



YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CG

INDEX NO

CHEMISTRY

9729/01

Paper 1 Multiple Choice

18 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, class and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on 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 Answer Sheet very carefully.

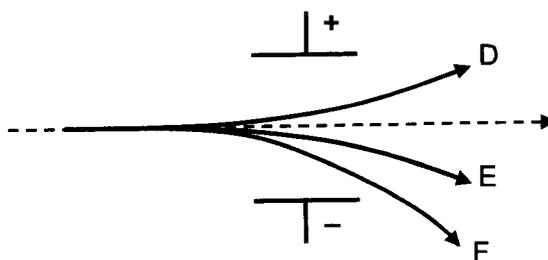
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

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

This document consists of **17** printed pages and **3** blank pages.

- 1 Three different charged particles are fired with equal velocity into an electric field. The diagram below shows how each particle is deflected.

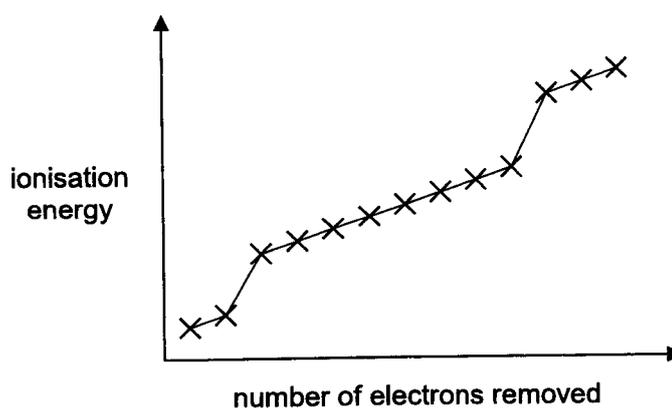


Which row gives the correct identities of D, E and F?

	D	E	F
A	$^{14}\text{N}^+$	$^{28}\text{Si}^{2-}$	$^{14}\text{C}^{2-}$
B	$^{14}\text{N}^-$	$^{28}\text{Si}^{2+}$	$^{14}\text{C}^{2+}$
C	$^{16}\text{O}^{2+}$	$^{16}\text{O}^{2-}$	$^{28}\text{Si}^-$
D	$^{16}\text{O}^{2-}$	$^{16}\text{O}^{2+}$	$^{28}\text{Si}^+$

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

The graph shows the first thirteen successive ionisation energies for element G.



What can be deduced about element G from the graph?

- A** It is aluminium.
- B** It is a d-block element.
- C** It is in Period 3 of the Periodic Table.
- D** The outermost electronic configuration is ns^2 .

3

3 Which statement describes a phenomenon caused by intermolecular hydrogen bonding?

- A The boiling point of an alcohol increases with increasing carbon chain length.
- B Hydrochloric acid forms H_3O^+ when dissolved in water.
- C CH_3CHO has a higher boiling point than $\text{CH}_3\text{CH}_2\text{CH}_3$.
- D Ice has a lower density than water at $0\text{ }^\circ\text{C}$.

4 In certain microwave ovens, the wave energy produced is absorbed by polar molecules.

Which molecules would absorb microwave energy?

- 1 $\text{CH}_3\text{CH}_2\text{OH}$
- 2 AlCl_3
- 3 CO_2
- 4 CH_3F

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

5 Element J is in Period 3 of the Periodic Table. The four statements below describe the properties of element J or its compounds.

Three statements are correct descriptions. One of the statements is not correct because it does not fit with the other three.

Which statement is **not** correct?

- A Element J is a solid at room temperature which conducts electricity.
- B The oxide of element J dissolves in water to give an alkaline solution.
- C Element J forms a trichloride, JCl_3 , which reacts with water to give an acidic solution.
- D The oxide of element J reacts with both hydrochloric acid and sodium hydroxide solution.

- 6 The table below shows the observations when a hot wire is inserted into separate samples of hydrogen chloride, hydrogen bromide and hydrogen iodide gas.

hydrogen halide	observation
HCl	no observable change
HBr	reddish brown vapour only when wire is very hot
HI	purple vapour immediately forms

Which statements explain the observations?

- 1 Valence orbital size increases from Cl to Br to I.
- 2 Bond strength decreases from H-Cl to H-Br to H-I.
- 3 The electron cloud size of the hydrogen halide increases from HCl to HBr to HI.

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

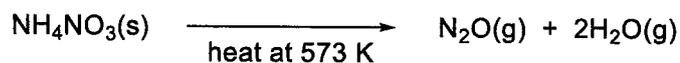
- 7 Which statements are correct?

- 1 The relative isotopic mass is the ratio of the mass of an atom of an isotope compared with $\frac{1}{12}$ of the mass of a carbon-12 atom.
- 2 The relative molecular mass is the ratio of the average mass of an atom in a molecule compared with $\frac{1}{12}$ of the mass of a carbon-12 atom.
- 3 One mole of a compound is the amount that contains the same number of atoms as there are atoms in 12.00 g of carbon-12.

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

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

Upon heating to 573 K, ammonium nitrate, NH_4NO_3 , decomposes into dinitrogen monoxide and water vapour.



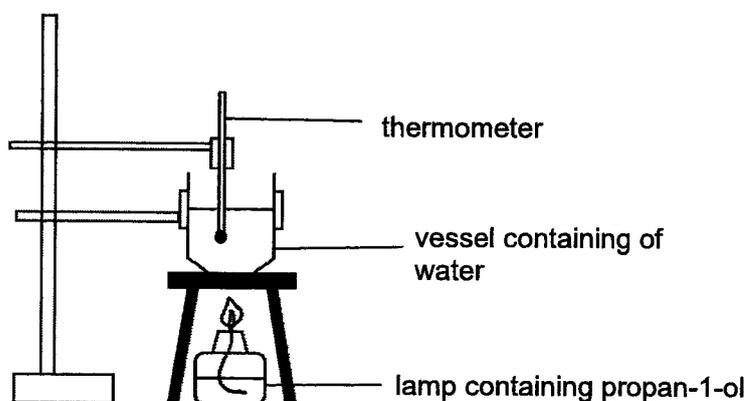
0.2 g of NH_4NO_3 is heated to 573 K and then cooled. At room temperature and pressure, the amount of gas is 0.00208 mol.

What percentage of NH_4NO_3 has decomposed?

- A 27.8% B 29.4% C 83.3% D 88.1%
- 9 *Use of the Data Booklet is relevant to this question.*

The experimental set-up below has a heat transfer efficiency of 90%.

In an experiment, 1.00 g of propan-1-ol ($M_r = 60.0$) was burnt under a vessel containing 200 g of water. It was found that the temperature of the water rose by 39.5 °C.



Which value for the enthalpy change of combustion of propan-1-ol is given by these results?

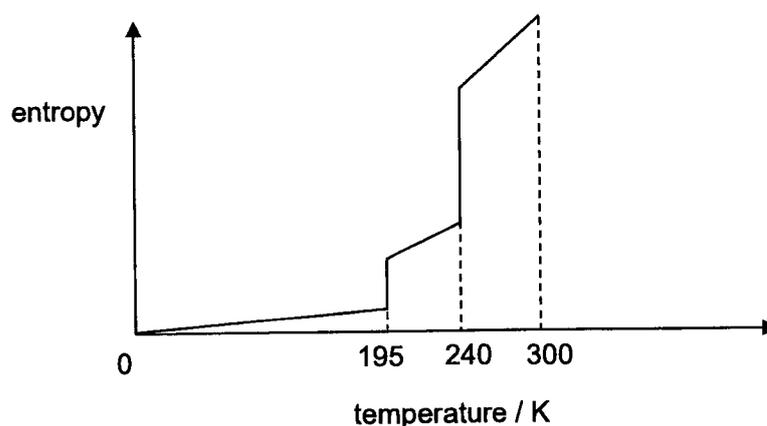
- A -1780
 B -2200
 C -15700
 D -17400

- 10 The nitride ion, N^{3-} , is usually found in compounds used for hard, heat-resistant materials, while the azide ion, N_3^- , is found in compounds that are used in airbags.

Which compound has the least negative value for lattice energy?

- A magnesium azide
 B magnesium nitride
 C sodium azide
 D sodium nitride
- 11 The melting point of ammonia is 195 K and the boiling point of ammonia is 240 K.

The graph below shows how the entropy of NH_3 changes between 0 K and 300 K.

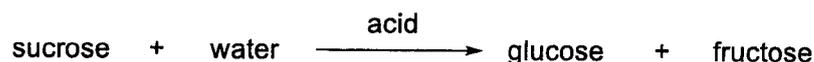


Which statements explain the shape of the graph?

- 1 Between 0 K and 195 K, entropy is low as the NH_3 molecules are held in their fixed positions in the solid state.
- 2 Between 195 K and 240 K, there is an increase in the number of ways to distribute energy among NH_3 molecules.
- 3 At 240 K, there is an increase in the number of NH_3 molecules and hence number of ways to arrange NH_3 molecules.

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

- 12 The hydrolysis of sucrose to glucose and fructose is catalysed by acid.



The reaction is first order with respect to sucrose and first order with respect to acid.

Which row correctly describes the effect on rate of reaction and half-life of sucrose when [acid] is doubled?

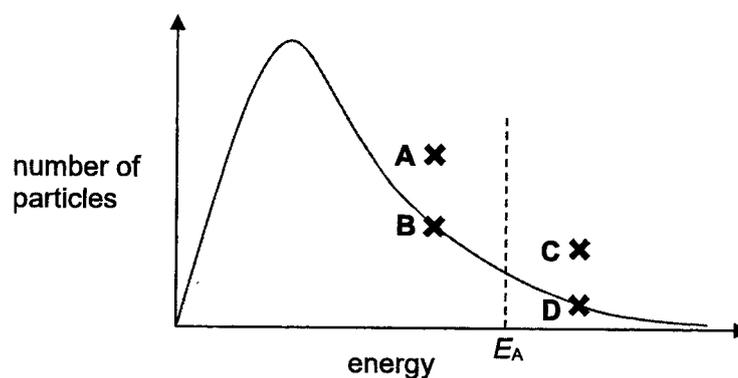
	rate of reaction	half-life of sucrose
A	remains the same	remains the same
B	remains the same	halves
C	doubles	remains the same
D	doubles	halves

- 13 The diagram shows the Boltzmann distribution for a sample of a reacting gas at a constant temperature.

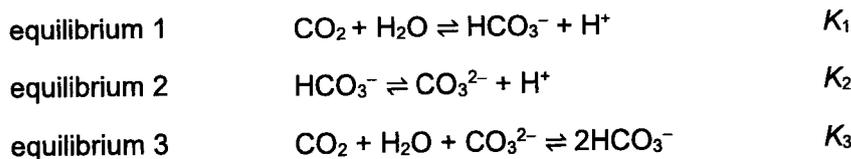
The activation energy, E_A , for the uncatalysed reaction is marked.

A catalyst is added to the sample of gas under constant temperature.

Which point could show the intercept of the Boltzmann distribution curve with the value of the activation energy of the reaction?



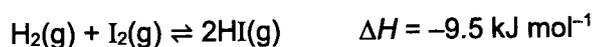
- 14 Consider the following three equilibria and their equilibrium constants, K_1 , K_2 and K_3 .



What is the correct expression for K_3 ?

- A $K_1 \times K_2$ B K_2 / K_1 C K_1 / K_2 D $1 / (K_1 \times K_2)$
- 15 In this question, you should assume that all gases behave ideally.

Hydrogen and iodine react reversibly in the following reaction. The system is allowed to reach dynamic equilibrium.



Which row correctly describes how the equilibrium position and K_p are affected by an increase in temperature?

	equilibrium position	K_p
A	shifts left	increases
B	shifts left	decreases
C	shifts right	increases
D	shifts right	decreases

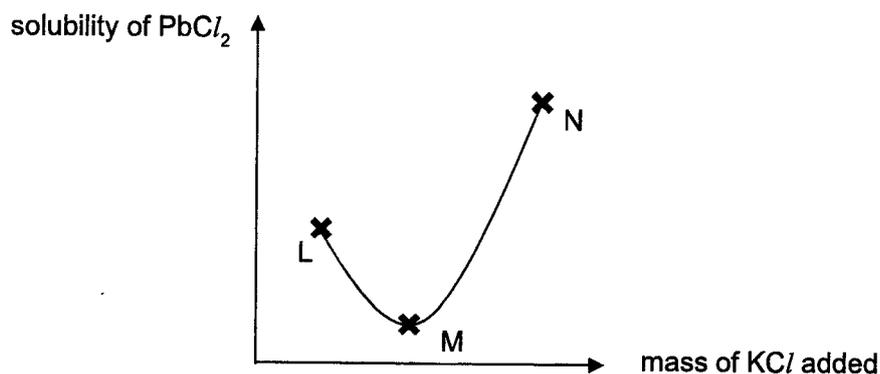
- 16 H_3PO_4 is a triprotic acid. At 25 °C, H_2PO_4^- has a K_a value of $6.3 \times 10^{-8} \text{ mol dm}^{-3}$.

What does the following expression represent?

$$\frac{1.00 \times 10^{-14}}{6.3 \times 10^{-8}}$$

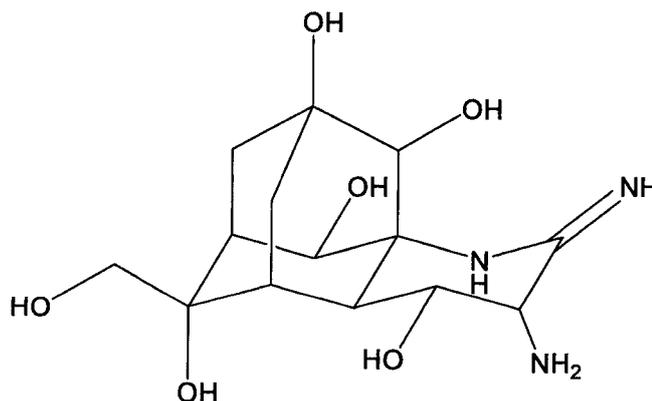
- A K_a of H_3PO_4 B K_a of HPO_4^{2-} C K_b of H_2PO_4^- D K_b of HPO_4^{2-}

- 17 The graph shows how the solubility of a sparingly soluble salt lead(II) chloride, PbCl_2 , changes upon addition of solid potassium chloride, KCl , under constant temperature.



Which statement about the graph is **incorrect**?

- A K_{sp} remains constant along L to N.
 B The change in solubility along L to M is due to increased chloride ion concentration.
 C At M, the molar concentration of Cl^- ions in the solution is twice that of Pb^{2+} ions.
 D The change in solubility along M to N is due to the formation of a complex ion.
- 18 The structure below shows a derivative of tetrodotoxin.

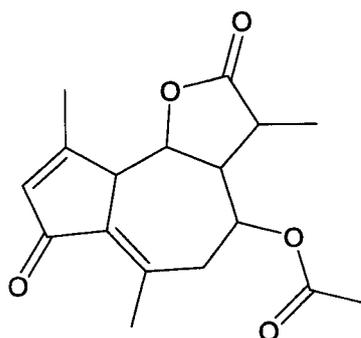


Which statements regarding this structure are correct?

- 1 It contains more secondary alcohol groups than tertiary alcohol groups.
 - 2 It contains only one primary alcohol group.
 - 3 It contains two primary amine groups.
- A 1 and 2 only B 2 and 3 only C 1 only D 2 only

10

- 19 Matricarin occurs in oil of chamomile.

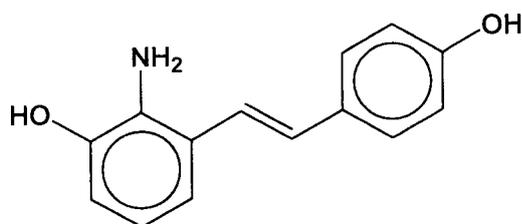


matricarin

When matricarin is treated with cold acidified KMnO_4 , compound P is formed.

How many chiral centres does P have?

- A 7 B 8 C 9 D 10
- 20 Compound Q is a resveratrol derivative that is being explored for its role in neurodegenerative diseases like Parkinson's.



Q

When treated with aqueous bromine, what is the maximum number of bromine atoms that can be incorporated into a molecule of compound Q?

- A 5 B 6 C 7 D 8

- 21 2-Chlorobutane reacts with the :CH_3^- nucleophile to produce 2-methylbutane via nucleophilic substitution.

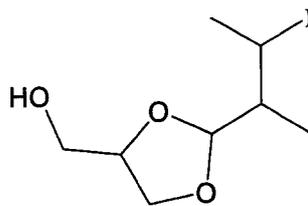
Before the reaction, the sample of 2-chlorobutane rotates plane-polarised light. After the reaction, the reaction mixture containing 2-methylbutane does not rotate plane-polarised light.

What can be concluded from the information given?

- 1 The reaction proceeds via $\text{S}_{\text{N}}1$.
- 2 The reaction proceeds via $\text{S}_{\text{N}}2$.
- 3 The rate of reaction is dependent on the concentration of 2-chlorobutane.

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

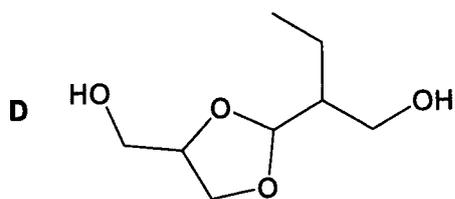
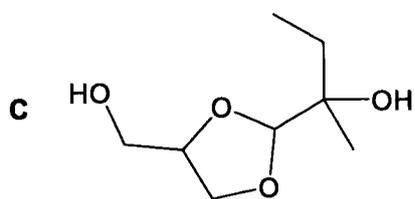
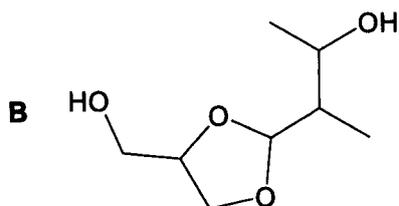
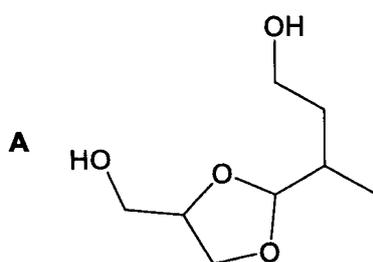
- 22 Iodinated glycerol is used in the symptomatic treatment of patients with chronic obstructive pulmonary disease.



iodinated glycerol

What is the major product formed when iodinated glycerol is reacted with alcoholic KOH, followed by steam in the presence of concentrated phosphoric acid?

[The C–O–C bond in the structure is inert to these reagents.]



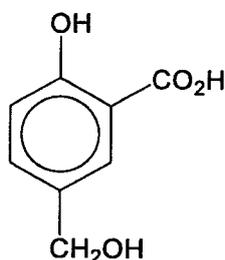
- 23 Three colourless liquids with the following formulae are contained in separate unlabelled bottles.



Which two tests, when carried out sequentially on separate samples of each liquid, will allow you to successfully identify all three liquids?

	Test 1	Test 2
A	warm alkaline aqueous iodine	PCl_5
B	Fehling's solution	NaHCO_3
C	PCl_5	warm acidified potassium dichromate(VI)
D	warm acidified potassium dichromate(VI)	Fehling's solution

- 24 2-hydroxy-5-(hydroxymethyl)benzoic acid is commonly used in biochemical systems as a buffer.



2-hydroxy-5-(hydroxymethyl)benzoic acid

Which statements are correct?

- 1 When the compound is reacted with PCl_5 , the product contains 3 chlorine atoms.
- 2 When the compound is reacted with NaOH , two moles of NaOH is needed to react with 1 mole of compound.
- 3 When the compound is reacted with an excess of ethanoyl chloride, the product contains 4 more carbon atoms.

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

25 Carbonyl compounds are reduced by LiAlH_4 but alkenes cannot be reduced by LiAlH_4 .

Which statements explain this observation?

- 1 Alkenes have an electron rich $\text{C}=\text{C}$ bond.
- 2 Carbonyl compounds have a polar $\text{C}=\text{O}$ bond.
- 3 Alkenes have greater steric hindrance than carbonyl compounds.

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

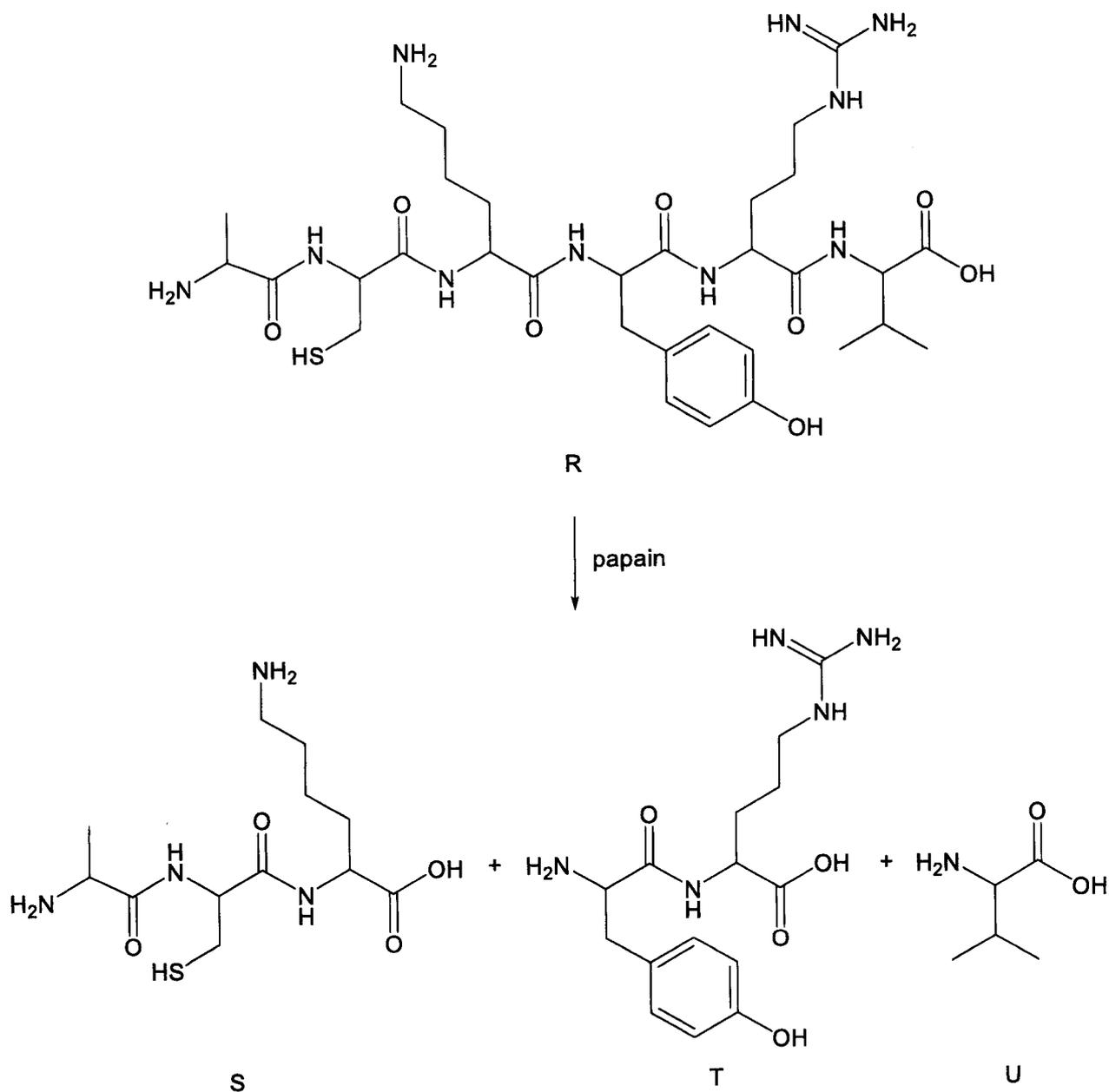
26 The compound $\text{C}_2\text{H}_5\text{CONH}_2$ is an amide.

Which statement about this amide is correct?

- A It can react with $\text{H}_2\text{SO}_4(\text{aq})$ in an acid-base reaction.
- B When heated with $\text{NaOH}(\text{aq})$, it will form sodium propanoate.
- C When heated with $\text{H}_2\text{SO}_4(\text{aq})$, it will form ethanoic acid.
- D It can be formed using propanoic acid and $\text{NH}_3(\text{aq})$ at room temperature.

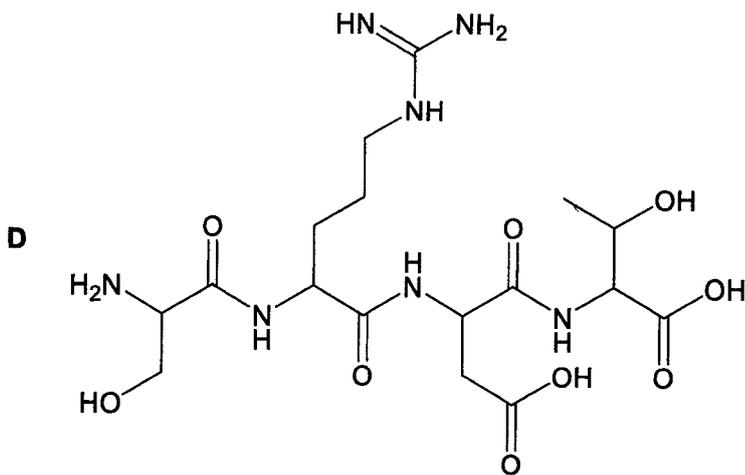
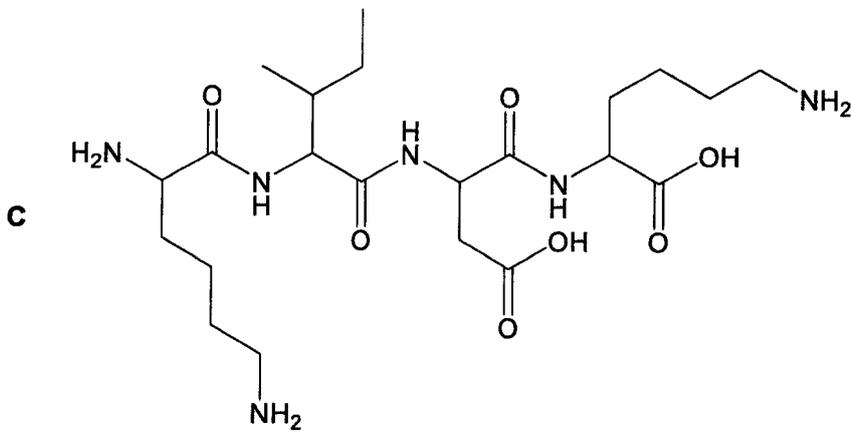
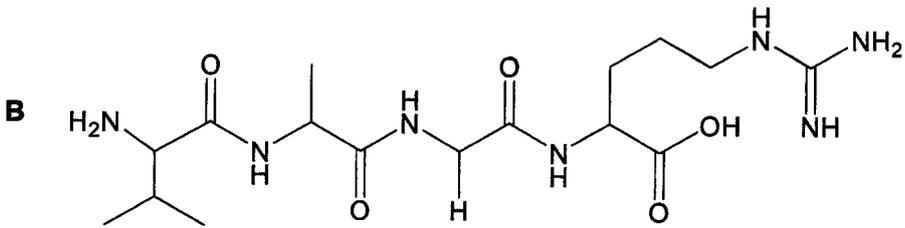
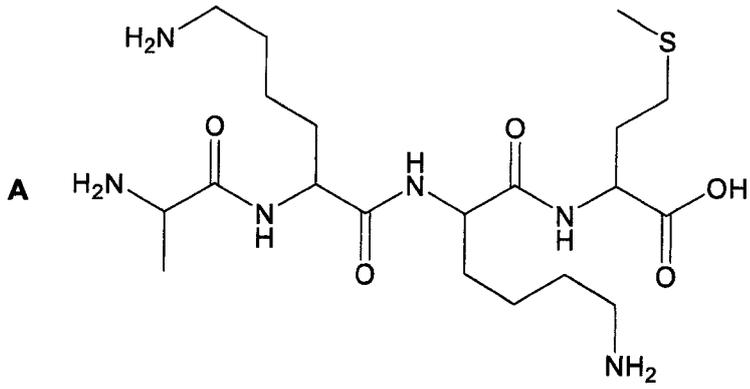
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- 27 Papain is an enzyme that tenderises meats by hydrolysing proteins in meat into smaller polypeptides and amino acids. It specifically hydrolyses the peptide bond on the carboxyl side of a residue that contains a nitrogen in the side chain. For example, the polypeptide R is hydrolysed into S, T and U.



Which of the four tetrapeptides on the page 17 will form two different **dipeptides** when hydrolysed by papain?

17



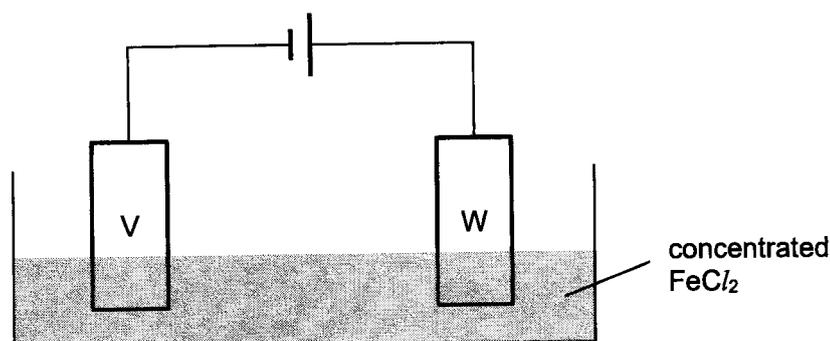
28 Use of the Data Booklet is relevant to this question.

Which pair of substances will react spontaneously?

- A Ca^{2+} and MnO_4^- B Cl^- and Cu C Br_2 and Fe^{2+} D Al^{3+} and Cl^-

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

The diagram shows an electrolysis cell set-up of concentrated iron(II) chloride. V and W are platinum electrodes.



Which row identifies the products formed at electrodes V and W?

	product formed at V	product formed at W
A	Fe	Cl_2
B	Cl_2	Fe
C	Fe	O_2
D	O_2	Fe

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

When 0.95 g of a chromium compound is first dissolved in water and treated with an excess of aqueous silver nitrate solution, 0.50 g of white precipitate was collected.

Given that the general formula for the chromium compound is $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$, what is the formula of the chromium-containing ion?

- A Cr^{3+} B $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ C $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}$ D $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$

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YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CG

INDEX NO

CHEMISTRY

9729/02

Paper 2 Structured Questions

1 September 2025

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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 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.

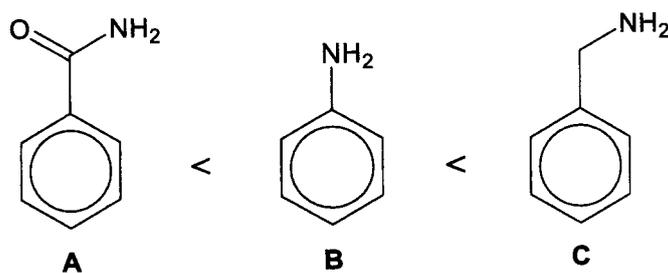
For Examiner's Use		
1	/ 18	
2	/ 24	
3	/ 17	
4	/ 16	
Penalty	units	significant figures
Overall	/ 75	

This document consists of **21** printed pages and **3** blank pages.

2

Answer **all** the questions in the spaces provided.

- 1 (a) Compounds **A**, **B** and **C** are shown in order of increasing basicity. Explain this order.



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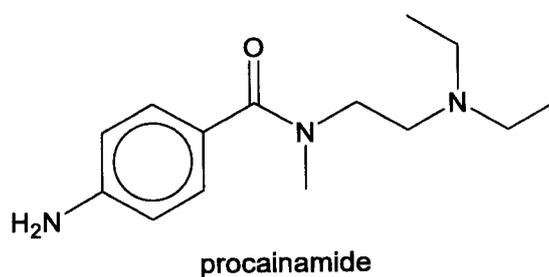
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[3]

- (b) Amides can be found in many drugs such as paracetamol and procainamide. Procainamide can be used for the treatment of cardiac arrhythmias.



Predict the products obtained when procainamide undergoes reaction with hot, dilute H_2SO_4 .

[2]

3

- (c) Compound J can be synthesised by the following route in Fig. 1.1, with all the carbon atoms coming from compound E.

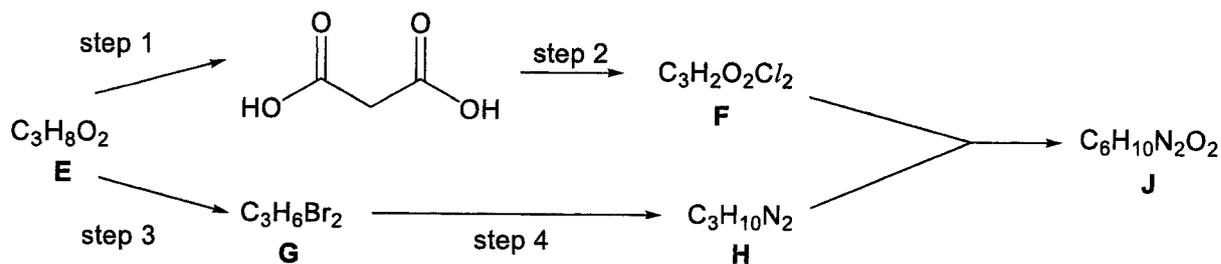
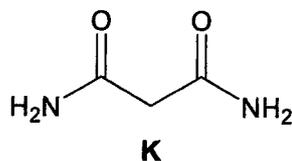
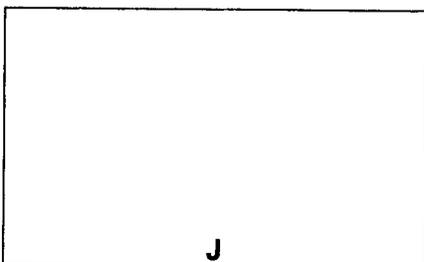
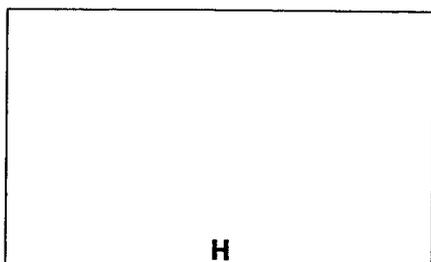
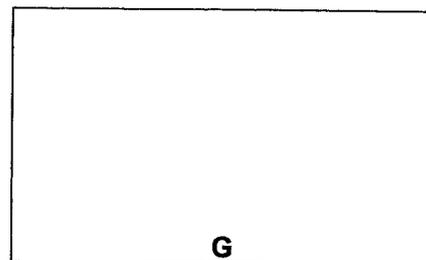
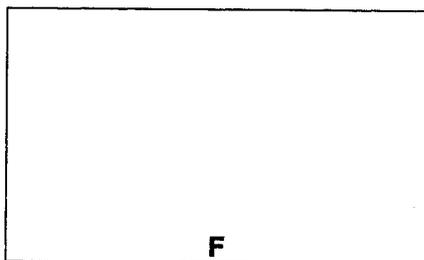
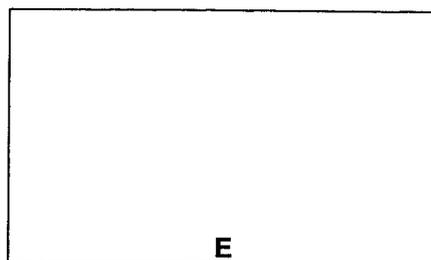


Fig. 1.1

- Compound E does not react with NaOH(aq) but reacts with Na to give a gas that extinguishes a lighted splint with a 'pop' sound.
- Compound H is soluble in dilute HCl and can also be obtained from the reaction of compound K with LiAlH₄.



- Compound J is neutral and is a cyclic molecule.
- (i) Draw the structure of compounds E to H, and J.



[5]

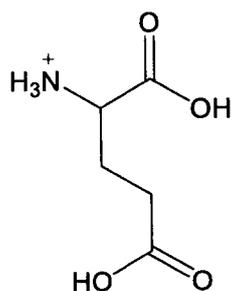
- (ii) State the reagents and conditions for steps 2 and 4.

step 2

step 4

4

- (d) The compounds responsible for the umami flavour of soy sauce are salts of glutamic acid.



glutamic acid

Glutamic acid has pK_a values of 2.1, 4.1 and 9.5. Draw the structure of the zwitterion. Suggest a pH at which the predominant species of glutamic acid is a zwitterion.

[2]

- (e) A polypeptide contains 9 amino acid residues. It was partially hydrolysed to give a mixture of tripeptides.

asp-gly-tyr
 glu-tyr-lys
 gly-glu-tyr
 met-asp-gly
 tyr-ala-gly

Determine the sequence of amino acids that make up the primary structure of the polypeptide.

[1]

5

- (f) Halogenoalkanes can react with NH_2^- to produce amines.

A sample that contains only one enantiomer of 2-bromobutane reacts completely with NH_2^- to produce a mixture that does not rotate plane-polarised light.

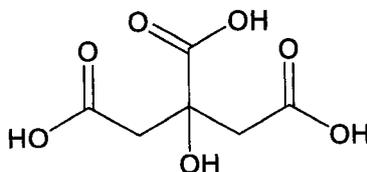
Draw a mechanism for the reaction between NH_2^- and 2-bromobutane. Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

[Total: 18]

- 2 Citric acid, $C_6H_8O_7$, is a naturally occurring weak organic acid found in citrus fruits. It has a wide range of applications in the food, cleaning products and healthcare industries.

It is triprotic and has the following structure.



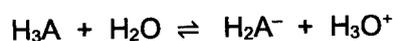
- (a) (i) Citric acid is a Brønsted-Lowry acid.

Explain what is meant by this statement.

..... [1]

- (ii) The dissociation of citric acid in water occurs in three steps.

Using H_3A as a simplified representation of citric acid, the first dissociation step is as shown:



Write the balanced equation for the second dissociation step of citric acid in water.

..... [1]

- (iii) Identify the two conjugate acid-base pairs in the dissociation step you have written in (a)(ii).

acid	conjugate base
base	conjugate acid

[1]

- (iv) Explain why the carboxylic acid group on citric acid is a stronger Brønsted-Lowry acid than the hydroxyl group.

..... [1]

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- (b) The pK_a values for citric acid are shown in Table 2.1.

Table 2.1

	pK_1	pK_2	pK_3
citric acid	3.1	4.8	6.4

- (i) Calculate the pH of 0.10 mol dm^{-3} citric acid at 298 K (ignore the effect of pK_2 and pK_3 on the pH). Show your working.

[2]

- (ii) A buffer solution with a pH of 3.40 is made by adding 50 cm^3 of solution L containing monosodium citrate to 100 cm^3 of $0.0200 \text{ mol dm}^{-3}$ citric acid.

Calculate the concentration of monosodium citrate in solution L.

You may use NaH_2A to represent monosodium citrate, and H_3A to represent citric acid.

[3]

- (iii) Using an equation, explain how the citric acid/monosodium citrate buffer solution in (b)(ii) resists pH changes when a small amount of acid is added to it.

.....

.....

..... [2]

- (iv) 10 cm³ of 0.100 mol dm⁻³ citric acid was titrated against 0.100 mol dm⁻³ sodium hydroxide. The titration curve is shown in Fig. 2.1.

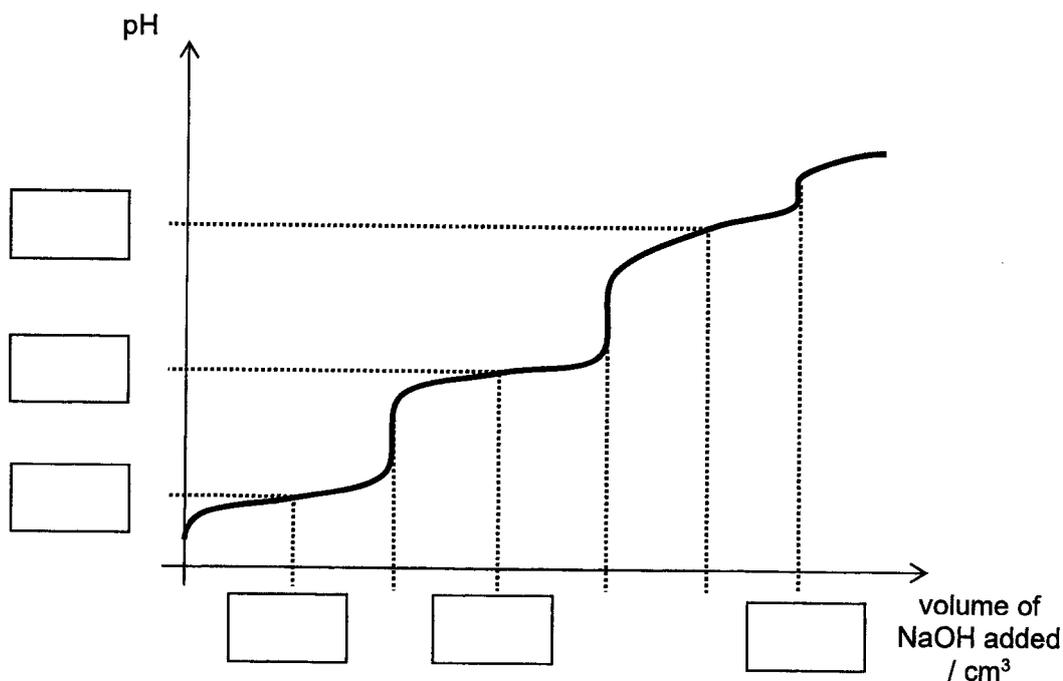
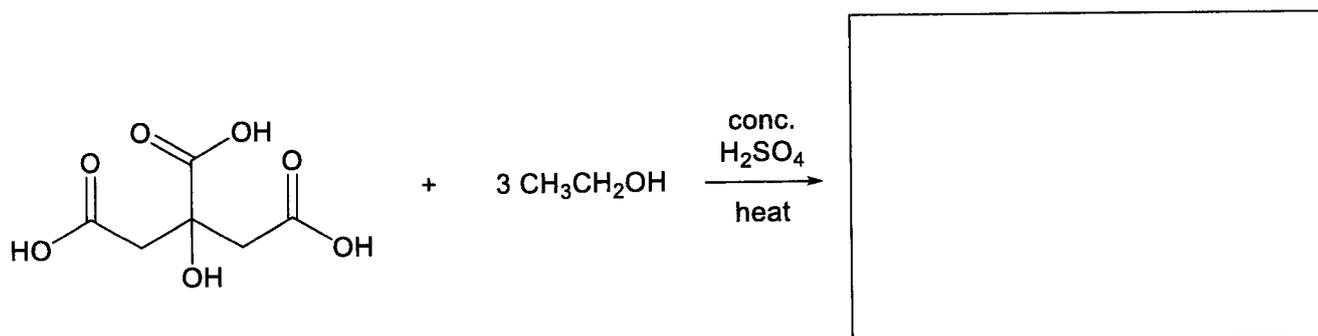


Fig. 2.1

Fill in the boxes above with the correct pH values and NaOH volumes.

[2]

- (c) A sample of citric acid is heated with excess ethanol in the presence of a small amount of concentrated sulfuric acid.

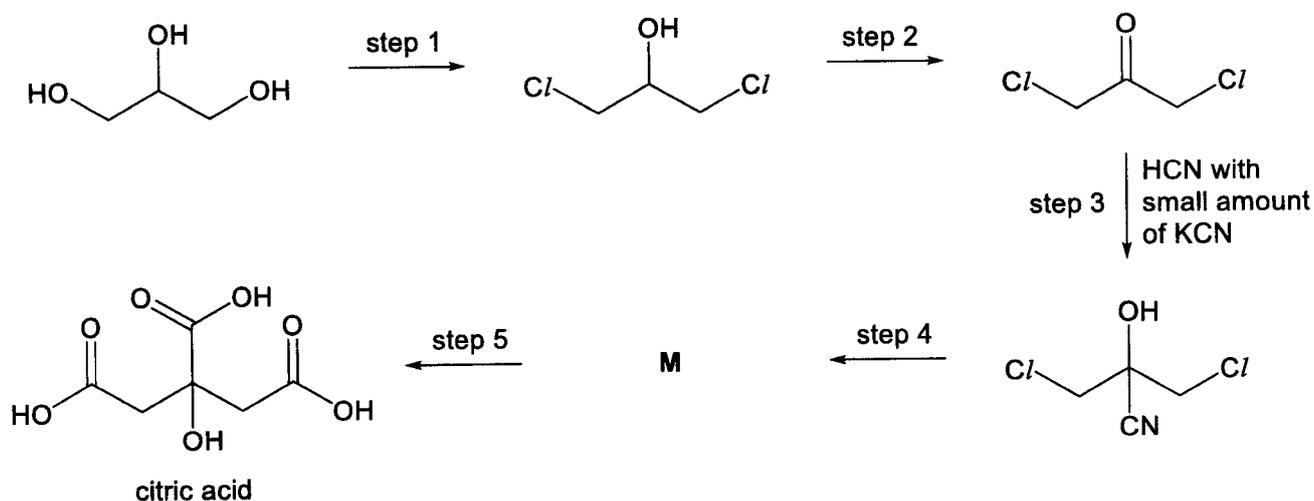


- (i) In the box above, draw the skeletal structure of the organic product formed. [1]

- (ii) State the type of reaction that has occurred.

[1]

- (d) Citric acid can be synthesised from glycerol in 5 steps according to the following reaction scheme.



- (i) Step 1 is a nucleophilic substitution reaction. Using specific reagents and conditions, only the primary alcohol groups of glycerol are substituted to produce a chloroalkane.

Suggest why substitution occurs only at the primary alcohol groups.

.....

.....

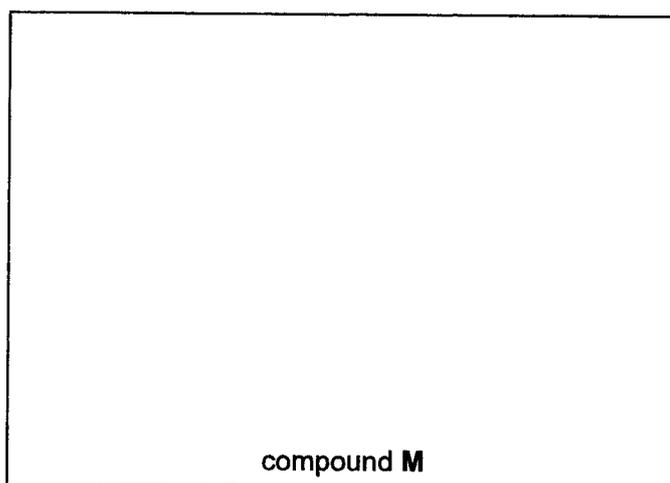
.....

[1]

- (ii) Draw the mechanism for step 3 of the reaction scheme. Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

- (iii) Draw the structure of the intermediate compound, **M**, and state the reagents and conditions for steps 4 and 5.



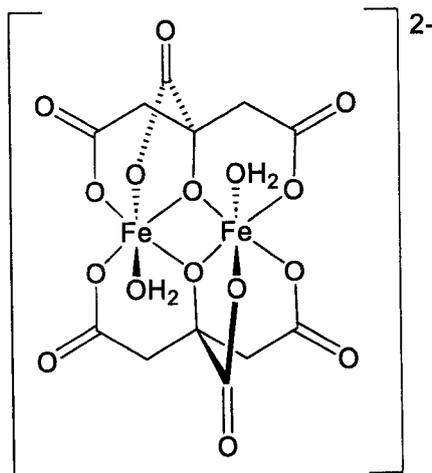
step 4

step 5

[3]

12

- (e) Fully-deprotonated citric acid, $C_6H_4O_7^{4-}$, can form soluble complexes with iron ions. The structure of one such complex which involves two $C_6H_4O_7^{4-}$ as ligands is shown below.



- (i) Determine the oxidation state of iron in this complex. Show how you arrived at your answer.

[1]

- (ii) A solution containing $C_6H_4O_7^{4-}$ removes rust by forming a soluble complex with iron ions, while a solution containing citric acid removes rust via an acid-base reaction.

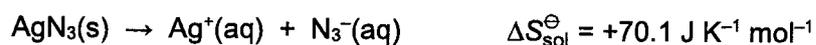
Suggest a reason why $C_6H_4O_7^{4-}$ is preferred over citric acid in removing rust from steel.

.....
 [1]

[Total: 24]

3 Silver azide, AgN_3 , is sparingly soluble in water at 25 °C.

(a) The equation for the entropy change of solution is shown.



The standard enthalpy change of formation for these species are shown in Table 3.1.

Table 3.1

species	$\text{AgN}_3(\text{s})$	$\text{Ag}^+(\text{aq})$	$\text{N}_3^-(\text{aq})$
$\Delta H_f^{\ominus} / \text{kJ mol}^{-1}$	+315.0	+105.9	+272.7

(i) Explain the significance of the sign of the entropy change for the dissolution of silver azide.

.....

.....

..... [1]

(ii) Calculate $\Delta H_{\text{sol}}^{\ominus}$ and $\Delta G_{\text{sol}}^{\ominus}$ for silver azide and use this information to explain why AgN_3 is only sparingly soluble in water at 25 °C.

Show your working.

.....

.....

..... [3]

- (b) In an experiment, solid sodium azide, $\text{NaN}_3(\text{s})$, was added slowly to a 1 dm^3 solution containing $2.00 \times 10^{-4} \text{ mol}$ of $\text{Ag}^+(\text{aq})$, and the amount of AgN_3 precipitated out was measured.

Fig. 3.1 shows the graph of amount of AgN_3 precipitated out against amount of NaN_3 added. The graph is not drawn to scale.

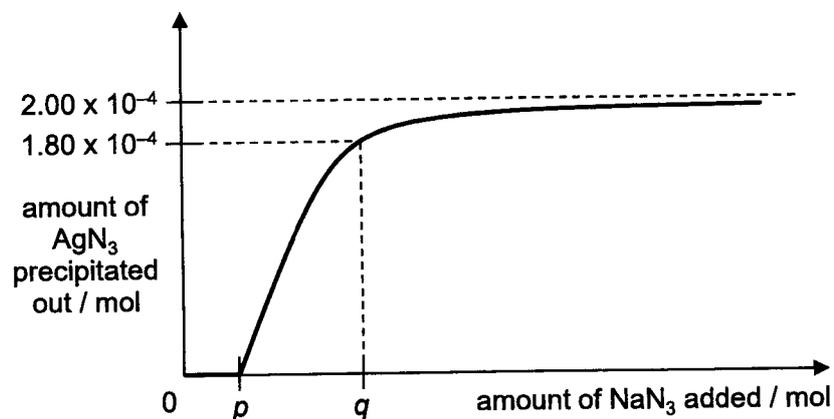


Fig. 3.1

The K_{sp} value of AgN_3 is 2.80×10^{-9} .

- (i) Explain why AgN_3 is just about to precipitate out when p mol of NaN_3 was added.

.....
 [1]

- (ii) Hence, or otherwise, determine the value of p .

[1]

15

- (iii) Calculate the $[Ag^+]$ remaining in the solution when 1.80×10^{-4} mol of AgN_3 has precipitated out.

[1]

- (iv) By considering your answer in (b)(iii) and the $[N_3^-]$ remaining in solution, determine the value of q , which is amount of NaN_3 to be added for 1.80×10^{-4} mol of AgN_3 to precipitate out.

[1]

- (v) Comment on the change in gradient of the graph as it approaches 2.00×10^{-4} on the y-axis.

.....
.....
..... [1]

- (c) Some information about N_3^- is provided in Table 3.2.

Table 3.2

shape of N_3^- ion	linear
N–N–N bond angle	180°

The bond length between nitrogen atoms in different molecules is shown in Table 3.3.

Table 3.3

molecule containing nitrogen-nitrogen bond	bond length / nm
N_2	0.110
N_3^-	0.116
$\text{H}_2\text{N}-\text{NH}_2$	0.145

Fig. 3.2 shows one possible arrangement of valence electrons and bonds in N_3^- .



Fig. 3.2

- (i) Nitrogen atoms undergo the same type of hybridisation as carbon atoms.

Using Fig. 3.2 and/or information from Table 3.2, suggest the hybridisation of the central N atom in N_3^- .

Explain your answer.

.....

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..... [2]

- (ii) Use information from Table 3.3 to explain why Fig. 3.2 does **not** represent an accurate model for the bonding in N_3^- .

.....

.....

..... [1]

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- (d) N_3^- is frequently used as a nucleophile in organic reactions because it allows nitrogen to be introduced into an organic compound.

Fig. 3.3 shows how an acid chloride can be converted into an amine with the use of N_3^- as one of the reagents.

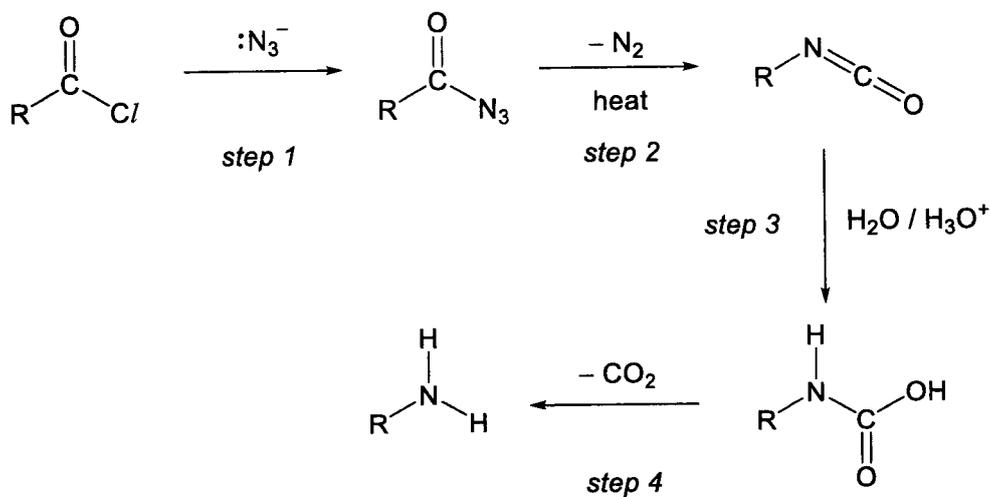


Fig. 3.3

- (i) Suggest the type of reaction in *step 3*.

[1]

- (ii) Draw the structure of the acid chloride that will be converted to phenylamine through the process shown in Fig. 3.3.

[1]

- (iii) On Fig. 3.4, draw curly arrows to complete the mechanism for *step 3*. Show all relevant dipoles and lone pairs in your answer. [2]

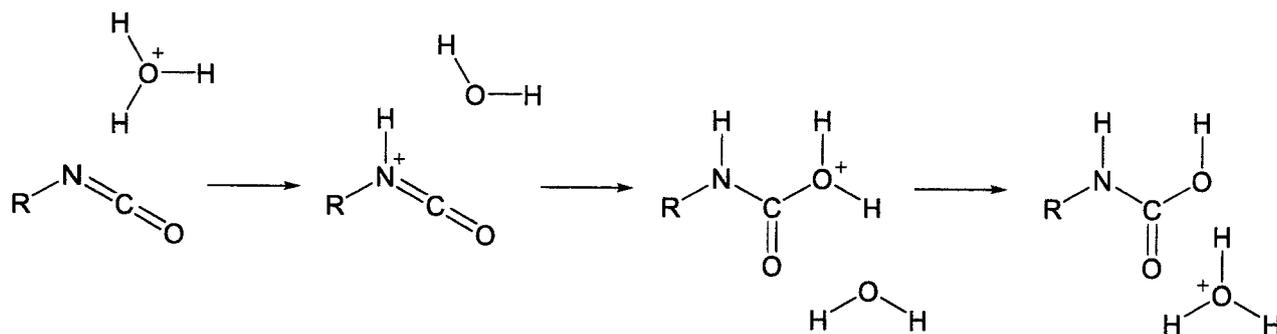


Fig. 3.4

- (iv) In Fig. 3.4, H_3O^+ serves two roles. One of the roles it serves is that of a Brønsted-Lowry acid. Deduce the other role of H_3O^+ . Explain your answer.

.....
 [1]

[Total: 17]

4 This question is about the chemistry of noble gases in Group 18 of the Periodic Table.

(a) Noble gases are known for their behaviour that closely resembles an ideal gas, especially under certain conditions.

(i) State and explain the **two** conditions under which a real gas behaves most closely to an ideal gas.

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..... [2]

(ii) Explain why Ne behaves more closely to an ideal gas than HF.

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..... [2]

21

(b) A 3 dm^3 vessel containing He at 4.0 kPa is connected to an empty 2 dm^3 vessel at constant temperature.

(i) Show that the pressure of He after the two vessels are connected is 2.4 kPa .

[1]

Xe is then pumped into the connected vessels until the total pressure inside the vessels is 6.0 kPa .

(ii) Calculate the partial pressure of Xe in the vessels.

[1]

(iii) Hence, or otherwise, calculate the mole fraction of Xe.

[1]

Table 4.1 provides information on some noble gases.

Table 4.1

	He	Ne	Ar	Kr	Xe
relative atomic mass	4.0	20.2	39.9	83.8	131.3
atomic radius / nm	0.140	0.160	0.190	0.202	0.216
density / g dm ⁻³	0.179	0.900	1.78	3.71	5.85
first ionisation energy / kJ mol ⁻¹	2370	2080	1520	1350	1170
boiling point / °C	-269	-246	-186	-152	-107

(c) Noble gases were long believed to be totally unreactive but stable compounds of Kr and Xe are now known. Highly electronegative elements such as fluorine and oxygen form many compounds with Xe, for example, XeF₂, XeF₄ and XeO₄. All of these compounds are simple covalent molecules.

(i) Ne is in period 2 and does not form any compound at all. Explain why.

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..... [1]

(ii) Describe the covalent bond in a molecule of XeF₄.

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..... [1]

(iii) Draw the 'dot-and-cross' diagram for XeO₄.

Use VSEPR theory to predict the shape of and bond angle in XeO₄. Explain your answer.

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..... [3]

(iv) Xe can form XeF_2 and XeF_4 but Kr can only form KrF_2 .

Use information from Table 4.1 to suggest a reason why Kr does not form a compound with four fluorine atoms.

.....

 [1]

(d) The first noble gas compound was synthesised by reacting Xe with PtF_6 .

PtF_6 is a strong oxidant that is able to extract an electron from Xe, thus forming $\text{Xe}^+[\text{PtF}_6]^-$, which is an ionic compound.

(i) Explain why the Xe^+ ion can be described as a radical.

.....
 [1]

(ii) Although PtF_6 is able to extract an electron from Xe, it is unable to do so from He and Ne. Use information from Table 4.1 to suggest why this is so.

.....

 [1]

(e) He has an unusually low abundance in earth's atmosphere despite being the most abundant Group 18 element in the solar system.

Use information from Table 4.1 to suggest a reason for the low abundance of He in earth's atmosphere.

.....

 [1]

[Total: 16]

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YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CG

INDEX NO

CHEMISTRY

9729/03

Paper 3 Free Response

16 September 2025

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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 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.

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		
Section A		
1		/ 17
2		/ 18
3		/ 25
Section B		
4 or 5		/ 20
Penalty	units	significant figures
Overall		/ 80

This document consists of **28** printed pages.

3 (a) Chromium, a transition metal, is widely used in stainless steel production for its corrosion resistance.

(i) State the electronic configurations of a Cr atom and of a Cr^{3+} cation. [2]

(ii) Describe two ways in which compounds containing Cr^{3+} ions are different from those containing Ca^{2+} ions in terms of their chemical behaviour. [2]

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(b) Chromium(III) bromide, CrBr_3 , is a dark-coloured solid used in chemical synthesis and research, particularly for studying magnetic and electronic properties of transition metal halides.

(i) Define the term *lattice energy*. [1]

(ii) Use data from Table 3.1 and the *Data Booklet* to calculate a value for the lattice energy of $\text{CrBr}_3(\text{s})$. Show your working. [3]

Table 3.1

	value/ kJ mol^{-1}
first electron affinity of bromine	-324.6
standard enthalpy change of vapourisation of bromine molecules	+29.6
standard enthalpy change of atomisation of chromium	+397
standard enthalpy change of formation of $\text{CrBr}_3(\text{s})$	-400.4

(iii) Chromium(III) bromide and chromium(III) iodide have the same crystal structure.

There is closer agreement between the experimental and theoretical values of lattice energy for CrBr_3 than for CrI_3 . Suggest a reason for this. [1]

- (c) Potassium dichromate(VI), $K_2Cr_2O_7$, is an oxidising agent.

Outline how you would obtain a sample of propanal from propan-1-ol using potassium dichromate(VI). [1]

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- (d) The cobalt(II) ion, Co^{2+} , is another oxidising agent.

(i) With the aid of relevant half equations from the *Data Booklet*, draw a fully labelled diagram of the electrochemical cell set-up used to measure the relative oxidising powers of $Cr_2O_7^{2-}$ and Co^{2+} under standard conditions, and calculate the E^\ominus_{cell} of the electrochemical cell. [4]

(ii) Write the overall equation for when current flows. [1]

(iii) Use your answer to (d)(ii) to calculate the standard Gibbs free energy change, ΔG^\ominus , for this electrochemical reaction. [1]

(iv) Using relevant data from the *Data Booklet*, deduce how the value of E^\ominus_{cell} will change when aqueous ammonia is added to the Co^{2+}/Co half-cell. [1]

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- (b) Many organic compounds contain more than one functional group. With certain reagents and conditions, more than one functional group could react. Sometimes, this is undesirable as chemists only want a particular functional group to be transformed.

For example, in Fig. 5.2, when the keto-ester methyl 3-oxobutanoate reacts with a reagent known as the Grignard reagent, CH_3MgBr , both the ketone functional group and the ester functional group could react. This results in a mixture of products and a low yield of the desired compound.

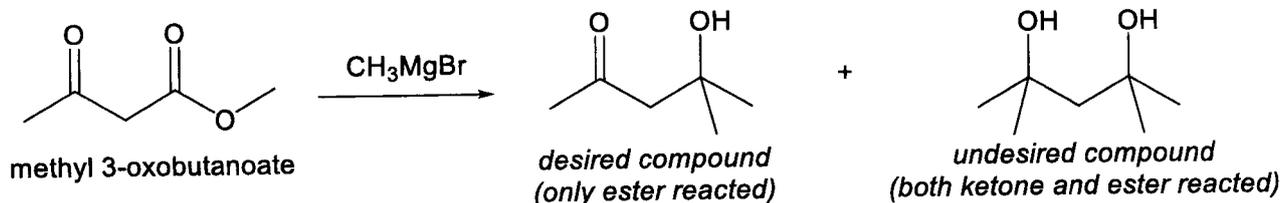


Fig. 5.2

If a chemist wants only the ester to react, the chemist must first convert the ketone into an acetal functional group that does not react with the Grignard reagent. This acetal-ester compound is then reacted with the Grignard reagent, before the acetal is converted back to the ketone. The acetal is thus known as a *protecting group*, as it seems to have “protected” the ketone functional group from undesired reactions.

The formation of an acetal from a ketone and an alcohol under acidic conditions is a reversible reaction. An example is shown in Fig. 5.3 using butanone and methanol.

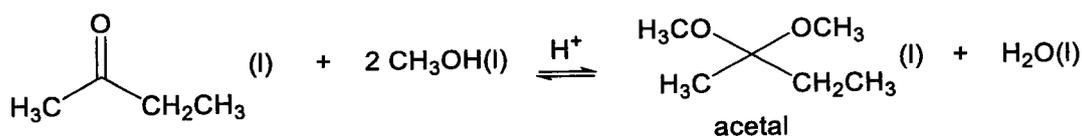


Fig. 5.3

0.100 mol of butanone and 0.100 mol of methanol are mixed in a 1.00 dm³ flask with H^+ as a catalyst. After equilibrium is established, 0.020 mol of the acetal is present.

- (i) Explain what is meant by *reversible reaction*. [1]
- (ii) Write the expression for the equilibrium constant, K_c , for the equilibrium in Fig. 5.3, stating its units. [1]
- (iii) Use the information provided to calculate a value for K_c . [3]
- (iv) A Dean-Stark apparatus is a piece of laboratory glassware used in organic synthesis to remove water produced in an organic reaction.

Suggest why the use of a Dean-Stark apparatus improves the yield of acetal formation. [1]

- (v) Sketch two labelled graphs, on the same axes, to show how [acetal] changes over time with and without a catalyst for the equilibrium. Explain your answer. [2]

