ST ANDREW'S JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
HIGHER 2

CANDIDATE NAME

CLASS

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CHEMISTRY

9729/02

Paper 2 Structured Questions **30 August 2023**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work that 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.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use		
Q1		**9**
Q2		**21**
Q3		**17**
Q4		**9**
Q5		**19**
Total		**75**

This document consists of __ printed pages (including this cover page).

1 **(a)** Table 1.1 lists the number of protons, neutrons and electrons in five different particles. Each particle may be an atom, an anion or a cation.

Table 1.1

particle	number of protons	number of neutrons	number of electrons
A	17	18	17
B	17	20	17
C	17	20	18
D	18	22	18
E	18	22	17
F	19	20	19
G	19	20	18

(i) Use the information in Table 1.1 to identify

- the two particles which are a pair of isotopes of the same element

A and B

- the uncharged particle with no unpaired electrons

D [2]

(ii) Deduce which particle is smaller, **F** or **G**. Explain your answer. [2]

F have the same number of protons as **G** and hence, same nuclear charge. **F** has one more electron shell than **G**, so there is stronger attraction between the nucleus and the remaining electrons / electrons would be closer to the nucleus in **G** and **G** would be smaller.

(b) Phosphorus pentachloride, PCl_5, is a useful reagent in organic synthesis. It exists in equilibrium with PCl_3 and chlorine gas as shown below:

$$PCl_5\,(g) \rightleftharpoons PCl_3\,(g) + Cl_2\,(g) \qquad \Delta H = +124\ \text{kJ mol}^{-1}$$

At equilibrium, at 200 °C and a total pressure of 5 atm, 40% of PCl_5 is dissociated.

(i) Write an expression for K_p for the above equilibrium. [1]

$$K_p = \frac{p_{PCl_3}p_{Cl_2}}{p_{PCl_5}}$$

(ii) Calculate a value for K_p at 200 °C and state its units. [2]

	$PCl_5 \rightleftharpoons$	PCl_3 +	Cl_2
Initial / mol	**Z**	0	0
Change / mol	-0.4 **z**	+0.4 **z**	+0.4 **z**
Eqm / mol	0.6 **z**	0.4 **z**	0.4 **z**

Total moles = 1.4 **z**

P_{PCl5} = (0.6 **z** / 1.4 **z**) x 5 = 2.143 atm

P_{PCl3} = P_{Cl2} = (0.4 **z** / 1.4 **z**) x 5 = 1.429 atm

K_p = 0.953 atm

(iii) Predict and explain the effect of increasing the temperature on the value of K_p. [2]

When temperature increases, the system will favour the (**endothermic) forward reaction** to **absorb the excess heat** / **decrease the temperature**. Hence, **rate constant, $k_{forward}$ increases more than rate constant, $k_{backward}$ / position of equilibrium shifts right**. Hence, **K_p increases**.

[Total: 9]

2 (a) Table 2.1 gives data about some physical properties of the elements potassium, calcium and iron.

Table 2.1

Property	potassium	calcium	iron
relative atomic mass	39.1	40.1	55.8
atomic radius (metallic) / nm	0.243	0.197	0.126
ionic radius (charge) / nm	0.138 (1+)	0.099 (2+)	0.061 (2+)
melting point / K	337	1112	1811
density / g cm^{-3}	0.89	1.54	7.87
electrical conductivity / 10^6 S m^{-1}	0.14	0.298	1.00

(i) Explain why the atomic radius of calcium is less than that of potassium. [2]

Nuclear charge is higher for calcium than potassium, while shielding effect by inner shells of electrons remains relatively constant. Hence, effective nuclear charge is higher for calcium than potassium. Attraction between the valence electrons and nucleus is stronger / distance between the valence electrons and the nucleus is smaller in calcium than potassium, resulting in smaller atomic radius for calcium.

(ii) Use relevant data from Table 2.1 to suggest why the density of calcium is greater than that of potassium. [2]

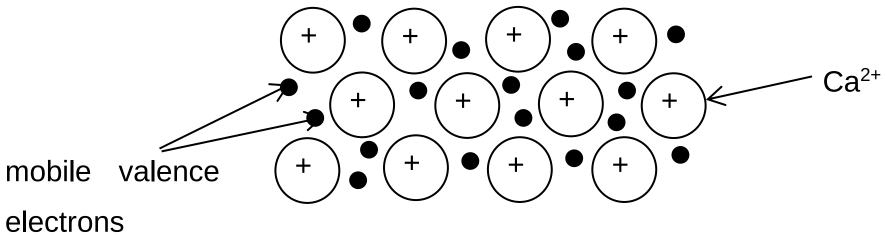
You may assume that both elements have the same packing arrangement of atoms.

The relative atomic mass of calcium (40.1) is higher than that of potassium (39.1). The atomic radius of calcium (0.197 nm) is smaller than that of potassium (0.243 nm).

Since density is mass per unit volume , with a higher relative atomic mass (quote data) and smaller atomic radius , the calcium atoms are packed more closely and the density is higher.

(iii) Describe the structure and bonding in calcium with the aid of a labelled diagram. [2]

Calcium has a giant metallic structure. Electrostatic forces of attractions (metallic bonding) exist between the Ca^{2+} and the sea of delocalised valence electrons.



(b) The high conductivity of iron is a consequence of its electronic configuration.

(i) Complete the electronic configuration of an iron atom and Fe^{2+} ion. [1]

Fe $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

Fe^{2+} $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^6$

(ii) Despite its high electrical conductivity, iron is rarely used in electrical wires, unlike copper. [1]

Apart from its physical properties, suggest a reason why iron is less preferred than copper in electrical wiring.

Iron is prone to oxidation / corrosion, especially in the presence of moisture and oxygen. This can lead to the formation of iron oxide (rust), which negatively impacts the conductivity of the wire and can cause it to deteriorate over time.

Copper, on the other hand, has excellent corrosion resistance, making it a more durable choice for electrical wiring.

(iii) Iron can form octahedral complexes. In an octahedral complex, the d subshell of a transtion metal ion is split into two energy levels. [1]

On the Cartesian axes in Fig. 2.1, draw a **fully-labelled** diagram of one d orbital at the lower energy level in an octahedral complex.

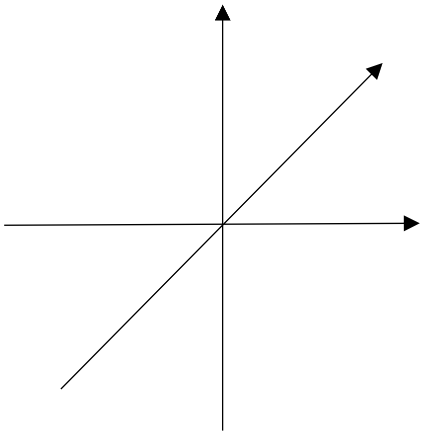
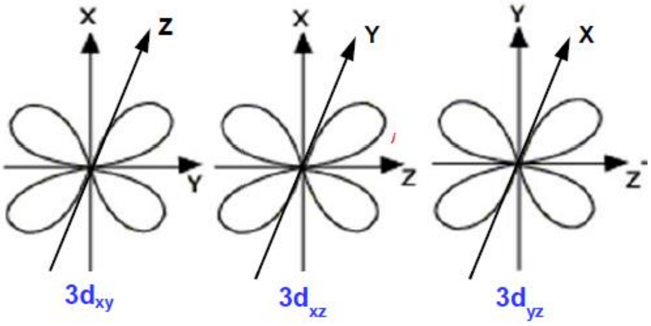


Fig. 2.1

Lower: any



(iv) Describe two ways in which compounds containing Fe^{2+} ions are different from those containing Ca^{2+} ions in terms of their chemical behaviour. [2]

Compounds containing Fe^{2+} ions are more readily reduced than those containing Ca^{2+} ions.

Compounds containing Fe^{2+} can act as catalysts but not Ca^{2+}.

Fe^{2+} formed coloured complex but not Ca^{2+}

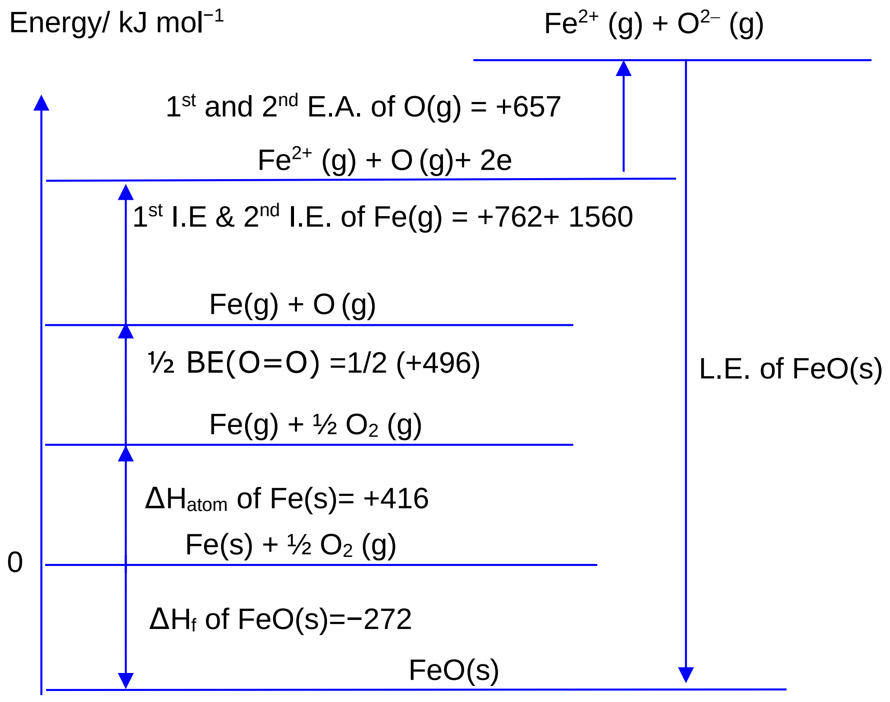
(c) Iron(II) compounds are generally only stable in neutral, non-oxidising conditions.

It is difficult to determine the lattice energy of FeO experimentally.

(i) Use data from the *Data Booklet* and relevant data in Table 2.2 to construct a labelled Born-Haber cycle to determine the enthalpy change of lattice energy of FeO(s). [3]

Table 2.2

	Δ*H*/kJ mol^{-1}
Enthalpy change of atomisation of Fe(s)	+416
Sum of first and second electron affinity of O(g)	+657
Enthalpy change of formation of FeO(s)	-272



−272 = +416+ ½ (496) + 762 + 1560 + 657 + LE

LE = – 3915 kJ mol^{-1}

(ii) State and explain how the lattice energy of FeO(s) compares to the lattice energy of CaO(s). [2]

$$\left|\text{lattice energy}\right| \propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$$

Since anions are the same and Fe^{2+} and Ca^{2+} have same charge but Fe^{2+} has smaller radius, there is stronger ionic bonds/greater attractionbetween Fe^{2+} and O^{2-}.

Hence LE of FeO is more exothermic/more negative than that of CaO.

(iii) Most naturally occurring samples of iron(II) oxide are found as the mineral wüstite.

Wüstite has formula $Fe_{20}O\boldsymbol{x}$. It contains both Fe^{2+} and Fe^{3+} ions.

90% of the iron is present as Fe^{2+} and 10% is present as Fe^{3+}.

Deduce the value of ***x***. [1]

Charge of cations = charge of anions (per unit of $Fe_{20}O_x$)

$20 \times [0.9(+2) + 0.1(+3)] = 2x$

$20 \times [0.9(+2) + 0.1(+3)] - 2x = 0$

$x = 21$

OR

Total charge of cations = 18(+2) + 2(+3) = +42

Total charge of anions (O^{2-}) = -42

No. of anions = 42/2 = 21

x = 21

(d) Heating of FeO results in the formation of Fe_3O_4, as shown.

$4FeO \rightarrow Fe + Fe_3O_4$ ------------------------**reaction 1**

Each formula unit of Fe_3O_4 contains one Fe^{2+} and two Fe^{3+} ions.

(i) Deduce the type of reaction in **reaction 1**. Explain your answer. [1]

Disproportionation as Fe^{2+} is reduced to Fe and oxidised to Fe^{3+} simultaneously/ or oxidation state of Fe changes from +2 in Fe^{2+} to 0 in Fe and +3 in Fe_3O_4 simultaneously.

(ii) Molten Fe_3O_4 can be electrolysed using inert electrodes to form Fe.

Calculate the maximum mass of iron metal formed when molten Fe_3O_4 is electrolysed for six hours using a current of 50 A.

Assume the one Fe^{2+} and two Fe^{3+} ions are discharged at the same rate. [3]

$Q = It = 50 \times 6 \times 60 \times 60 = 1.08 \times 10^6$ C

Amt of e^- = $1.08 \times 10^6 \div 96500$ = **11.19 mol**

$Fe^{2+} + 2Fe^{3+} + 8e^- \rightarrow 3Fe$ OR words to the same effect e.g. 8e for 3 Fe

Amt of Fe = **3 / 8** × 11.19 = **4.197 mol**

Mass of Fe = 55.8 × 4.197 = **234.2 g**

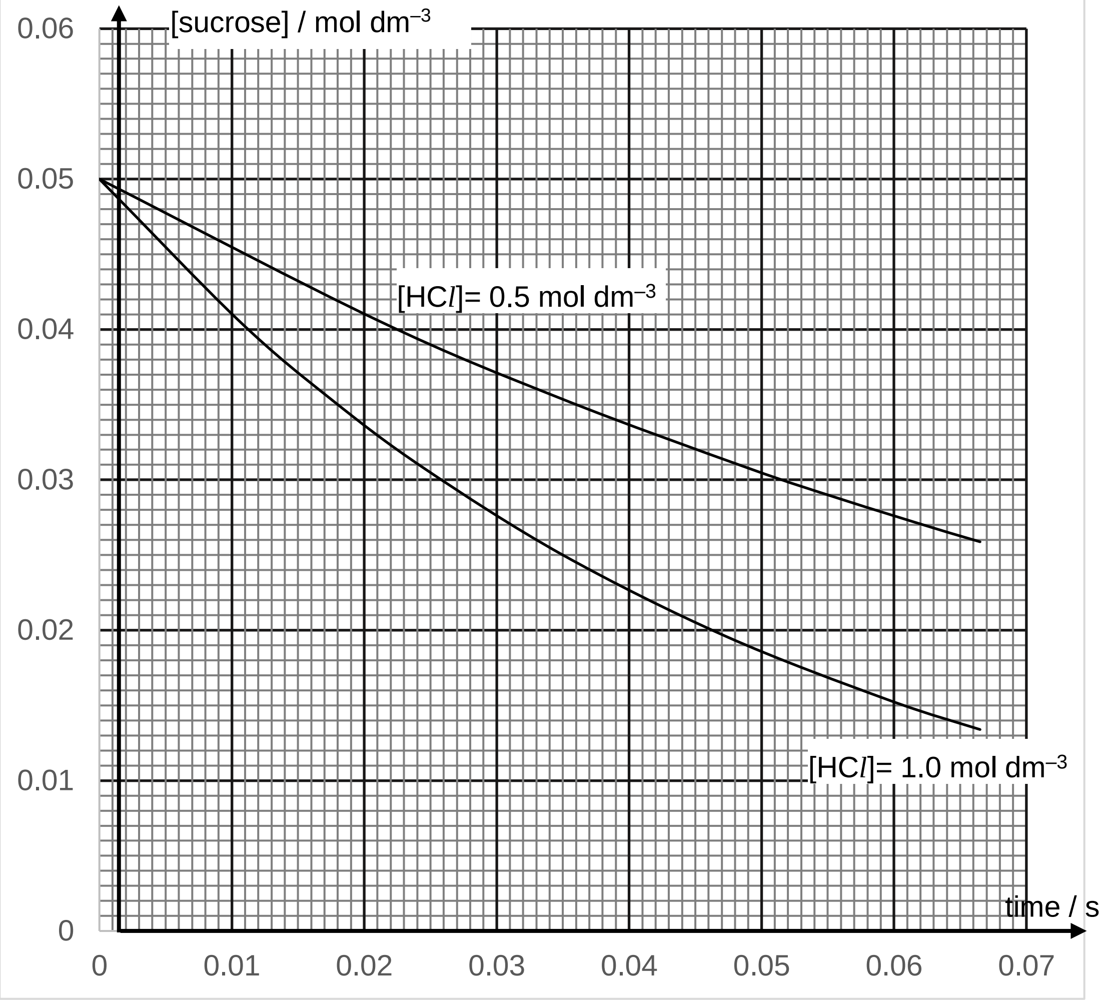
[Total: 21]

3 **(a)** Sucrose can be hydrolysed in the presence of dilute acids. This reaction can be represented by:

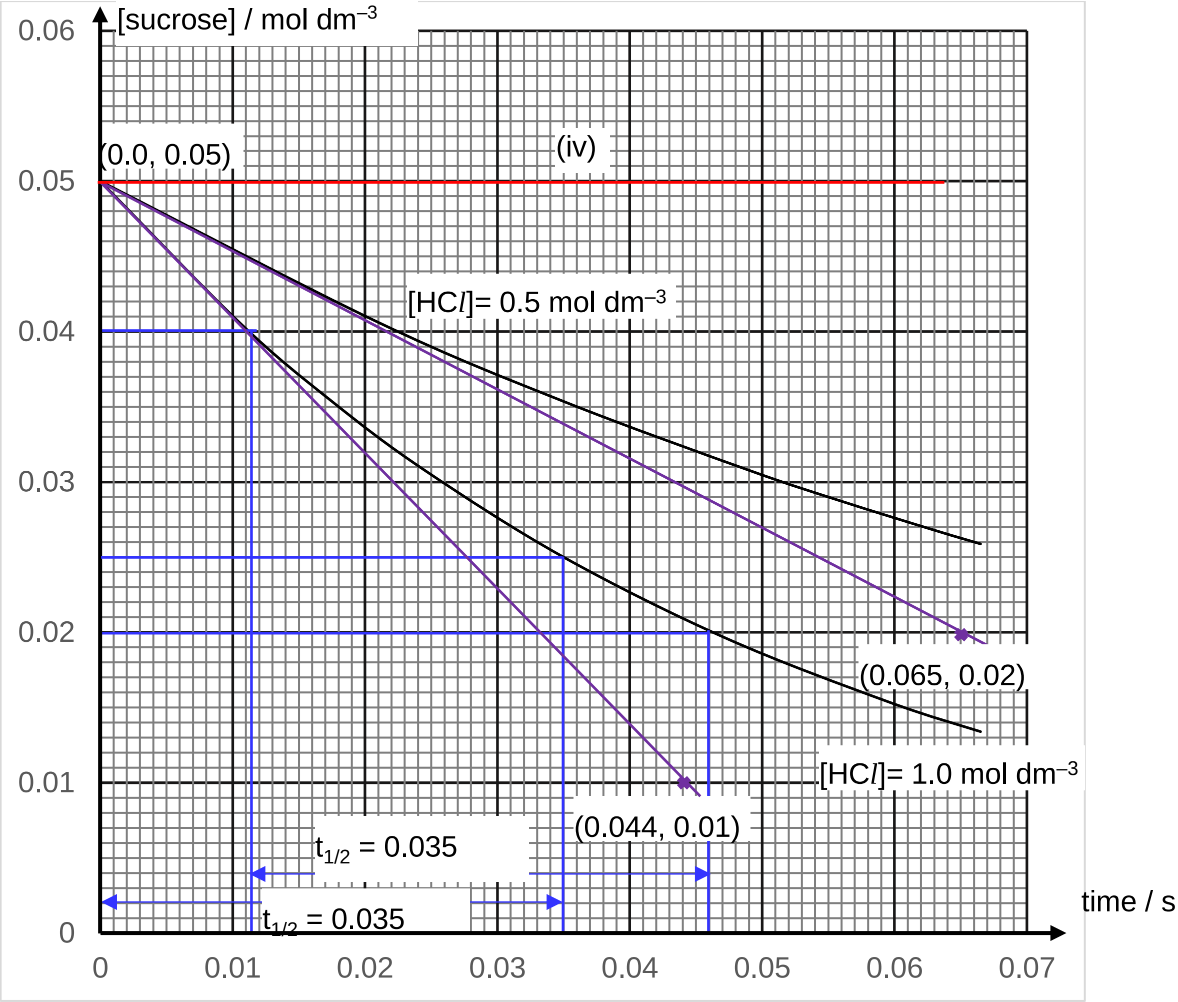
sucrose + water → glucose + fructose

In an investigation of the kinetics of this reaction, sucrose was reacted in two separate experiments with different concentrations of HC*l*.

The following graph was obtained with the initial concentration of sucrose in the reaction mixture = 0.05 mol dm^{-3}. The concentrations cited in the graph indicate the initial concentrations of each reagent in the reaction mixture.



(i) Use the graphs to determine the order of reaction with respect to [sucrose] and [HC*l*]. [3]



For [sucrose], check using $t_{1/2}$

From 0.05 to 0.025 mol dm^{-3} of [sucrose], $t_{1/2}$ is 0.035 s.

From 0.04 to 0.02 mol dm^{-3} of [sucrose], $t_{1/2}$ is 0.035 s.

Since **$t_{1/2}$ is constant, order of reaction wrt [sucrose] is 1**

For [HC*l*], use initial rate method,

When [HC*l*] = 1, initial rate = |(0.01 – 0.05)/(0.044 – 0)| = 0.909 (mol dm^{-3} s^{-1})

When [HC*l*] = 0.5, initial rate = |(0.02 – 0.05)/(0.065 – 0)| = 0.462 (mol dm^{-3} s^{-1}) [1 mark]

Since **initial rate doubles when concentration of HC*l* doubles, order of reaction wrt [HC*l*] is 1**.

(ii) Write the rate equation for the hydrolysis of sucrose. [1]

Rate = k[sucrose][HC*l*]

(iii) Calculate the rate constant, *k*, for this reaction. [1]

$0.909 = k[0.05]$

$k = 18.1\ \text{mol}^{-1}\ \text{dm}^{3}\ \text{s}^{-1}$

Based on student values, and they can use either initial rate.

Or

$t_{1/2} = \ln 2/\ k[\text{HCl}]$

$0.035 = \ln 2/\ k(1.0)$

$k = 19.8\ \text{mol}^{-1}\ \text{dm}^{3}\ \text{s}^{-1}$ since HCl is in large excess.

(iv) A third experiment was conducted with the following initial concentrations:

$[\text{sucrose}] = 0.05\ \text{mol dm}^{-3}$ and $[\text{HC}l] = 1.0 \times 10^{-6}\ \text{mol dm}^{-3}$

Calculate the half-life of this reaction and sketch on the graph how [sucrose] would change with respect to time. [2]

$\text{rate} = k[\text{sucrose}][\text{HC}l]$

Since [sucrose]>>[HC*l*], $k' = k[\text{sucrose}]$ (pseudo-1st order)

$k' = 18.1\ (0.05) = 0.905$

$t_{1/2} = (\ln 2)\ /\ k' = 0.766$ s

The concentration sketch should show that the concentration of [sucrose] should remain constant. [1m for horizontal line]

(v) Sucrose in this question is represented by $R_1\text{-O-}R_2$.

Two possible mechanisms have been suggested for the hydrolysis of sucrose, mechanism A and mechanism B.

Mechanism A

$R_1\text{-O-}R_2 + H^+ \rightarrow R_1\text{-O-}R_2H^+$ slow step

$R_1\text{-O-}R_2H^+ + H_2O \rightarrow R_1\text{-OH} + R_2\text{-OH} + H^+$ fast step

Mechanism B

$R_1\text{-O-}R_2 \rightarrow R_1\text{-O}^- + R_2^+$ slow step

$R_2^+ + H_2O \rightarrow H^+ + R_2\text{-OH}$ fast step

$H^+ + R_1\text{-O}^- \rightarrow R_1\text{-OH}$ fast step

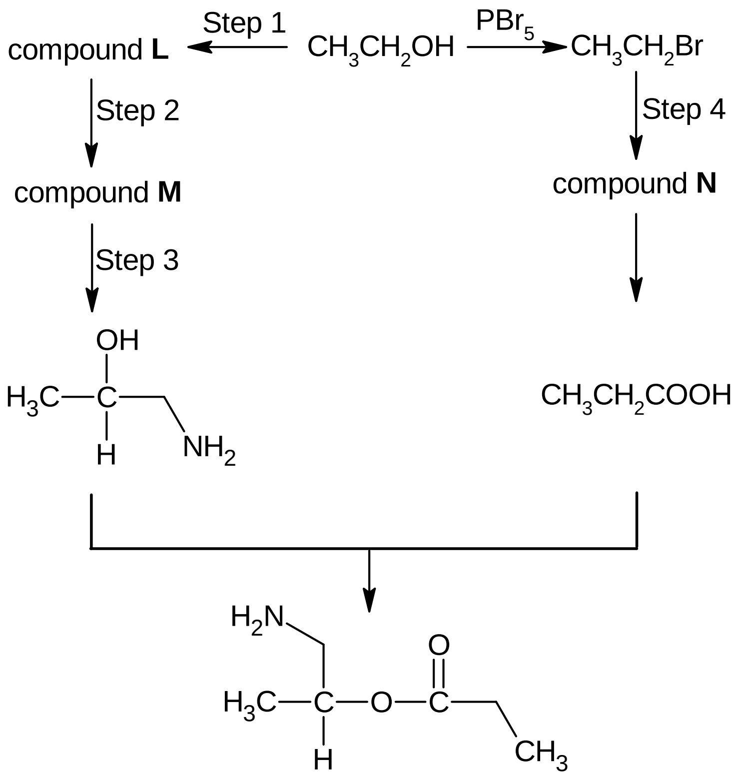
[2]

Based on your answer in **(a)(ii)**, which is the correct mechanism for the hydrolysis of sucrose? Explain your answer.

Mechanism A is the correct mechanism as it involves **1 mole of sucrose and 1 mole of H^+ in the slow step.**

(b) Ethanol is one of the products from the fermentation of sucrose, and can be used to synthesise a variety of chemicals.

Fig. 3.1 shows the synthesis of a compound **K** from ethanol.



compound **K**

Fig. 3.1

(i) Draw the structures of compounds **L**, **M**, and **N**. [3]

CH_3CHO	$CH_3CH(OH)CN$	CH_3CH_2CN
Compound **L**	Compound **M**	Compound **N**

(ii) Suggest the reagents and conditions for Steps 1, 2, 3 and 4. [4]

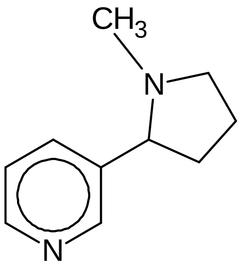
	Reagents and conditions
Step 1	$K_2Cr_2O_7$(aq), H_2SO_4(aq), heat with immediate distillation
Step 2	HCN, trace NaCN/NaOH, cold (or 10 – 20°C)
Step 3	$LiAlH_4$, dry ether or H_2/Ni, heat or H_2 , Pt
Step 4	Ethanolic/Alcoholic KCN, heat

(iii) Explain why compound **K** is soluble in water. [1]

The energy released from the formation of **hydrogen bonds between compound K and water molecules** is **sufficient** to break the **hydrogen bonds in compound K** and **hydrogen bonds in water**.

[Total: 17]

4 Nicotine is a stimulant found in the leaves of the tobacco plant. It is a highly addictive substance present in products such as cigarettes, cigars and chewing tobacco.



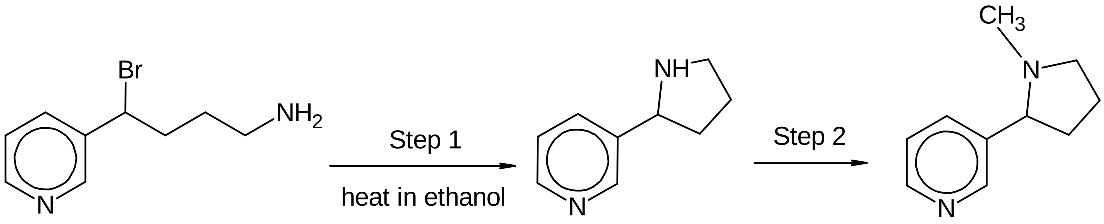
nicotine

(a) Nicotine has a chiral carbon and can exist as two enantiomers.

Suggest why it is important to ensure the correct enantiomer of nicotine is used in commercial products. [1]

Using the wrong enantiomer of nicotine may result in different biological effects/ lack of stimulating effect/higher toxicity/more/less addictive.

(b) While nicotine occurs naturally in tobacco, it can also be synthetically produced. Fig. 4.1 shows the synthesis of nicotine from an optically active compound **A** ($C_9H_{13}BrN_2$).

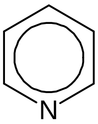


compound **A** racemic mixture of intermediate **X** nicotine

Fig. 4.1

(i) Other than pyridine, identify the functional groups in compound **A**.

Structure of pyridine



[1]

Secondary halogenoalkane / alkyl halide, primary amine.

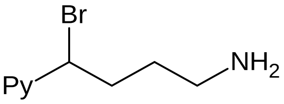
(ii) Suggest the reagents and conditions required for step 2. [1]

Limited CH_3Cl (CH_3I or CH_3Br), heat

(iii) In step 1, a racemic mixture of products was formed. [3]

Complete Fig. 4.2 to name and suggest a mechanism for this reaction. Show the relevant dipoles, charges, and structure of the intermediate formed. Indicate the movement of electron pairs by using curly arrows, as well as the slow step.

You may represent compound **A** as



Name of mechanism: ……………………………………..

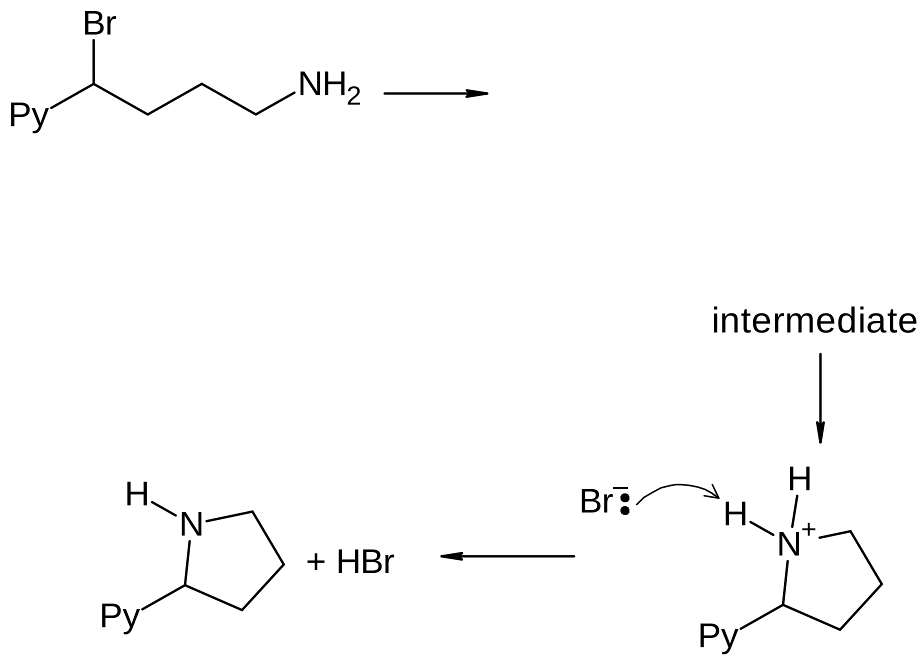
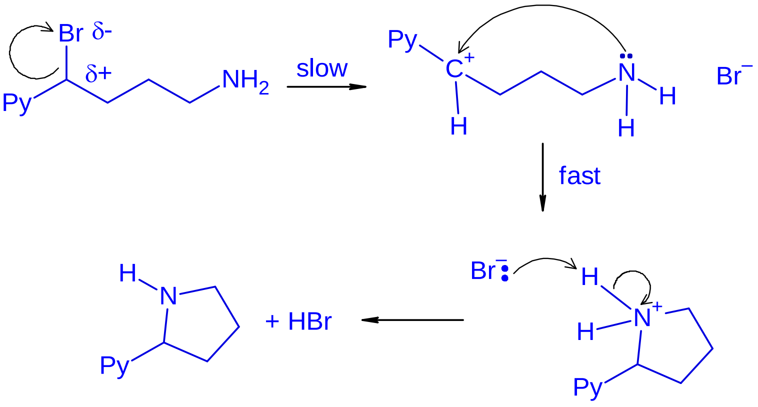


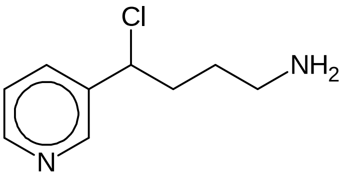
Fig. 4.2

Nucleophilic substitution, S_N1



- Dipoles on C and Br
- Arrow to show bond breaking in step 1+ Arrow pointing from lone pair on N to C+
- Arrow to show loss of proton
- Slow/fast step
- Balanced equations (must show Br^- and H^+)

(c) Compound **B** can also be used as the starting material in the reaction scheme in Fig. 4.1 to synthesise nicotine.



compound **B**

Suggest a reason why compound **B** as the starting material to synthesise nicotine is less preferred as compared to compound **A**. [1]

C-C*l* is a stronger bond than C-Br, hence rate of reaction will be slower/ more energy needed/harder to break.

(d) Carbocations frequently undergo structural changes, called rearrangements, to form more stable ions as shown in Fig. 4.3.

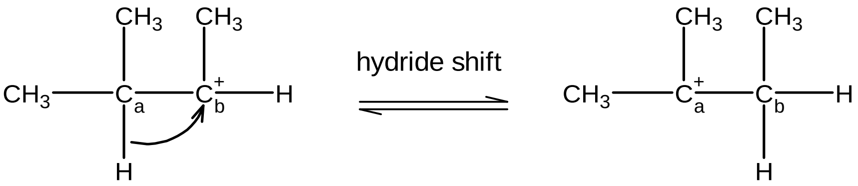
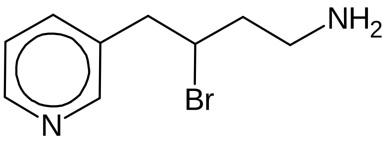


Fig. 4.3

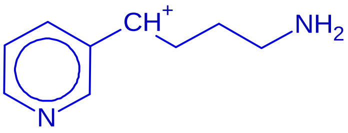
(i) Compound **C** is a constitutional isomer of compound **A** which can also be used as a reactant in Fig. 4.1, forming intermediate compound **X**.



compound **C**

By considering the relative stabilities of the carbocation intermediates, explain why hydride shift would readily occur when compound **C** is used. [1]

When hydride shift occurs, the positive charge will be on the benzylic C adjacent to the pyridine ring.



The positive charge is dispersed into the ring resulting in a more stable carbocation.

(ii) Compound **C** can undergo the same reaction as compound **A** to form intermediate compound **X**.

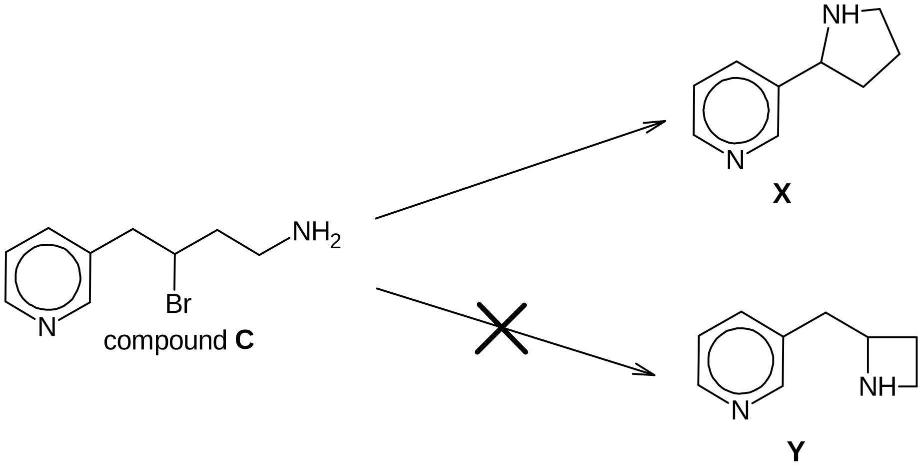


Fig. 4.4

By considering the structures of intermediate compounds **X** and **Y** in Fig. 4.4, suggest why intermediate compound **Y** is not formed. [1]

X is a 5-membered ring and experience less ring/angle strain compared to **Y** which is a 4-membered ring.

[Total: 9]

5 Refrigerants are cooling agents that absorb and release heat in a refrigerator or air-conditioning unit. Common refrigerants are simple covalent molecules such as hydrocarbons like propane, hydroflurocarbons (HFCs) etc, and they exist in both the gaseous and liquid phases in a refrigerator.

(a) State the three basic assumptions of the kinetic theory as applied to an ideal gas. [2]

Any 3 from the following (recommended to use the 1st three)

- The **molecular size/ volume of the gas particles is negligible compared to the total volume occupied by the gas.**
- There are **negligible forces of attraction between the gas particles**.
- When the particles collide, the **collision is perfectly elastic** / results in **no loss of kinetic energy**.
- The gas particles are in **constant random** motion, colliding occasionally with one another and with the walls of the container (gives rise to pressure).
- The **average kinetic energy of the particles is proportional to the absolute temperature**.

(b) The refrigeration cycle in a refrigerator works based on the principles of heat transfer and phase change as it circulates through different components of the system as shown in Fig. 5.1.

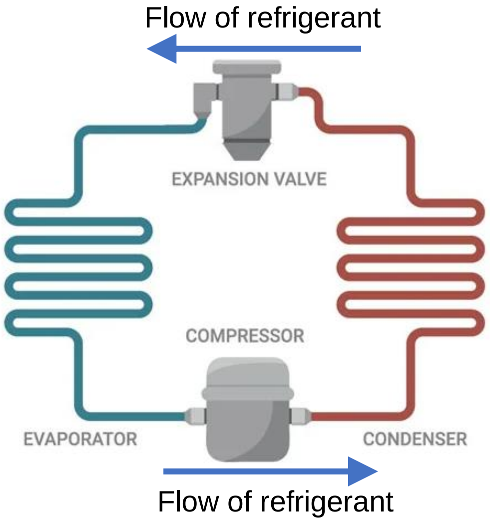


Fig. 5.1

1. At the compressor, the gaseous refrigerant is compressed, increasing the temperature of the refrigerant.
2. The high-pressure, high-temperature refrigerant then flows into the condenser coils located at the back or bottom of the refrigerator and comes into contact with a cooling medium such as air. Heat is released to the surroundings during this process, causing the refrigerant to condense and cool down.
3. The high-pressure liquid refrigerant passes through an expansion valve.
4. The low-pressure, low-temperature refrigerant mixture enters the evaporator coils and reduces the temperature of the contents (e.g. food) of the refrigerator. The refrigerant vaporises after absorbing the heat.
5. The gaseous refrigerant returns to the compressor and the refrigerator cycle repeats.

(i) Describe, in terms of kinetic theory of gases, the change in the behaviour of the gas particles when the refrigerant passes through the compressor. [1]

During **compression**, the refrigerant is subjected to an increase in pressure, causing the molecules to come closer together and collide more frequently with the walls of the compressor.

OR **Increase in temperature** (from description), gas particles gain kinetic energy and collide more frequently.

(ii) Explain, in terms of kinetic theory of gases, why the gaseous refrigerant is condensed when in contact with the cooling medium at the condenser. [2]

Heat is transferred from the refrigerant molecules to the cooler environment, leading to a decrease in kinetic energy of the molecules. The intermolecular forces of attractions become more significant and bring the molecules closer together, causing condensation to take place.

(iii) Explain, in terms of intermolecular forces, why liquid refrigerants vaporise at the evaporator. [2]

In the liquid state, the refrigerant molecules are simple covalent molecules, held together by weak intermolecular forces of attractions (IMF) /instantaneous dipole-induced dipole attractions (id-id)/permanent dipole-permanent dipole attractions. As the low-pressure liquid flows through the evaporator, it absorbs heat from surrounding, the refrigerant molecules gain kinetic energy to overcome the id-id/IMF and hence vaporise. The absorption of heat energy from surroundings lead to cooling.

(iv) Explain why an ideal refrigerant should have a high enthalpy change of vaporisation. [1]

The ideal refrigerant should have high enthalpy change of vaporisation in order to absorb the most heat as it vaporises.

(c) Table 5.1 shows a list of possible refrigerants. An ideal refrigerant has the following features:

Low Ozone Depletion Potential
Low Global Warming Potential
Non-flammable
Non-toxic

Table 5.1

Compound	ΔH_{vap}	**Ozone Depletion Potential**	**Global Warming Potential**	**Flammability**	**Toxicity**
Chloroethene, C_2H_3Cl	High	Low	Low	Flammable	High
Dichlorodifluoromethane, CCl_2F_2	High	High	High	Non-flammable	Low

Isobutane, $CH(CH_3)_3$	High	Low	Low	Flammable	Low
Oxygen, O_2	Low	Low	Low	Non-flammable	Low
1,1,1,2 -Tetrafluoroethane, CF_3CH_2F	High	Low	High	Non-flammable	Low
Water, H_2O	High	Low	Low	Non-flammable	Low

(i) Of the list of compounds in Table 5.1, water has the highest melting point of 0 °C. Explain. [1]

Water has simple covalent structure with strong intermolecular **hydrogen bonds** between the molecules, which require more energy to overcome, hence it has the highest melting point.

(ii) Suggest why water is not suitable as a refrigerant for temperatures below 0 °C. [1]

Water has a high melting point, which restricts its cooling to temperatures above 0 °C.

Or

Water would freeze, become ice, and cannot move.

Or words to that effect.

(iii) Explain why 1,1,1,2-tetrafluoroethane, CF_3CH_2F, has lower ozone depletion potential compared to dichlorodifluoromethane, CCl_2F_2. [1]

The C-F bond is very strong, requires a lot of energy to break, and hence does not generate fluorine radicals which would react with ozone.

(iv) Which of the compounds in Table 5.1 would you choose as a refrigerant? Explain your choice and suggest how its drawbacks could be mitigated. [2]

Isobutane as it scores well on all factors except flammability.

As it is flammable, the refrigerant system must be **tightly sealed** to prevent leakage, and not be exposed to flame.

Or

1,1,1,2–Tetrafluroethane as it scores well on all factors except global warming potential.

As the gas has high global warming potential, during **disposal/servicing** the gas **cannot be allowed to escape** into the atmosphere. OR **don't let it leak (for both).**

(d) In the past, industrial refrigerators usually are made of common materials such as copper and iron. However, the use of ammonia as the refrigerant has many issues.

(i) Liquid ammonia behaves similarly to water and undergoes auto-ionisation to form ammonium as one of the products. Construct an equation to illustrate this behaviour of liquid ammonia. [1]

$2\,NH_3 \rightleftharpoons NH_2^- + NH_4^+$

(ii) One of the main issues with the use of ammonia together with iron piping in the refrigerators is the formation and accumulation of hydrogen gas. Suggest the role of iron in the formation of hydrogen gas. [1]

$2\,NH_3 \rightleftharpoons N_2 + 3H_2$

The iron would catalyse the decomposition of ammonia to form nitrogen and hydrogen gas respectively.

(iii) A leak of the refrigerant in old refrigerators made in 1800s would often result in a blue solution being found at the collection tray at the bottom of the refrigerator.

Explain, with the aid of the *Data Booklet*, how the blue solution is formed. [2]

$Cu + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+} + 2e^-$ -0.05 V

$O_2 + 2H_2O + 4e^- \rightleftharpoons 4\,OH^-$ $+0.40$V

$E_{cell} = +0.40 - (-0.05) = +0.45$ V

Copper wiring coming into direct contact with the ammonia, results in the direct formation of dark blue copper complex.

OR

$CuO + 2NH_4^+ \rightarrow Cu^{2+} + H_2O + 2NH_3$

(As the refrigerator, being old, would have many of its parts oxidised, inclusive of the copper being used.) The copper (II) compounds (most likely CuO) present would undergo acid-base reaction with ammonium ions to form $Cu^{2+}(aq)$.

$Cu^{2+} + 4NH_3 \rightleftharpoons Cu(NH_3)_4^{2+}$

It would then undergo ligand exchange to form the dark blue solution at the bottom of the refrigerator.

(iv) Ammonia, NH_3, is commonly used in modern industrial refrigeration systems utilising plastic components as it has no effect on the ozone layer.

Suggest, with a reason, why ammonia has zero ozone depletion potential. [1]

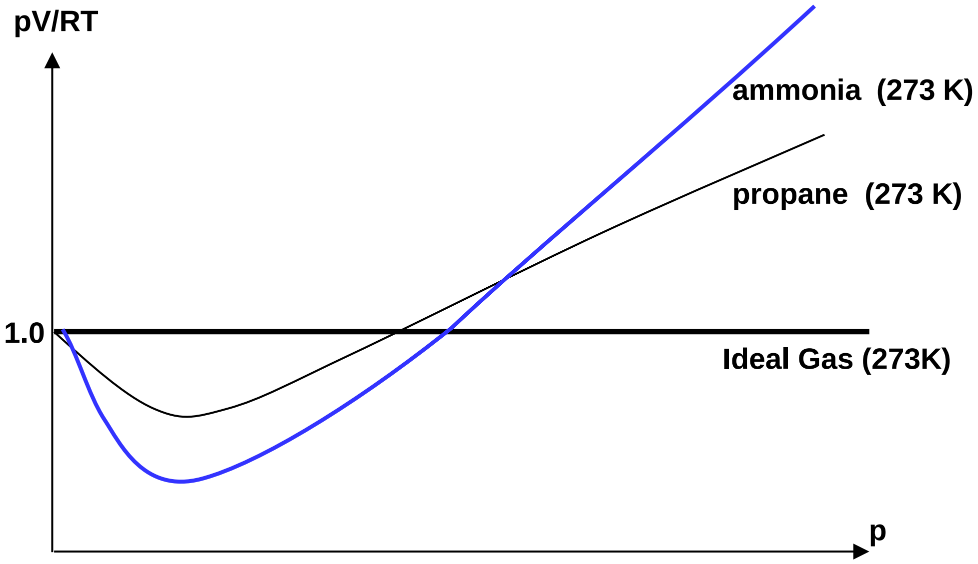
Ammonia does not dissociate to form radicals and hence does not result in ozone depletion.

OR

N-H bond is strong and does not break homolytically to form radicals.

(v) The plots of pV/RT against p for one mole of an ideal gas and one mole of propane at 273 K are given below.

On the same diagram, sketch a curve for the behaviour of 1 mol of ammonia at 273 K. [1]



[Total: 19]