TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

H2 CHEMISTRY **9729/01**

Paper 1 Multiple Choice **25 September 2025**

1 hour

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

There are **thirty** questions in this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the use of the Answer Sheet very carefully.

You are advised to fill in the Answer Sheet as you go along. No additional time will be given for the transfer of answers once the examination has ended.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

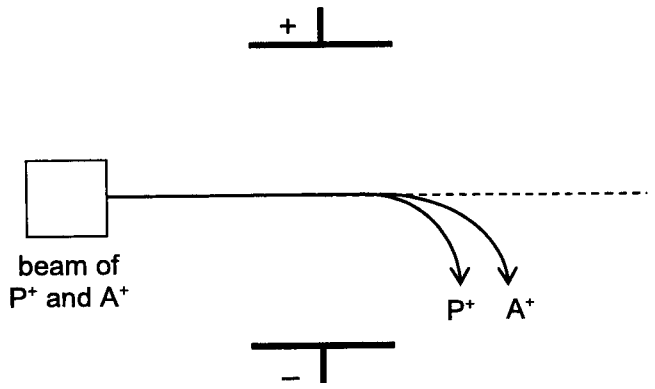
Use of the Answer Sheet

Ensure you have written your name, class, date and subject on the Answer Sheet. Shade the last four digits of your centre/index number on the Multiple Choice Answer Sheet. (e.g. if your centre/index number is 3054**1234**, shade 1234).

Use a **2B** pencil to shade your answers on the Answer Sheet; erase any mistakes cleanly. Multiple shaded answers to a question will not be accepted.

1 *Use of the Data Booklet is relevant to this question.*

In an experiment, a sample containing phosphorus and an unknown element A is vapourised, ionised and passed through an electric field as shown below.



Given that the extent of deflection for A^+ is smaller than P^+, which could be the identity of element A?

A sulfur **B** silicon **C** sodium **D** nitrogen

2 *Use of the Data Booklet is relevant to this question.*

Which particle contains the largest number of unpaired electrons?

A O **B** Cl^- **C** K^+ **D** Fe

3 In a microwave oven, the microwave produced is absorbed by polar molecules.

Which molecules would absorb microwave energy?

1 SO_3

2 CH_2F_2

3 CH_3CH_2OH

A 3 only **B** 1 and 2 only **C** 2 and 3 only **D** 1, 2 and 3

4 The melting point of potassium is lower than the melting point of magnesium.

Which statement is most relevant in explaining the difference?

A Potassium ion has a smaller radius than magnesium ion.

B Potassium ion has a lower charge than magnesium ion.

C Potassium atom contains fewer electrons than magnesium atom.

D Potassium atom is heavier than magnesium atom.

5 Which of the following cannot be explained by hydrogen bonding?

A The existence of hydrogen–difluoride anion, HF_2^-.

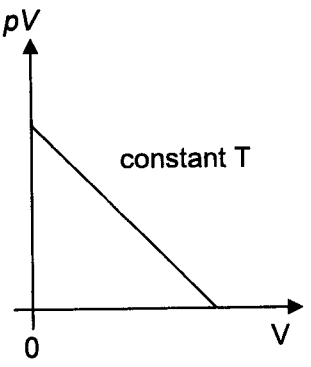
B The difference in volatility between pentan–1–ol and hexan–1–ol.

C The difference in melting point between 2–nitrophenol and 4–nitrophenol.

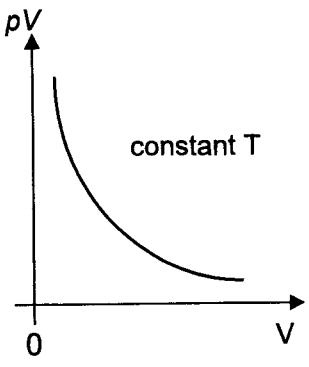
D The relative molecular mass of ethanoic acid in organic solvent is higher than expected.

6 Which diagram correctly describes the behaviour of a fixed mass of an ideal gas?

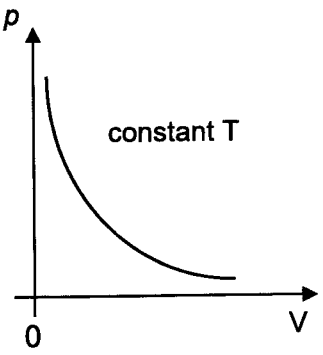
A



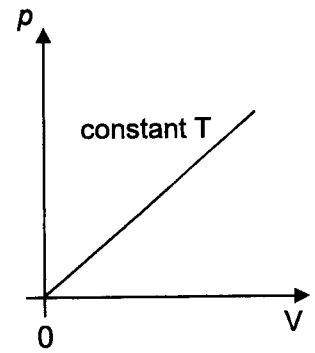
B



C



D



7 *Use of the Data Booklet is relevant to this question.*

Sodium percarbonate, $(Na_2CO_3)_x \cdot y(H_2O_2)$, is an oxidising agent used in laundry cleaning products.

On acidification, 10.0 cm^3 of 0.100 mol dm^{-3} sodium percarbonate releases 48.0 cm^3 of carbon dioxide at room temperature and pressure.

An identical sample, on titration with 0.0500 mol dm^{-3} $KMnO_4$, requires 24.0 cm^3 before the first pink colour appears. 2 moles of $KMnO_4$ reacts with 5 moles of H_2O_2.

What is the ratio of y/x?

A $\frac{1}{3}$ B $\frac{2}{3}$ C $\frac{3}{2}$ D 3

8 **G**, **H** and **J** are three elements found in Period 3 of the Periodic Table.

Among the elements in Period 3,
- the melting point of **G** is the highest.
- the electrical conductivity of **H** is the highest.
- the melting point of the oxides of **J** is the highest.

Which of the following elements is **not** represented by **G**, **H** or **J**?

A Na **B** Mg **C** Al **D** Si

9 Which equation defines standard enthalpy change of formation correctly?

A $Na(s) + Cl(g) \rightarrow NaCl(s)$

B $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

C $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(s)$

D $H_2(g) + S(s) + 2O_2(g) \rightarrow H_2SO_4(l)$

10 Hydrogen can be made from steam.

$$H_2O(g) + C(s) \longrightarrow H_2(g) + CO(g)$$

The Gibbs free energy change of reaction at two different temperatures are shown.

At 378 K, $\Delta G_1 = +78$ kJ mol^{-1}
At 1300 K, $\Delta G_2 = -58$ kJ mol^{-1}

Which row gives the correct signs of ΔH and ΔS for this reaction?

	ΔH	ΔS
A	–	+
B	–	–
C	+	–
D	+	+

11 The equation for the formation of hexaamminecobalt(III), $[Co(NH_3)_6]^{3+}$ complex ion is shown below.

$$2Co^{2+} + 12NH_3 + H_2O_2 \longrightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$$

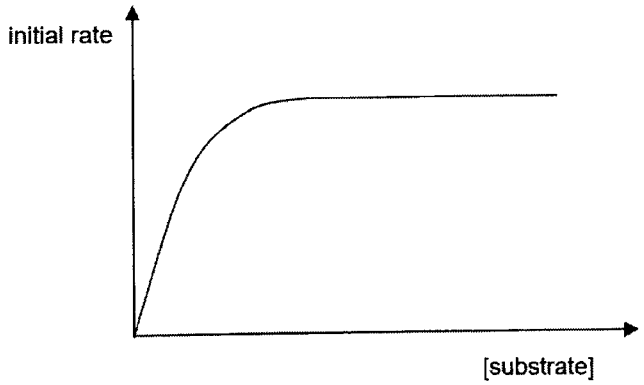
The rate equation is rate = $k\,[Co^{2+}][NH_3]^3[H_2O_2]$.

When the concentration of each reactant is x mol dm^{-3}, the initial rate was found to be y mol dm^{-3} s^{-1}.

What will be the initial rate of the reaction if $[Co^{2+}]$ is 2x, $[NH_3]$ is $\frac{1}{2}x$ and $[H_2O_2]$ is 2x?

A $\frac{1}{8}y$ **B** $\frac{1}{2}y$ **C** 2y **D** 8y

12 The Michaelis-Menten graph shows how the initial rate of reaction vary as the concentration of the substrate changes for an enzyme-catalysed reaction.



Which statement could explain the shape of the graph?

A The enzyme is acting as a limiting reagent and is being used up in the reaction.

B Substrate molecules inhibit the enzyme at high concentrations which resulted in a constant rate.

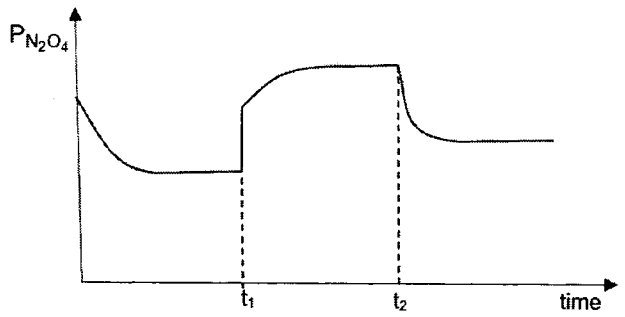
C The reaction will reach a constant rate when all active sites of the enzyme are occupied.

D At high substrate concentration, the order of reaction with respect to substrate is 1

13 A sample of N_2O_4 was placed in a closed vessel and allowed to reach equilibrium as shown below.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^\ominus = +57.3 \text{ kJ mol}^{-1}$$

When the partial pressure of a sample of N_2O_4 in a closed vessel was investigated, the following graph was obtained.



Which row correctly describes the changes applied to the reaction vessel at times t_1 and t_2?

	t_1	t_2
A	Volume decreased	Temperature increased
B	Volume decreased	Temperature decreased
C	Volume increased	Temperature increased
D	Volume increased	Temperature decreased

14 10.0 cm^3 of 8.00 x 10^{-3} mol dm^{-3} HC*l*(aq) is added to 10.0 cm^3 of 6.00 x 10^{-3} mol dm^{-3} $Ba(OH)_2$(aq).

What is the pH of the resulting solution?

A 3.0 **B** 4.7 **C** 9.6 **D** 11.3

15 A saturated solution of $Ca(OH)_2$ is found to have a pH of 12.4 at 25 °C.

Which statements are correct?

1 The K_{sp} of $Ca(OH)_2$ is 7.92×10^{-6} mol^3 dm^{-9}.

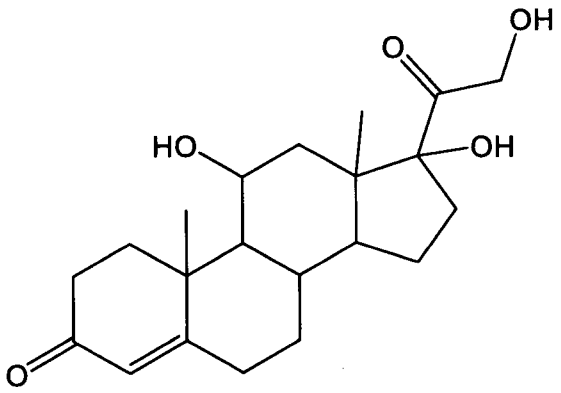
2 The solubility of $Ca(OH)_2$ will increase when aqueous HC*l* is added.

3 The solubility of $Ca(OH)_2$ would increase when temperature is raised to 40 °C.

4 The pH of the solution would increase when solid $Ca(NO_3)_2$ is added.

A 1 and 2 only **B** 2 and 3 only **C** 3 and 4 only **D** 1, 2 and 3 only

16 Cortisol is a hormone that plays a critical role in regulating glucose metabolism.

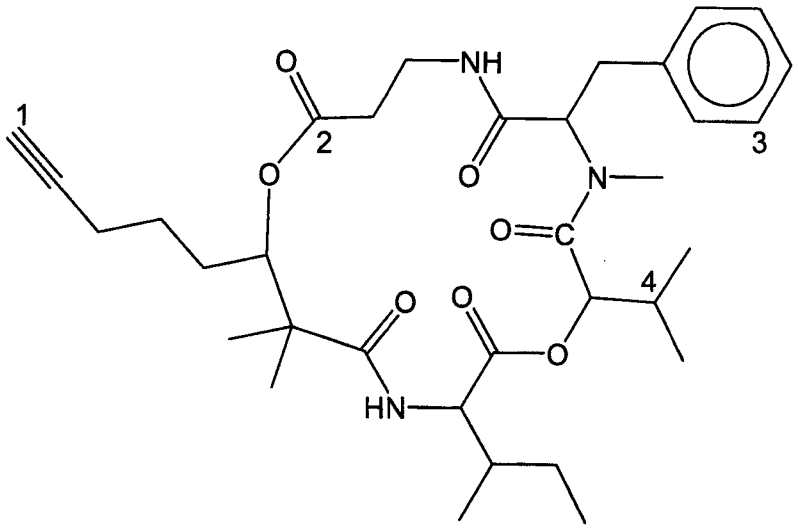


cortisol

After cortisol is reacted with an excess of hydrogen gas in the presence of platinum catalyst, how many chiral carbon atoms would there be in the product?

A 8 **B** 9 **C** 10 **D** 11

17 Yanucamide B can be extracted from a marine sponge.



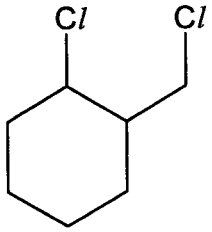
yanucamide B

What is the hybridisation of each of the carbon atoms, C-1 to C-4?

	C-1	C-2	C-3	C-4
A	sp^2	sp^2	sp	sp^3
B	sp	sp^2	sp^2	sp^3
C	sp^2	sp^3	sp^2	sp^2
D	sp	sp^2	sp	sp^2

18 Which compounds, on heating with ethanolic sodium hydroxide, produce **only one** product with molecular formula C_7H_{10}?

1



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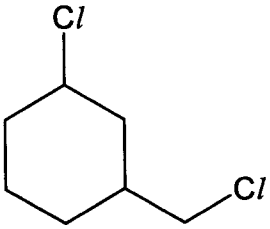

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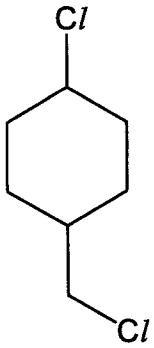


A 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

19 A catalytic converter is part of the exhaust system of many modern cars.

Which reaction does **not** occur in a catalytic converter?

A $CO_2 + NO \longrightarrow CO + NO_2$

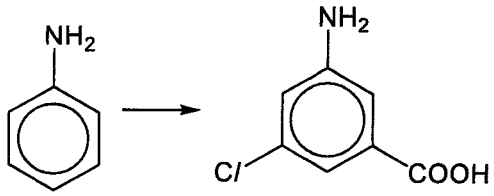
B $2CO + 2NO \longrightarrow 2CO_2 + N_2$

C $2CO + O_2 \longrightarrow 2CO_2$

D $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$

20 Use of the Data Booklet is relevant to this question.

Which of the following routes is most suitable to synthesise 3-amino-5-chlorobenzoic acid from phenylamine?



A neutralisation → chlorination → alkylation → oxidation → neutralisation

B neutralisation → alkylation → oxidation → chlorination → neutralisation

C reduction → alkylation → chlorination → oxidation → neutralisation

D reduction → alkylation → oxidation → chlorination → neutralisation

21 The molecular formula of compound **X** is $C_5H_{12}O$. The following shows the reactions compound **X** undergoes:

- reacts with alkaline aqueous iodine
- can be dehydrated to form two alkenes only

What could be the identity of compound **X**?

A $(CH_3)_2CHCH(OH)CH_3$

B $(CH_3)_2C(OH)CH_2CH_3$

C $CH_3CH_2CH(CH_3)CH_2OH$

D $CH_3CH_2CH_2CH(OH)CH_3$

22 A sample of bromoethane was warmed with ethanolic silver nitrate, and a cream precipitate was observed after about 4 minutes.

Under similar reaction conditions, which of the following compounds will result in precipitate formation only after 8 minutes?

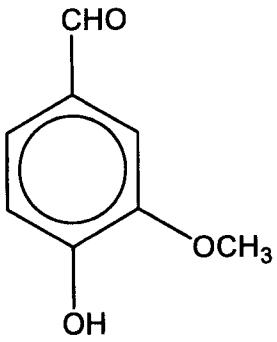
A chlorobenzene

B chloroethane

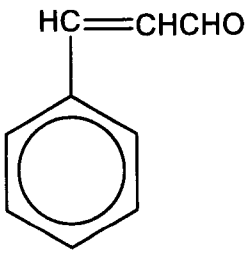
C iodoethane

D ethanoyl bromide

23 Vanillin and cinnamaldehyde are found in natural products and have very pleasant fragrances.



vanillin



cinnamaldehyde

Which reagents could be used to distinguish between the two compounds? You may assume that the $-OCH_3$ group in vanillin is inert.

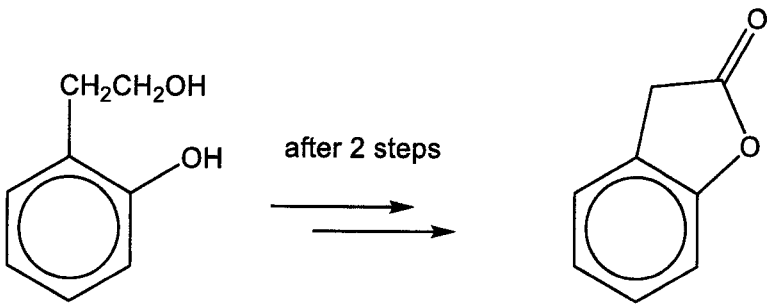
1 2,4-dinitrophenylhydrazine

2 Fehling's solution

3 Tollen's reagent

A 1 only **B** 2 only **C** 1 and 2 only **D** 1, 2 and 3

24 Compound **B** can be converted to compound **C** as shown below.



Which reagents are involved in the 2-steps synthesis?

1 hot acidified $KMnO_4$

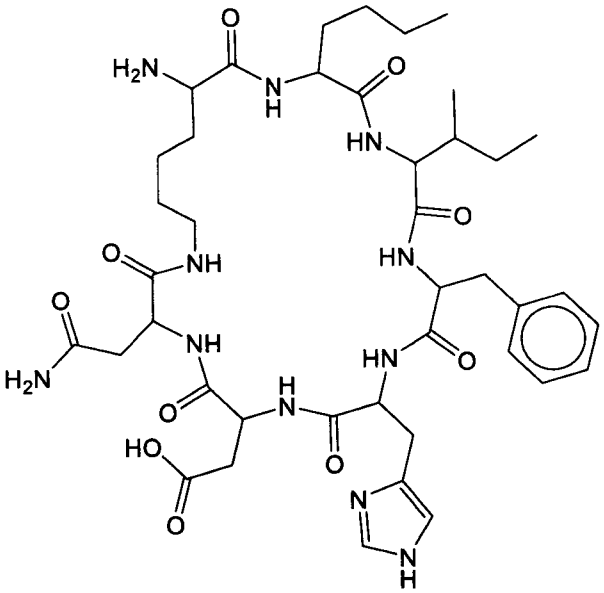
2 hot acidified $K_2Cr_2O_7$

3 PCl_5

4 concentrated H_2SO_4

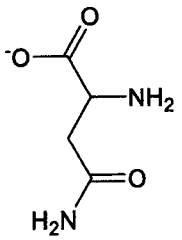
A 1 and 3 only **B** 1 and 4 only **C** 2 and 3 only **D** 2 and 4 only

25 Consider the structure of the following cyclic polypeptide.

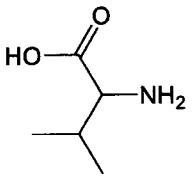


Which one of the following is a product of hydrolysis with hot NaOH(aq)?

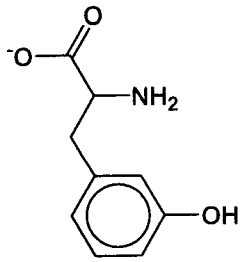
A



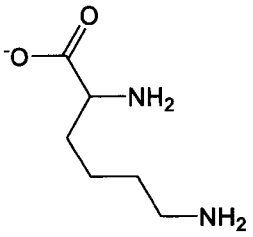
B



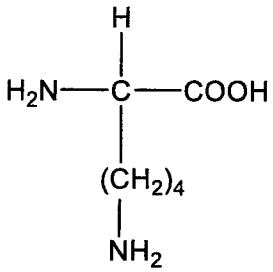
C



D



26 Lysine is an amino acid. The structure of lysine is shown below.



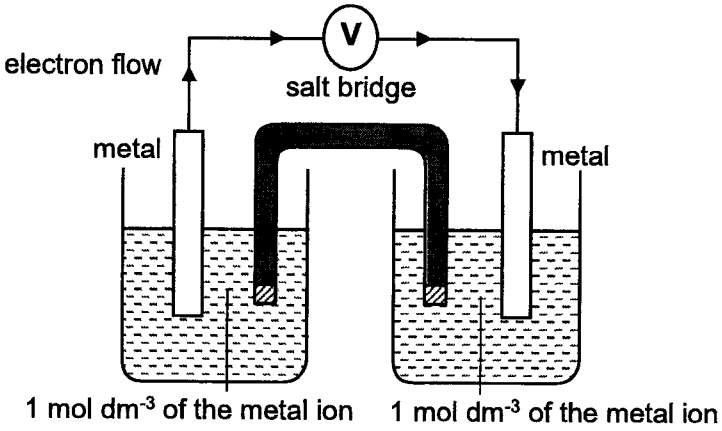
The pKa values of lysine are 2.18, 8.25 and 10.53.

Which of the following pH would result in a zwitterion to be predominantly formed?

A pH 1 **B** pH 5 **C** pH 9 **D** pH 13

27 *Use of the Data Booklet is relevant to this question.*

The half-cells for three metals: Ag, **X** and **Y** were in turn connected in pairs and the value of the potential difference was recorded at 298 K.



The results obtained are as shown in the table below.

negative electrode	positive electrode	e.m.f /V
X	Ag	+ 0.46
Y	X	+ 0.47

What is the identity of metal Y?

A Co **B** Ni **C** Pb **D** Zn

28 *Use of the Data Booklet is relevant to this question.*

A current of 8 A is passed for 100 minutes through molten aluminium oxide using inert electrodes.

What is the approximate volume of gas liberated, measured at s.t.p.?

A 2.8 dm^3 **B** 3.0 dm^3 **C** 8.4 dm^3 **D** 11.2 dm^3

29 Copper is a typical transition element and calcium is an s-block element.

Which property is greater for calcium than for copper?

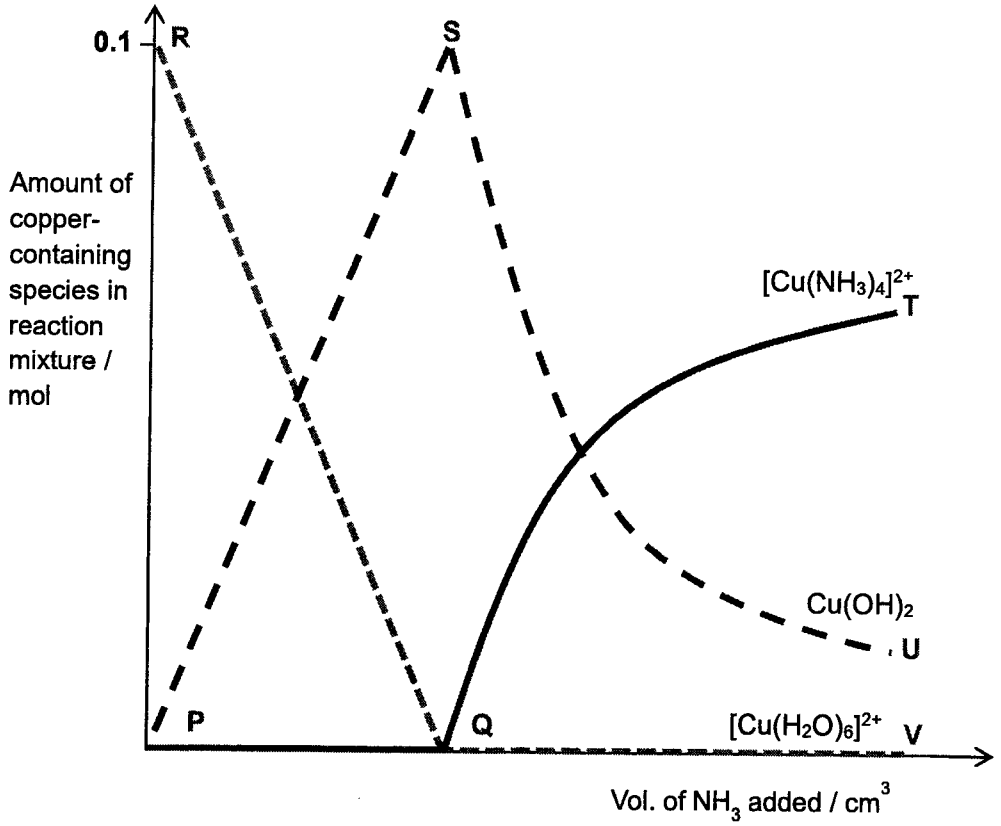
A density

B melting point

C reducing power

D electrical conductivity

30 An experiment was conducted by adding $NH_3(aq)$ gradually to $CuSO_4(aq)$ in a beaker. The amounts of three major copper-containing species, $[Cu(H_2O)_6]^{2+}$, $Cu(OH)_2$ and $[Cu(NH_3)_4]^{2+}$ were determined and plotted against the volume of $NH_3(aq)$ added.



Which portion of the graph best represents each of the processes described?

	precipitation	dissolution	complex formation
A	QT	SU	QT
B	PS	RQ	SU
C	QT	RQ	SU
D	PS	SU	QT

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TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME

CIVICS GROUP

H2 CHEMISTRY **9729/02**

Paper 2 Structured Questions **18 September 2025**

2 hours

Candidates answer on the Question Paper.

Additional materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams and graphs.

Do not use 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	/ 7
2	/ 16
3	/ 11
4	/ 12
5	/ 16
6	/ 13
Total	/ 75

This document consists of **24** printed pages.

1(a) The graph in Fig. 1.1 shows the atomic radii of some Period 4 metals.

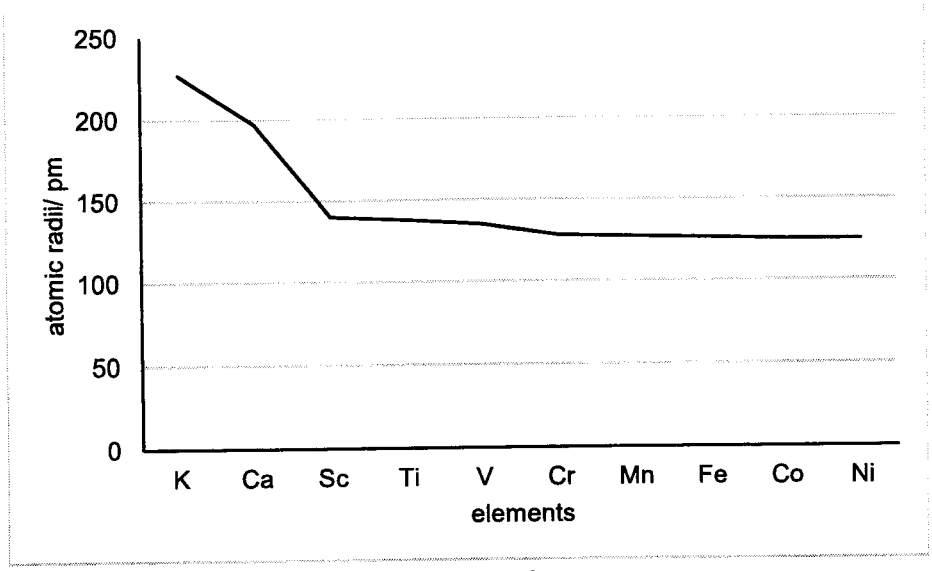


Fig. 1.1

(i) With reference to Fig. 1.1, explain briefly why the atomic radius of Ca is smaller than K.

.....

.....

.....

..... [1]

(ii) With reference to Fig. 1.1, describe and explain why the atomic radii from Cr to Ni are relatively constant.

.....

.....

.....

.....

.....

.....

..... [2]

(b) **(i)** Shibuichi is an alloy of copper and silver and is used in traditional Japanese sword fittings. A particular sample of Shibuichi produced the following peaks in its mass spectrum as shown in Fig. 1.2.

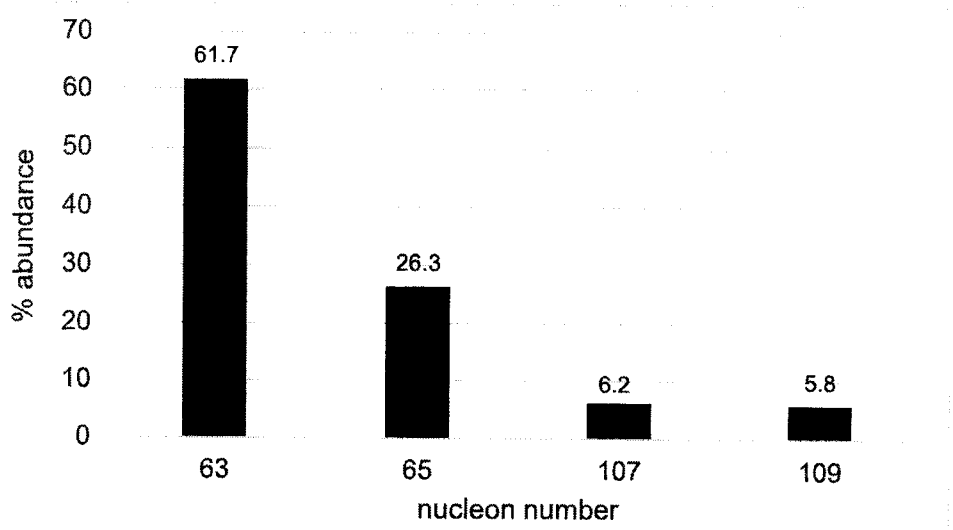


Fig. 1.2

Calculate the average A_r of copper from these data. [1]

(ii) With reference to Fig. 1.2, state the number of protons and neutrons present in the atom with nucleon number 109.

Number of protons: _____

Number of neutrons: _____

[1]

(c) Table 1.2 shows the successive ionisation energies of element **B**.

Table 1.2

	1st	2nd	3rd	4th	5th	6th	7th	8th
I.E. / kJ mol^{-1}	900	1800	3250	4900	6050	12690	14200	16250

(i) State which group does element **B** belongs to.

.....[1]

(ii) Both element **A** and element **B** are consecutive elements in the Periodic Table and that element **A** is positioned to the left of element **B**.

Explain why the 3rd ionisation energy of element **B** is lower than element **A**.

.....

.....

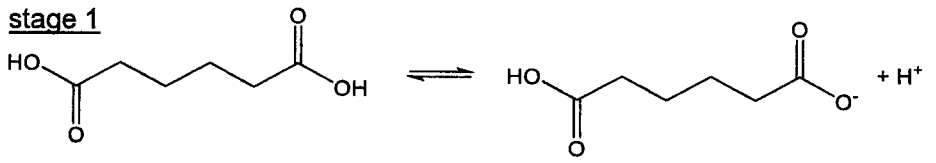
.....

.....[1]

[Total: 7]

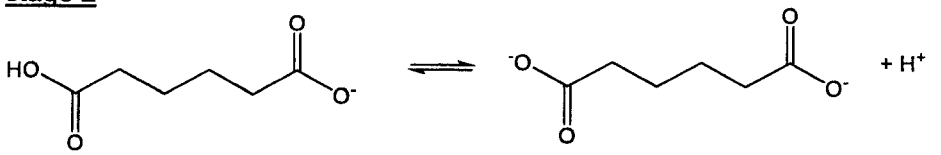
2 Adipic acid, $HOOC(CH_2)_4COOH$, is a flexible food additive used as a gelling aid, firming and buffering agent and can be found in many foods. It is a dibasic acid that ionises in 2 stages.

stage 1



$K_{a1} = 3.72 \times 10^{-5}$

stage 2



$K_{a2} = 3.89 \times 10^{-6}$

(a) **(i)** Write an expression for the first acid dissociation constant of adipic acid, K_{a1}.

[1]

(ii) Suggest a reason why the value of K_{a2} is lower than that of K_{a1}.

.....

.....

..... [1]

A mixture of adipic acid and its potassium salt can function as a buffer.

(iii) With the aid of a chemical equation, briefly explain how this mixture can act as a buffer when a small amount of base is added.

The effects of K_{a2} can be ignored in any buffer action.

.....

.....

.....

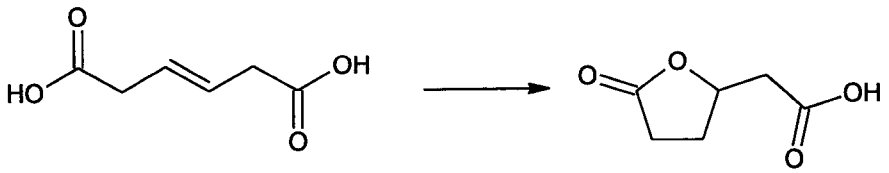
..... [2]

(iv) Determine the volume of 0.200 mol dm^{-3} KOH(aq) that needs to be added to 100 cm^3 of 0.200 mol dm^{-3} adipic acid to form a buffer of pH 4.7.

[2]

3-hexenedioic acid can be converted to adipic acid and 3-bromohexanedioic acid which serve as precursors or intermediates for organic synthesis.

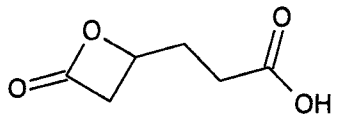
(b) **(i)** Propose a 2-step reaction synthesis to convert 3-hexenedioic acid to **D**. Show clearly all reagents and conditions and the structures of intermediates for each step.



3-hexenedioic acid **D**

[3]

(ii) Another possible product that could be produced from the synthesis method in **(i)** is shown below. Suggest why **D** is more likely to be formed than **E**.



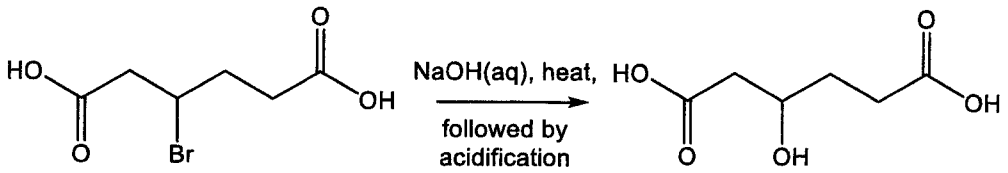
E

.....

.....

..... [1]

(c) A sample of 3-bromohexanedioic acid was able to rotate plane polarised light. After reacting with hot NaOH(aq) followed by acidification, the product obtained was no longer able to rotate plane polarised light. The reaction between 3-bromohexanedioic acid and NaOH(aq) is shown in the equation below.



(i) Describe the mechanism for the reaction between 3-bromohexanedioic acid and NaOH(aq). Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

(ii) State the type of isomerism displayed by the products of the above reaction.

..... [1]

(iii) Draw the isomers produced in the above reaction.

[2]

[Total: 16]

3(a) Chlorate(V), ClO_3^-, reacts with chloride ions according to the equation as shown below.

$$2ClO_3^-(aq) + 2Cl^-(aq) + 4H^+(aq) \longrightarrow Cl_2(g) + 2ClO_2(aq) + 2H_2O(l)$$

An experiment was conducted using a mixture in which the concentrations of the reactants are as follows: 4.80×10^{-4} mol dm^{-3} of ClO_3^-, 0.1 mol dm^{-3} of Cl^- and 0.4 mol dm^{-3} of H^+.

At five-minute intervals, small samples of the reaction mixture were withdrawn, quenched and placed into the UV–vis spectrometer to record its absorbance value. The absorbance value corresponds to the concentration of the product ClO_2.

The graph of absorbance against time is shown in Fig. 3.1.

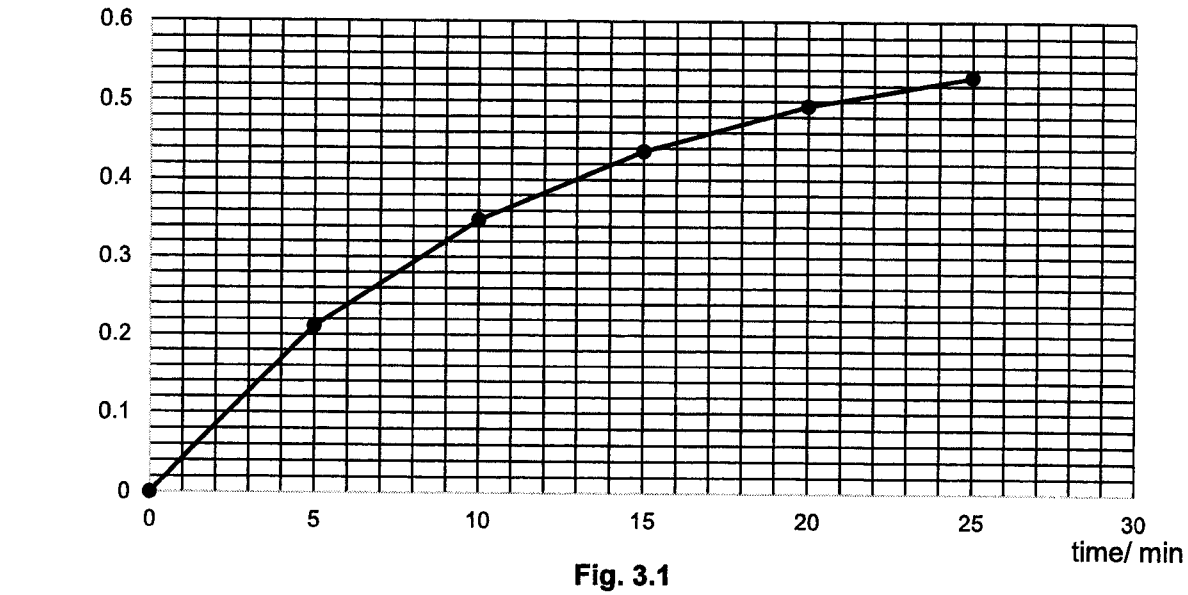


Fig. 3.1

(i) Beer-Lambert's Law states that the absorbance values is directly proportional to the concentration of absorbing species, c, as shown below.

$$A = \varepsilon cl$$

where ε is the molar extinction coefficient and l is the path length, which is usually 1.0 cm.

This equation can be used to calculate the absorbance value when maximum amount of ClO_2 was formed.

Calculate the concentration of ClO_2 in the reaction mixture. Show that the maximum absorbance value of the reaction is 0.600, given that ε of ClO_2 is 1250 $mol^{-1}\,dm^3\,cm^{-1}$.

[2]

(ii) With reference to Fig. 3.1, show that the reaction is first order with respect to ClO_3^-. Draw clearly any construction lines on the graph.

.....

.....

..... [2]

(iii) Another experiment was carried out using 2.40×10^{-4} mol dm^{-3} of ClO_3^- while keeping concentration of Cl^- and H^+ the same.

Deduce the half–life of ClO_3^- in this experiment.

.....

..... [1]

(b) A series of experiments were carried out to investigate the order of reaction with respect to H^+. The results are shown in Table 3.2.

Table 3.2

Experiment	$[ClO_3^-]$ / mol dm^{-3}	$[Cl^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.050	0.100	0.300	3.38×10^{-4}
2	0.100	0.100	0.100	7.50×10^{-5}

(i) Using the information in Table 3.2, determine the order of reaction with respect to H^+.

[2]

(ii) The rate of reaction was measured using different initial $[H^+]$ and keeping $[ClO_3^-]$ and $[Cl^-]$ constant. Sketch the graph of rate against initial $[H^+]$ in Fig. 3.3.

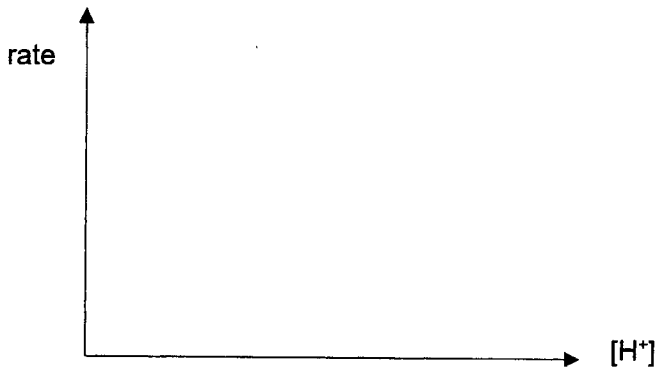


Fig. 3.3

[1]

(iii) Explain, with the aid of a labelled Boltzmann distribution diagram, the effect on a rate constant of increasing temperature.

.....

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.....

..... [2]

(iv) The reaction between ClO_3^- and Cl^- can take place in the presence of Mn^{2+} catalyst. The five d orbitals in Mn^{2+} ion are degenerated but split into two levels when it is in an octahedral complex.

Sketch and label one d orbitals that is found in the higher energy level.

[1]

[Total: 11]

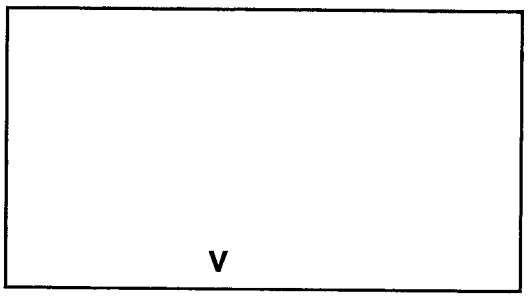
4(a) Compounds **V** and **W** both have molecular formula $C_5H_{10}O_2$. **V** has 2 chiral centres whereas **W** has none.

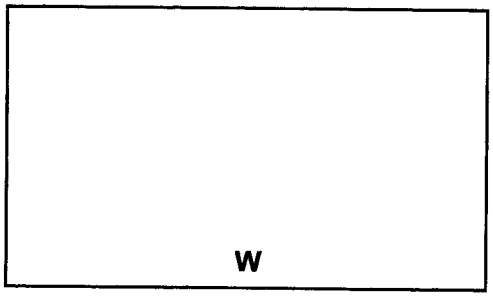
Table 4.1 shows the observations that occurred when separate samples of **V** and **W** were added to different reagents under specific conditions in two separate tests.

Table 4.1

test	reagents and conditions	observations with **V**	observations with **W**
1	heat with acidified $KMnO_4(aq)$	mixture changes from purple to colourless single organic product made that • forms an orange precipitate with 2,4-dinitrophenylhydrazine • forms effervescence with $Na_2CO_3(aq)$	no change
2	heat with alkaline $I_2(aq)$	pale yellow precipitate forms	pale yellow precipitate forms

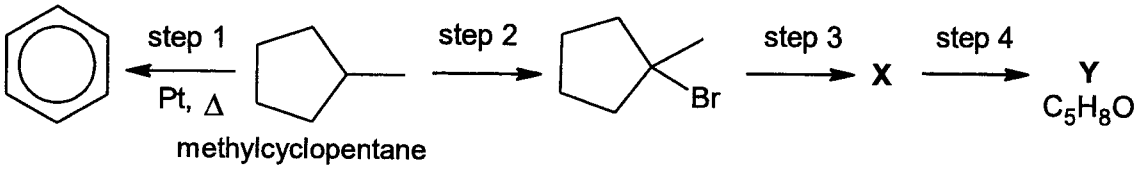
Draw a structure for **V** and for **W**.





[2]

(b) The following flowchart shows reactions of methylcyclopentane.



(i) In Step 1, methylcyclopentane is converted into benzene for the production of gasoline from petroleum. Suggest the type of reaction in step 1.

.....[1]

(ii) Name and describe the mechanism in step 2.

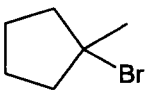
[3]

(iii) Other than the product shown in step 2, three other mono-substituted bromo-alkanes can also be formed in step 2.

Complete Table 4.2 with

- the structures of the three other bromo-alkanes.
- the expected ratio in which the four bromo-alkanes will be formed.

Table 4.2

Bromo -alkane				
Ratio				

[2]

(iv) Given that **Y** reacts with 2,4–DNPH, draw the structures of **X** and **Y**. Suggest the reagents and conditions for steps 3 and 4.

X

Y

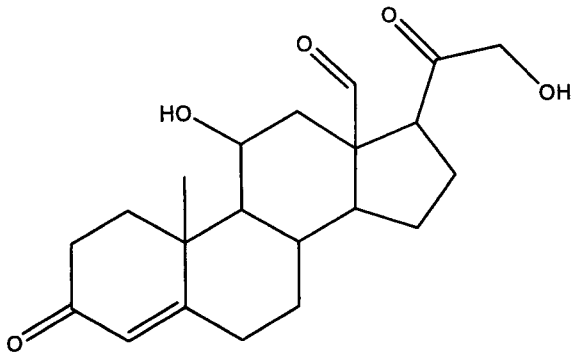
	reagents and conditions
step 3	
step 4	

[4]

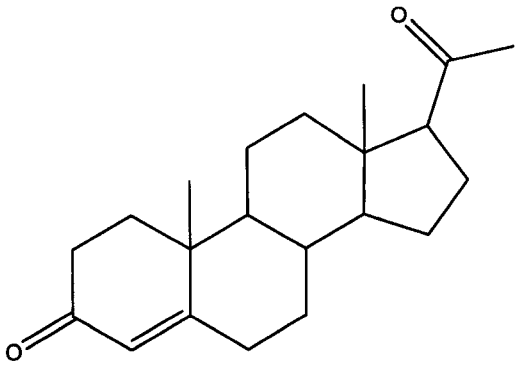
[Total: 12]

5 Steroids are a class of natural or synthetic organic compounds characterised by a molecular structure of 17 carbon atoms arranged in four rings. Natural-occurring steroids are found in hormones in living organisms while synthetic steroids have anti-inflammatory properties.

(a) The chemical structures of some of the naturally occurring steroids are shown below.



aldosterone



progesterone

(i) Identify all functional groups found in aldosterone

.....

[2]

(ii) Describe a chemical test that can be performed to distinguish between aldosterone and progesterone.

.....

.....

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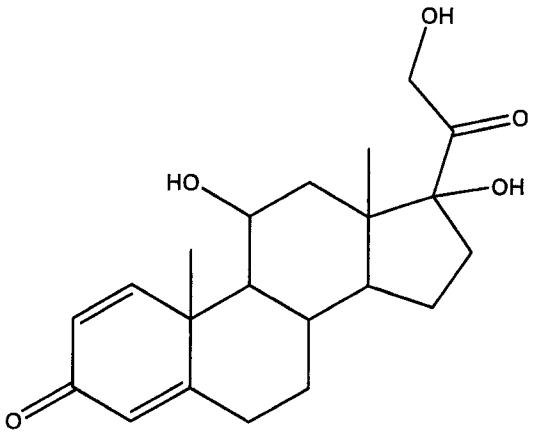
.....

[2]

Another steroid prednisolone (M*r* = 360.4) is a medicine used to treat allergies, blood disorders and inflammation. However, prolonged use of prednisolone comes with side-effects like fatigue and mood swings.



prednisolone

Prednisolone tends to be more fat-soluble than water soluble. When a medicine, such as prednisolone, is not very soluble in blood stream, it will have a low bioavailability, which gives a low efficiency. Bioavailability is defined as the percentage of the administered drug that reaches the blood circulation system. To increase the bioavailability of predinisolone, it is micronised into a smaller size than a conventional drug particle. On average, micronized prednisolone has a bioavailability of 86%.

The prescription of prednisolone depends on the severity of the patient's condition and body weight. The maximum intake of prednisolone each day should not exceed 0.5 mg per kg of the body weight of the patient. [1 mg = 0.001 g]

(b) A patient who weighs 60kg was put on a prednisolone course for four weeks. He was told to consume the maximum intake of prednisolone each day for the first week. This is what his prescription looked like on his medication packaging.

Tampines Meridian Clinic

Prescription:

First Week	**X** tablets each day, taken after breakfast
Second Week	4 tablets each day, taken after breakfast
Third Week	2 tablets each day, taken after breakfast
Fourth Week	1 tablet each day, taken after breakfast

Each tablet contains 5 mg of prednisolone.

(i) Based on the information given, show that the number of tablets, **X**, the patient ingested each day during the first week is 6.

[1]

(ii) Taking into consideration the bioavailability of prednisolone, calculate the total amount of prednisolone that reaches the blood circulation system of the patient in the four weeks.

[2]

(iii) In theory, if two patients have the same body weight and severity of the same condition, suggest why the patient who has higher percentage of body fat will require a higher dosage of prednisolone.

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..... [1]

(iv) Suggest why micronising a medicine into particles with a smaller size can increase its bioavailability and lead to higher efficiency.

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..... [1]

(c) The following Table 5.1 shows the solubility of prednisolone in some common solvents.

Table 5.1

solvent	solubility of prednisolone
water	sparingly soluble
ethanol	soluble

(i) By considering all types of interactions between the solute and solvent, explain why ethanol is a better solvent than water to dissolve prednisolone.

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..... [2]

(ii) Another way to increase the solubility of prednisolone in water is to synthesise prednisolone as prednisolone phosphate salt without compromising its anti-inflammatory property.

Using Fig. 5.1, illustrate how a water molecule interacts with the prednisolone phosphate ion to increase its solubility. Label the main type of interaction involved.

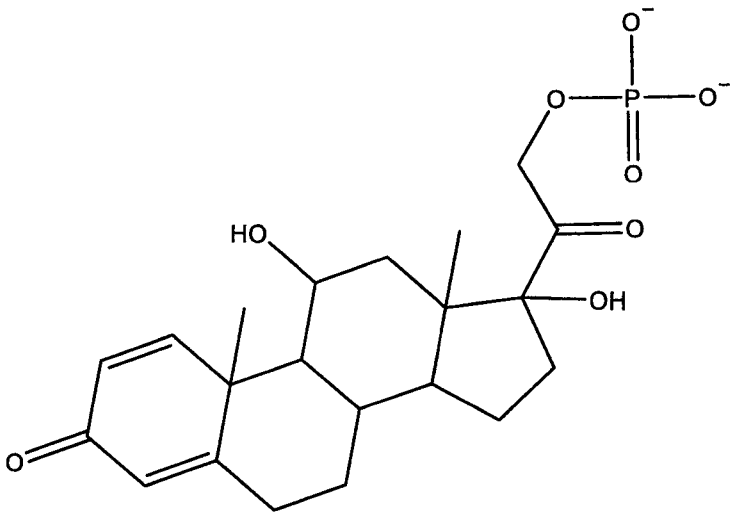


Fig. 5.1

[1]

(d) The half-life of a drug refers to the amount of time it takes for the concentration of its active component in the body to decrease by 50%. A drug is generally regarded as eliminated from the body, with no remaining clinical effect, after 5.5 half-lives.

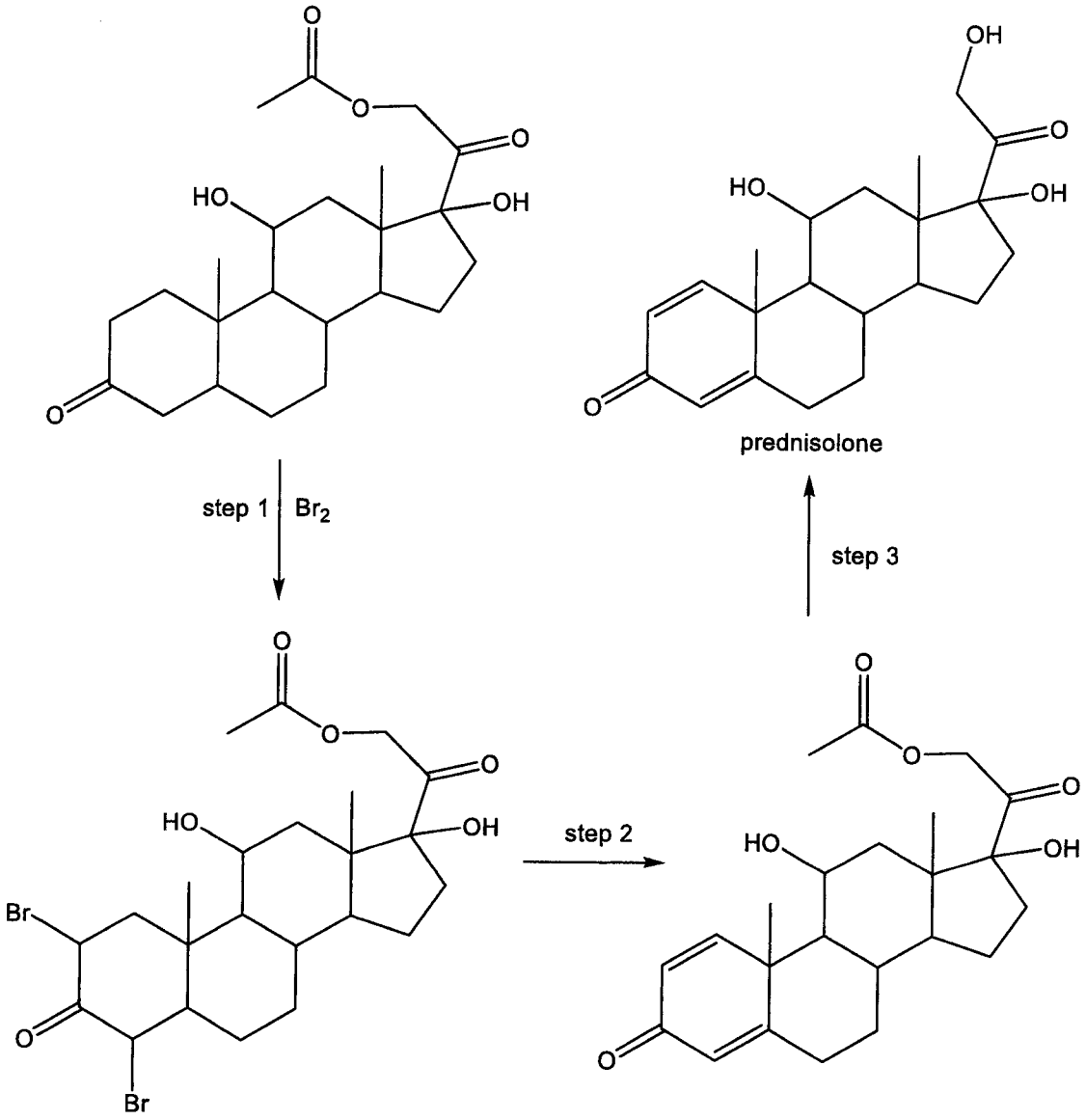
(i) Calculate the half-life of prednisolone given that the effect of prednisolone will last 16.5 hours after ingestion.

[1]

(ii) Calculate the percentage of prednisolone that remained in the body after 5.5 half-lives.

[1]

(e) The reaction scheme below shows the synthesis of prednisolone in the pharmaceutical industry.



Identify the type of reaction, and suggest the reagents and conditions required to achieve steps 2 and 3.

	reagents and conditions	type of reaction
step 2		
step 3		

[2]
[Total: 16]

6 Dimethyl ether, CH_3OCH_3, is a colourless gas commonly used as a fuel, a spray and a refrigerant. It can react with carbon dioxide to produce carbon monoxide and hydrogen gas as shown in the equation below:

$$CH_3OCH_3(g) + CO_2(g) \rightleftharpoons 3CO(g) + 3H_2(g) \qquad \Delta H = +245 \text{ kJ mol}^{-1}$$

In an experiment, a mixture of CH_3OCH_3 and CO_2 was introduced into a 2500 dm^3 sealed vessel at 600 K and the initial total pressure was 15 atm. The reaction was allowed to reach dynamic equilibrium.

(a) **(i)** Explain what is meant by *dynamic equilibrium*.

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.....

..... [1]

(ii) Write an expression for the equilibrium constant, K_p, stating its units.

[2]

(iii) At equilibrium, the amount of H_2 was found to be 280 mol. Show that the equilibrium partial pressure of H_2 in the vessel was 5.5 atm.

[1]

(b) **(i)** It was found that 75% of the CH_3OCH_3 had dissociated at equilibrium at 600K. Calculate the equilibrium pressures of CH_3OCH_3 and CO_2 in atm.

[3]

(ii) Hence, calculate the value of K_p, for this reaction. Express your answer to 2 significant figures.

[1]

(c) **(i)** At constant temperature and volume, partial pressure of a gas is proportional to mole fraction. Hence, calculate the average M_r of the gaseous mixture at 600K.

[1]

(ii) Explain the effect on the equilibrium position and the average M_r of the gaseous equilibrium mixture when the experiment was conducted at 700 K instead of 600 K.

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..... [2]

(d) A key property of an aerosol propellant is that it must exist as a gas under room temperature and pressure conditions.

The behaviour of 1 mol of ideal gas and 1 mol of CH_3OCH_3 at 293 K is shown in Fig. 6.1.

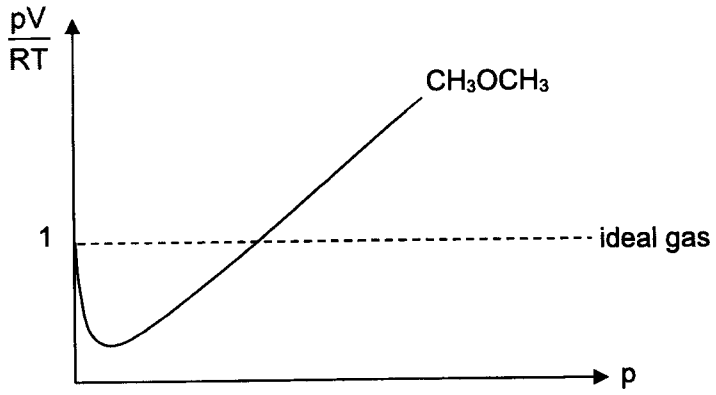

Fig. 6.1

On the **same** axes in Fig. 6.1, sketch and label the graph for 1 mol of CO_2 at 293 K. Explain your answer.

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..... [2]

[Total: 13]

TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME

CIVICS GROUP

H2 CHEMISTRY **9729/03**

Paper 3 Free Response **23 September 2025**

2 hours

Candidates answer on the Question Paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.

Write in dark blue or black pen.

You may use an 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.

If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A
Answer all questions.

Section B
Answer **one** question.

A Data Booklet is provided.
The use of an approved scientific calculator is expected, where appropriate.

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

For Examiner's Use		Percentage
Paper 1	/ 30	/ 15
Paper 2	/ 75	/ 30
Paper 3		
Section A		
1	/ 19	
2	/ 20	
3	/ 21	
Section B		
4	/ 20	
OR		
5	/ 20	
Paper 3 Total	/ 80	/ 35
Paper 4	/ 55	/ 20
Grand Total		/ 100

Section A

Answer **all** the questions in this section.

1 (a) Describe and explain the trend in the thermal stabilities of the Group 2 carbonates. [2]

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(b) Calcium carbonate is used in flue-gas desulfurisation applications to remove harmful SO_2 and NO_2 emissions from fossil fuels burnt in power stations.

(i) Draw dot-and-cross diagrams to show the bonding in the molecules of SO_2 and NO_2. [2]

(ii) With reference to your answer in **(b)(i)**, explain why the bond angle in SO_2 is found to be 118° while that in NO_2 is 134°. [2]

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(c) Magnesium carbonate, $MgCO_3$, can be prepared in the laboratory by the reaction between magnesium chloride solution and aqueous sodium bicarbonate according to the equation:

$$MgCl_2(aq) + 2\ NaHCO_3(aq) \longrightarrow MgCO_3(s) + 2\ NaCl(aq) + H_2O(l) + CO_2(g)$$

$$\Delta H^{\ominus} = +\ 107\ kJ\ mol^{-1}$$
$$\Delta S^{\ominus} = +\ 360\ \ J\ mol^{-1}\ K^{-1}$$

(i) Explain why the reaction shows an overall positive value for $\Delta S^{\ominus}$. [1]

(ii) Calculate ΔG, in kJ mol^{-1}, for the reaction at 50 °C. [1]

(iii) Explain qualitatively how temperature affects the feasibility of this reaction. [2]

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(d) High purity magnesium carbonate, $MgCO_3$, is produced industrially at high pressure via a two-step process.

step 1: $Mg(OH)_2 + 2CO_2 \longrightarrow Mg(HCO_3)_2$

step 2: $Mg(HCO_3)_2 \longrightarrow MgCO_3 + CO_2 + H_2O$

When 150 kg $Mg(OH)_2$ was reacted with excess carbon dioxide gas, and the resultant $Mg(HCO_3)_2$ vacuum dried to remove carbon dioxide and water, 168 kg $MgCO_3$ was produced.

Determine the percentage yield of this industrial process. [2]

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(e) Titanium dioxide, TiO_2, is a widely used white pigment employed to provide whiteness and opacity for paints, papers and toothpaste.

Explain, in terms of structure and bonding, why carbon dioxide sublimes at –78 °C while titanium dioxide is a crystalline solid with a melting point of 1840 °C. [2]

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(f) The industrial manufacture of titanium dioxide involves reacting titanium(IV) chloride, $TiCl_4$, with oxygen gas according to the equation as shown.

$$TiCl_4(l) + O_2(g) \longrightarrow TiO_2(s) + 2Cl_2(g) \qquad \Delta H_1^{\ominus} = -136 \text{ kJ mol}^{-1}$$

(i) Define the term *bond energy of Ti–Cl bond.* [1]

(ii) Using the $\Delta H_1^{\ominus}$ value given above and the data in Table 1.1, together with appropriate data from the *Data Booklet*, construct a fully labelled energy cycle and use it to calculate the average bond energy of the Ti–C*l* bond in $TiCl_4$.

Table 1.1

enthalpy change of vaporisation of $TiCl_4(l)$	+ 41 kJ mol^{-1}
standard enthalpy change of formation of $TiO_2(s)$	– 945 kJ mol^{-1}
standard enthalpy change of atomisation of Ti(s)	+ 471 kJ mol^{-1}

[4]

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[Total: 19]

2 Chromium is a hard, corrosion-resistant transition metal with variable oxidation states. It is widely used in energy-efficient and long-lasting redox flow batteries. One example would be the zinc dichromate battery, also known as the bichromate cell. The reaction at one of the electrodes is given.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$$

The other electrode in this cell is the zinc electrode in the presence of $H_2SO_4(aq)$ as the electrolyte.

(a) (i) Construct the overall equation for the reaction when 1 mol of $Cr_2O_7^{2-}$ reacts with zinc. Use relevant data from the *Data Booklet* to calculate the $E^{\ominus}_{cell}$ for this reaction. [2]

(ii) Hence, calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, of the reaction. [1]

(iii) The cathode of the bichromate cell usually operates at pH 3 and 298 K. The concentration of $Cr_2O_7^{2-}$ ions and Cr^{3+} ions are kept at 1 mol dm^{-3}. The Nernst Equation is often used to calculate the electrode potential, E, generated under non-standard conditions.

$$E = E^{\ominus} - \frac{RT}{nF} \ln Q$$

n is the number of moles of electrons transferred per mole of equation,

R is the molar gas constant,

F is the Faraday constant,

Q is the reaction quotient, where $Q = \dfrac{[Cr^{3+}]^2}{[Cr_2O_7^{2-}][H^+]^{14}}$

Show that the electrode potential, E, at the cathode is +0.916 V. Hence, explain qualitatively why the E value is less positive than its $E^{\ominus}$ value? [2]

(iv) Suggest, with reasoning, what happens to the cell potential, $E^{\ominus}_{cell}$, when the cathode is diluted with water. [1]

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(b) Fig. 2.1 shows the reactions of the *transition element* chromium and its compounds.

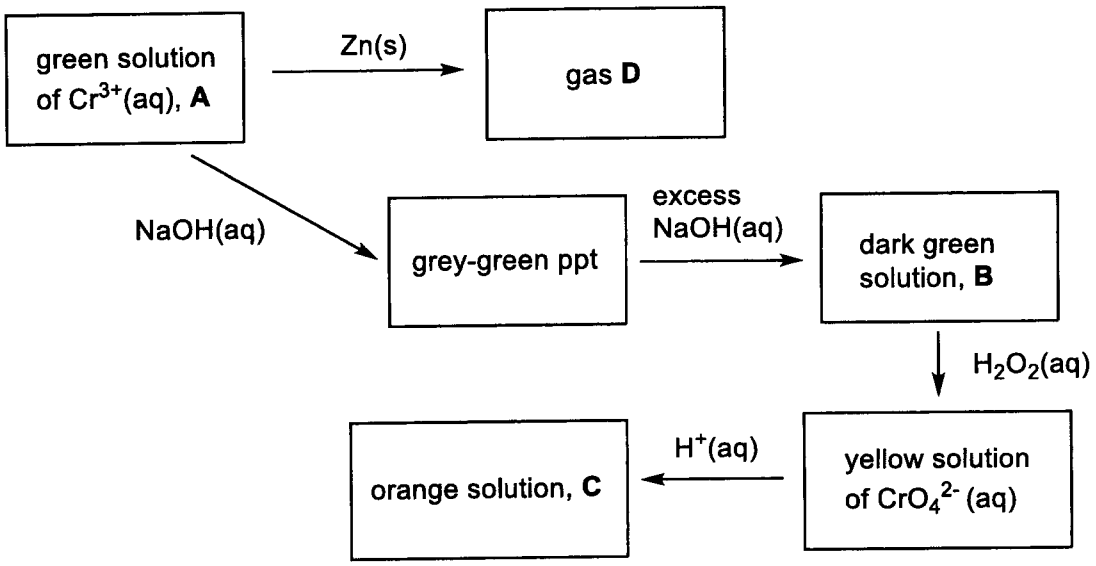

Fig. 2.1

(i) Define the term *transition element*. [1]

(ii) Explain why chromium complexes are usually coloured. [3]

(iii) State the identities of **B**, **C** and **D.** [3]

(iv) Chromium(II) ions form octahedral complexes. There are two isomeric complexes with the formula $Cr(H_2O)_4(Cl)_2$. Suggest the structures of the two isomers. [1]

(v) Write an equation to account for why solution **A** is acidic. [1]

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(c) Acidified $K_2Cr_2O_7$ can oxidise both $\mathbf{M}^{2+}$ and $C_2O_4^{2-}$ in $\mathbf{M}C_2O_4$. One of the products formed is CO_2. 25.00 cm^3 of 0.0200 mol dm^{-3} acidified $K_2Cr_2O_7$ is required to completely oxidise 15.0 cm^3 of 0.0500 mol dm^{-3} $\mathbf{M}C_2O_4$.

(i) Show that the volume of $K_2Cr_2O_7$ required to oxidise $C_2O_4^{2-}$ **only** is 12.5 cm^3. [2]

(ii) Hence, calculate the oxidation state of **M** in the final product. [3]

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[Total: 20]

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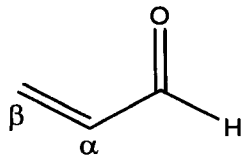
3 The Michael addition is a nucleophilic addition reaction where a nucleophile, such as an enolate ion, reacts with an α,β-unsaturated carbonyl compound.

An α,β-unsaturated carbonyl compound is a compound that contains both a carbonyl group and an alkene double bond that are adjacent to each other. An example is propenal, as shown in Fig. 3.1.



propenal

Fig. 3.1

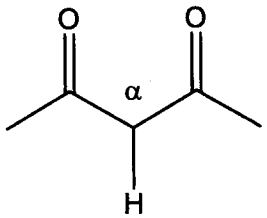
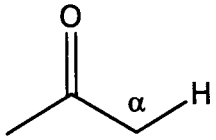
An enolate ion is formed by deprotonating an α-hydrogen of a carbonyl compound with a base such as NaOH(aq). An example of an enolate ion formed from the reaction using propanone, is shown below in Fig. 3.2.

propanone enolate ion

Fig. 3.2

(a) The K_a value of the α-hydrogen for pentane-2,4-dione and propanone are shown in Table 3.1.

Table 3.1

compound	K_a
 pentane-2,4-dione	1.26×10^{-9}
 propanone	1.00×10^{-19}

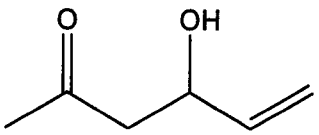
(i) Explain why pentane-2,4-dione is a stronger acid as compared to propanone. [2]

Weakly basic enolate ions would attack the β-carbon of the α,β-unsaturated carbonyl compound, while strongly basic enolate ions would attack the carbonyl carbon of the α,β-unsaturated carbonyl compound.

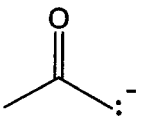
(ii) The reaction between propanone and propenal resulted in the carbonyl carbon to be attacked by the enolate ion, while the reaction between pentane-2,4-dione and propenal resulted in the β-carbon to be attacked by the enolate ion.

Using Fig. 3.1 and Table 3.1, explain for the above observations. [1]

(iii) The enolate ion of propanone reacts with propenal in NaOH(aq) to give compound **F** in a nucleophilic addition reaction.



F

Describe the mechanism for this reaction, using  as the nucleophile. Include all relevant lone pairs, dipoles, curly arrows and charges. [3]

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(b) The structure of propenal can be represented by two different structures as shown in Fig. 3.3. The ⟷ indicates that the actual structure of propenal is somewhere between these two structures, with the potential formation of a carbocation on the β-carbon.

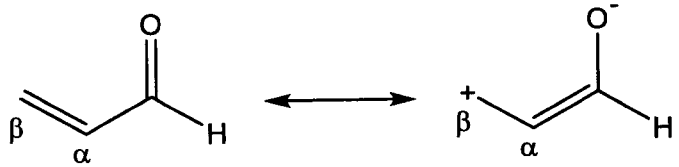

Fig. 3.3

Explain, by considering the orbitals involved, how delocalisation of electrons occurs in propenal. [1]

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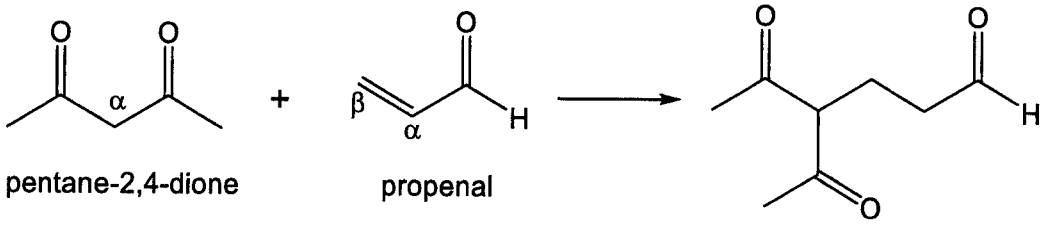
(c) The following description describes the mechanism of the Michael addition reaction between propenal and pentane-2,4-dione in NaOH(aq).

Step 1: The lone pair of electrons of OH^- attacks the α-hydrogen of pentane-2,4-dione, resulting in the formation of water and an enolate ion.

Step 2: The lone pair of electrons of the enolate ion attacks the β-carbon of propenal, breaking the π bond and pushing electrons towards the α-carbon of propenal, leading to the formation of a carbanion intermediate.

Step 3: The lone pair of electrons on the carbanion deprotonates the hydrogen from a water molecule, leading to the final Michael addition product and an OH^- ion.

The overall equation for the Michael addition reaction is shown below in Fig. 3.4.



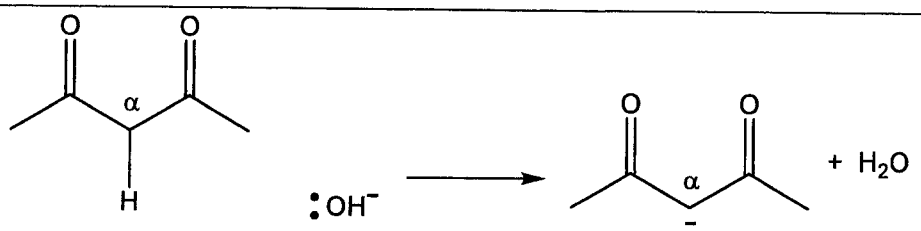
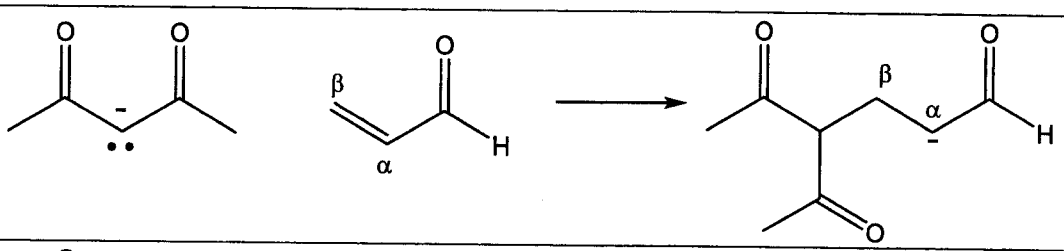
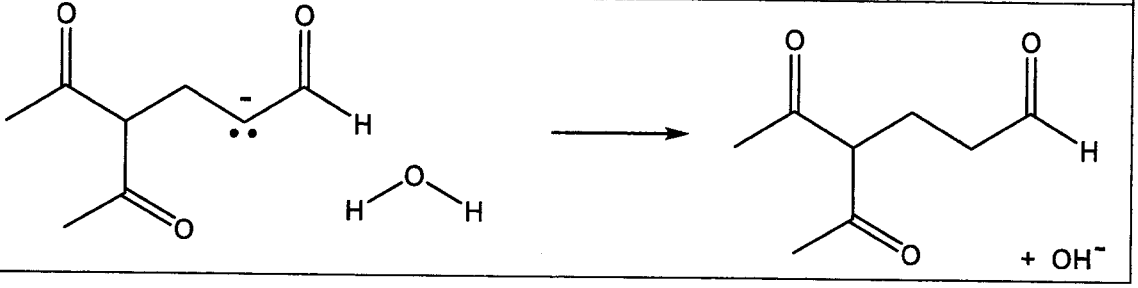
pentane-2,4-dione propenal

Fig. 3.4

(i) Complete the mechanism by adding **two** curly arrows to **each** step in Table 3.2.

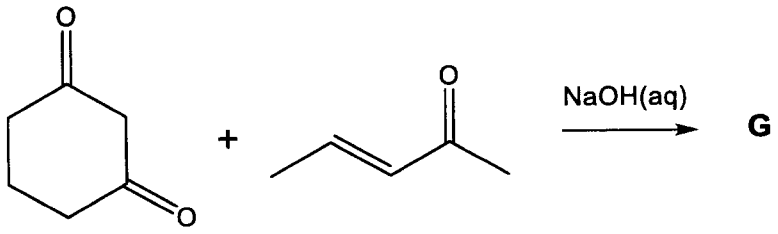
[3]

Table 3.2

step	mechanism
1	
2	
3	

(ii) Suggest a chemical test to confirm that all the propenal in the reaction mixture in **(c)(i)** has completely reacted. [2]

(iii) Based on the mechanism in **(c)(i)**, suggest the structure of the final organic product **G** for the Michael addition reaction between the following compounds. [1]



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(d) Draw the organic product formed when propenal reacts with

(i) $LiAlH_4$ in dry ether

(ii) 2,4–dinitrophenylhydrazine [2]

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(e) Propenal can react with dry hydrogen chloride gas.

(i) State the mechanism and draw the structure of the organic product formed. [2]

(ii) By considering the mechanism stated in **(e)(i)**, explain why the product formed does not rotate plane-polarised light. [2]

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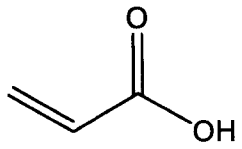
(f) Additionally, propenal can undergo oxidation to form propenoic acid. The structure of propenoic acid is shown below in Fig. 3.5.



propenoic acid

Fig. 3.5

(i) A student suggested the use of hot acidified $KMnO_4$ to oxidise propenal to propenoic acid. However, it was observed that no organic compound was produced. Suggest a balanced equation for the reaction that occurred.
Use [O] to represent the oxidising agent in the reaction. [1]

(ii) Hence, state a suitable reagent and condition that could be used for the conversion of propenal to propenoic acid. [1]

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Section B

Answer **one** question from this section.

4 (a) When solid sodium halides react with concentrated sulfuric acid, an acid-base reaction occurs. This results in the formation of white fumes of hydrogen halide, HX.

$$NaX(s) + H_2SO_4(l) \longrightarrow HX(g) + NaHSO_4(s) \quad \text{where X = C}l\text{, Br or I}$$

The HX formed can undergo further reaction with concentrated sulfuric acid. Depending on the reducing strength of HX, the reaction may result in the formation of X_2, a sulfur-containing product and water.

The observations for the reaction of the different sodium halides with concentrated sulfuric acid are shown in Table 4.1.

Table 4.1

sodium halide	observations
NaC*l*	White fumes of HC*l* formed.
NaBr	White fumes of HBr formed, followed by the formation of a red-brown Br_2 liquid and a colourless SO_2 gas.
NaI	White fumes of HI formed. Violet I_2 gas condensed to form a black solid. A pungent H_2S gas is evolved.

(i) Using Table 4.1, write a balanced equation for the reaction between gaseous HBr and concentrated H_2SO_4. [1]

(ii) Using relevant data from the *Data Booklet* and by considering the change in oxidation state, explain the observations in Table 4.1 in terms of the relative reducing powers of HX. [4]

(iii) Explain the variation for the thermal stabilities of hydrogen halides. [2]

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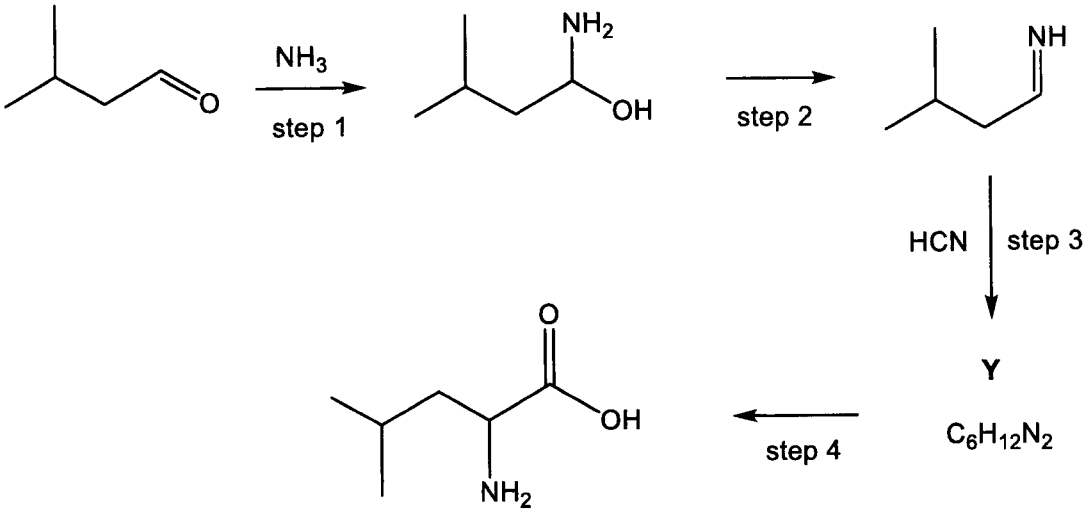
(b) The Strecker synthesis is a method used to produce amino acids through the reaction of an aldehyde with ammonia and hydrogen cyanide. The amino acid, leucine, can be synthesised using this approach, as illustrated in Fig. 4.1.



leucine

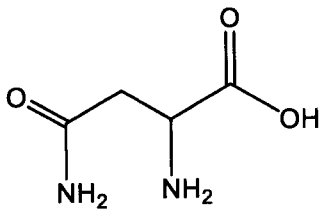
Fig. 4.1

(i) Suggest the type of reaction occurring in steps 1 and 2. [2]

(ii) Draw the structure of compound **Y**. [1]

(iii) State the reagents and conditions for step 4. [1]

(iv) Asparagine, a non-essential amino acid, is crucial for protein synthesis and various metabolic processes.

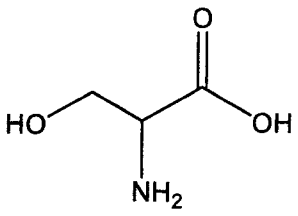


asparagine

Asparagine can be prepared from aldehyde **Z** via the Strecker synthesis. Suggest the structure for aldehyde **Z**. [1]

(v) Explain the difference in basicity of the two nitrogen-containing functional groups present in asparagine. [2]

(vi) Serine is a naturally occurring amino acid with the following structure.



serine

Draw the structure of a dipeptide that can be formed between asparagine and serine. [1]

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(c) Hydrogen cyanide, HCN, can lead to serious health effects when ingested. HCN has a pK_a value of 9.20 at 25 °C.

(i) A solution of HCN was placed in an acidic solution. Calculate the concentration of CN^- ions when the concentration of HCN is 0.0500 mol dm^{-3} at pH 3. [1]

Zinc cyanide, $Zn(CN)_2$, is sparingly soluble in water.
The numerical value of its solubility product, K_{sp}, is 3.00×10^{-23} at 25 °C.

(ii) Write an expression for the solubility product of $Zn(CN)_2$, stating its units. [1]

(iii) $Zn^{2+}(aq)$ was added to the HCN solution in **(c)(i)**. Determine the minimum concentration of $Zn^{2+}(aq)$ required to cause the precipitation of $Zn(CN)_2$ at pH 3.

If you were unable to obtain an answer in **(c)(i)**, use the value of $[CN^-] = 2.50 \times 10^{-8}$ mol dm^{-3}. [2]

(iv) Explain how the solubility of $Zn(CN)_2$ is affected by adding HC*l*(aq). [1]

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5 **(a)** The acid-base behaviour of aluminium oxide, Al_2O_3, shows similarities to that of sodium oxide, Na_2O, on one hand, and sulfur trioxide, SO_3, on the other.

(i) Describe what these similarities are and write equations for all reactions you choose to illustrate your answer. [3]

(ii) Explain why beryllium oxide, BeO, exhibits similar acid-base properties as Al_2O_3. [1]

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(b) Electroplating uses electrolysis to deposit a layer of metal onto a surface. Nickel plating is widely employed to plate coins, enhancing their durability and resistance to corrosion. In this process, the electrolyte used is a solution of nickel(II) sulfate.

(i) Draw a labelled diagram of the electrolysis cell used to plate coins with nickel. Include details of cathode, anode, electrolyte and the direction of electron flow. [2]

(ii) A constant current is passed through the cell for 6.5 min and 77 mg of Ni is being plated onto the coin. Calculate the current used. [2]

(iii) In another similar set-up, the concentration of the $NiSO_4$ solution is doubled while all other conditions remain the same. Explain the effect, if any, on the mass of nickel deposited on the coin. [1]

(c) Reduction and oxidation are important reactions in organic chemistry.

Nickel is an effective catalyst for catalytic hydrogenation, particularly for reducing unsaturated compounds. However, not all possible functional groups can be reduced at room temperature. Applying heat will increase nickel's catalytic activity.

Fig. 5.1. shows some reduction and oxidation reactions that compound **U** can undergo.

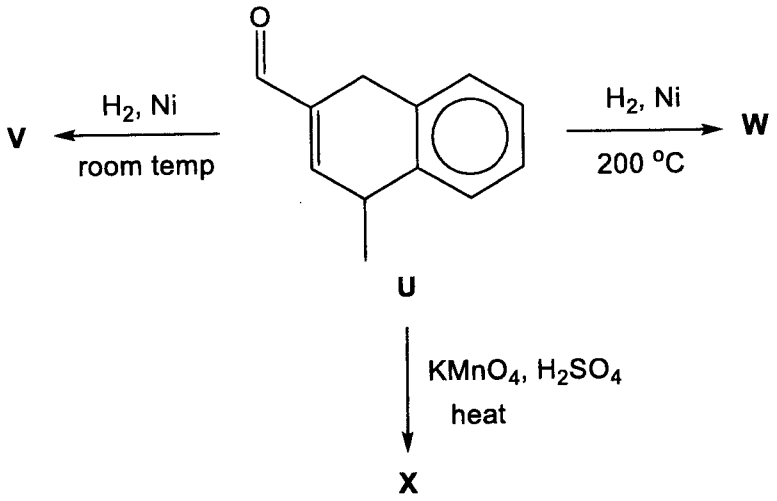

Fig. 5.1

Both **V** and **W** form salts with sodium. **W** does not contain π electrons.

U can undergo oxidation with hot acidified $KMnO_4$ to give **X**.

The M_r values for **V** is 176 and **W** is 182.

(i) State the type of catalysis for the formation of **V** from **U**. Explain why Ni is a suitable catalyst for this reaction. [2]

(ii) State the number of π electrons in compound **U**. [1]

(iii) Suggest the identities of **V**, **W** and **X**. [3]

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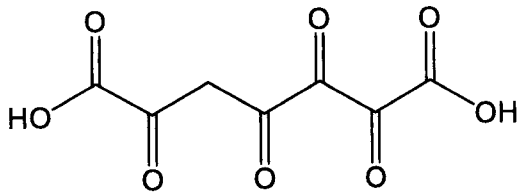
(d) Compound **P** has the molecular formula, $C_7H_{10}O_5$ and contains a 6-membered ring. **P** gives effervescence with Na_2CO_3. **P** does not produce an orange precipitate with 2,4-DNPH. On treatment with $H_2(g)$ and platinum catalyst, compound **Q** was formed. 1 mole of **P** reacts exactly with 4 moles of PCl_5 to give compound **R**.

P also decolourises hot acidified potassium manganate(VII) solution to give a single compound **S.** The structure of compound **S** is shown below.



compound **S**

Suggest the structures for for **P**, **Q** and **R**, and explain the reactions involved.

[5]

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