NAME _____ CLASS **20S**

JURONG PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2021

CHEMISTRY **9729/02**

Higher 2

Paper 2 Structured Questions

15 September 2021

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class 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, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/14
2	/20
3	/11
4	/15
5	/15
Penalty (delete accordingly)	
Bond linkages	**–1 / NA**
Significant figures & units	**–1 / NA**
Total	/75

This document consists of **17** printed pages and **1** blank page.

Answer **all** the questions.

For Examiner's Use

1 (a) The reducing agent $LiAlH_4$ can be synthesised by reacting aluminium chloride with lithium hydride, LiH.

(i) Lithium hydride contains the ions Li^+ and H^-. State the electronic configuration of these two ions.

Li^+ …… H^- …… [1]

(ii) Explain why Li^+ ion has a smaller radius than H^- ion.

……

…… [1]

(iii) $LiAlH_4$ decomposes slowly according to the mechanism below.

Step 1 $3LiAlH_4 \rightarrow Li_3AlH_6 + 2Al + 3H_2$

Step 2 $2Li_3AlH_6 \rightarrow 6LiH + 2Al + 3H_2$

Step 3 $2LiH + 2Al \rightarrow 2LiAl + H_2$

Use the above mechanism to deduce the overall equation for this decomposition.

…… [1]

(iv) $LiAl$(s) has a melting point of 718 °C and conduct electricity when in solid and molten states.

Suggest the structure and describe the type of bonding for $LiAl$(s).

……

……

……

…… [2]

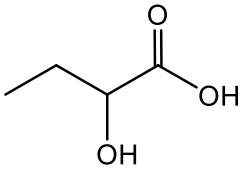
(v) Assuming the same packing arrangement of atoms, suggest why $LiAl$(s) has a lower density than Al(s).

……

…… [1]

For Examiner's Use

(b) Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

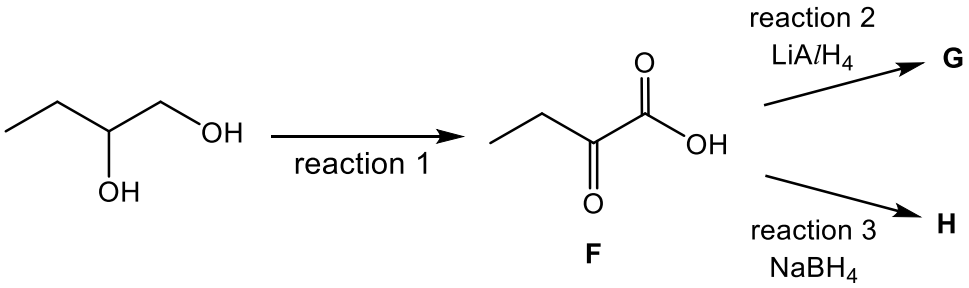


2-hydroxybutanoic acid

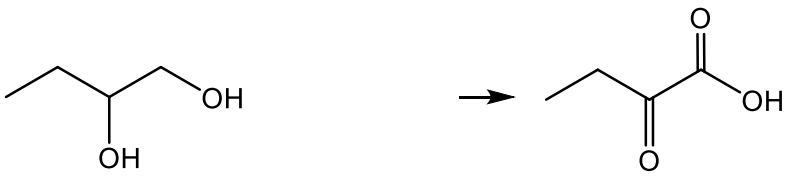
Both students oxidise butane-1,2-diol to form **F** in reaction 1.

One student then reduces **F** using $LiAlH_4$. **G** is formed.

The other student reduces **F** using $NaBH_4$. **H** is formed.



(i) Complete the equation to show the conversion of butane-1,2-diol to **F** in reaction 1. Use [O] to balance your equation.



[1]

(ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which compound, **G** or **H,** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

……

……

…… [2]

(c) Draw a labelled diagram to show how hydrogen bonding occurs between two molecules of butane-1,2-diol.

[2]

(d) Like butane-1,2-diol, compound **J** contains only carbon, hydrogen and oxygen.

The following information of **J** is known.

- **J** has a M_r of 192 and does not rotate plane polarised light.
- Complete combustion of 4.32 g of compound **J** produces 5.94 g of CO_2 and 1.62 g of H_2O.
- 1 mole of **J** requires 3 moles of dilute NaOH for complete neutralisation.

Calculate the C:H ratio and deduce the molecular formula of **J**.

Hence, suggest a possible structure for **J**.

[3]

[Total: 14]

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For Examiner's Use

2 (a) Concentrated sulfuric acid is a versatile reagent.

(i) When solid NaC*l* reacts with concentrated sulfuric acid, white fumes of HC*l*(g) and sodium hydrogen sulfate, $NaHSO_4$, are formed.

However, when solid NaI reacts with concentrated sulfuric acid, purple fumes of I_2(g) and hydrogen sulfide gas, H_2S(g), are also formed.

State the role of concentrated sulfuric acid in each reaction. Explain how you arrive at your answer.

- reaction of solid NaC*l* with conc. H_2SO_4

  role of conc. H_2SO_4 …….

  explanation ……...

  …….

- reaction of solid NaI with conc. H_2SO_4

  role of conc. H_2SO_4 …….

  explanation ……...

  ……. [3]

(ii) Suggest why NaC*l* and NaI differ in their reactions with concentrated sulfuric acid.

…….

……. [1]

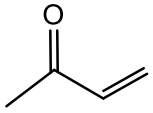
(iii) The addition of concentrated sulfuric acid to solid sodium bromide, NaBr, produces reddish brown fumes and an acidic gas that decolourises acidified potassium manganate(VII) solution. This acidic gas is a significant contributor to acid rain.

Complete the equation to show the reaction of concentrated sulfuric acid with sodium bromide.

…. NaBr(s) + …. $H_2SO_4(l)$ → …. $NaHSO_4$(s) + ... + ... + …. $H_2O(l)$ [2]

For Examiner's Use

(b) Butenone is shown.

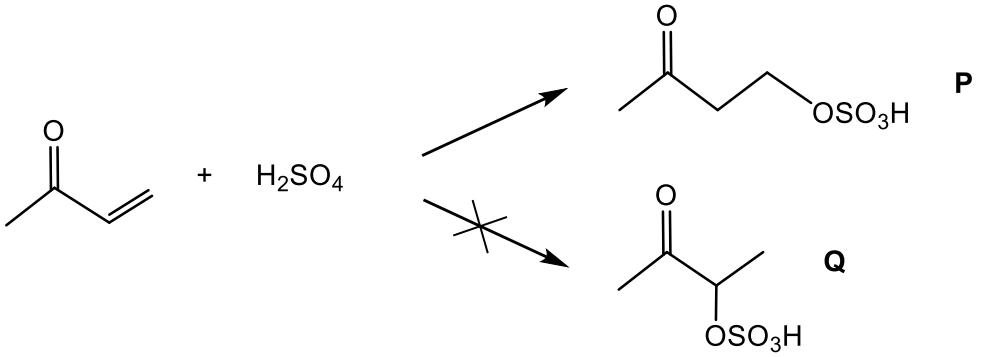


(i) By reference to the bonding, suggest why the $H_2C=C–C=O$ part of the molecule is planar.

……

…… [1]

(ii) When mixed with concentrated sulfuric acid, butenone undergoes electrophilic addition reaction to give isomer **P** rather than isomer **Q**.



Complete Fig. 2.1 to suggest a mechanism for this reaction. Include any dipoles, lone pairs and curly arrows to the movement of electron pairs.

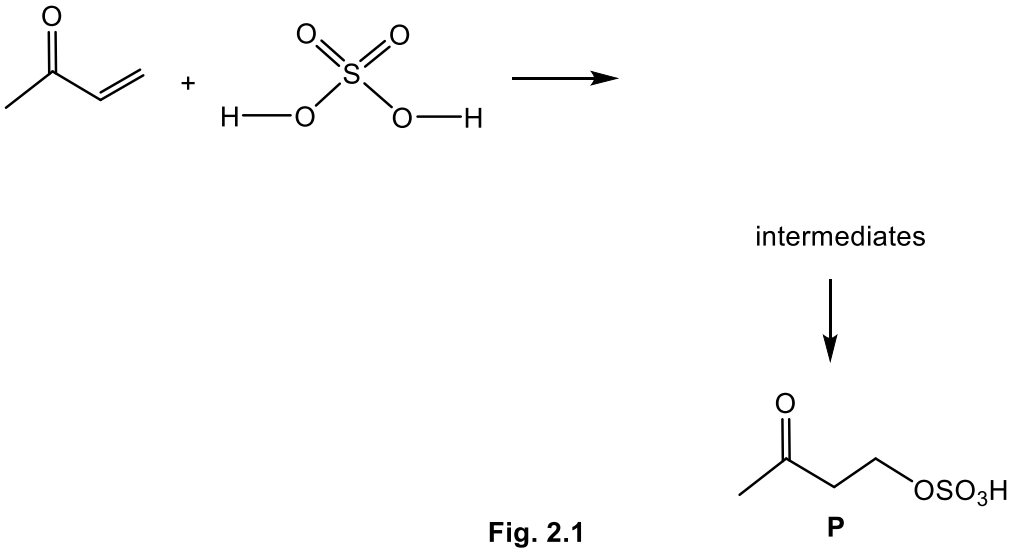


Fig. 2.1 [2]

(iii) With reference to the mechanism you have drawn in **(b)(ii)**, explain why isomer **Q** is not produced.

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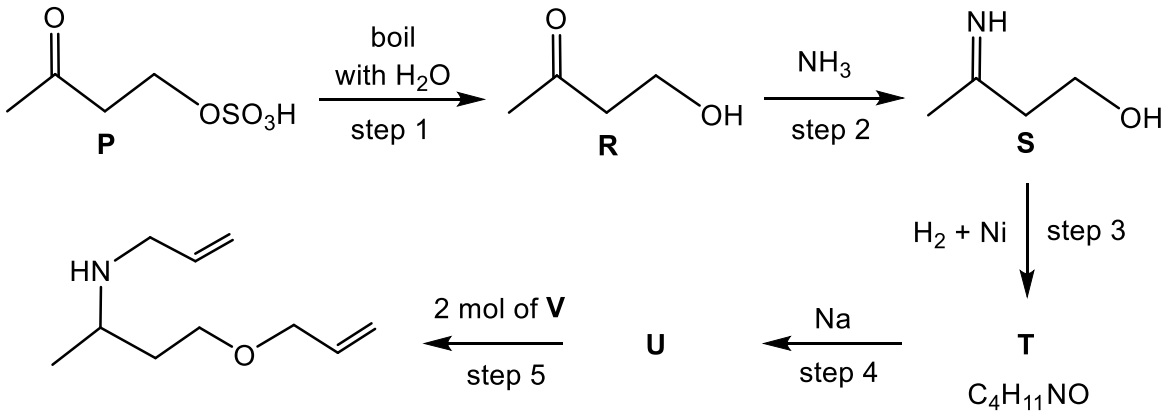
……

…… [1]

For Examiner's Use

(c) When isomer **P** is boiled in water, alcohol **R** is obtained, which undergo further reactions as shown below.



(i) Name the *types of reaction* that occur during each of the steps 1 and 2.

step 1 ……..

step 2 …….. [2]

(ii) Draw the structures of **T**, **U** and **V**.

T

U

V [3]

(iii) In step 3, Ni was used as a heterogeneous catalyst.
Explain how this *type* of catalysis works.

……

……

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……

…… [2]

For Examiner's Use

(iv) **S** exists as a mixture of two stereoisomers.
Draw the structure of each stereoisomer of **S** and explain how this type of isomerism arise.

……

……

…… [3]

[Total: 20]

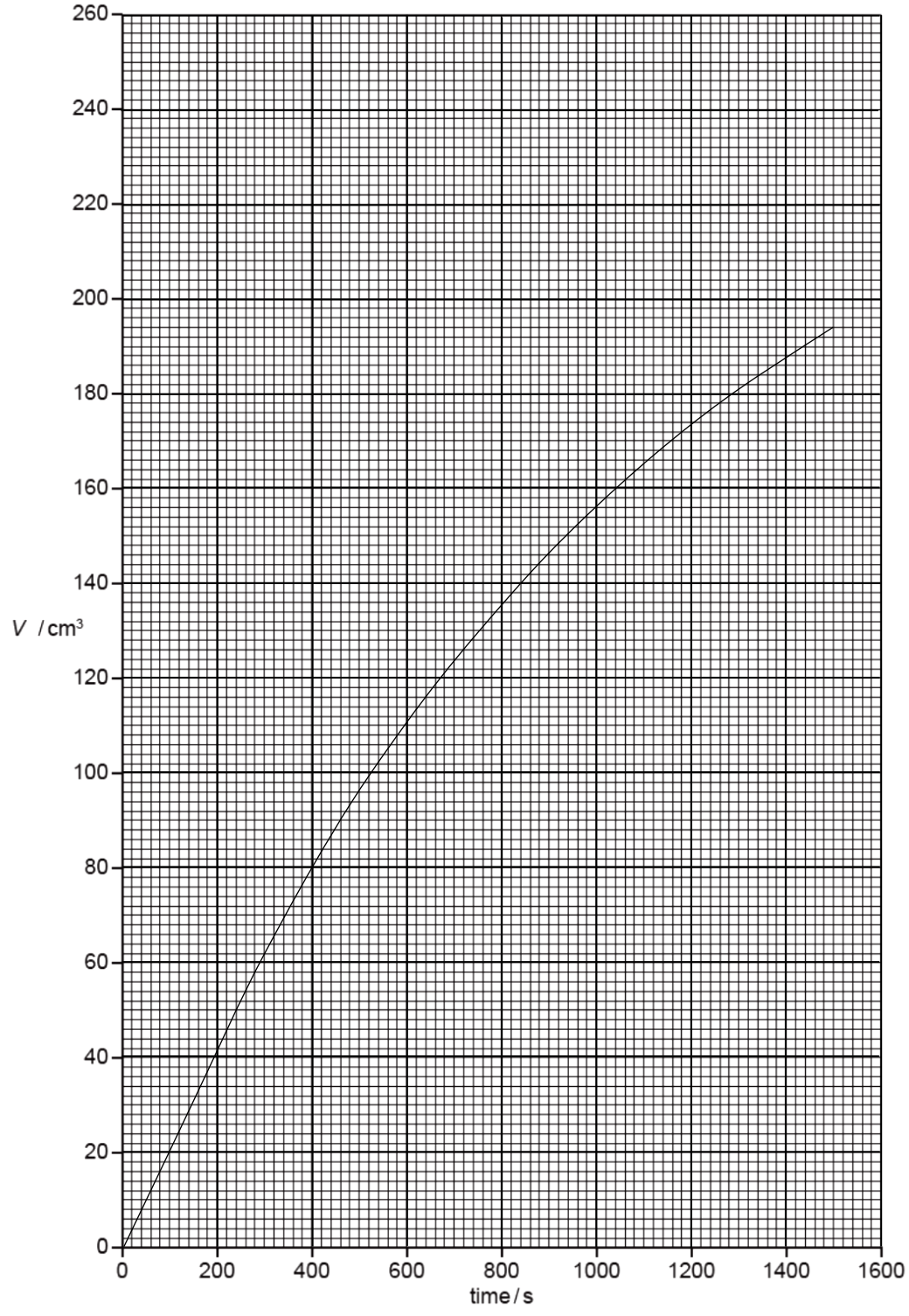
For Examiner's Use

3 Benzenediazonium chloride, $C_6H_5N_2Cl$, is readily hydrolysed at temperatures above 5 °C.

$$C_6H_5N_2Cl(aq) + H_2O(l) \rightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$

Some chemists investigate the rate of this hydrolysis reaction. They measure the volume of nitrogen gas, *V*, produced over time, *t*.

The volume of the solution used in the experiment is 100 cm^3 and the final volume of gas produced, V_{final}, is found to be 252 cm^3 at 45 °C and 101 kPa.



For Examiner's Use

(a) **(i)** By determining two half-lives, show the reaction is first order with respect to $[C_6H_5N_2Cl]$. Show all your working, and draw clearly any construction lines on your graph.

……

…… [2]

(ii) Calculate the rate constant, *k*, for this reaction. Include units in your answer.

[2]

(iii) Why is it not possible to determine the order with respect to water?

……

…… [1]

(b) **(i)** The progress of the reaction in this experiment can also be followed using a pH meter.

Using relevant information in the question, calculate the pH of the solution at the end of the reaction.

[3]

(ii) Besides gas collection and measuring pH, suggest one other method with which the chemists could measure the progress of the reaction.

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…… [1]

For Examiner's Use

(c) The chemists carried out the reaction at several temperatures and plotted a graph of ln k against $\frac{1}{T}$ as shown in Fig. 3.2.

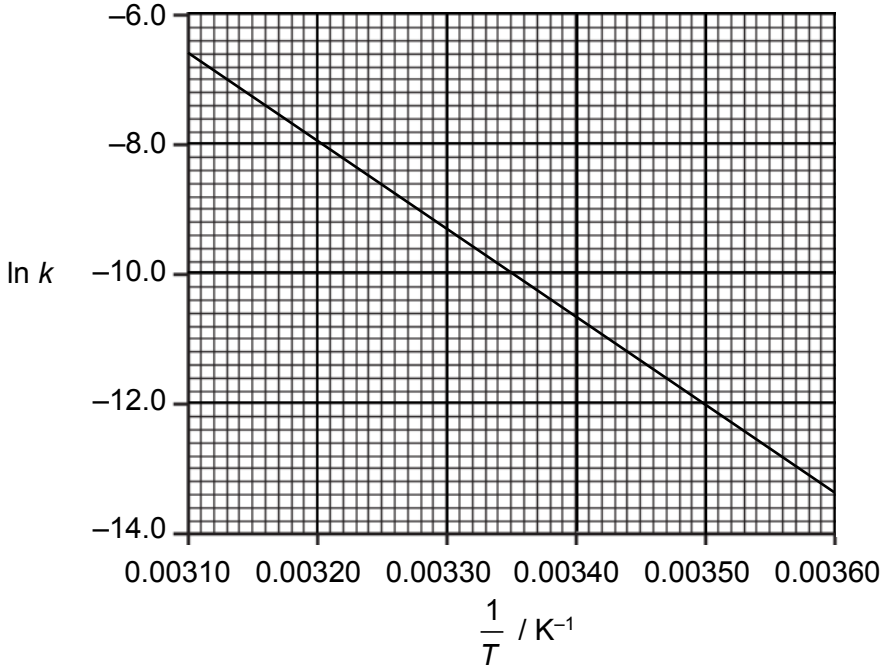

Fig. 3.2

The activation energy, E_a, is related to temperature T by the following equation.

$$k = Ae^{-\frac{E_a}{RT}}$$ where A is the pre-exponential factor

Use the graph in Fig. 3.2 to determine a value for E_a. Show all your working.

[2]

[Total: 11]

For Examiner's Use

4 (a) Aluminium reacts with chlorine to form aluminium chloride. At low temperatures, solid aluminium chloride has the formula of Al_2Cl_6.

(i) Draw a displayed formula of Al_2Cl_6 to illustrate the different types of bonding present.

[1]

(ii) The following enthalpy changes are useful for this question.

enthalpy change of formation of Al_2Cl_6(s)	= –1401 kJ mol^{-1}
enthalpy change of atomisation of Al(s)	= +326 kJ mol^{-1}
enthalpy change of sublimation of Al_2Cl_6(s) → Al_2Cl_6(g)	= +116 kJ mol^{-1}

Using relevant data in the *Data Booklet* and the information given in the list above, complete the energy level diagram in Fig. 4.1 which can be used to calculate the average bond energy of the Al–Cl bond in Al_2Cl_6.

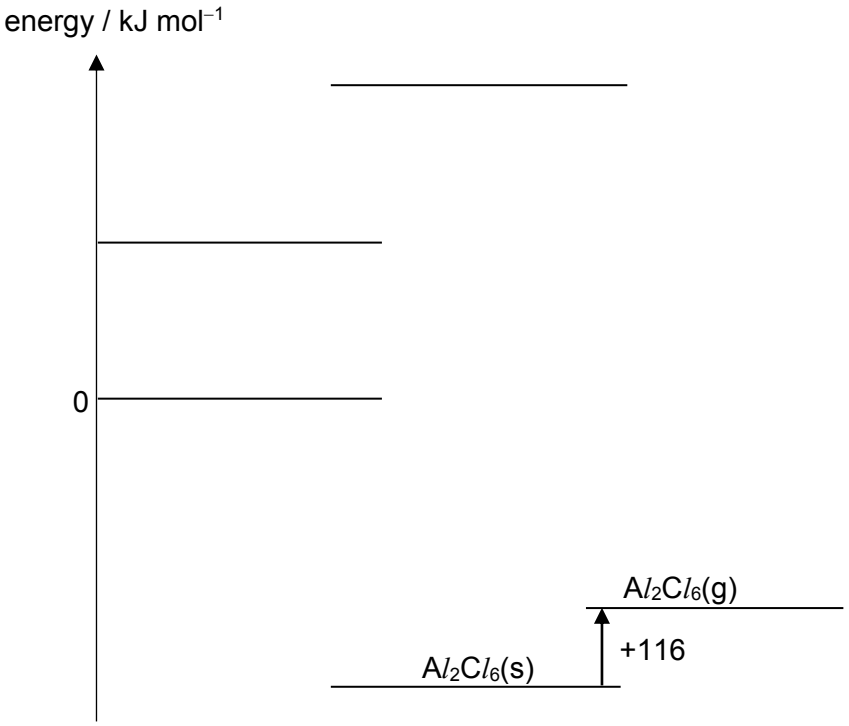

Fig. 4.1

[2]

(iii) Calculate a value for average bond energy of Al–Cl in Al_2Cl_6.

[2]

(iv) When solid Al_2Cl_6 dissolves in water, a weakly acidic solution is obtained. Explain the observations and write an equation for the formation of the acidic solution. Suggest the pH of the resulting solution.

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…… [3]

(b) In an electrolytic cell, a current of 0.250 A is passed through a concentrated solution of $FeCl_x$, producing iron metal and chlorine gas.

(i) With reference to $E^{\ominus}$ values in the *Data Booklet*, explain why chlorine gas instead of oxygen gas is produced at the anode.

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…… [2]

(ii) When the cell operates for 2 hours, 0.521 g of iron is deposited at one of the electrodes. Determine the value of x in $FeCl_x$.

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…… [2]

For Examiner's Use

(c) Chlorine can react with other halogens to form interhalogen compounds such as ClF_3. ClF_3 reacts with cesium fluoride, CsF, to form $CsClF_4$.

$$CsF + ClF_3 \rightarrow CsClF_4$$

Draw the structures and suggest the shapes of ClF_3 and $[ClF_4]^-$.

ClF_3	$[ClF_4]^-$
shape: ……	shape: ……

[3]

[Total: 15]

For Examiner's Use

5 A refrigerant is a working fluid used in the refrigeration cycle of air conditioning systems and heat pumps where in most cases, they undergo a repeated phase transition from a liquid to a gas and back again. However, refrigerants are heavily regulated due to their toxicity, flammability and the contribution to ozone depletion and climate change.

Some common refrigerants, together with their properties, are listed below.

Table 5.1

code	chemicals	boiling point / °C	toxicity	flammability	ozone depletion potential
R-11	CCl_3F	24	low	non-flammable	1.00
R-12	CCl_2F_2	–30	low	non-flammable	1.00
R-22	$CHClF_2$	–41	low	non-flammable	0.055
R-32	CH_2F_2	–52	low	low flammability	0
R-290	$CH_3CH_2CH_3$	–42	low	high flammability	0
R-717	NH_3	–33	high	low flammability	0
R-1130	$CHCl=CHCl$	60	low	non-flammable	0

(a) In the 1920s, refrigeration and air conditioning systems used compounds such as ammonia and propane as refrigerants. However, in the early 1970s, chlorofluorocarbon gases (CFCs) such as R-11, R-12 and R-22 dominated the market of refrigerants.

Based on the information in Table 5.1, suggest **one** reason for the widespread use of CFCs?

……... [1]

(b) One consideration for a good refrigerant is to have a low vapour pressure.

Based on this consideration, together with the data in Table 5.1, state which of these compounds, R-11 (CCl_3F) or R-717 (NH_3), is a better refrigerant. Explain your choice.

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……...

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……...

…… [3]

(c) In the year 1981, R-11 (CCl_3F) and R-12 (CCl_2F_2) were banned by Montreal Protocol due to its destructive effect on the ozone layer.

In the stratosphere where there is a strong presence of ultra-violet light, ozone, O_3, is believed to be destroyed by chlorine *radicals* from CFCs.

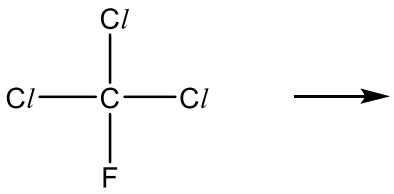
$$2O_3 \rightarrow 3O_2$$

(i) Explain what is meant by the term *radical*.

……

…… [1]

(ii) Using curly arrows, show the formation of a chlorine radical from one R-11 (CCl_3F) molecule for the first step of the mechanism.



Name the type of bond breaking: …… [2]

(iii) Propose the propagation steps involving chlorine radical and ozone. There is no need to show curly arrows in your equations.

First propagation step: ……

Second propagation step: …… [2]

(iv) Propose one possible termination step for the mechanism.

…… [1]

(v) With reference to your answer in **(c)(ii)** and quoting appropriate data from *Data Booklet*, explain why R-32 (CH_2F_2) does not deplete ozone layer, as compared to other CFCs, such as R-11 (CCl_3F) or R-12 (CCl_2F_2).

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…… [2]

For Examiner's Use

(vi) Suggest a reason why R-1130 (CHC*l*=CHC*l*) does not deplete ozone layer as compared to other CFCs.

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…… [1]

(d) Hydrocarbons, such as R-290 ($CH_3CH_2CH_3$), have been long used as refrigerants before they were replaced by the CFCs.

After the Montreal Protocol and the banning of most CFCs, hydrocarbons regain popularity, replacing the CFCs since they do not destroy the ozone layer.

Suggest **one** additional advantage and **one** potential hazard of using R-290 instead of CFCs as refrigerant.

advantage: ……

potential hazard: …… [2]

[Total: 15]

END OF PAPER