SINGAPORE CHINESE GIRLS' SCHOOL
Preliminary Examination
Secondary Four

CANDIDATE NAME							
CLASS	4			REGISTER NUMBER			
CENTRE NUMBER					INDEX NUMBER			

CHEMISTRY

6092/02

Paper 2 Theory

20 August 2024

1 hour 45 minutes

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Answer **all** questions in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page 20.

The use of an approved scientific calculator is expected, where appropriate.

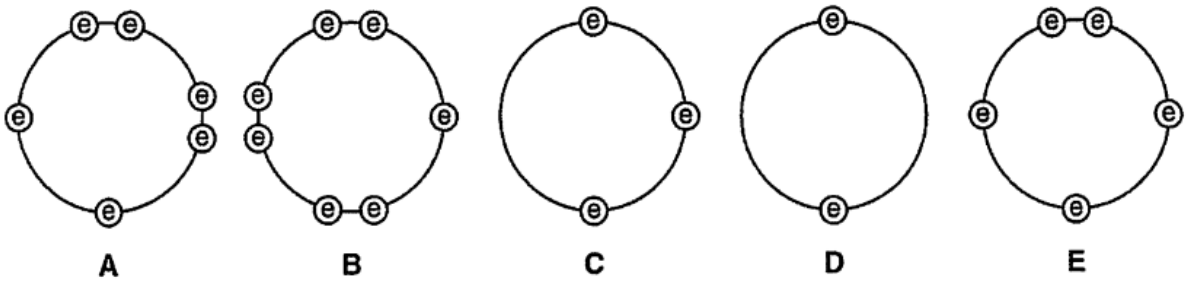
For Examiner's Use	
Section A	/70
Section B	/10
Total	/80

This question paper consists of 20 printed pages.

Section A

Answer **all** questions

1 These diagrams show the electron arrangement in the outer shells of five elements, **A** to **E**. All elements are from Period 3 of the Periodic Table.



Use the letters **A** to **E** to answer the following questions.
You may use each letter once, more than once or not at all.

(a) Which elements are most likely to be non-metals?

A, B, E ..... [1]

(b) Which elements can act as reducing agents?

C, D ..... [1]

(c) Which element has an atomic number of 16?

A ..... [1]

(d) Which element will form three covalent bonds when it forms compounds?

E ..... [1]

(e) Which two elements will form a compound with the formula of the type YZ_2?

D and B / A and B ..... [1]

(f) Which element will form an oxide that reacts with both acids and bases?

C ..... [1]

[Total: 6]

2 Ethylamine, $CH_3CH_2NH_2$, behaves similarly to ammonia in terms of its chemical properties. The equation below shows what happens when ethylamine is dissolved in water.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$

(a) According to the Brønsted-Lowry theory, an acid is defined as a species that can donate protons (H^+), while a base is a species that can accept protons.

Based on the Brønsted-Lowry theory and the given equation, explain whether ethylamine acts as an acid or a base.

Ethylamine acts as a base as it accepts a proton from water.

.....[1]

(b) The pH scale is a method to measure the acidity or alkalinity of a substance. Predict the pH of an aqueous solution of ethylamine.

8–11 .....[1]

(c) Explain, in terms of structure and bonding, why ethylamine has a low boiling point.

Only a small amount of energy is required to overcome the weak intermolecular forces of attraction [1] in ethylamine's simple molecular structure. [1]

.....[2]

(d) A student conducted an experiment to measure the electrical conductivity of an aqueous solution of sodium hydroxide and an aqueous solution of ethylamine.

Predict and explain which solution will be a better electrical conductor.

NaOH [1] will be a better electrical conductor as it is a strong base that is fully ionised to produce more mobile ions [1].

.....[2]

(e) Ethylamine can react with acids to form a salt. For example, ethylamine reacts with hydrochloric acid according to the equation below:

$$CH_3CH_2NH_2 + HCl \rightarrow CH_3CH_2NH_3Cl$$

Deduce the formula of the salt formed when ethylamine reacts with sulfuric acid.

$(CH_3CH_2NH_3)_2SO_4$ .....[1]

[Total: 7]

3 Nitrogen oxides in the upper atmosphere cause damage to the ozone layer. Aircraft engines are one source of nitrogen oxides.

(a) (i) Explain how nitrogen oxides are formed in the engine of an aircraft.

At the **high** operating **temperature** of an aircraft engine, **nitrogen** and **oxygen** from **air** react to form nitrogen oxides. [1]

(ii) Give one **natural** source of nitrogen oxides in the atmosphere.

Lightning activity [1]

(b) Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two-step reaction.

$NO + O_3 \rightarrow NO_2 + O_2$ step 1
$NO_2 + O_3 \rightarrow NO + 2O_2$ step 2

(i) Use oxidation states to identify which element is **oxidised** in step 1.

element N [1]

change in oxidation state +2 to +4 [1] [2]

(ii) Write the equation for the overall reaction between nitrogen monoxide and ozone.

$2O_3 \rightarrow 3O_2$ [1] [1]

(iii) Hence, state the role of NO in the reaction.

Catalyst [1] [1]

(c) Nitrogen oxides are removed from car exhaust emissions with the aid of the platinum catalyst within catalytic converters.
In a converter, nitrogen monoxide reacts with carbon monoxide.

(i) Briefly explain why carbon monoxide is harmful to humans.

CO binds irreversibly / binds more readily to haemoglobin in blood and **reduces the ability of blood to transport oxygen** in the body. [1] [1]

(ii) Explain, in terms of colliding particles, how the presence of the platinum catalyst speeds up the reaction between nitrogen monoxide and carbon monoxide.

The catalysts on a catalytic converter **lower the activation energy of the reaction** by providing an **alternative reaction pathway** [1]. More particles possess energy greater than or equal to activation energy, resulting in a **higher frequency of effective collisions**. [1] [2]

(iii) Cars fitted with catalytic converters still give out environmentally harmful gases. Name one environmentally harmful gas that is emitted in large amounts and describe the problem it causes.

Carbon dioxide is emitted in large quantities, which leads to **global warming** and causes the melting of polar ice caps and flooding of low-lying areas. [1]

[Total: 10]

4 Cobalt can be extracted from one of its ores, linnaeite (a cobalt sulfide compound containing traces of other metal compounds), through a 3-stage process.

Stage 1:

The ore is roasted to form a mixture of metals and metal oxides. The mixture is then heated with dilute sulfuric acid. Copper metal and an aqueous mixture of the sulfates of cobalt and other metals are formed.

↓

Stage 2:

Sodium hypochlorite (NaOC*l*) is then added to the aqueous mixture leading to the formation of cobalt(III) hydroxide.

$2Co^{2+}(aq) + NaOCl(aq) + 4OH^{-}(aq) + H_2O(l) \rightarrow 2Co(OH)_3(s) + NaCl(aq)$

↓

Stage 3:

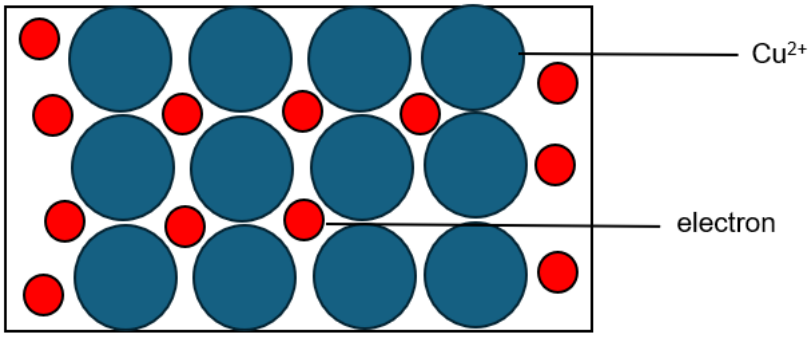
Cobalt(III) hydroxide is decomposed to form cobalt(III) oxide and steam. The cobalt(III) oxide is further reduced by carbon to form cobalt metal.

(a) (i) Why is copper metal left after treating with sulfuric acid in **Stage 1**?

Copper is **unreactive** and **does not react with acids**. [1]

..... [1]

(ii) Draw a labelled diagram in the box below to show the structure of copper metal.



[1]

(iii) A sample of cobalt sulfide contain 58% of cobalt and 42% by mass of sulfur. Determine the empirical formula of the cobalt sulfide.

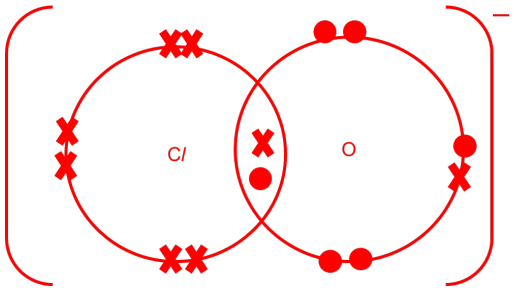
element	Co	S
Percentage by mass / %	58	42
Number of moles in 100 g / mol	0.9831	1.313
Mole ratio	3	4

empirical formula Co_3S_4 ..... [2]

(b) (i) Explain using oxidation states whether sodium hypochlorite is an oxidising agent or reducing agent in **Stage 2**.

It is an oxidising agent as it was reduced. The oxidation number of chlorine decreased from +1 in NaOC*l* to –1 in NaC*l* / Cobalt has been oxidised as the oxidation number of cobalt increased from +2 in Co^{2+} to +3 in $Co(OH)_3$. [2]

(ii) Draw a dot and cross diagram for the hypochlorite ion, $C\mathit{l}O^-$. It has a single bond between the chlorine atom and oxygen atom.
Show outer electrons only.



[2]

(c) State how cobalt(III) hydroxide can be separated from the reaction mixture after **Stage 2** is completed.

Filtration. [1]

(d) Write chemical equations for the two reactions occurring in **Stage 3**.

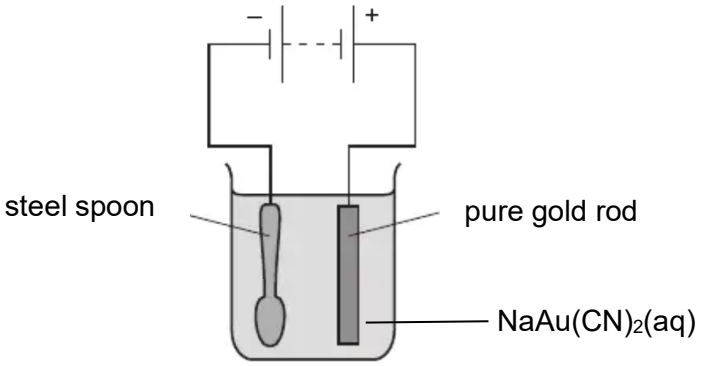
$2Co(OH)_3 \rightarrow Co_2O_3 + 3H_2O$ [1]

$2Co_2O_3 + 3C \rightarrow 4Co + 3CO_2$ [1] / $Co_2O_3 + 3C \rightarrow 2Co + 3CO$ [2]

[Total: 11]

5 Electroplating is the process of using an electrical current to deposit a thin layer of metal onto an object. An example of electroplating is gold-plating.

During an experiment to gold-plate a spoon, the apparatus was set up as shown below:



Aqueous sodium dicyanoaurate, $NaAu(CN)_2$, dissociates in water to form sodium ions, gold ions, and cyanide ions (CN^-).

(a) Give the formula of all the ions that are attracted to the cathode, after aqueous $NaAu(CN)_2$ dissociates.

H^+, Na^+, Au^+. [1]

(b) **(i)** Gold is deposited at the cathode. Write the half-equation for the reaction at the cathode.

H^+, Na^+, Au^+. [1]

(ii) Explain why gold ions are selectively discharged at the cathode.

$Au^+ + e^- \rightarrow Au$ [1]

[1]

(c) A student measures the concentration of the $NaAu(CN)_2$ electrolyte before and after the gold-plating experiment. Predict and explain the results that the student will obtain.

The concentration remains the same. [1] The rate at which Au^+ is reduced at the cathode is equal to the rate at which the Au is ionising to form Au^+. [1]

[2]

(d) In a separate experiment, the gold electrode was replaced with graphite. Describe and explain a difference in observation during this experiment, compared to the experiment using the gold electrode. Include an equation in your explanation.
You may assume that CN^- ions are inert and do not take part in the reaction.

The anode does not dissolve, but instead an effervescence of O_2 gas is observed at the anode. [1] As the graphite anode does not undergo oxidation unlike the Au anode, OH^- ions are discharged to form O_2 instead. [1] $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ [1]

[3]

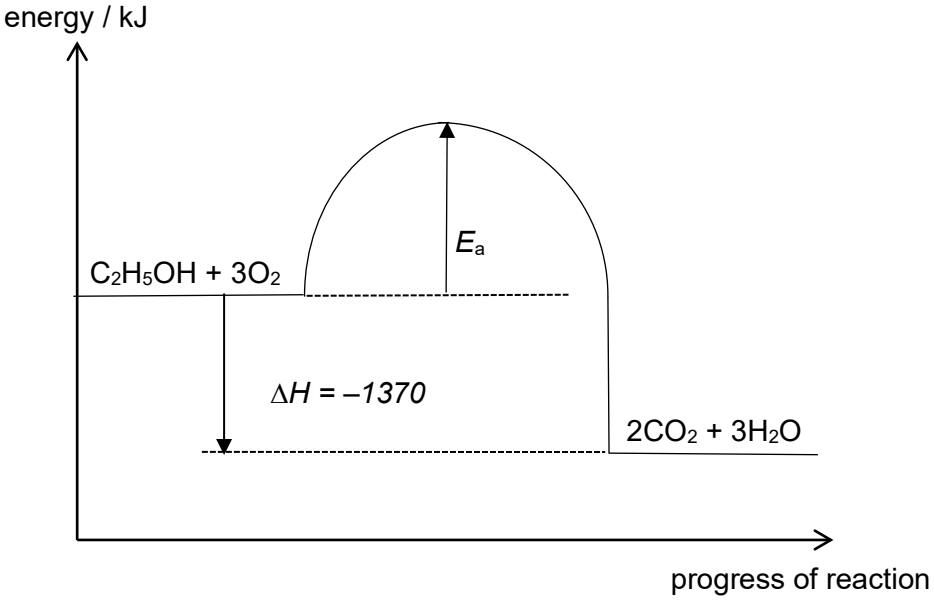
[Total: 8]

6 The combustion of ethanol or hydrogen releases energy. This enables them to be used as fuel.

(a) The complete combustion of ethanol is represented by the following equation.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \qquad \Delta H = -1370 \text{ kJ per mole of } C_2H_5OH$$

(i) Complete the energy profile diagram below for the combustion of ethanol.
Your diagram should include labels for the reaction enthalpy change and activation energy.



[2]

(ii) Explain, in terms of bond breaking and bond making, why this reaction is exothermic.

More energy is released during bond formation in CO_2 and H_2O [1], compared to the energy absorbed during bond breaking in C_2H_5OH and O_2, [1] hence there is a net release of energy to the surroundings, causing a rise in temperature. [2]

(b) The complete combustion of hydrogen is represented by the following equation.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Use the bond energies given in the table below to calculate the energy released on burning **1 mole** of hydrogen.

bond	bond energy / kJ mol^{-1}
H–H	436
O=O	496
O–H	460

Energy change = 2(436) + 496 – 4(460) [1] = –472 kJ/mol

Energy released per mole of H_2 = 472 ÷ 2 = 236 kJ/mol [1]

Energy released = ……236 kJ/mol…… [2]

(c) Calculate the energy released when:

(i) 1 g of hydrogen is burned in excess oxygen.

energy released = 236 ÷ 2 = 118 kJ

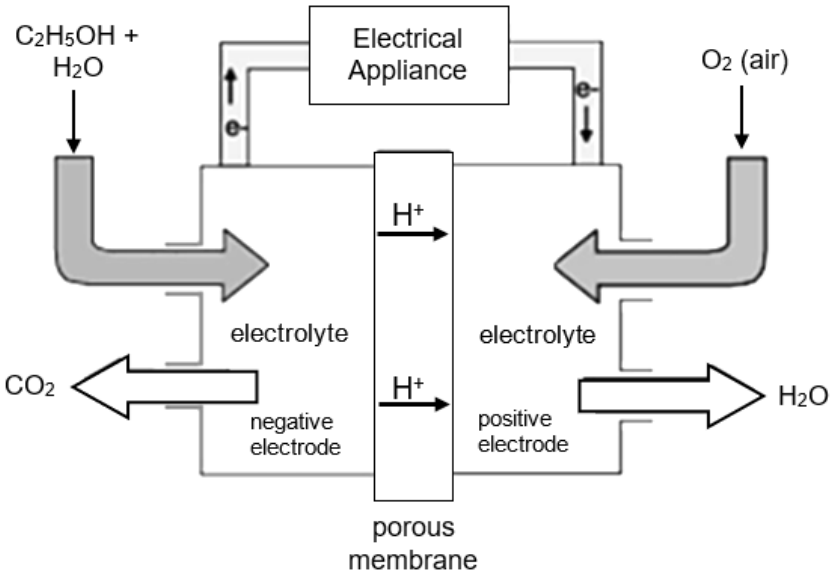
Energy released = 118 kJ [1]

(ii) 1 g of ethanol is burned in excess oxygen.

energy released = 1370 ÷ 46 = 29.8 kJ (3 s.f.)

Energy released = 29.8 kJ (3 s.f.) [1]

(d) Hydrogen and ethanol can also be used in fuel cells to power electric cars. The figure below shows a direct ethanol fuel cell (DEFC).



The half-equation for the DEFC at the negative electrode is:

$$C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$$

(i) With reference to the diagram, what would be the half-equation at the positive electrode in a DEFC?

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ [1]

(ii) Write the overall equation for the reaction occurring in a DEFC.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ [1]

[Total: 10]

7 This question is about the chemistry of group 17 elements. Group 17 elements are also known as halogens or "salt-producers", based on their ability to form salts with sodium. Table 7.1 below shows some information regarding the size of the halogen atoms, also known as the atomic radius.

Table 7.1

element	**atomic radius / x 10^{-12} m**
fluorine	42
chlorine	79
bromine	94
iodine	140

Group 17 elements have the ability to gain electrons during chemical reactions. One method of measuring how readily elements gain electrons is by measuring their standard electrode potential ($E^{\ominus}$). $E^{\ominus}$ is measured in volts (V) and the more positive the $E^{\ominus}$ value, the greater the tendency of a species to gain electrons. $E^{\ominus}$ is represented by half-equations showing the gain of electrons of the respective species. The $E^{\ominus}$ of some of the halogens are shown in Table 7.2 below.

Table 7.2

element	**$E^{\ominus}$ / V**
$F_2 + 2e^- \rightarrow 2F^-$	+2.87
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+1.36
$Br_2 + 2e^- \rightarrow 2Br^-$	
$I_2 + 2e^- \rightarrow 2I^-$	+0.54

The melting points of some salts formed from group 17 elements are shown in Table 7.3 below.

Table 7.3

salt	**melting point / °C**
sodium fluoride	993
sodium iodide	661
magnesium fluoride	1263

Melting an ionic compound involves overcoming the ionic bonds present between the ions. One way of measuring the strength of the ionic bonds in ionic compounds is to compare their Lattice Energy (*L.E.*). The *L.E.* of ionic compounds can be determined by the formula:

$$L.E. \; \alpha \; \frac{q^+ \times q^-}{r^+ + r^-}$$

where q^+ is the charge of the cation

q^- is the charge of the anion

r^+ is the radius of the cation

r^- is the radius of the anion

α is the mathematical symbol for "proportionate to"

Besides reacting with metals to form salts, group 17 elements react with hydrogen to form hydrogen halides. The bond energies of the hydrogen-halogen bond of some hydrogen halides are shown below in Table 7.4.

Table 7.4

bond	bond energy / kJ mol^{-1}
H–F	562
H–C*l*	431
H–Br	366
H–I	299

The hydrogen halides can dissolve in water to form aqueous acids. The acids produced can then undergo dissociation according to the general equation:

$$HX(aq) \rightleftharpoons H^+(aq) + X^-(aq) \qquad \text{where X = F, C}l\text{, Br, or I}$$

During the dissociation of the acids, the H–X bond is broken in the process.

The strength of an acid can be quantified by the acid dissociation constant, K_a. The larger the magnitude of K_a, the stronger the acid. Table 7.5 shows the K_a values of some aqueous acids formed from hydrogen halides:

Table 7.5

aqueous acid	K_a / mol dm^{-3}
HF(aq)	6.6×10^{-4}
HC*l*(aq)	1.4×10^{6}
HBr(aq)	1.0×10^{9}
HI(aq)	3.2×10^{9}

(a) Describe and explain the trend in atomic radius shown in Table 7.1.

The atomic radius **increases down the group** [1] due to an **increase in the number of electron shells**. [1]

[2]

(b) **(i)** The $E^\ominus$ value for bromine is not given in Table 7.2. State a possible $E^\ominus$ value for bromine.

any value between **+**0.55 and **+**1.35 V [1]

(ii) Hence or otherwise, arrange the group 17 elements shown in Table 7.2 based on their strength as oxidising agents, starting with the strongest oxidising agent first.

$F_2 > Cl_2 > Br_2 > I_2$ [1]

(c) Use suitable information provided in the question to explain the differences in melting points of the salts shown in Table 7.3.

The melting point of NaI is lower than NaF due to the larger radius of I^- which decreases the magnitude of the L.E. [1]. The melting point of MgF_2 is higher than NaF as Mg^{2+} has a higher charge than Na^+. [1]

[2]

(d) Describe the trend in the strength of the aqueous acids shown in Table 7.5.
Use data from Table 7.4 to suggest an explanation for the trend.

The strength of the acids **increase from HF<HCl<HBr<HI**. [1] This is due to the decreasing strength of the H-X bonds, exemplified by the **decrease in B.E.** from H-F to H-I shown in table 7.4. Thus, **the extent of dissociation increases** / as **less energy is required to break the H-X bond**. [1] [2]

The aqueous acids in Table 7.5 can be reacted with magnesium metal to liberate hydrogen gas. 50 cm^3 of 0.1 mol/dm^3 HBr(aq) was reacted with excess magnesium at room temperature and pressure. The volume of gas evolved over time is plotted in **Figure 7.1** below:

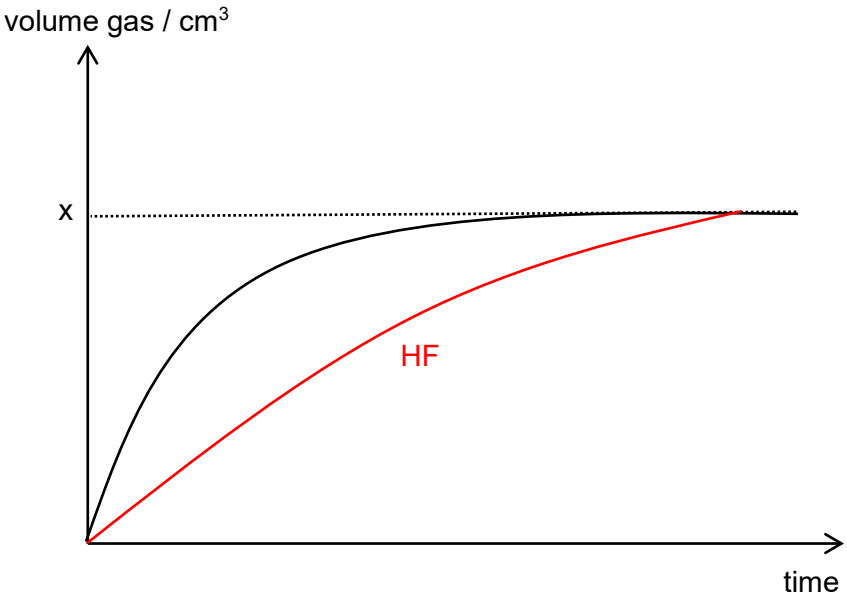


Figure 7.1

(e) **(i)** Calculate the volume of hydrogen produced, x, shown in **Figure 7.1**.

$Mg + 2HBr \rightarrow MgBr_2 + H_2$

No. of moles of HBr = (50/1000) x 0.1 = 0.005 mol [1]

Volume of H_2, x = (0.005/2) x 24000 = 60 cm^3 [1]

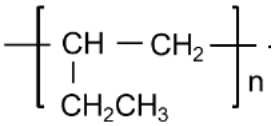
[2]

(ii) Sketch, on **Figure 7.**1, the graph that would be obtained for the reaction between 50 cm^3 of 0.1 mol/dm^3 HF(aq) and excess magnesium, assuming all other conditions remain the same. Label your graph as HF. [1]

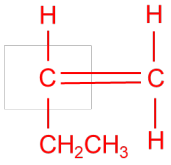
[Total: 11]

8 A company manufactures polymers. It sells one of its polymers under the trade name of "*PB-1*".

The table shows some information about *PB-1*. The term "softening temperature" is used for materials that have no definite melting point.

structure	molecular mass	softening temperature
	5600	115 °C

(a) (i) Draw the structural formula of the monomer used to make *PB-1*.



[1]

(ii) Name this monomer.

Butene. .....[1]

(iii) What type of polymerisation occurs when *PB-1* forms from its monomers?

Addition polymerisation .....[1]

(b) The company sells two types of *PB-1*.

The polymer in the table is low molecular mass *PB-1*.

(i) Calculate the number of monomer units in each molecule of low molecular mass *PB-1*.

M_r of monomer = 12(4) +8(1) = 56
No. of monomer units = **5600 ÷ 56 = 100**

Number of monomer units .....100..... [1]

(ii) High molecular mass *PB-1* has different properties.

Suggest the softening temperature of high molecular mass *PB-1*.
Explain your answer.

Softening temperature Between 116 to 500 °C

Explanation With a higher molecular mass, the intermolecular forces are stronger and require more energy to overcome. [2]

(iii) Explain why *PB-1* has no definite melting point.

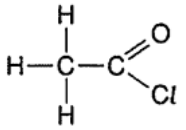
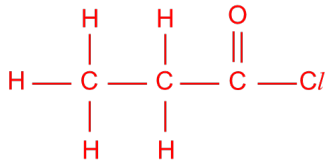
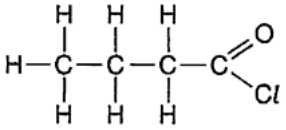
They are **mixtures** [1] consisting of macromolecules of different chain lengths. [1]

[Total: 7]

Section B

Answer **one** question from this section.

9 The table shows some information about the homologous series of a class of organic compounds called acyl chlorides.

name	condensed formula	displayed formula
ethanoyl chloride	CH_3COCl	
propanoyl chloride	C_2H_5COCl	
butanoyl chloride	C_3H_7COCl	

(a) (i) Fill in the table to show the name and displayed formula of the acyl chloride that occurs between ethanoyl chloride and butanoyl chloride in the homolgous series. [1]

(ii) Explain how you can tell that these molecules are from the same homologous series.

They have the same $COCl$ functional group and successive members differ in formulae by a $–CH_2–$ group / same general formula $C_nH_{2n+1}COCl$.

[2]

(iii) Predict the condensed formula of the acyl chloride that contains 7 carbon atoms.

$C_6H_{13}COCl$ [1]

(b) Ethanoyl chloride reacts with methanol in the following reaction.

$$CH_3COCl + CH_3OH \rightarrow \underset{\text{compound X}}{CH_3COOCH_3} + HCl$$

(i) What is the name of compound X?

Methyl ethanoate [1]

(ii) When 64 g of methanol was reacted with excess ethanoyl chloride, 140 g of compound X was obtained. Calculate the percentage yield of compound X.

No. of moles of methanol = 64 ÷32 = 2 mol [1]

Theoretical mass of X = 2 x 74 = 148 g

Percentage yield = (140 ÷ 148) x 100% = **94.6%** (3 s.f.) [1]

[2]

(iii) Ethanoic acid also reacts with methanol.
Write an equation for the reaction of ethanoic acid and methanol.

$CH_3CO_2H + CH_3OH \rightleftharpoons CH_3CO_2CH_3 + H_2O$ ..... [1]

(iv) Give one similarity and one difference between the reaction of ethanoyl chloride with methanol and the reaction of ethanoic acid with methanol.

similarity Both produce the same ester / an ester is formed as the product / a small molecule is removed during the reaction / both are condensation reactions .....

difference The side product is H_2O and HCl respectively for the reaction between ethanoic acid and methanol, and the reaction between ethanoyl chloride and methanol. ..... [2]

[Total: 10]

10 Table 10.1 shows the formulae of the first three members of the alcohol homologous series.

Table 10.1

alcohol	**formula**
methanol	CH_3OH
ethanol	C_2H_5OH
propanol	C_3H_7OH

(a) State the general formula of the alcohol homologous series.

$C_nH_{2n+1}OH$ / $C_nH_{2n+2}O$ .....[1]

(b) Ethanol can be manufactured from either ethene or glucose.

(i) Write an equation for the production of ethanol from ethene and state the conditions under which the reaction takes place.

$C_2H_4 + H_2O \rightarrow C_2H_5OH$. [1] High temperature and pressure in the presence of H_3PO_4 catalyst. [1]

.....[2]

(ii) The fermentation of glucose can be represented by the following equation.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

When 3.6 kg of glucose was fermented, 1.5 kg of ethanol was obtained. Calculate the percentage yield of ethanol.

no. of moles of glucose = 3600 ÷ 180 = 20 mol

theoretical no. of moles of C_2H_5OH = 2 x 20 = 40 mol [1]

theoretical mass of C_2H_5OH produced = 40 x 46 = 1840 g [1]

percentage yield = (1500 ÷ 1840) x 100% = **81.5%** (3 s.f.) [1]

[3]

(iii) Explain why ethanol made from ethene is a non-renewable fuel but that made from glucose is a renewable fuel.

Ethene is obtained from fossil fuels, which is a finite and non-renewable resource. glucose is obtained from crops that have a relative short life cycle and thus can be considered to be renewable resources.

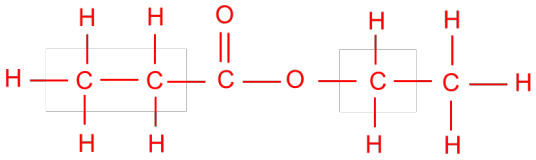
.....[2]

(c) Propanol reacts in a similar way to ethanol.

(i) Name the organic product of the reaction between propanol and warm, acidified potassium manganate(VII).

propanoic acid. .....[1]

(ii) Draw the structure of the compound formed when the organic product in **(c)(i)** reacts with ethanol.



[1]

[Total: 10]

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}\ mol^{-1}$