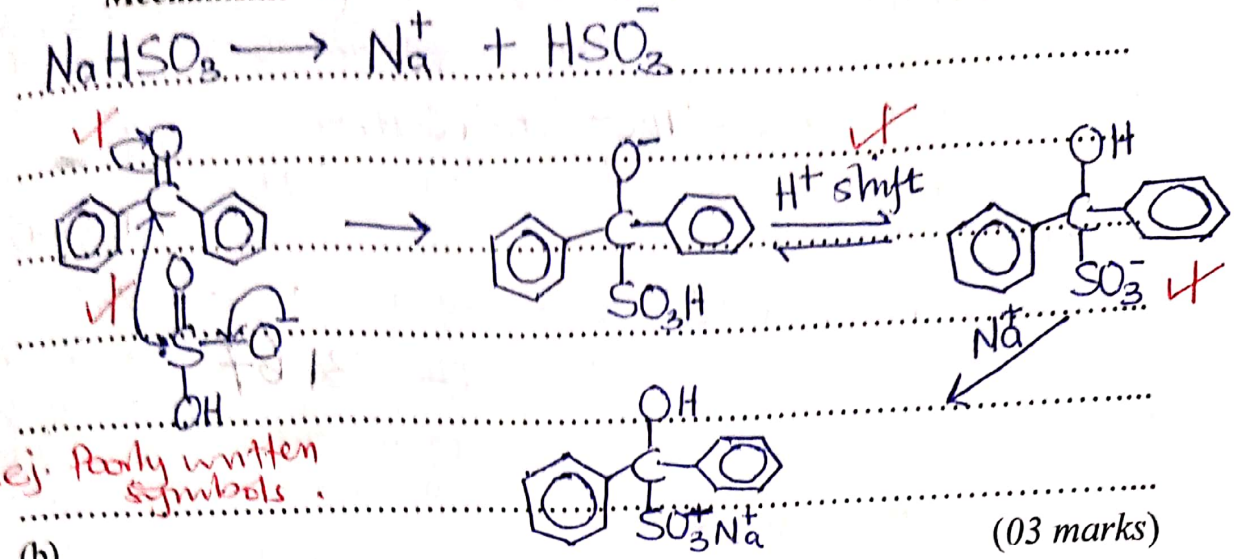
- wrong symbols
- Hanging bonds
- wrong spellings

3. Complete the following equations and write a mechanism for the reaction in each case:

06

(a)  $+ NaHSO_3 \longrightarrow$  ✓ *(03 marks)*

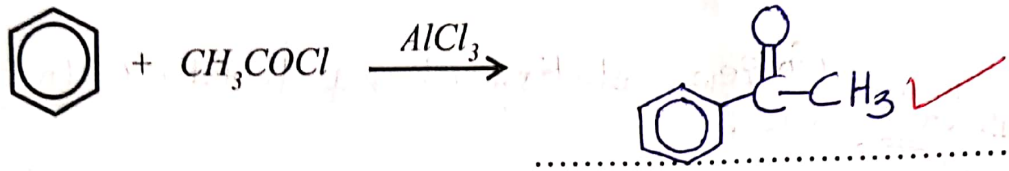
Mechanism:



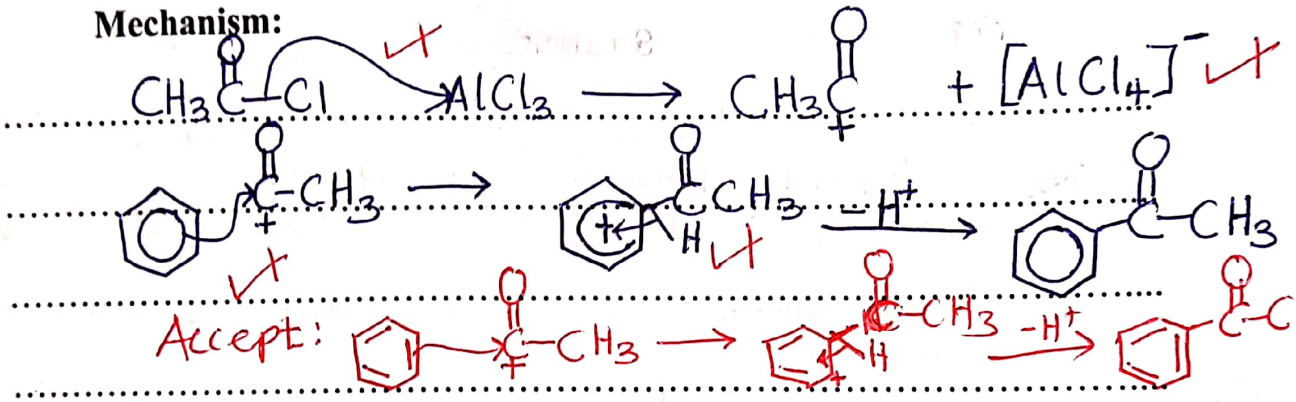
Rej. Poorly written symbols.

(03 marks)

(b)



Mechanism:



4. (a) State what is meant by **bond energy**. (1½ marks)

Block marks.

The amount of heat absorbed; to break one mole of a covalent bond; to form gaseous atoms;

(b) Table 2 shows standard average bond energies for some selected bonds.

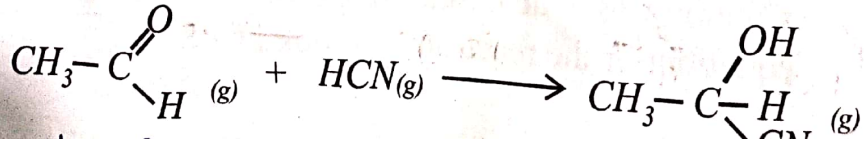
Table 2

Bond	C−C	C−O	C−H	H−O	C=O
Average bond energy (kJmol^{-1})	348	360	412	463	743

½

Use the data in the table to determine the standard enthalpy change of the reaction.

(03 marks)



$\Delta H^{\ominus}_{reaction}$ = Total average bond energy of reactants − Total average bond energy of products

= (1(C−C) + 5(C−H) + 1(C=O) + 1(C≡N)) − (2(C−C) + 4(C−H) + 1(C−O) + 1(C≡N) + 1(H−O))

= ((1×348) + (5×412) + (1×743)) − ((2×348) + (4×412) + (1×360) + (1×464))

= (+3151) − (+3167)

= −16 kJ mol^{-1}

~~= −4888 kJ mol^{-1}~~

5. (a) To a mixture of chromium(III) sulphate solution and excess sodium hydroxide solution, was added hydrogen peroxide solution and the resultant mixture heated.

(i) State what was observed. (½ mark)

Green solution changed to yellow solution

Block mark.

(ii) Write an equation for the reaction that took place. (1½ marks)

$2Cr^{3+}_{(aq)} + 10OH^-_{(aq)} + 3H_2O_{2(aq)} \longrightarrow 2CrO^{2-}_{4(aq)} + 8H_2O_{(l)}$

– Award 01 mark if states missing

– Reject if equation is not balanced.

(b) The resultant solution in (a) was divided into portions and treated as follows:

(i) To the first portion dilute sulphuric acid was added. State what was observed and write an equation for the reaction that took place.

Observation:

Block mark

Yellow solution turned to orange solution (½ mark)

Equation:

$2CrO^{2-}_{4(aq)} + 2H^+_{(aq)} \longrightarrow Cr_2O^{2-}_{7(aq)} + H_2O_{(l)}$ (1½ marks)

– Award 01 mark if states missing

– Reject if equation is not balanced.

(ii) To the second portion, a few drops of lead(II) ethanoate solution was added. State what was observed and write an equation for the reaction that took place.

Observation:

Yellow precipitate is formed (½ mark)

Equation:

$(CH_3COO)_2Pb(aq) + CrO_4^{2-}(aq) \rightarrow PbCrO_4(s) + 2CH_3COO^-$ (1½ marks)

- Award 01 mark if equation is missing state (aq)
- Reject all marks if equation is not balanced.
- Deny

6. (a) State what would be observed if benzene was added to water. (01 mark)

Two layer solution mixture of colourless liquids

(b) An organic compound **Q** is soluble in both water and benzene. 0.5 moles of **Q** was shaken with a mixture containing 40 cm^3 of water and 20 cm^3 of benzene and the mixture allowed to stand until equilibrium was attained.

(*KD for* **Q** *between benzene and water at 25 °C is 5.*)

Calculate the number of moles of **Q** in the water. (04 marks)

0.5

Let the number of moles of Q in water be x.

No of moles of Q in benzene = 0.5 − x

$K_D = \frac{[Q] \text{ in benzene}}{[Q] \text{ in water}} = \frac{0.5-x}{20} \div \frac{x}{50} = 5$

$x = 0.1667$ moles

7. (a) Propylamine is a weak base.

Write an;

(i) equation for the dissolution of propylamine in water. (1½ marks)

$CH_3CH_2CH_2NH_2(aq) + H_2O(l) \rightleftharpoons CH_3CH_2CH_2\dot{N}H_3(aq) + \bar{O}H($

- Award ½ mark if full arrow is used.
- Reject wrong symbols.

(ii) expression for the base dissociation constant, K_b for propylamine. *(01 mark)*

$K_b = \frac{[CH_3CH_2CH_2\overset{+}{N}H_3][\bar{O}H]}{[CH_3CH_2CH_2NH_2]}$ ✓

(b) Determine the degree of dissociation of a 0.1 M propylamine solution. (K_b *for propylamine* 6.918×10^{-4}) *(2½ marks)*

05

Assumption $[CH_3CH_2CH_2\overset{+}{N}H_3] \simeq [\bar{O}H]$ ✓

$K_b = \frac{[\bar{O}H]^2}{[CH_3CH_2CH_2NH_2]} = \frac{[OH]^2}{0.1} = 6.918 \times 10^{-4}$ ✓

$[OH] = 8.3175 \times 10^{-3}\ mol\,dm^{-3}$ ✓ Deny mark if unit is correctly stated.

$[\bar{O}H] = C\alpha = (0.1 \times \alpha) = 8.3175 \times 10^{-3}$ ✓

$\alpha = 0.083$ ✓

∴ Degree of dissociation = 0.083

* No substitution mark awarded if relevant formula is not well stated.

8. The industrial reaction in which sulphur dioxide is converted into sulphur trioxide in the contact process is reversible and exothermic.

(a) Write equation to illustrate the reaction. *(02 marks)*

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \quad -\Delta H$ ✓ ✓

- Award 1 mark if $-\Delta H$ is not indicated.
- Award no mark if full arrows are used

(b) Giving reason(s) in each case, state the effect on the equilibrium position of the reaction in (a) if;

(i) the temperature was increased. *(1½ marks)*

Equilibrium shifts to the left; ✓ Backward reaction is favoured; ✓ since the SO_3 absorbs heat and decomposes; ✓ to form SO_2 and O_2.

(ii) helium was added to the reaction mixture at constant volume. *(1½ marks)*

05

There is no effect ✓ on the equilibrium position; ✓ Helium doesn't affect the concentration ✓ of any ✓ the components ✓ of the system; since its inert;

9. Write equations to show how the following compounds can be synthesized: *(03 marks)*

(a) $(CH_3CH_2)_2O$ from ethene.

$CH_2=CH_2 \xrightarrow[warm]{H_2O/H^+} CH_3CH_2OH \xrightarrow[140^\circ C]{Conc.\ H_2SO_4} (CH_3CH_2)_2O$

$CH_2=CH_2 \xrightarrow{HCl} CH_3CH_2Cl \xrightarrow[heat]{NaOH} CH_3CH_2OH$

* Deny poorly written symbols.
* Conditions must be correct for full marks to be awarded.

OR

(b) Propanone from 1, 2 - dibromopropane. *(03 marks)*

$CH_3CHBrCH_2Br \xrightarrow[Ethanol.]{excess\ Hot\ KOH} CH_3C\equiv CH \xrightarrow[HgSO_4, 60^\circ C]{H_2O, H_2SO_4} CH_3CCH_3$ (O)

06

SECTION B (54 MARKS)

Answer **six** *questions from this section.*
Any additional question(s) answered will **not** *be marked.*

10. Nitrogen reacts with hydrogen according to the following equation:

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(a) State the condition(s) that favour formation of ammonia. *(1½ marks)*

High pressure of about ~~4B~~ 200 atmosp

High temperature of about 450°C

Presence of Iron fillings as catalyst

(b) Write equation(s) to show how ammonia can be converted to nitric acid. *(4½ marks)*

$4NH_{3(g)} + 5O_{2(g)} \longrightarrow 4NO_{(g)} + 6H_2O_{(l)}$

$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

$4NO_{2(g)} + 2H_2O_{(l)} + O_{2(g)} \longrightarrow 4HNO_{3(aq)}$

* Rej. if equations are not balanced.
* Deny marks for wrong symbols.

(c) Write an equation for the reaction between tin and

(i) cold dilute nitric acid. *(1½ marks)*

$4Sn(s) + 10HNO_3(aq) \rightarrow 4Sn(NO_3)_2 + NH_4NO_3(aq) + 3H_2O$

(ii) hot concentrated nitric acid. *(1½ marks)*

$Sn(s) + 4HNO_3(aq) \rightarrow H_2SnO_3(aq) + 4NO_2(g) + H_2O$

11. Ethylbromide reacts with aqueous sodium hydroxide solution according to the following equation:

$$CH_3CH_2Br + NaOH_{(aq)} \xrightarrow{heat} CH_3CH_2OH + NaBr_{(aq)}$$

(a) Write the mechanism for the reaction. *(02 marks)*

$NaOH(aq) \longrightarrow Na^+(aq) + \bar{O}H(aq)$

$CH_3CH_2Br + \bar{O}H \longrightarrow CH_3CH_2OH + Br^-$

Deny: $CH_3CH_2Cl \xrightarrow{slow} CH_3CH_2^+ + Cl^-$

(b) Name the type of mechanism in (a). *(01 mark)*

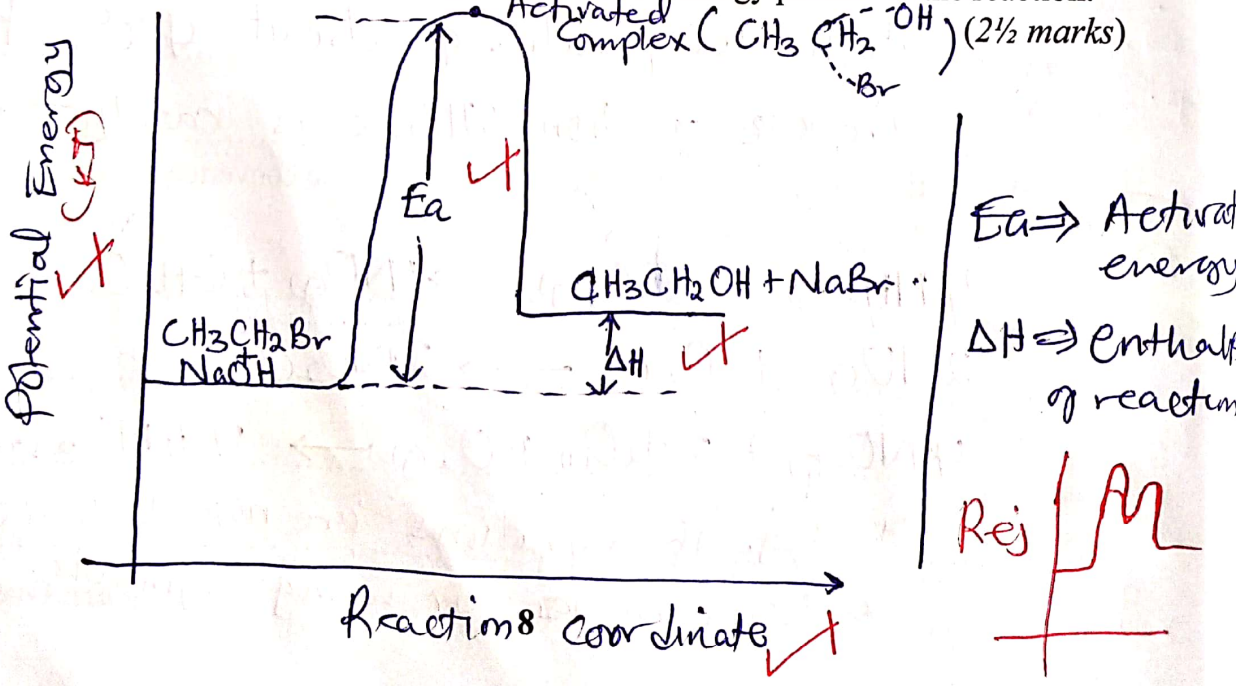
Block mark — Substitution nucleophilic bimolecular

(c) Write the rate equation for the reaction. *(01 mark)*

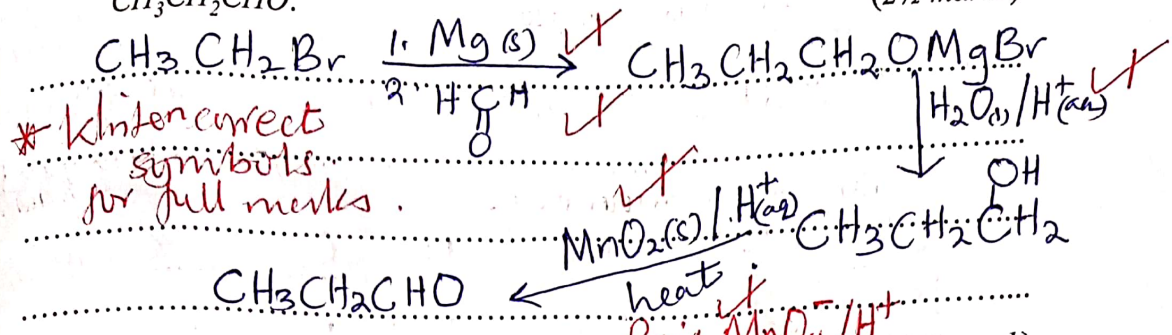
Rej. wrong symbols — $Rate = K[CH_3CH_2Br][NaOH]$ or

$Rate = K[CH_3CH_2Br][\bar{O}H]$

(d) Sketch a labelled diagram to show an energy profile for the reaction. *(2½ marks)*



(e) Write equations to show how CH_3CH_2Br can be converted to CH_3CH_2CHO. (2½ marks)



* Klinter correct symbols for full marks.

Rej; MnO_4^-/H^+

12. (a) State what is meant by the term **enthalpy of hydration**. (01 mark)

Block mark

Amount of heat liberated when one mole of gaseous ions is completely surrounded by water molecules to form an infinitely dilute solution.

(b) The hydration energies of barium and chloride ions are -1275 kJ mol^{-1} and -394 kJ mol^{-1} respectively and the lattice energy of barium chloride is -2056 kJ mol^{-1}.

Calculate the;

(i) hydration energy of barium chloride. (1½ marks)

$\Delta H^{\ominus}_{Hydration\ of\ BaCl_2} = \Delta H^{\ominus}_{Hydration\ of\ Ba^{2+}} + 2(\Delta H^{\ominus}_{Hydration\ of\ Cl^-})$

$= -1275 + 2(-394)$

$= -2063\ KJmol^{-1}$ (1½ marks)

Rej. without units.

(ii) heat of solution of barium chloride.

Heat of solution = Hydration energy + lattice energy

$= (+2056 + -2063) = -7\ KJmol^{-1}$

Rej. without units

(c) (i) State **two** factors that can affect the magnitude of enthalpy of hydration. (01 mark)

- ionic charge
- ionic size

(ii) Explain how the factors you have stated in (c) (i) affect the enthalpy of hydration. (04 marks)

Increase in ionic charge of gaseous ions increases hydration energy due to increase in attraction for water molecules by the gaseous ions.

Increase in ionic size of gaseous ions decreases the hydration energy due to decrease in attraction for water molecules by gaseous ions due to increase in distance of separation

Turn Over

13. (a) A compound J contains 19.1% nitrogen, 43.6% oxygen by mass, the rest being manganese.

(i) Calculate the empirical formula of J. (2½ marks)

Percentage of manganese = 100 − (19.1 + 43.6)
= 37.3 % ✓4

Elements:	Mn	N	O
Percentage Composition:	37.3	19.1	43.6
moles:	$\frac{37.3}{54.9}$	$\frac{19.1}{14.0}$	$\frac{43.6}{16.0}$ ✓
	0.6794	1.3643	2.725
mole ratio:	$\frac{0.6794}{0.6794}$	$\frac{1.3643}{0.6794}$	$\frac{2.725}{0.6794}$ ✓4
	1	2	4 ✓

Empirical formula is MnN_2O_4 ✓ ✓

(ii) 10 g of J in 1000 g of water lowered the freezing point of water by 0.127 °C. Determine the molecular formula of J.
(K_f for water = 1.86 °C mol^{-1} kg^{-1}) (02 marks)

89

0.127°c is the depression in freezing point caused by 10g of J ✓
1.86°c is the depression in freezing point caused by $\left(\frac{10}{0.127} \times 1.8\right)$

∴ Molecular mass of J is 146.457g. ✓ = 146.457

(Empirical formula)n = molecular mass

$(MnN_2O_4)n = 146.457$ ✓

$(54.9 + (2 \times 14) + (16 \times 4))n = 146.457$

$n = 0.997 \simeq 1$

Molecular formula = $(MnN_2O_4) \times 1$

∴ Molecular formula is $Mn(NO_2)_2$ ✓

(b) When a few drops of concentrated nitric acid were added to a solution of **J**, followed by a little lead(IV) oxide and the mixture boiled, a purple coloured solution was formed.

Write the;

(i) formula and name of **J**. *(01 mark)*

Formula:

$Mn(NO_2)_2$ ✓ Rej MnN_2O_4

Name:

Manganese (II) Nitrite ✓

(ii) equation for the reaction leading to formation of the purple coloured solution. *(1½ marks)*

~~2MnO~~ Rej wrong symbols.

$2Mn^{2+}_{(aq)} + 4H^{+}_{(aq)} + 5PbO_{2(s)} \longrightarrow 2MnO_{4(aq)}^{-} + 5Pb^{2+}_{(aq)} + 2H_2O$

(c) A few drops of aqueous sodium carbonate was added to a solution of **J**.

(i) State what was observed. *(½ mark)*

Bubbles of a colourless gas ✓

(ii) Write an equation for the reaction that took place. *(1½ marks)*

$Mn^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} + H_2O_{(l)} \longrightarrow Mn(OH)_{2(s)} + CO_{2(g)}$ ✓✓

14. Name a reagent that can be used to distinguish between each of the following pairs of compounds. In each case state what would be observed if each member of the pair was separately treated with the reagent you have named.

(a) C_6H_5CHO and CH_3CHO. *(03 marks)*

Iodine solution and sodium hydroxide solu ✓

C_6H_5CHO – No observable change ✓

CH_3CHO – A yellow precipitate is formed ✓

9

(b) $CH_3CH_2C\equiv CH$ and $CH_3CH_2CH=CH_2$. (03 marks)

Ammonia solution and silver Nitrate solution

$CH_3CH_2C\equiv CH$ — White precipitate is formed.

$CH_3CH_2CH=CH_2$ — No observable change.

Accept: Ammonical silver Nitrate solution

(c) CH_3CHCH_2OH and $CH_3CHCH_2CH_3$. (03 marks)

CH_3 OH

Iodine solution and sodium hydroxide solution

$CH_3CHCH_2CH_3$ — A yellow precipitate is formed.

CH_3CHCH_2OH — No observable change.

CH_3

Accept: Anhydrous Zinc chloride and concentrated hydrochloric acid

15. (a) Briefly explain what is meant by the term **basic buffer**. (02 marks)

A solution which consists of a weak base/alkali and its salt with a strong acid. The solution resists change in pH when a small amount of an acid or alkali/Base is added.

(b) 500 cm^3 of a 1 M solution of ammonia was mixed with 500 cm^3 of a 1 M ammonium chloride solution.

Calculate the ***pH*** of the resultant solution.

(***p**K*$_b$ *of ammonia solution = 4.74*) (05 marks)

$1000cm^3$ of solution contain 1 mole of $NH_{3(aq)}$

$500cm^3$ of solution contain $\left(\frac{1}{1000}\times 500\right) = 0.5$ moles

$1000cm^3$ of solution contain 1 mole of NH_4Cl

$500cm^3$ of solution contain $\left(\frac{1}{1000}\times 500\right)$ 0.5 moles

Total volume $= (500+500) = 1000\,cm^3$.

$\therefore [NH_3] = 0.5\ mol\ dm^{-3}$

$[NH_4Cl] = 0.5\ mol\ dm^{-3}$

$K_b = \frac{[NH_4^+][OH^-]}{[NH_{3(aq)}]}$

Assumption: $[NH_4^+] \simeq [NH_4Cl]$

$10^{-4.74} = \frac{0.5\times[OH^-]}{0.5}$

$[OH^-] = 1.8197\times10^{-5}\ M$

$[OH^-] = \frac{K_w}{[H^+]} = \frac{1\times10^{-14}}{[H^+]} = 1.8$

$[H^+] = 5.4954\times10^{-10}$

$pH = -\log_{10}(5.4954\times10^{-10}) = 9.26$

OR: $pOH = -\log_{10}[OH] = -\log_{10}(1.8197 \times 10^{-5}) = 4.74$

$pH = pKw - pOH = (14 - 4.74) = 9.26$

Accept any other relevant method used.

(c) Two drops of dilute sodium hydroxide solution were added to the resultant solution in (b). State what happened to the ***pH*** of the solution. Give a reason for your answer. *(02 marks)*

The pH remained relatively constant

Reason: The resultant solution is a buffer solution; The excess added hydroxide ions from complete dissociation of sodium hydroxide are neutralised by the large reservior of Ammonium ions (NH_4^+)

16. (a) State **three** properties in which cobalt differs from calcium. *(1½ marks)*

- Cobalt forms complex ions where as calcium doesnt
- Cobalt shows colour transitions in its compounds where as calcium doesnt.
- Cobalt can form compounds of vanable oxidation states

(b) To an aqueous solution containing cobalt(II) ions was added concentrated hydrochloric acid dropwise until in excess.

Name the cobalt species present in the solution;

(i) before addition of hydrochloric acid. *(½ mark)*

Hexaaquacobalt(II) ions

(ii) after addition of excess hydrochloric acid. *(½ mark)*

Tetrachlorocobaltate (II) ions

09

$\times 10^{-5}$

$pH = -\log_{10}[H^+]$

(c) Concentrated ammonia solution was added dropwise until in excess to a solution containing cobalt(II) ions and the mixture allowed to stand.

(i) State what was observed. *(02 marks)*

A pink precipitate, (Accept Blue) which dissolves in excess ammonia solution to form a pale yellow (brown) solution, which turns pink on standing

(ii) Write equation(s) for the reactions that took place. *(4½ marks)*

$[Co(H_2O)_6]^{2+} + 2OH^-_{(aq)} \rightarrow Co(OH)_{2(s)} + 6H_2O$

OR: $Co^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Co(OH)_{2(s)}$

$Co(OH)_{2(s)} + 6NH_{3(aq)} \rightarrow [Co(NH_3)_6]^{2+}_{(aq)} + 2OH^-$

$[Co(NH_3)_6]^{2+}_{(aq)} \rightarrow [Co(NH_3)_6]^{3+} + e^-$

17. (a) A 2% solution of a monomer, **M** has the same osmotic pressure as 11.6 cm^3 of a solution containing 1.65 g of a polymer of molecular mass 1040 at 298 K.

Calculate the relative molecular mass of **M**. *(03 marks)*

From $\pi V = nRT = \frac{m}{Mr}RT$

$\pi = \frac{mRT}{V.Mr} = \left(\frac{1.65 \times 8.314 \times 298}{11.6 \times 10^{-6} \times 1040}\right)$

$\pi = 338,858.9025$ Pa

09

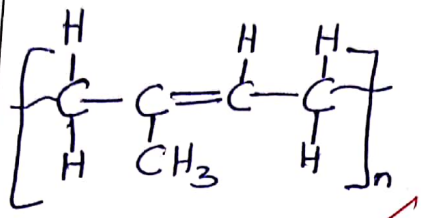
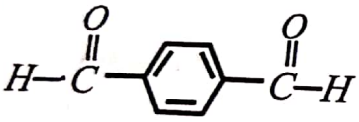
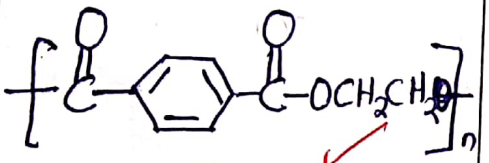
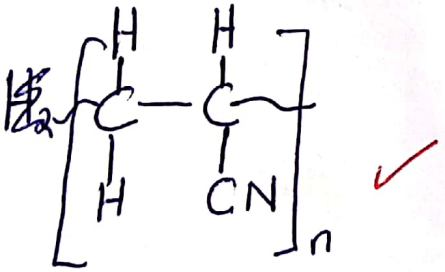
$Mr = \frac{mRT}{\pi V} \Rightarrow m = 2g$; $V = 100 \times 10^{-6}\ m^3$.

$Mr = \left(\frac{2 \times 8.314 \times 298}{338858.9025 \times 100 \times 10^{-6}}\right) = 146g$

∴ Molecular mass of M is 146g.

(b) The structural formulae of some monomers are shown in the table 3. Complete the table by writing in the spaces provided; the structural formula of the polymers formed, type of polymerisation and **one** use of each polymer.

Table 3 *(06 marks)*

Structural formula of monomer (s)	**Structural formula of polymer**	**Type of Polymerisation**	**Use of Polymer**
(i) $CH_2=C(CH_3)-CH=CH_2$		Addition polymensatin ✓	- making of car tyres ✓
(ii) $HOCH_2CH_2OH$ + 		Condensation polymerisatin ✓	making of clothes. ✓
ii) $CH_2=CH-CN$		Addition polymensatin ✓	making of clothes ✓

Accept any other relevant uses

Periodic Table

1	2											3	4	5	6	7	8
1.0 H 1																1.0 H 1	4.0 He 2
6.9 Li 3	9.0 Be 4											10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.2 Ne 10
23.0 Na 11	24.3 Mg 12											27.0 Al 13	28.1 Si 14	31.0 P 15	32.1 S 16	35.4 Cl 17	40.0 Ar 18
39.1 K 19	40.1 Ca 20	45.0 Sc 21	47.9 Ti 22	50.9 V 23	52.0 Cr 24	54.9 Mn 25	55.8 Fe 26	58.9 Co 27	58.7 Ni 28	63.5 Cu 29	65.7 Zn 30	69.7 Ga 31	72.6 Ge 32	74.9 As 33	79.0 Se 34	79.9 Br 35	83.8 Kr 36
85.5 Rb 37	87.6 Sr 38	88.9 Y 39	91.2 Zr 40	92.9 Nb 41	95.9 Mo 42	98.9 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 TI 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
223 Fr 87	226 Ra 88	227 Ac 89															

139 La 57	140 Ce 58	141 Pr 59	144 Nd 60	147 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	162 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71
227 Ac 89	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pu 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	256 Md 101	254 No 102	260 Lw 103