

Catholic Junior College

JC2 Preliminary Examinations Higher 2

CANDIDATE	
NAME	

CLASS

CHEMISTRY

Paper 3 Free Response

9729/03 Friday 30 August 2019

2 hours

Candidates answer on separate paper.

2T

Additional Materials: Answer Paper Data Booklet

READ THESE INSTRUCTIONS FIRST

WORKED SOLUTIONS

Section A Answer all the questions in this section.

 (a) Chemical energy can be directly converted to electrical energy in batteries and fuel cells. Fuel cells require a continuous source of fuel and oxygen to sustain the chemical reaction, whereas in batteries, the chemical energy is usually derived from reactions of metals or metal oxides present in the battery.

> The nickel-cadmium (NiCd) battery is a rechargeable battery used in many devices such as handphones and laptops. A simplified diagram of the NiCd electrochemical cell is as shown:



Electrode **X** is made of a solid nickel compound, NiO(OH), and electrode **Y** is made of solid cadmium. The electrolyte is aqueous potassium hydroxide. During discharge, Ni(OH)₂(s) and Cd(OH)₂(s) are formed at the respective electrodes.

(i) Construct the half-equations at the electrodes of this alkaline NiCd electrochemical cell. Hence, give the balanced overall equation for the reaction that occurs during discharge.

Electrode X: NiO(OH) + H₂O + $e^- \rightarrow Ni(OH)_2 + OH^-$

Electrode Y: Cd + $2OH^- \rightarrow Cd(OH)_2 + 2e^-$

Overall equation: Cd + $2NiO(OH) + 2H_2O \rightarrow Cd(OH)_2 + 2Ni(OH)_2$

(ii) Write a cell representation for the NiCd electrochemical cell, indicating clearly the direction of electron flow in the external circuit.
 [2]

```
e<sup>−</sup> flow

↓

Cd(s), Cd(OH)<sub>2</sub>(s) // NiO(OH)(s), Ni(OH)<sub>2</sub>(s)
```

 (iii) NiCd batteries can be recharged by applying a current across the two electrodes. How long would it take to recharge a NiCd battery at a current of 2.0 A, if 5.6 g of cadmium was converted to Cd(OH)₂?

Moles of Cd converted = 5.6 / 112.4 = 0.0498 mol Moles of electrons required = $0.0498 \times 2 = 0.0996$ mol

Total charge required =
$$0.0996 \times 96500 = 9615 \text{ C}$$

Time required = $9615 / 2.0 = 4807 \text{ s}$ (or 80.1 min)

(b) Methane gas, CH₄, is the simplest alkane used to power a fuel cell. The methane-oxygen fuel cell has recently been shown to be an efficient source of electrical energy. In the simplest version of this fuel cell, an acid is used as the electrolyte and methane undergoes reaction at one of the electrodes while oxygen undergoes reaction at the other electrode.

 $CO_2 + 8H^+ + 8e^- \stackrel{<}{=} CH_4 + 2H_2O$ $E^{\theta} = +0.17 V$ $O_2 + 4H^+ + 4e^- \stackrel{<}{=} 2H_2O$

(i) By using the half–equations above and relevant data from the *Data Booklet*, calculate the E^{θ}_{cell} of this fuel cell. [1]

 $O_2 + 4H^+ + 4e^- ≈ 2H_2O$ $E^θ = +1.23 V$ $E^θ_{cell} = 1.23 - (0.17) = +1.06 V$

(ii) Draw a fully labelled diagram of the electrochemical cell you could use to measure this E_{cell}^{θ} . [3]



- (c) An alternative fuel used in fuel cells is dimethyl oxalate, $(CH_3)_2C_2O_4$, which is obtained by the esterification of ethanedioic acid, $H_2C_2O_4$, with methanol, CH_3OH . The ethanedioate ion, $C_2O_4^{2-}$, is commonly found in ionic salts such as XC_2O_4 . When these ethanedioate salts, XC_2O_4 , are oxidised by acidified potassium manganate(VII), KMnO_4, both the X^{2+} and $C_2O_4^{2-}$ ions are oxidised. Carbon dioxide gas is formed as one of the products in the reaction.
 - (i) Write a balanced equation for the reaction between MnO₄⁻ and C₂O₄²⁻ under acidic conditions.
 [1]

 $5C_2O_4^{2-} + 2MnO_4^{-} + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$

(ii) 25.0 cm³ of 0.1 mol dm⁻³ XC₂O₄ solution was titrated with 0.1 mol dm⁻³ of acidified KMnO₄. Determine the volume of KMnO₄ needed to oxidise C₂O₄²⁻ only. [2]

Moles of $C_2O_4^{2-}$ ions = 0.025 x 0.1 = 0.0025 mol Since $C_2O_4^{2-}$: MnO₄⁻ is 5 : 2, Moles of MnO₄⁻ needed to oxidise $C_2O_4^{2-}$ = 0.0025 x 2/5 = 0.001 mol Volume of MnO₄⁻ needed = (0.001 / 0.1) x 1000 = 10 cm³ (iii) Given that 15.00 cm³ of acidified KMnO₄ was required to completely oxidise 25.0 cm³ of 0.1 mol dm⁻³ XC₂O₄ solution, and using your answer in (c)(ii), find the oxidation state of X in the product. [3]

Volume of MnO_4^- ions needed to oxidise X^{2+} ions = $15 - 10 = 5 \text{ cm}^3$ Moles of MnO_4^- ions = $(5 / 1000) \times 0.1 = 0.0005 \text{ mol}$ From Data Booklet, $MnO_4^- + 8H^+ + 5e^- \implies Mn^{2+} + 4H_2O$ Moles of electrons gained by $MnO_4^- = 0.0005 \times 5 = 0.0025$ mol Moles of X^{2+} ions = $0.025 \times 0.1 = 0.0025$ mol Therefore, mole ratio of X^{2+} : e = 1 : 1Since 1 mole of X^{2+} loses 1 mole of electrons, Oxidation state of X in the product = +3

(d) Potassium manganate(VII), KMnO₄, can be used to oxidise alkenes in different ways. Alkene P, C₈H₁₆, reacts with hot acidified KMnO₄ to form one organic product only, which gives a yellow precipitate with hot aqueous alkaline iodine. P also reacts with cold alkaline KMnO₄ to form an optically inactive diol, Q. When P is treated with chlorine in ultraviolet light, it produces a mixture of chlorinated compounds, including R, C₈H₁₄Cl₂, which does not have any chiral carbon. When R is reacted with ethanolic NaOH, compound S, C₈H₁₂, is the only product formed. S produces two compounds, CO₂ and CH₃COCO₂H in equimolar amounts when it is oxidised by hot acidified KMnO₄.



(i) Suggest the structural formulae for compounds P, Q, R and S.

[4]



(ii) Draw the structural formula of an isomer of R, C₈H₁₄Cl₂, that could give S on dehydrochlorination.



(iii) Suggest, with a reason, the number of stereoisomers for compound **S**. [1]

There is 1 alkene double bond that is capable of exhibiting cis-trans isomerism as there are 2 different groups attached to each C atom across C=C double bond; no of stereoisomers= $\underline{2}$.

[Total:22]

- 2 With the prospect that fossil fuels will become increasingly scarce in the future, many compounds are being considered for use in internal combustion engines. One of these is DME or dimethyl ether, CH₃OCH₃. DME is a gas which can be synthesised from methanol. Methanol can be obtained from biomass, such as plant waste from agriculture.
 - (a) Write a balanced equation to define the term *standard enthalpy change of combustion*, $\Delta H_c^{-\phi}$, of DME. [1]

 $CH_3OCH_3(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

- (b) A 0.31 g sample of DME was completely burnt in air. The heat produced raised the temperature of 200 g of water by 11.7 °C. Assume no heat losses occurred during this experiment.
 - (i) Use relevant data from the *Data Booklet* to calculate the amount of heat released in this experiment. [1]

heat released = mc ΔT = 200 × 4.18 × 11.7 = 9781 J (or 9.78 kJ)

(ii) Hence calculate the enthalpy change of combustion, ΔH_c^{\bullet} , of DME. [1]

*M*_r of DME, CH₃OCH₃ = 2(12.0) + 6(1.0) + 16.0 = 46.0 0.31 g of DME produce 9.78 kJ ∴ $\Delta H_c^{-\Theta}$ of DME = $-\frac{9.78 \times 46.0}{0.31}$ = -1451 kJ mol⁻¹

(c) (i) Use the bond energies given in the *Data Booklet* to calculate another value for the *enthalpy change of combustion*, ΔH_c^{\bullet} , of DME. [2]

 $CH_3OCH_3(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Bonds broken (ΔH_1 / kJ mol ⁻¹)		<u>Bonds formed</u> (ΔH_2 / kJ mol ⁻¹)	
2 C –O	2(+360)	4 C=O	4(-805)
6 C–H	6(+410)	6 O–H	6(-460)
3 O=O	3(+496)		

 $\therefore \Delta H_c^{-+} = 2(+360) + 6(+410) + 3(+496) + 4(-805) + 6(-460)$ $= -1312 \text{ kJ mol}^{-1}$

(ii) Suggest a reason for the discrepancy, if any, between this $\Delta H_c^{-\bullet}$ value and that calculated in (b)(ii). [1]

This ΔH_c^{\bullet} value is <u>less exothermic</u> than that calculated in (b)(ii) because <u>bond</u> energies given in <u>Data Booklet</u> are <u>average</u> values and do not relate to any specific compound.

(d) DME may be synthesised from methanol according to the following equation.

$$2CH_3OH(l) \rightarrow CH_3OCH_3(g) + H_2O(l)$$
 $\Delta H^{\oplus} = +7.10 \text{ kJ mol}^{-1}$

(i) The entropy change for this reaction, $\Delta S^{-\Phi}$, is +83.62 J K⁻¹ mol⁻¹. Explain the significance of the sign of $\Delta S^{-\Phi}$.

 ΔS^{\bullet} is <u>positive</u>, which shows that the reaction proceeds with an <u>increase in</u> <u>disorderliness</u> due to the <u>increase in number of moles of gas</u> from <u>0 mol to 1 mol</u>.

(ii) Use the value of $\Delta S^{-\bullet}$ and $\Delta H^{-\bullet}$ given above to calculate a value for the standard Gibbs Free energy, $\Delta G^{-\bullet}$, for this reaction. [1]

 $\Delta G^{-\bullet} = \Delta H^{-\bullet} - T \Delta S^{-\bullet}$ = +7.10 - (298)(+83.62 × 10⁻³) = -17.82 kJ mol⁻¹

(iii) By considering the effect of temperature on the spontaneity of this reaction, suggest and explain whether high or low temperature should be used to produce DME.

As temperature <u>decreases</u>, the term $(-T\Delta S^{\bullet})$ becomes <u>less negative</u> and so, ΔG^{\bullet} will become <u>less negative</u>; and the reaction is <u>less spontaneous</u>. OR

As temperature <u>increases</u>, the term $(-T\Delta S^{\bullet})$ becomes <u>more negative</u> and so, ΔG^{\bullet} will become <u>more negative</u>; and the reaction is <u>more spontaneous</u>.

- To ensure that the reaction remains spontaneous (△G → < 0), the production of DME should be carried out at <u>high temperature</u>.
- (iv) Explain, in molecular terms, how the rate of the above reaction is affected by changing the concentration of methanol. [2]
 - rate of reaction <u>increases</u> when concentration of methanol is <u>increased</u> due to increase in frequency of collisions between methanol molecules which are now closer together, and this <u>increases the number of</u> <u>successful/effective collisions</u>.
 - OR rate of reaction <u>decreases</u> when concentration of methanol is <u>decreased</u> due to <u>decrease in frequency of collisions</u> between methanol molecules which are now <u>further apart</u>, and this <u>reduces</u> the <u>number of successful</u> <u>collisions</u>.

[1]

(e) Methanol is also a reagent to synthesise vanillin. Vanillin is an important raw material for the production of L-DOPA used in the treatment of Parkinson's disease.



A student carried out some reactions with samples of L-DOPA and vanillin using reagents **X**, **Y** and **Z**.

- Reagent X reacted with L-DOPA and with vanillin.
- Reagent **Y** reacted with L-DOPA but **not** with vanillin.
- Reagent Z reacted with vanillin but not with L-DOPA.

Assume that the CH₃O– group in vanillin is inert and does not react.

Suggest possible identities of reagents **X**, **Y** and **Z** and give the structures of the organic products formed in each case. [7]

•Reagent X: for <u>phenol</u> - any one of aq. Br₂; NaOH, Na, RCOC*l*; OR

LiA/H₄ for reduction of carboxylic acid & aldehyde

- Reagent Y: for <u>carboxylic acid</u> any one of Na₂CO₃; NaHCO₃, SOC*l*₂, PC*l*₅, ROH + H₂SO₄; OR for <u>amines</u> - any one of HC*l*, CH₃C*l*
- Reagent Z: for <u>aldehyde</u> any one of Tollens' reagent, 2,4-dinitrophenylhydrazine; acidified K₂Cr₂O₇, HCN + trace NaCN/NaOH, NaBH₄

[Total: 19]

3 (a) The hydroformylation reaction is an industrial process for the production of aldehydes from alkenes. For example, butanal can be synthesised from propene, C_3H_6 , as follows:



(i) Write an expression for K_p of the reaction, including units. [2]

 $\mathcal{K}_{p} = \frac{p_{CH_{3}CH_{2}CH_{2}CH0}}{(p_{CH_{3}CH=CH_{2}})(p_{CO})(p_{H_{2}})} \operatorname{atm^{-2} or Pa^{-2}}$

(ii) Given that the magnitude of K_p for the above reaction is 775, deduce what the K_p value indicates about the position of equilibrium. Hence, state the sign of ΔG^{\bullet} for the reaction. [2]

As $\underline{K_p}$ is large, and thus position of equilibrium lies very much to the right. ΔG^{e} is negative.

(iii) Given that the above reaction is exothermic, suggest, with a reason, the effect of an increased temperature on the amount of butanal formed at equilibrium. [1]

When the temperature is increased, the <u>position of equilibrium shifts to the left</u> as the <u>reverse reaction</u> is <u>endothermic</u> and absorbs heat. Thus, the amount of butanal at equilibrium <u>decreases</u>.

(iv) The mechanism of hydroformylation of propene resembles the electrophilic addition of alkenes and can result in the formation of two isomeric products. Apart from butanal, suggest the structure of the other isomer that can be formed. [1]



(b) In the Leuckart-Wallach reaction, a carbonyl compound reacts with a primary amine to form a secondary amine.



(i) Stage 1 occurs in 2 steps. The first step involves a nucleophilic attack while in the second step, a proton transfer occurs within the intermediate to form the alcohol group.

Name and outline the 2-step mechanism for Stage 1, to form Compound **A**. Show relevant lone pairs and dipoles, and use curly arrows to indicate the movement of electron pairs. [3]

Nucleophilic Addition



- (ii) Compound B undergoes reduction in Stage 3. Describe the change in oxidation state of carbon which occurs in this stage.
 [1] There is a decrease in oxidation number of the C (of the C=N) from +1 to -1
- (iii) Unlike primary amines, amides cannot be used in the Leuckart-Wallach reaction. Explain why this is so. [1]

In amides, the lone pair of electrons on the nitrogen atom can delocalise into the π electron cloud of the adjacent C=O bond/electron-withdrawing C=O group. Hence, the lone pair of electrons is not available for donation/less available to accept a proton and unable to act as a nucleophile in Stage 1.

(iv) 2-bromopyrrolidine, a cyclic amine, can be synthesised via the Leuckart-Wallach reaction.

2-bromopyrrolidine

Draw the displayed formula of the starting compound used in the synthesis of 2-bromopyrrolidine. [1]



(v) State and explain the relative basicities of 2-bromopyrrolidine and compound **C**. [2]

2-bromopyrrolidine is a <u>weaker base</u> than compound C. 2-bromopyrrolidine has an <u>electron-withdrawing Br atom</u>, and thus the <u>lone pair of electrons on</u> <u>nitrogen is less available for donation to a proton</u>.

(c) Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds are given in the table below.

Compound	Structure	Dipole moment	Boiling point / °C
CS ₂	S=C=S	0	46
COS	S=C=O	0.71	-50
COSe	Se=C=O	x	-22

- Explain, in terms of structure and bonding, the difference in the boiling point of CS₂ and COS.
 Both CS₂ and COS have simple molecular structures. CS₂ has a larger number of electrons (or larger electron cloud) than COS. More energy is required to overcome the stronger instantaneous dipole-induced dipole attractions between CS₂ molecules than the permanent dipole-permanent dipole attractions between COS molecules. Hence, CS₂ has a higher boiling point.
- (ii) Predict a value for the dipole moment of COSe, *x*, and explain. [1]

0.73 (> 0.71)

<u>C=S bond is more polar than C=Se</u> (since S is more electronegative than Se). There is smaller difference in the dipole moment of C=O and C=S as compared to that between C=O and C=Se.

(iii) Aside from the common oxides, carbon forms a series of straight-chained reactive oxocarbons. One such compound is tricarbon monoxide, C₃O, a reactive molecule found in space. Suggest a displayed structure of tricarbon monoxide. Indicate clearly any lone pairs of electrons present in your structure.

[1]

(iv) Tricarbon monoxide is isoelectronic to cyanogen, (CN)₂. The molecule of cyanogen contains a C–C single bond.
 Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from each of the two carbon atoms and those from the two nitrogen atoms.

[Total: 19]

Section B

Answer **one** question from this section.

4 (a) Benzene is a widely used starting organic compound to synthesize other chemicals, such as benzenesulfonic acid and 2-methylphenol.

Benzenesulfonic acid can be produced by heating benzene under reflux with concentrated sulfuric acid for several hours. This process is similar to the nitration of benzene.



benzenesulfonic acid

The first step of the mechanism involves the protonation of one molecule of sulfuric acid by another and the loss of a molecule of water.

(i) Describe the mechanism for the above reaction. Show relevant lone pairs and charges, and use curly arrows to indicate the movement of electrons. [4]
 Electrophilic substitution

 $H_2SO_4 + H_2SO_4 \rightarrow HSO_3^+ + H_2O + HSO_4^-$



(ii) Similarly, methylbenzene also reacts with concentrated sulfuric acid to form a mixture of the three isomers, in equilibrium.



Suggest why there is a lower concentration of 1,2-isomer than that of 1,4isomer in the equilibrium mixture. [1]

This may be due to steric hindrance of $-CH_3$ group, as the $-CH_3$ group may have electrostatic repulsion with the large incoming SO₃H⁺ group.

(iii) The chlorinated compound MCPA, widely used as a weed killer, can be synthesized from 2-methylphenol.



Using **not** more than 3 steps, draw a reaction scheme to show how MCPA can be synthesised from 2–methylphenol. [5]



(b) The chemical reactions of benzene sometimes require iron as a catalyst. Iron is a hard grey transition metal which is resistant to corrosion at ordinary temperatures. In contrast, calcium is a fairly soft, silvery-grey Group 2 metal which quickly tarnishes in air.

(i) By considering relevant electronic configurations, explain why the atomic radius of iron is smaller than that of calcium, even though iron has more electrons. [2]

Ca: [Ar] 4s² Fe: [Ar] 3d⁶4s² The atomic radius of iron is smaller (0.126nm) than that of Ca (0.197 nm). Iron has a <u>higher nuclear charge</u> (due to greater no. of protons) and <u>relatively</u> <u>poor shielding effect by the 3d electrons</u>, the outermost 4s electrons are <u>more</u> <u>strongly attracted by the nucleus</u>.

(ii) Iron can exist in different oxidation states whereas calcium does not. Explain why. [2]

The <u>3d and 4s electrons are of similar energy</u> so <u>different number of 3d and 4s</u> <u>electrons can be removed</u> to form ions of similar stability, giving rise to variable oxidation states.

However, for s-block elements, <u>only the valence s electrons can be removed. A</u> <u>lot of energy is required to remove the inner shell p electrons</u> as they are more closely bound by the nucleus. Thus, s-block elements have fixed oxidation states.

(iii) Explain why iron(II) complexes are green in colour.

[3]

In the <u>presence of ligands</u>, the <u>partially-filled degenerate d orbitals in Fe²⁺</u> <u>become non-degenerate</u> and split into <u>two groups of non-degenerate d</u> <u>orbitals with a small energy gap.</u> When exposed to visible light, d electron in a d orbital of lower energy absorbs

energy in the <u>red region</u> and is <u>promoted</u> to a higher energy d* orbital. This is called <u>*d*-*d** electronic transition</u>, where d* is the higher energy orbital. The <u>complementary colour</u> of red, i.e. green, is <u>not absorbed</u> and thus green is seen as the colour of the complex.

(iv) Iron(III) ions catalyse the reaction between I⁻ ions and S₂O₈²⁻ ions through homogeneous catalysis.
 Explain why iron(III) ions can be described as a homogeneous catalyst. By considering relevant E^e values from the *Data Booklet*, show by means of balanced equations, how the iron(III) ions carry out its role in this reaction. [3] Fe³⁺ operates in the same phase as the reactants (iodide and peroxodisulfate) and is regenerated.

[Total: 20]

- **5** (a) Aluminium oxide, Al₂O₃, and aluminium chloride, AlCl₃, are widely used in various industrial and commercial applications.
 - (i) Aluminium oxide has a melting point of 2072 °C while aluminium chloride sublimes at 180 °C. Explain the difference in melting points in terms of structure and bonding in each compound.

Aluminium oxide has a <u>giant ionic structure</u> while aluminium chloride has a <u>simple</u> <u>molecular structure</u>. A larger amount of energy is needed to overcome the <u>stronger ionic bonds</u> (electrostatic force of attraction) between Al^{3+} ions and O^{2-} ions than the <u>weaker</u> instantaneous dipole-induced dipole attractions between aluminium chloride <u>molecules</u>.

 (ii) Describe the reactions, if any, of aluminium oxide and aluminium chloride with water, suggesting the pH of the resulting solutions and writing equations, where appropriate.

For Al₂O₃: Does not dissolve in water, pH of resultant solution= 7

 $\begin{array}{l} \underline{\text{For } AlCl_3:} \\ AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^{-}(aq) \\ [Al(H_2O)_6]^{3+}(aq) + H_2O(l) & \qquad [Al(H_2O)_5(OH)]^{2+}(aq) + H_3O^{+}(aq) \end{array}$

The Al^{3+} ion has a <u>high charge density</u> (higher charge and smaller radius compared to Na⁺) The small, <u>highly polarizing Al^{3+} cation then weakens the O-H bonds of the water molecules</u> in its sphere of coordination and results in the <u>release of H⁺ ions</u> in the solution. **pH of solution of AlCl₃ ≈ 3**

(b) The reaction between chlorine gas and hot sodium hydroxide is as follows.

 $3Cl_2 + 6NaOH \rightarrow 5 NaCl + NaClO_3 + 3H_2O$

(i) State the type of reaction occuring.

[1]

[2]

Disproportionation

(ii) State the change in oxidation numbers of chlorine that occur during this reaction.

The oxidation number of Cl is decreased from <u>0</u> in Cl₂ to <u>-1</u> in Cl⁻ (reduction) and increased from <u>0</u> in Cl₂ to <u>+5</u> in ClO₃⁻ (oxidation).

(c) Ethers are a class of organic compounds that has two organic groups bonded to the same oxygen atom, R-O-R'. The organic groups could be alkyl and aryl groups. Williamson synthesis could be used to synthesis ethers by a reaction between primary alkyl halides and metal alkoxides.

A typical example of the Williamson synthesis is a two-step reaction to synthesize *tert*-butyl methyl ether.

The first step of the reaction involved the preparation of sodium alkoxide in the presence of sodium hydride, NaH.



The second step of the reaction involved the reaction between the alkoxide ion and the primary alkyl halide.



- (i) Suggest the role of sodium hydride in step 1. [1] Base
- (ii) Suggest the type of reaction which occurs in step 2. [1] <u>S_N2 nucleophilic substitution</u>
- (iii) Suggest why primary alkyl halide is used in Williamson synthesis instead of secondary or tertiary alkyl halide.
 [1] The alkoxide, which acts as a nucleophile has 3 bulky substituents. Only a primary alkyl halide that has smaller hydrogen atoms compared to bulky alkyl groups in secondary or tertiary alkyl halide will cause less steric hindrance and allow the bulky nucleophile to attack the carbon centre easily from the rear.
- (iv) The following scheme shows a three-step synthesis of compound L from 1-chloropropane. Given that step 3 involves Williamson synthesis, suggest the reagents and conditions you would use for each step and identify the intermediates J and K.



- (d) (i) Using monohalogenethanes, C₂H₅X, as examples, describe and explain the relative reactivities of chloro- and bromo-compounds with respect to hydrolysis. [1] Bromoethane is more reactive towards hydrolysis (nucleophilic substitution) as <u>C-Br bond is weaker</u> and thus requires less energy to break the bond.
 - (ii) There are other methods to synthesise ethers. A cyclic ether N could be formed as shown below. Predict the outcomes of the following transformations, drawing the structures of the intermediate M and the product N.



[2]



