PART 1 (60 marks = 30% of paper)

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided. Each question in this part is worth 2 marks.

1	**B**	11	**D**	21	**D**
2	**B**	12	**B**	22	**A**
3	**A**	13	**C**	23	**C**
4	**D**	14	**B**	24	**A**
5	**A**	15	**C**	25	**C**
6	**A**	16	**D**	26	**C**
7	**C**	17	**B**	27	**D**
8	**C**	18	**C**	28	**C**
9	**C**	19	**D**	29	**D**
10	**D**	20	**C**	30	**C**

END OF PART 1

PART 2 (70 marks = 35% of paper)

Answer ALL questions in Part 2 in the spaces provided below.

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1. Write equations for any reactions that occur in the following procedures. If no reaction occurs, write 'no reaction'.

   In each case describe in full what you would observe, including any: colours; odours; precipitates (give the colour); or gases evolved (give the colour or describe as colourless). If a reaction occurs but the change is not visible, then you should state this.

(a) Solid potassium carbonate is added to excess nitric acid.

Equation **$K_2CO_{3(s)} + 2\ H^+_{(aq)} \rightarrow 2\ K^+_{(aq)} + H_2O_{(l)} + CO_{2(g)}$** ✓✓

Observation **A white solid dissolves forming a colourless solution <u>and</u> an odourless, colourless gas evolves *(must have both)*** ✓

(b) Dilute sulfuric acid is added to barium chloride solution.

Equation **$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$** ✓✓

Observation **Two colourless solutions are mixed forming a white precipitate** ✓

(c) Nickel(II) oxide is added to an ethanoic acid solution.

Equation **$NiO_{(s)} + 2\ CH_3COOH_{(aq)} \rightarrow Ni^{2+}_{(aq)} + 2\ CH_3COO^-_{(aq)} + H_2O_{(l)}$** ✓✓

Observation **A grey (green acceptable) solid dissolves forming a green solution** ✓

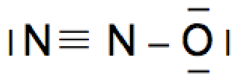
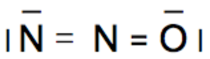
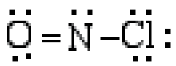
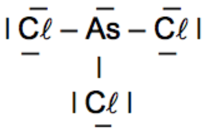
(d) A piece of sodium is added to ethanal.

Equation **No reaction** ✓✓

Observation **No visible reaction** ✓

(12 marks)

2. For each species listed in the table below draw the structural formula, representing all valence shell electron pairs either as : or –.

Species	*Structural formula*	*Shape*	*Polarity*
N_2O (NNO)	 **or**  ✓✓	**Linear** ✓	**Polar** ✓
ONCl	 ✓✓	**Bent** ✓	**Polar** ✓
$AsCl_3$	 ✓✓	**Trigonal pyramidal** ✓	**Polar** ✓

(12 marks)

3. Identify the most important forces of attraction in determining the melting point of the following solids:

(a) NH_4Cl **Ionic bonds** ✓

(b) SO_3 **Dispersion forces** ✓

(c) CH_3NH_2 **Hydrogen bonds** ✓

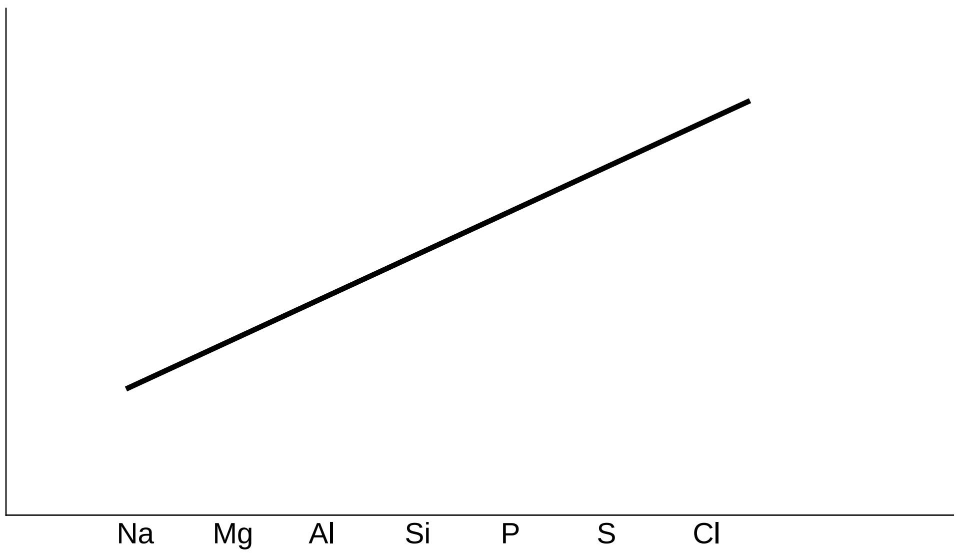
(d) SiC **Covalent bonds** ✓

(4 marks)

4. Sketch graphs that depict the following trends:

(a) Electronegativity of the period 3 elements

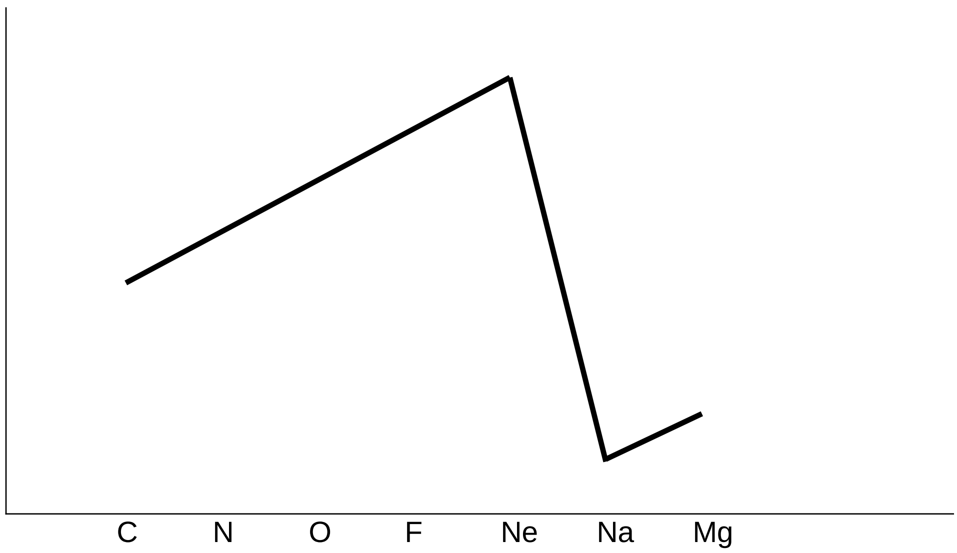
Electronegativitiy



✓ (1 mark)

(b) First ionisation energies of elements carbon to magnesium.

First ionisation energy



✓ 'peak' at Ne, ✓ 'trough' at Na (2 marks)

5. Account for the trend in solubility in water for the following alcohols:

Alcohol	*Solubility (g/100g water at 20ºC)*
methanol	miscible in all proportions
ethanol	miscible in all proportions
1-propanol	miscible in all proportions
1-butanol	8.14
1-pentanol	2.64
1-hexanol	0.59
1-heptanol	0.09

Methanol → propanol

Miscible in all proportions because the hydrogen bonds formed between these alcohols and water are similar in strength to that between water molecules and between the alcohol molecules.

✓✓

Butanol → heptanol

Decreasing solubility with increasing chain length because the dispersion forces that form between the hydrocarbon 'tail' and water molecules are much weaker than the hydrogen bonds between water molecules (and dispersion forces between larger alcohols).

✓✓

(4 marks)

6. (a) Use the numbers 1 to 6 to rank the following molecules from highest boiling point (1) to lowest boiling point (6)

Name	*Molar mass ($g\ mol^{-1}$)*	*Rank*
butane, $CH_3CH_2CH_2CH_3$	58.1	**5**
ethanoic acid, CH_3COOH	60.1	**1**
methylpropane, $CH_3CH(CH_3)CH_3$	58.1	**6**
propanal, CH_3CH_2CHO	58.1	**4**
1-propanol, $CH_3CH_2CH_2OH$	60.1	**2**
2-propanol, $CH_3CH(OH)CH_3$	60.1	**3**

1/2 each (3 marks)

(b) Account for the difference in boiling point between propanal and 1-propanol.

Both have a similar molecular mass and shape, therefore similar dispersion forces ✓

1-propanol - hydrogen bonding; propanal - dipole-dipole forces ✓

Since hydrogen bonding is stronger more energy is required to overcome intermolecular forces, therefore 1-propanol has the higher boiling point. ✓

(3 marks)

7. Consider the following information:

Compound **A**, a colourless liquid with formula C_3H_8O, reacts with concentrated phosphoric acid to give compound **B**, with formula C_3H_6, which rapidly discolours a solution of bromine water.

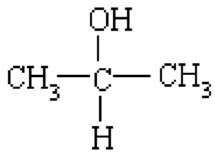
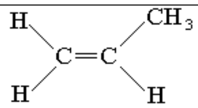
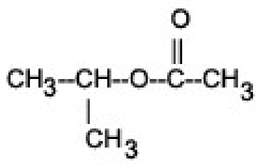
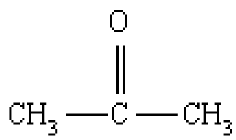
When a piece of sodium is added to compound **A** an odourless, colourless gas evolves.

When compound **A** is treated with concentrated ethanoic acid compound **C**, a sweet smelling liquid with formula $C_5H_{10}O_2$, is formed.

When compound **A** is completely oxidised by reaction with acidified potassium dichromate compound **D**, with formula C_3H_6O, is formed.

When a piece of sodium is added to compound **D**, there is no visible reaction.

(a) Draw structural formula and give IUPAC names for the following:

Compound	*Structural formula*	*IUPAC name*
A		**2-propanol**
B		**propene**
C		**2-propyl ethanoate**
D		**propanone**

✓ **each** (8 marks)

(b) (i) Write an equation for the reaction of compound **A** with sodium.

$$\mathbf{2\ (CH_3)_2CHOH\ +\ 2\ Na\ \rightarrow\ 2\ (CH_3)_2CHO^{-}Na^{+}\ +\ H_2}$$ ✓✓

(ii) Name the organic product of the reaction.

sodium 2-propoxide ✓

(3 marks)

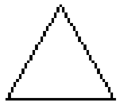
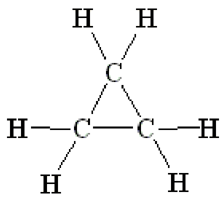
(c) (i) Write an equation for the reaction of compound **B** with a solution of bromine water.

CH_3CHCH_2 + Br_2 → $CH_3CHBrCH_2Br$ ✓✓

(ii) Name the organic product of the reaction.

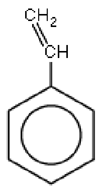
1,2-dibromopropane ✓

(iii) Name and sketch an isomer of compound **B**, which would not rapidly discolour a solution of bromine water.

cyclopropane ✓  **or**  ✓

(5 marks)

8. The structure of styrene is:

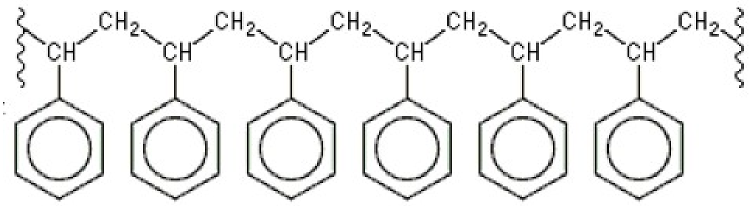


(a) Name type of polymer that styrene will form.

Addition polymer ✓

(1 mark)

(b) Sketch a section of polystyrene with at least three monomer units.



✓✓

(2 marks)

9. Ammonium carbamate (NH_4OCONH_2) decomposes forming ammonia and carbon dioxide, according to the following equilibrium:

$$NH_4OCONH_{2(s)} \rightleftarrows 2\,NH_{3(g)} + CO_{2(g)} \qquad \Delta H = -450 \text{ kJ mol}^{-1}$$

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

$K = [NH_3]^2.[CO_2]$ ✓

(1 mark)

(b) Three vessels contain an equilibrium mixture of this system, each of which is subjected to one of the changes described below. In each case, describe the effect of the change on:
- the rate of the forward reaction (increase, decrease, no change)
- the mass of CO_2 (increase, decrease, no change)
- the value of the equilibrium constant, K (increase, decrease, no change)

once equilibrium has been re-established.

Vessel	*Change*	*Forward reaction rate*	*Mass of CO_2*	*Value of K*
1	Increase in temperature	↑	↓	↓
2	Addition of neon gas at constant volume	–	–	–
3	Increase in volume at constant temperature	–	↑	–

✓ **each** (9 marks)

END OF PART 2

PART 3 (50 marks = 25% of paper)

Answer ALL questions in Part 3. The calculations are to be set out in detail in this Question/Answer booklet. Marks will be allocated for correct equations and clear setting out, even if you cannot complete the problem. When questions are divided into sections, clearly distinguish each section using (a), (b), and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information that may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you do not, you will lose marks.

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1. **(a)** $Ca^{2+}_{(aq)} + C_2O_4^{2-}{}_{(aq)} \rightarrow CaC_2O_{4(s)}$ ✓✓

(b) **$n(CaC_2O_4)$ = m/M = 0.937 / 128.1 = 0.007315 mol** ✓

$n(CaCO_3) = n(Ca^{2+}) = n(CaC_2O_4)$ = 0.007315 mol ✓

$m(CaCO_3)$ = n.M = 0.007315 x 100.09 = 0.7321 g ✓

$\%(CaCO_3)$ = 0.7321 / 1.42 = <u>51.6%</u> ✓

(c) **n(HCl) = n(H+) = 2 x $n(CaCO_3)$ = 0.01463 mol** ✓

V(HCl) = n/c = 0.01463 / 0.200 = <u>0.0731 L or 73.1 mL</u> ✓

2. **(a)** **$m(Fe_2O_3)$ = 25 x 10^6 g x 87/100 = 21.75 x 10^6 g** ✓

$n(Fe_2O_3)$ = m/M = 21.75 x 10^6 / 159.7 = 1.362 x 10^5 mol ✓

n(CO) = PV/RT = (110 x 1.53 x 10^7) / (8.315 x 750)
= 2.699 x 10^5 mol ✓

n(CO) required = 3 x n(Fe_2O_3) = 4.086 x 105 mol > actual ✓

Therefore, <u>CO is limiting</u>. ✓

(b) **n(Fe) = 2/3 n(CO) = 1.800 x 10^5 mol** ✓

m(Fe) = n.M = 1.800 x 10^5 x 55.85 = <u>1.00 x 10^7 g</u> ✓

or <u>10.0 tonnes</u>

3. **(a)** $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$ ✓

(b) $n(OH^-) = n(NaOH) = c.v = 0.150 \times 0.0920 = 0.01380$ mol ✓

$n(H^+) = n(OH^-) = 0.01380$ mol ✓

$[H^+] = n/V = 0.01380 / 0.0250 = \underline{0.552 \text{ mol L}^{-1}}$ ✓

(c) $Ba^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow BaSO_{4(s)}$ ✓

(d) $n(BaSO_4) = m/M = 1.56 / 233.36 = 0.006685$ mol ✓

$n(H_2SO_4) = n(SO_4{}^{2-}) = n(BaSO_4) = 0.006685$ mol ✓

Therefore, $[H_2SO_4] = n/V = 0.006685 / 0.0500 = \underline{0.134 \text{ mol L}^{-1}}$ ✓

(e) $[H^+]_{H2SO4} = 2 \times [H_2SO_4] = 0.267$ mol L^{-1} ✓

$[HNO_3] = [H^+]_{HNO3} = 0.552 - 0.267 = \underline{0.285 \text{ mol L}^{-1}}$ ✓

4. **(a)** $m(MnO_2) = 2.00 \times 10^6 \times 73/100 = 1.46 \times 10^6$ g ✓

$n(MnO_2) = m/M = 1.46 \times 10^6 / 86.94 = 16\,790$ mol ✓

Assuming 100% efficiency:

$n(Mn) = n(MnO_2) = 16\,790$ mol ✓

$m(Mn) = n.M = 16970 \times 54.94 = 9.226 \times 10^5$ g ✓

Taking into account efficiency:

$m(Mn) = 9.226 \times 10^5 \times 83/100 \times 94/100 = \underline{7.20 \times 10^5 \text{ g}}$ ✓✓

or $\underline{0.720 \text{ tonnes}}$

(b) **Assuming 100% efficiency:**

$n(O_2) = 1/3\ n(MnO_2) = 5597$ mol ✓

$V(O_2) = nRT/P = (5657 \times 8.315 \times 773.1) / 105 = 3.426 \times 10^5$ L ✓

Taking into account efficiency:

$V(O_2) = 3.426 \times 10^5 \times 83/100 = \underline{2.84 \times 10^5 \text{ L}}$ ✓

(c) $n(Mn) = m/M = 7.20 \times 10^5 / 54.94 = 13100$ mol

Assuming 100% efficiency:

$n(Al) = 5/9\ n(Mn) = 11650$ mol ✓

$m(Al) = n.M = 11650 \times 26.98 = 3.14 \times 10^5$ g ✓

Taking into account efficiency:

$m(Al) = 3.14 \times 10^5 \times 100/94 = \underline{3.34 \times 10^5 \text{ g}}$ ✓

or $\underline{0.334 \text{ tonnes}}$

5. **(a)** **n(C) = n(CO_2) = m/M = 7.48 / 44.01 = 0.1693 mol**

m(C) = n.M = 0.1693 x 12.01 = 2.033 g

%(C) = 2.033 / 5.00 x 100 = 40.66% ✓✓

n(H) = 2 x n(H_2O) = 2 x m/M = 2 x 2.77 / 18.016 = 0.3075 mol

m(H) = n.M = 0.3075 x 1.008 = 0.3100 g

%(H) = 0.3100 / 5.00 x 100 = 6.20% ✓✓

n(N) = n(NO_2) = m/M = 0.938 / 46.01 = 0.02039 mol

m(N) = n.M = 0.02039 x 14.01 = 0.2856 g

%(N) = 0.2856 / 3.00 x 100 = 9.52% ✓✓

%(O) = 100 - %(C) - %(H) - %(N) = 43.62% ✓

$$\mathbf{C : H : N : O}$$

$$\frac{40.66}{12.01} : \frac{6.20}{1.008} : \frac{9.52}{14.01} : \frac{43.62}{16}$$

$$\frac{3.39 : 6.15 : 0.680 : 2.73}{0.680}$$

$$4.98 : 9.04 : 1 : 4.01$$

Therefore, EF = $C_5H_9NO_4$ ✓

(b) **In 20.0 mL:**

n(OH^-) = c.v = 0.5 x 0.0248 = 0.0124 mol

n(H^+) = n(OH^-) = 0.0124 mol ✓

n(glutamic acid) = 1/2 n(H^+) = 0.00620 mol ✓

m(glutamic acid) = 4.56 x 20/100 = 0.912 g ✓

M(glutamic acid) = m/n = 0.912 / 0.00620 = 147.1 g mol^{-1} ✓

EFM = 147.132, therefore MF = EF = $C_5H_9NO_4$ ✓

END OF PART 3

PART 4 (20 marks = 10% of paper)

Points to be mentioned:

Preparation : Equilibrium and Rates principles

Conditions used	reasons
Temperature of 300ºC : a compromised temperature	Rate : this high temperature will increase rate of reaction : More collisions – KE inc; vel inc; collisions inc More molecules now have the required Act Eng. Yield : Since reaction is exothermic, an increase in temp. would favour the reverse reaction [the endo reaction] so yield suffers. Therefore 300ºC : compromise
Pressure of 60-70 atm	Rate will increase with this pressure since there will be more collisions. Yield will also increase since acc. to LCP the reaction will shift to side with less gas molecules [product]. The pressure used is not that high since there is a possibility of loss of ethane due to polymerization and also reduce cost of building very high Press Equipment
Catalyst : H_3PO_4	This increases the rate of reaction by lowering the act. Eng so now more molecules have the required E_a. However cat. Has no effect on yield.
< 1 vol steam	Although ratio of reactants are 1:1 less steam is used since it interferes with the catalyst.

Physical and Chemical Properties

Soluble in H_2O	Both are CMLiquids, both are polar and both have H-Bond as their intermolecular forces. So solute-solvent interactions are favourable
Boiling point	Unusually high since ethanol is CMLiquid, polar molecule and has H-Bond as its intermolecular forces.
+ Na	$2CH_3CH_2OH + 2 Na = H_2 + 2 CH_3CH_2O^-Na^+$; reacts spontaneously with reactive metals to give $H_2(g)$
+ O_2	Very good fuel; reacts with O_2 to give CO_2 and H_2O $CH_3CH_2OH + 3 O_2 = 2 CO_2 + 3 H_2O$ + heat
+ carboxylic acids :	Forms esters with acids $CH_3CH_2OH + CH_3COOH = H_2O + CH_3COOCH_2CH_3$
oxidation	With MnO_4^-/H^+ and $Cr_2O_7^{2-}/H^+$ it forms aldehyde CH_3CHO and then with excess CH_3COOH