



# RIVER VALLEY HIGH SCHOOL

## JC 2 PRELIMINARY EXAMINATION

CANDIDATE  
NAME

CLASS

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CENTRE  
NUMBER

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INDEX  
NUMBER

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## 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.

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

Write your name, class, centre number and index number on the Answer Sheet in the spaces provided.

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.**

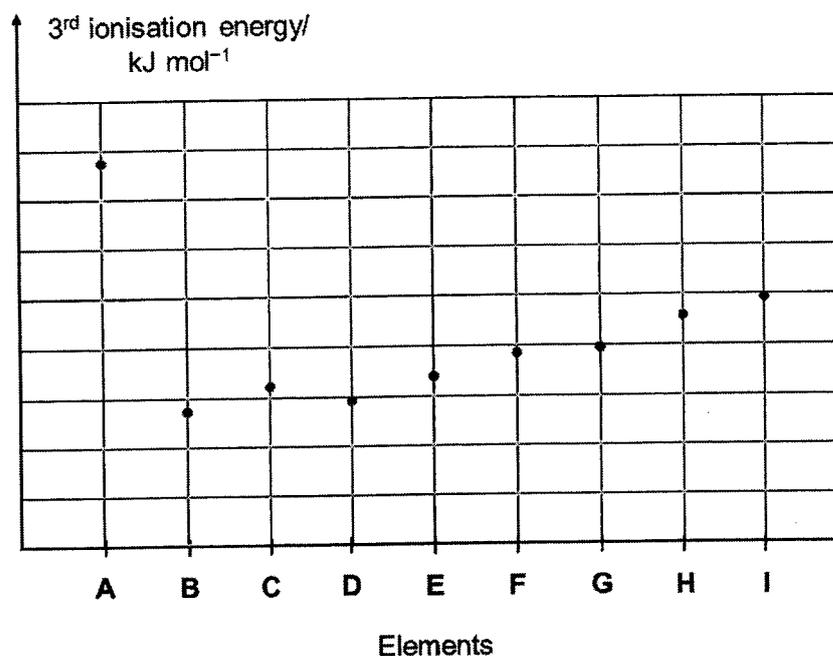
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

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

This document consists of **15** printed pages and **1** blank page.

- 1 The graph below shows the variation in the third ionisation energies for the consecutive elements **A** to **I**, all with atomic numbers smaller than 20. The symbols **A** to **I** do not represent actual elements.



Which of the following can be deduced from the information given?

- A**  $B^{2+}$  is smaller than  $C^{2+}$ .
- B** In an electric field,  $H^+$  is deflected to a smaller extent than  $I^+$ .
- C** The decrease in 3<sup>rd</sup> ionisation energy from **C** to **D** on graph is due to coulombic repulsion.
- D** **G** has noble gas electronic configuration.
- 2 A 50.00 cm<sup>3</sup> of a solution of 0.300 mol dm<sup>-3</sup> MoO<sub>x</sub><sup>2-</sup> was reduced to Mo<sup>3+</sup> using Zn powder. The filtrate required 45.00 cm<sup>3</sup> of 0.200 mol dm<sup>-3</sup> acidified KMnO<sub>4</sub> to revert to its original form of MoO<sub>x</sub><sup>2-</sup>.

What is the value of x?

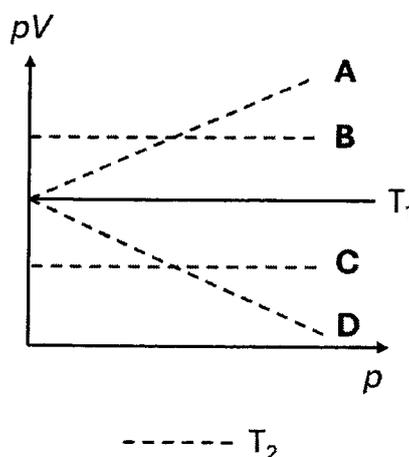
- A** 1                      **B** 2                      **C** 3                      **D** 4

- 3 When 20 cm<sup>3</sup> of a gaseous hydrocarbon was completely burnt in 120 cm<sup>3</sup> of oxygen, there is a contraction of 50 cm<sup>3</sup>. On further treatment with aqueous potassium hydroxide, the volume decreases by 60 cm<sup>3</sup>.

Which could be the formula of the organic compound?

All volumes being measured at the room temperature and pressure.

- A C<sub>2</sub>H<sub>2</sub>                      B C<sub>2</sub>H<sub>4</sub>                      C C<sub>3</sub>H<sub>6</sub>                      D C<sub>3</sub>H<sub>8</sub>
- 4 What is the order of increasing bond angle for four molecules?
- A BF<sub>3</sub> < SF<sub>2</sub> < SiF<sub>4</sub> < BrF<sub>5</sub>  
 B BF<sub>3</sub> < SiF<sub>4</sub> < SF<sub>2</sub> < BrF<sub>5</sub>  
 C BrF<sub>5</sub> < SiF<sub>4</sub> < SF<sub>2</sub> < BF<sub>3</sub>  
 D BrF<sub>5</sub> < SF<sub>2</sub> < SiF<sub>4</sub> < BF<sub>3</sub>
- 5 Nitrogen atoms undergo the same type of hybridisation as carbon atoms.  
 Which species contains the shortest nitrogen-oxygen bond length?
- A NO<sub>2</sub>                      B NO<sub>2</sub><sup>+</sup>                      C NO<sub>2</sub><sup>-</sup>                      D NO<sub>3</sub><sup>-</sup>
- 6 The volumes and pressures of a fixed mass of gas are investigated, at different temperatures.  
 The results are plotted on a graph of  $pV$  against  $p$  at a temperature of  $T_1$ . The gas behaves as an ideal gas under the conditions chosen.  
 Which plot shows the results for a lower temperature,  $T_2$ ?



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

When 0.860 g of ethanol undergoes complete combustion below a beaker containing 300 g of water, the temperature of the water rises by 18 °C.

The theoretical enthalpy change of combustion of ethanol is  $-1367 \text{ kJ mol}^{-1}$ .

What is the efficiency of the process?

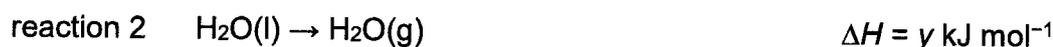
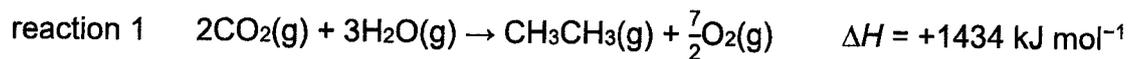
- A 2%
- B 7%
- C 31%
- D 88%

8 Using the enthalpy changes below, calculate the standard enthalpy change of formation of gaseous hydrogen chloride.

	enthalpy change/ $\text{kJ mol}^{-1}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	-92
$\text{N}_2(\text{g}) + 4\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{NH}_4\text{Cl}(\text{s})$	-629
$\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$	-176

- A  $-46.3 \text{ kJ mol}^{-1}$
- B  $-92.5 \text{ kJ mol}^{-1}$
- C  $-180 \text{ kJ mol}^{-1}$
- D  $-361 \text{ kJ mol}^{-1}$

9 Consider the following reactions.



The standard enthalpy change of combustion of ethane is  $-1542 \text{ kJ mol}^{-1}$ .

Which statements are correct?

- 1  $y$  is +36
- 2 At 373 K,  $\Delta S$  for reaction 2 is  $\frac{y}{373} \text{ kJ mol}^{-1} \text{ K}^{-1}$ .
- 3 Reaction 1 is spontaneous only at high temperatures.

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

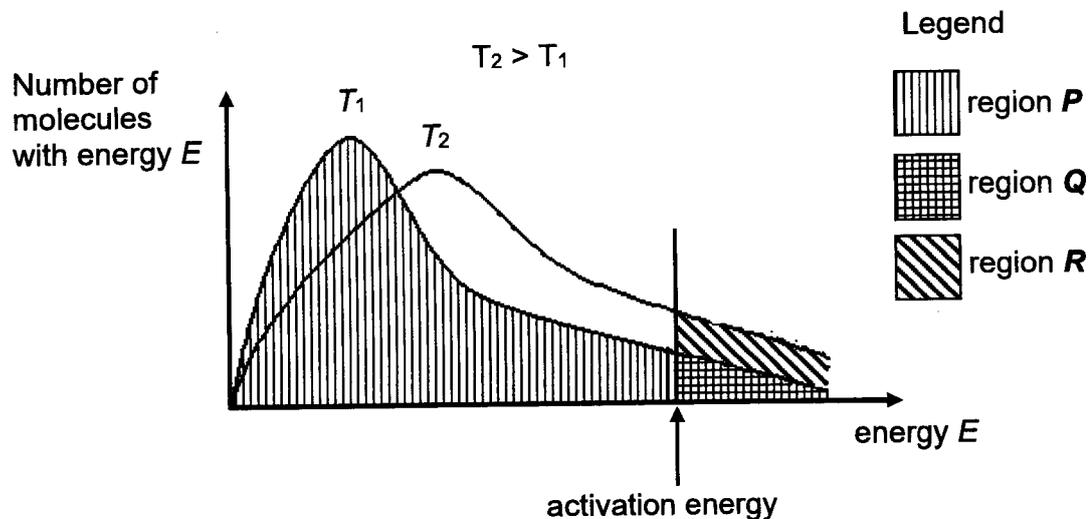
10 The half-life of a radioactive isotope **P** is twice that of another radioactive isotope **Q**. In a sample of rock, it is found that the number of atoms of **Q** is 4 times that of **P**.

What will be the ratio of the number of atoms of **P** to the number of atoms of **Q** in the rock after two half-lives of **P**?

- A**  $\frac{1}{16}$                       **B**  $\frac{1}{4}$                       **C**  $\frac{1}{2}$                       **D** 1

- 11 The distribution of the number of molecules with energy  $E$  is given in the sketch for two temperatures,  $T_1$  and  $T_2$ .

The letters  $P$ ,  $Q$ ,  $R$  refer to the separate and differently shaded areas. The activation energy is marked on the energy axis.



Which expression gives the fraction of the molecules present which have at least the activation energy at the higher temperature  $T_2$ ?

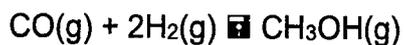
- A  $\frac{Q}{P}$       B  $\frac{Q+R}{P}$       C  $\frac{Q+R}{P+Q}$       D  $\frac{Q+R}{P+Q+R}$

- 12 Sulfur is converted to  $\text{SF}_6$  by fluorine, to  $\text{SCl}_2$  by chlorine and to  $\text{S}_2\text{Br}_2$  by bromine.

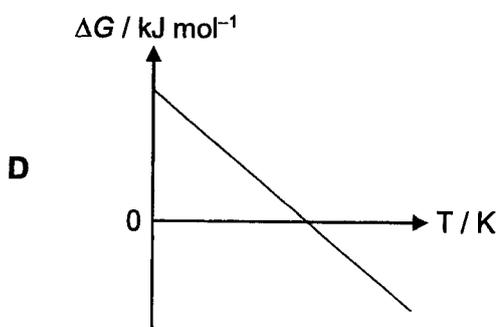
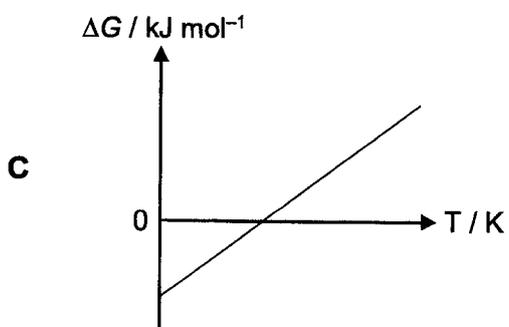
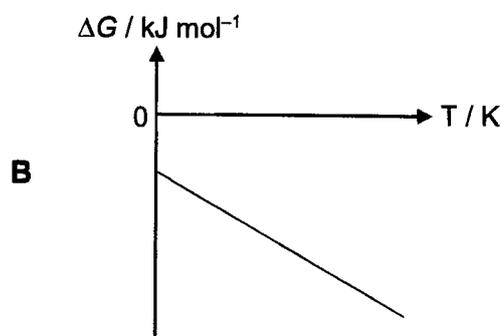
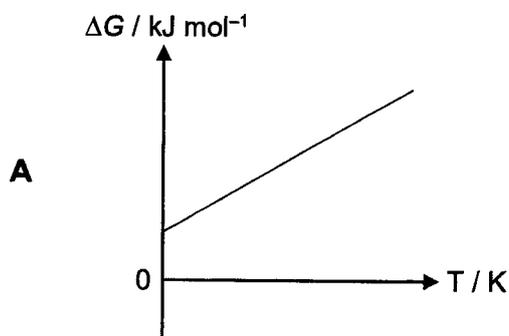
Which trend does this information best provide evidence for?

- A bond energy:  $\text{Cl}_2 > \text{Br}_2 > \text{F}_2$   
 B electronegativity:  $\text{F} > \text{Cl} > \text{Br}$   
 C first ionisation energy:  $\text{F} > \text{Cl} > \text{Br}$   
 D oxidising ability:  $\text{F}_2 > \text{Cl}_2 > \text{Br}_2$

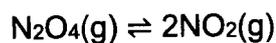
- 13 Methanol can be synthesised from carbon monoxide and hydrogen according to the equation.



A higher yield of methanol can be achieved at a lower temperature. Which graph corresponds to the forward process?

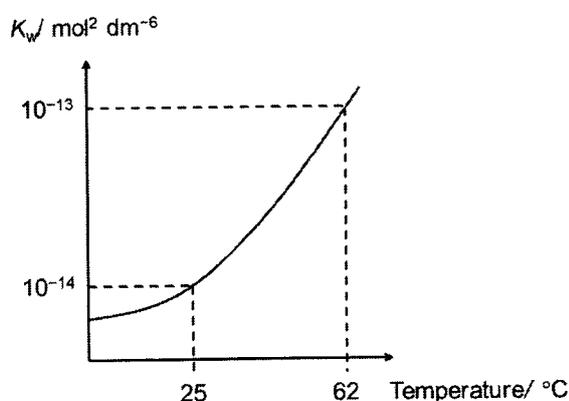


- 14 1.00 mol of  $\text{N}_2\text{O}_4$  and 0.200 mol of  $\text{NO}_2$  are added to a sealed vessel of fixed volume at 298 K. When the system reaches equilibrium, 0.680 mol of  $\text{NO}_2$  is present in the vessel.



Which statement about this equilibrium is correct?

- A 0.240 mol of  $\text{N}_2\text{O}_4$  is present at equilibrium.
- B The value for the equilibrium constant,  $K_c$ , is 0.608.
- C The pressure in the vessel at equilibrium is the same as the pressure before the reaction started.
- D The pressure in the vessel at equilibrium is higher than the pressure before the reaction started.
- 15 The value of the ionic product of water,  $K_w$ , varies with temperature.



Which statement is correct?

- A The ionic dissociation of water is an exothermic process.
- B The ionic dissociation of water increases 100 times between 25 °C and 62 °C.
- C Water becomes acidic as temperature increases.
- D  $[\text{OH}^-]$  increases as temperature increases.

- 16 Pyruvic acid,  $\text{CH}_3\text{COCO}_2\text{H}$ , and acetylsalicylic acid,  $\text{C}_6\text{H}_5\text{COOH}$ , are weak acids. Both acids dissociate in aqueous solutions as follows, where  $\alpha$  is the degree of dissociation.



The dissociation constants,  $K_a$  of  $\text{CH}_3\text{COCO}_2\text{H}$  and  $K_a$  of  $\text{C}_6\text{H}_5\text{COOH}$ , are given in the table below.

	$\text{CH}_3\text{COCO}_2\text{H}$	$\text{C}_6\text{H}_5\text{COOH}$
Dissociation constant/ $\text{mol dm}^{-3}$	$1.4 \times 10^{-4}$	$3.4 \times 10^{-4}$

Which statement is correct?

- 1 The pH of  $1 \text{ mol dm}^{-3}$  of  $\text{CH}_3\text{COCO}_2\text{H}$  is lower than that of  $1 \text{ mol dm}^{-3}$  of  $\text{C}_6\text{H}_5\text{COOH}$ .
  - 2 The value of dissociation constant in terms of initial concentration  $C$  and degree of dissociation is  $K_a = \frac{\alpha^2}{C(1-\alpha)}$ .
  - 3 The  $pK_b$  of  $\text{CH}_3\text{COCO}_2^-$  is smaller than that of  $\text{C}_6\text{H}_5\text{COO}^-$ .
- A 1 and 2 only    B 1 only    C 2 and 3 only    D 3 only
- 17 Which statement about phosphoric(V) acid,  $\text{H}_3\text{PO}_4$ , ( $pK_a = 2.0$ ) is **incorrect**?
- A  $\text{PO}_4^{3-}$  can react as a base.  
 B  $\text{H}_3\text{PO}_4$  has a higher  $K_a$  than  $\text{HPO}_4^{2-}$ .  
 C A buffer of pH 2.0 can be prepared using equal amount of  $\text{H}_3\text{PO}_4$  and  $\text{HPO}_4^{2-}$ .  
 D  $\text{HPO}_4^{2-}$  has a higher  $K_b$  value than  $\text{H}_2\text{PO}_4^-$ .

- 18 Chromium(III) hydroxide,  $\text{Cr}(\text{OH})_3$ , is sparingly soluble.

What is the minimum pH required to precipitate chromium(III) hydroxide from chromium(III) nitrate solution given that the concentration of chromium(III) ion in the solution is less than  $1.5 \times 10^{-15}$ ?

The numerical value of the solubility product of  $\text{Cr}(\text{OH})_3$  is  $6.3 \times 10^{-31}$ .

- A 5.13                      B 6.09                      C 7.91                      D 8.87

- 19 Two students separately are given equal volumes of  $0.100 \text{ mol dm}^{-3}$  of lead(II) nitrate, sodium chromate and potassium sulfate.

The first student, on mixing the potassium sulfate and lead(II) nitrate, obtains a white precipitate. On adding sodium chromate to this mixture, the precipitate turns yellow.

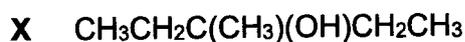
The second student, on mixing the sodium chromate and lead(II) nitrate, obtains a yellow precipitate. On adding potassium sulfate to this mixture, there is no further change.

Which statements about these observations are correct?

- 1 Lead(II) chromate is insoluble.
- 2 Lead(II) sulfate is more soluble than lead(II) chromate.
- 3 Chromate can oxidise sulfate.

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

- 20 Two constitutional isomers of molecular formula  $\text{C}_6\text{H}_{13}\text{OH}$  are shown.

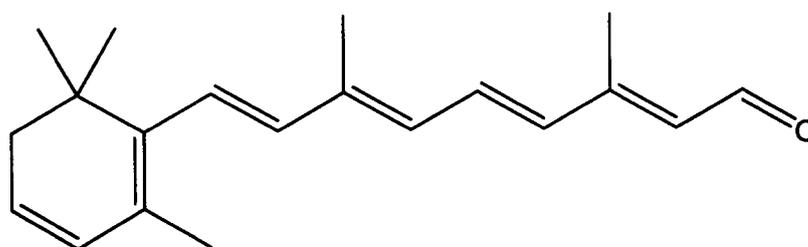


X and Y reacts with ethanolic KOH under reflux to form  $\text{C}_6\text{H}_{12}$ .

How many possible **constitutional** isomers each with molecular formula  $\text{C}_6\text{H}_{12}$ , could be produced by X and by Y?

	isomers formed by X	isomers formed by Y
A	2	2
B	2	3
C	3	2
D	3	3

- 21 Retinal is heated under reflux with acidified potassium manganate(VII).

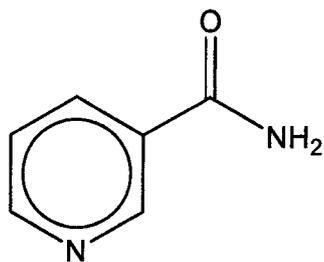


retinal

How many organic products are formed from this reaction?

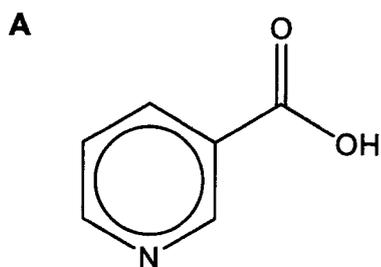
A 2      B 3      C 4      D 5

- 22 Nicotinamide, which is marketed as nicotine substitute, can be hydrolysed by aqueous sodium hydroxide.

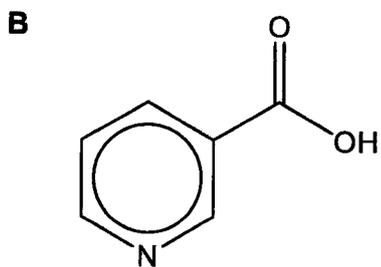


nicotinamide

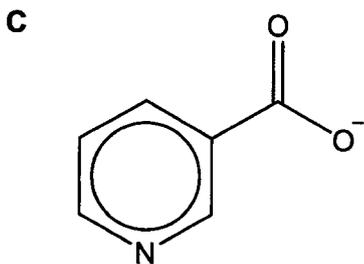
What are the products of this hydrolysis reaction?



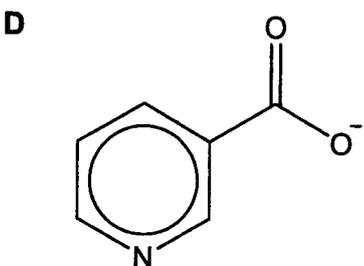
and  $\text{NH}_3$



and  $\text{NH}_4^+$



and  $\text{NH}_3$



and  $\text{NH}_4^+$

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

An organic acid is used as fruity taste food additive. It has the following features.

- It is dibasic.
- It is non-cyclic.
- It exhibits cis-trans isomerism.
- It has a relative molecular mass of 116.

How many carbon atoms are in one molecule of this organic acid?

- A 3                      B 4                      C 5                      D 6

24 Three compounds, benzyl chloride, phenol and chlorobenzene are separately warmed with concentrated nitric acid and concentrated sulfuric acid at appropriate temperature.

Which compound reacts the fastest and slowest respectively?

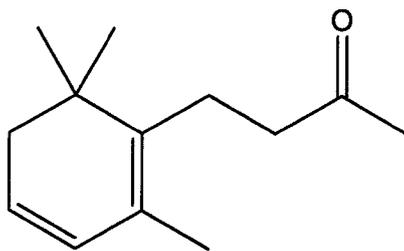
	Fastest reaction	Slowest reaction
A	benzyl chloride	chlorobenzene
B	benzyl chloride	phenol
C	phenol	chlorobenzene
D	phenol	benzyl chloride

25 2-methylbut-2-ene,  $\text{CH}_3\text{C}(\text{CH}_3)\text{CHCH}_3$ , reacts with aqueous bromine.

What is the structure of the major organic product?

- |   |  |   |  |
|---|--|---|--|
| A | $\text{CH}_3\text{CBr}(\text{CH}_3)\text{CHBrCH}_3$          | B | $\text{CH}_3\text{CBr}(\text{CH}_3)\text{CH}(\text{OH})\text{CH}_3$          |
| C | $\text{CH}_3\text{C}(\text{OH})(\text{CH}_3)\text{CHBrCH}_3$ | D | $\text{CH}_3\text{C}(\text{OH})(\text{CH}_3)\text{CH}(\text{OH})\text{CH}_3$ |

- 26  $\alpha$ -Ionone undergoes reduction to give a single product.  
The product decolourises aqueous bromine but does not give a yellow precipitate when 2,4-dinitrophenylhydrazine is added.

 $\alpha$ -ionone

Which of the following could be a reducing agent for the reduction of  $\alpha$ -ionone?

- 1  $\text{LiAlH}_4$  in dry ether
- 2  $\text{H}_2(\text{g})$ ,  $\text{Ni}(\text{s})$ , heat
- 3  $\text{NaBH}_4$

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

- 27 Chloroethene, chloroethane and ethanoyl chloride reacts with aqueous silver nitrate to form a white precipitate at different rates.

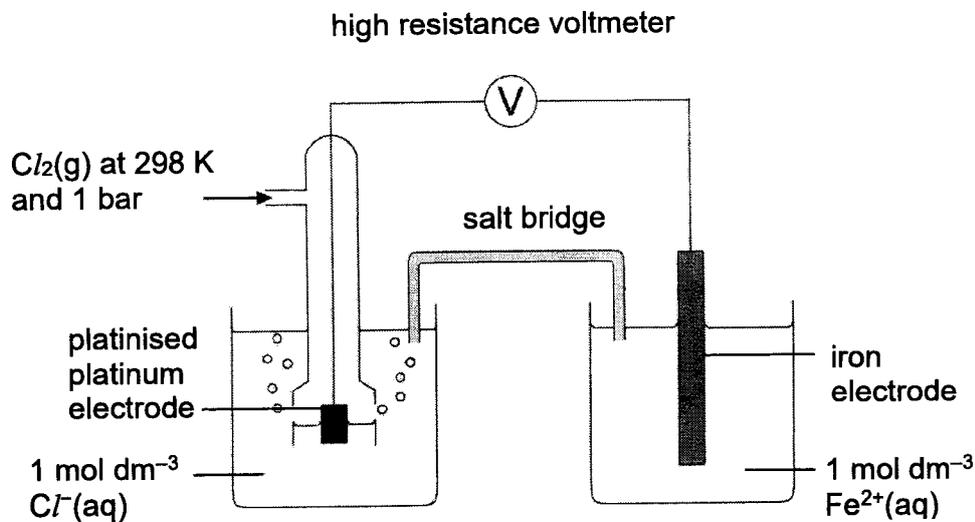
Which statements explain the difference in rate?

- 1 The carbon atom bonded to chlorine in ethanoyl chloride is more susceptible to nucleophilic attack.
- 2 Chloroethene reacts least readily with water.
- 3 Ethanoyl chloride is more acidic.

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

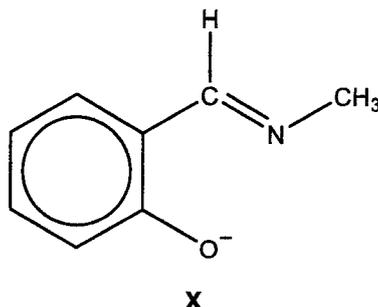
28 Use of the Data Booklet is relevant to this question.

What change to the half-cells could cause the high resistance voltmeter to show a decrease in value of cell potential?

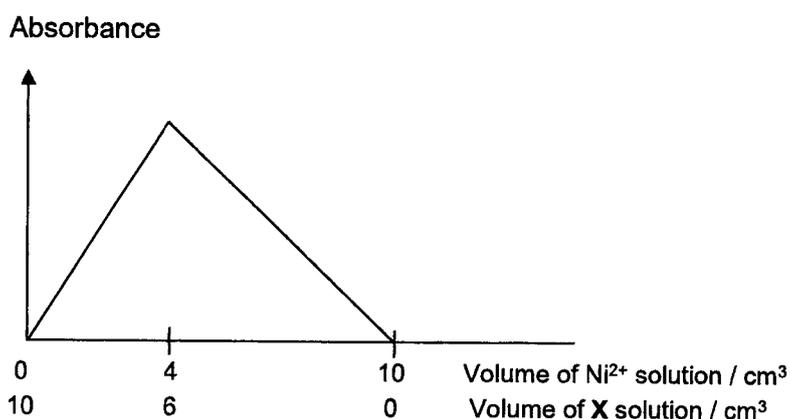


- A Using a bigger piece of iron electrode.
- B Adding water to the half-cell on the right.
- C Adding aqueous  $\text{AgNO}_3$  to the half-cell on the left.
- D Decreasing the pressure of the chlorine gas.

- 29 The complex of nickel with ligand **X** is thermochromic, being coloured red at room temperature but changing to yellow-green when heated to 170 °C.



The following graph sketch was obtained when the absorbances of mixtures of a  $4 \times 10^{-3} \text{ mol dm}^{-3}$  solution of **X** and a  $3 \times 10^{-3} \text{ mol dm}^{-3}$  solution of nickel(II) chloride were measured using a colorimeter at room temperature.



What is the charge on the nickel complex?

- A** 1+                      **B** 0                      **C** 1-                      **D** 4-
- 30 Which one of the following species is unlikely to exist?
- A**  $[\text{Cu}(\text{S}_2\text{O}_3)]^-$
- B**  $[\text{Cr}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$
- C**  $[\text{Mn}(\text{CN})_6]^{2+}$
- D**  $[\text{VO}(\text{H}_2\text{O})_5]^{2+}$

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# RIVER VALLEY HIGH SCHOOL

## JC 2 PRELIMINARY EXAMINATION

CANDIDATE  
NAME

CLASS

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CENTRE  
NUMBER

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INDEX  
NUMBER

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## H2 CHEMISTRY

**9729/02**

Paper 2 Structured Questions

**16 September 2025**

**2 hours**

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

### READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, class and name on all the work that you hand in.

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.

**DO NOT WRITE IN ANY BARCODES.**

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.

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								
Question Number	1	2	3	4	5	6		
Marks	13	15	9	16	10	12		
significant figures			units				Total	75

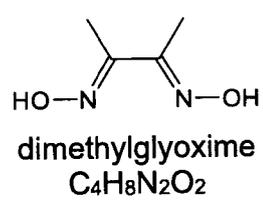
This document consists of **28** printed pages.





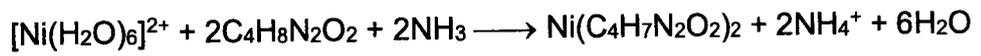


(d) Nickel(II) compounds can be analysed using dimethylglyoxime (C<sub>4</sub>H<sub>8</sub>N<sub>2</sub>O<sub>2</sub>).



An excess of a solution of dimethylglyoxime is first added to an acidic solution of a nickel(II) compound. When aqueous ammonia is next added, a nickel(II) complex, Ni(C<sub>4</sub>H<sub>7</sub>N<sub>2</sub>O<sub>2</sub>)<sub>2</sub>, is produced.

The following equation shows the reaction:



(i) State the role of ammonia in the above reaction.

.....  
 .....

[1]

(ii) Draw the structure of C<sub>4</sub>H<sub>7</sub>N<sub>2</sub>O<sub>2</sub><sup>-</sup>.

[1]

(iii) The Ni(C<sub>4</sub>H<sub>7</sub>N<sub>2</sub>O<sub>2</sub>)<sub>2</sub> complex is square planar in shape with respect to the nickel(II) ion. Each ligand in the complex is bidentate with the nitrogen atoms datively bonded to the nickel(II) ion. The -OH group in each ligand forms a hydrogen bond with another ligand.

Complete Fig. 1.2 to show the structure of the Ni(C<sub>4</sub>H<sub>7</sub>N<sub>2</sub>O<sub>2</sub>)<sub>2</sub> complex and label one of the two hydrogen bonds clearly.



Fig. 1.2

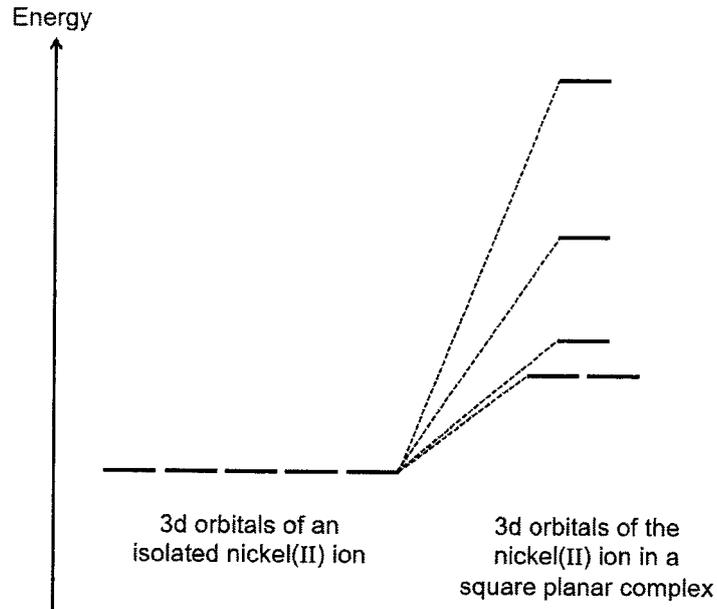
[2]

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- (iv) In the formation of a square planar complex, the ligands approach the central metal ion along the x and y axes.

Fig. 1.3 shows how the 3d orbitals of the nickel(II) ion in a square planar complex are split based on the crystal field theory.



**Fig. 1.3**

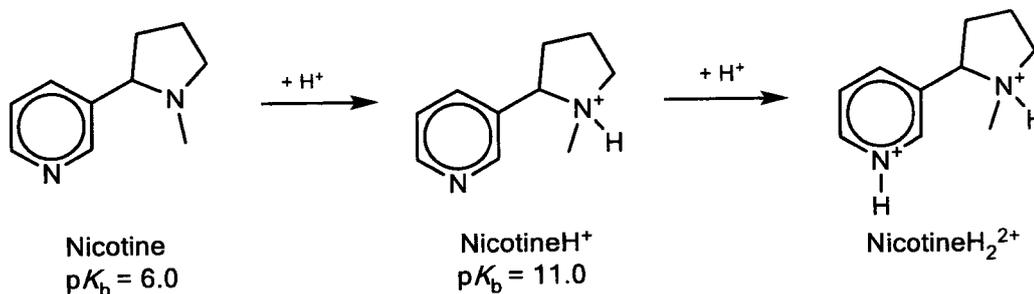
State the identity of the 3d orbital with the highest energy in the nickel(II) ion in a square planar complex.

..... [1]

[Total: 13]



- 2 Nicotine is a weak diprotic base consisting of an aromatic pyridine ring joined to a saturated pyrrolidine ring. It is highly addictive and is found in tobacco and vapes. Values for the base dissociation constants,  $pK_b$ , for nicotine is shown below.



- (a) State what is meant by the term *Lewis base*.

.....  
 .....

[1]

- (b) 25.00 cm<sup>3</sup> of an aqueous solution of nicotine was titrated against 0.100 mol dm<sup>-3</sup> hydrochloric acid, HCl. At the 2<sup>nd</sup> equivalence point, it was found that 49.0 cm<sup>3</sup> of HCl was added.

- (i) Calculate the concentration of NicotineH<sub>2</sub><sup>2+</sup>, in mol dm<sup>-3</sup>, at the 2<sup>nd</sup> equivalence point.

[1]

- (ii) Calculate the pH of the solution at the 2<sup>nd</sup> equivalence point.

[2]

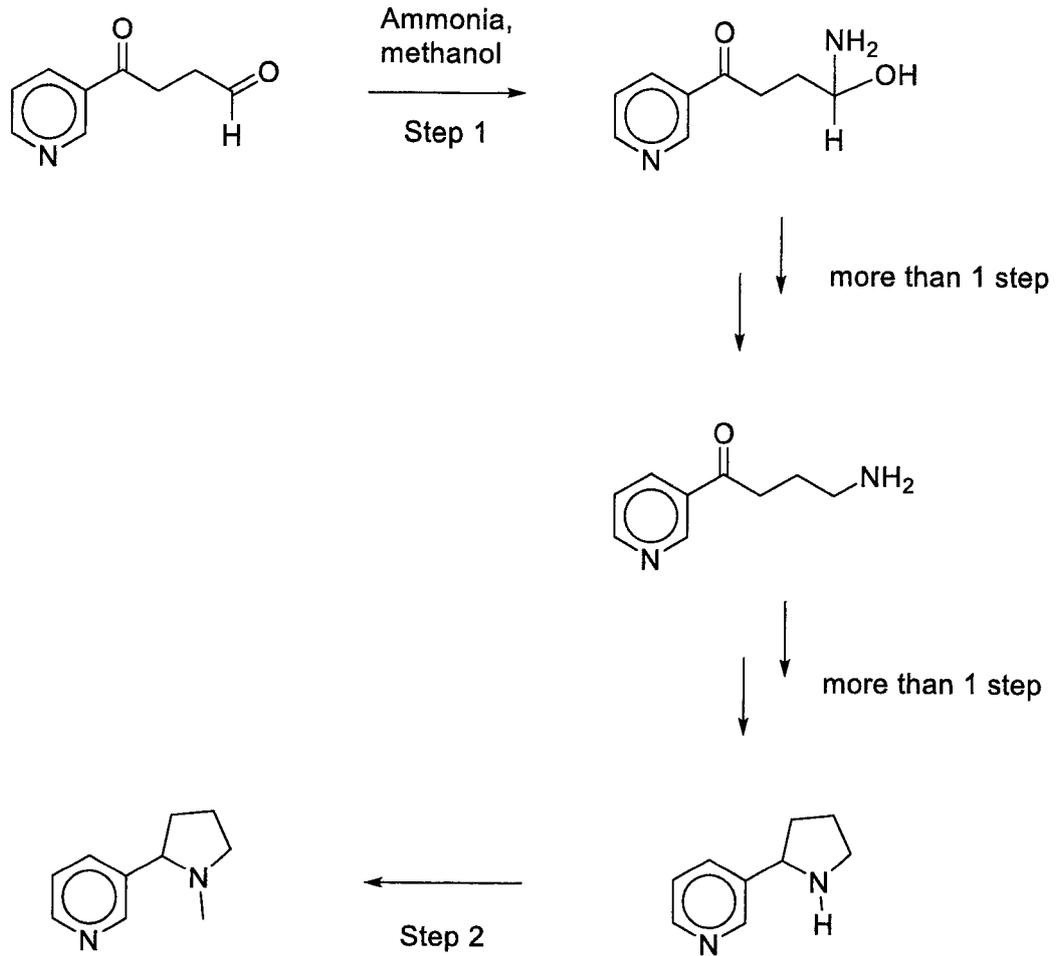
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- (d) The following diagram shows the partial synthesis route of nicotine formation:

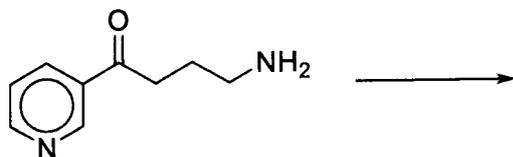


- (i) Suggest the type of reaction in Step 1.

..... [1]



- (ii) Complete Fig. 2.3 to suggest a mechanism for this reaction. Show the structure of the intermediate and the movement of the lone pairs, dipoles, curly arrows and charges.



intermediate



H<sup>+</sup> transfer

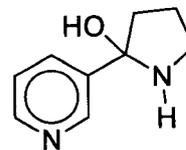


Fig. 2.3

[2]

- (iii) Suggest the reagent and conditions for Step 2.

..... [1]

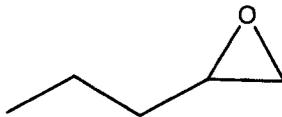
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- 3 Epoxides are a class of organic compounds with a three-membered ring structure. The three-membered ring in epoxides makes them highly reactive and susceptible to ring-opening reactions.

One such epoxide is 1,2-epoxypentane,  $C_5H_{10}O$ , with the structure as shown below.



- (a) Suggest why epoxides are susceptible to ring-opening reactions.

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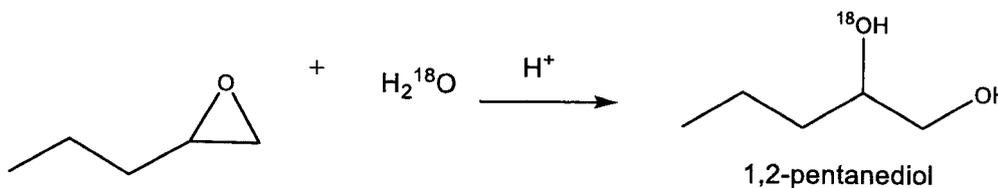
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[2]

- (b) An example of an epoxide ring-opening reaction is the hydrolysis of 1,2-epoxypentane in the presence of a strong acid catalyst to form 1,2-pentanediol. The hydrolysis is carried out using "heavy-oxygen water",  $H_2^{18}O$ .



It is found that the reaction follows a  $S_N1$  mechanism. Some details of the mechanism are given below.

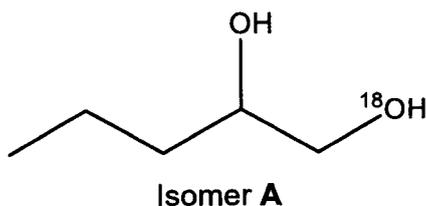
Step 1	
Step 2	Heterolytic fission of the C–O bond to generate a carbocation intermediate.
Step 3	Attack of the carbocation by one molecule of $H_2^{18}O$ to form a new C–O bond.
Step 4	Loss of a proton to form 1,2-pentanediol and regenerate the acid catalyst.



- (i) Describe Steps 2 to 4 of the  $S_N1$  mechanism. Show all relevant lone pairs and charges and indicate the movement of electron pairs with curly arrows.

[3]

- (ii) Presence of trace amounts of an isotopic isomer **A** is formed in the reaction too.



Suggest how isotopic isomer **A** could have been formed during the reaction and why it was formed only in trace amounts in the  $S_N1$  mechanism.

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[2]

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4 This question is about carbon-containing species.

Compounds **P**, **Q**, **R** and **S** are structural isomers with molecular formula of  $C_9H_{10}O_2$ . The results of six tests carried out on these isomers are shown in Table 4.1.

**Table 4.1**

Test	P	Q	R	S
Rotate plane-polarised light	Yes	Yes	No	Yes
Add $FeCl_3(aq)$	No purple complex	Purple complex	Purple complex	Purple complex
Heat with acidified $K_2Cr_2O_7$	Orange solution turns green	Orange solution turns green	Orange solution remains	Orange solution turns green
Warm with Fehling's reagent	No brick red ppt	Brick red ppt	No brick red ppt	No brick red ppt
Warm with Tollen's reagent	Grey ppt	Grey ppt	No grey ppt	No grey ppt
Add cold alkaline $KMnO_4$	Purple $KMnO_4$ remains	Purple $KMnO_4$ remains	Purple $KMnO_4$ remains	Purple $KMnO_4$ turns colourless

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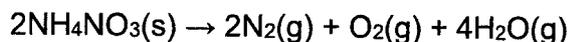






- 5 On 4 August 2020, a large explosion occurred at a port warehouse in Beirut, Lebanon, due to the defonation of approximately 2750 tonnes of ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) stored improperly. This explosion released energy comparable to 1.1 kilotons of trinitrotoluene (TNT) and generated a seismic event measuring 3.3 in magnitude on the Richter scale.

When heated or subjected to shock, ammonium nitrate can undergo the following decomposition reaction:



Data on the standard enthalpy changes of formation (at 298 K) and entropies are provided in the table below:

Substance	$\Delta H_f^\ominus/\text{kJ mol}^{-1}$	$S^\ominus/\text{J mol}^{-1} \text{K}^{-1}$
$\text{NH}_4\text{NO}_3(\text{s})$	-365	151
$\text{N}_2(\text{g})$	0	192
$\text{O}_2(\text{g})$	0	206
$\text{H}_2\text{O}(\text{g})$	-242	189

The standard enthalpy change of reaction,  $\Delta H^\ominus$ , can be calculated from relevant standard enthalpy changes of formation,  $\Delta H_f^\ominus$ . In the same way, the standard entropy change of reaction,  $\Delta S^\ominus$ , can be calculated from relevant entropies of the substances involved.

- (a) Show that the standard enthalpy change for the decomposition of one mole of ammonium nitrate is  $-119 \text{ kJ mol}^{-1}$ .

[1]



- (b) Calculate the standard entropy change for the decomposition of one mole of ammonium nitrate.

[1]

- (c) Calculate the standard Gibbs free energy change,  $\Delta G^\ominus$ , for the decomposition of one mole of ammonium nitrate at 298 K.

[1]

- (d) Suggest why heating or an external shock might still be required to initiate the reaction.

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 .....  
 .....

[1]

- (e) (i) Use of the *Data Booklet* is relevant to this question.

Calculate the total energy released, in MJ, when 2750 tonnes of ammonium nitrate were completely decomposed in the Beirut explosion.

[1 MJ =  $10^6$  J; 1 ton =  $10^6$  g]

[2]

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- 6 The troposphere is a layer of the atmosphere that begins at the Earth's surface and extends approximately to 15 km above the Earth's surface. Most types of clouds are found in the troposphere. Clouds hold water, either in the form of tiny water droplets or ice crystals.

The atmospheric pressure, measured in MPa, changes with altitude,  $x$  km, as follows.

$$\ln \frac{P_0}{P_x} = 0.119x$$

$P_0$  is the atmospheric pressure at the Earth's surface = 0.101325 MPa

$P_x$  is the atmospheric pressure at altitude  $x$  km

The melting temperature of ice,  $T$ , measured in kelvin, changes with atmospheric pressure, in MPa, as shown.

$$P_x - P_0 = 3595 \times \ln \left( \frac{T_x}{T_0} \right)$$

$T_x$  is melting temperature at altitude  $x$  km

$T_0$  is the melting temperature of ice at the Earth's surface

Cloud seeding is an engineering technique used to induce and enhance rainfall. The idea of cloud seeding is to introduce ice nucleating particles (INP), which induce ice formation in clouds. These ice crystals grow and become too heavy and eventually fall out of cloud. If the temperature is above the freezing point, rain is observed.

The most common INP is silver iodide, AgI. The crystalline structure of AgI is similar to that of ice, allowing it to induce freezing. Fig. 6.1 shows the structure of ice. In ice, all four hydrogen bonds are formed, resulting in a tetrahedral coordination around each water molecule.

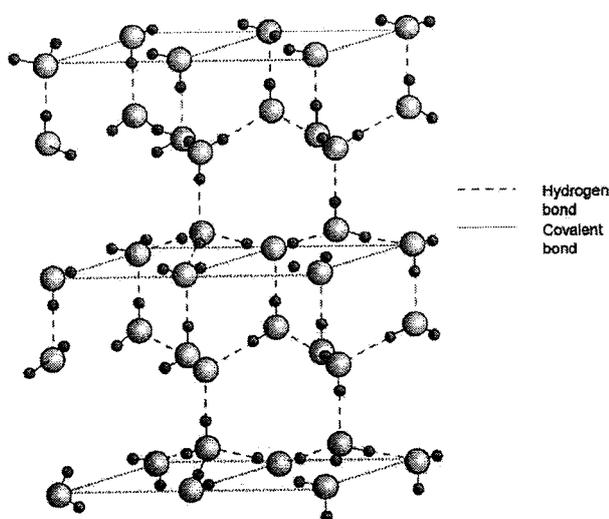


Fig. 6.1





(b) (i) Table 6.1 shows the structure of the simplest repeat unit in two possible crystalline structures of silver iodide.

In structure A, each  $\text{Ag}^+$  is surrounded by 8  $\text{I}^-$ . In structure B, each  $\text{Ag}^+$  is surrounded by 4  $\text{I}^-$ .

Table 6.1

	Structure A	Structure B
Number of $\text{Ag}^+$ in a unit cell	1	2
Number of $\text{I}^-$ in a unit cell	1	2
Cell parameters/ nm	$x = 0.656$	$a = 0.755, b = 0.466$

Using the information from Fig. 6.1 and Table 6.1, deduce which is the crystal structure of AgI that allows it to nucleate ice.

..... [1]

(ii) Hence, determine the density of AgI in  $\text{g cm}^{-3}$ .

[1 nm =  $10^{-7}$  cm]

[2]

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(d) (i)

Table 6.3

Compound	Experimental lattice energies/ $\text{kJ mol}^{-1}$	Theoretical lattice energies/ $\text{kJ mol}^{-1}$
Sodium chloride	-781	-766
Silver fluoride	-967	-953
Silver iodide	-889	-808

Silver fluoride has the same crystalline structure as sodium chloride, unlike silver iodide. Like sodium chloride, there is close agreement between the experimental and theoretical values of lattice energy for  $\text{AgF}$  but not  $\text{AgI}$ .

Suggest a reason for this.

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[1]

- (ii) Silver(I) ions are known to be highly toxic to aquatic life. However, scientific findings show that at the concentrations used during typical cloud seeding operations,  $\text{AgI}$  poses negligible environmental risk. This is postulated to be due to its endothermic enthalpy change of solution.

Use your knowledge of the enthalpy factors that are involved in the process of dissolving an ionic salt in water, suggest a reason for this.

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[2]

[Total: 12]

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# RIVER VALLEY HIGH SCHOOL

## JC 2 PRELIMINARY EXAMINATION

CANDIDATE  
NAME

CLASS

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CENTRE  
NUMBER

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INDEX  
NUMBER

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## 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 Centre number, index number, class and name on all the work that you hand in.

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.

**DO NOT WRITE IN ANY BARCODES.**

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** the questions.

#### Section B

Answer **one** question. **Circle** the question number of the question you attempted.

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								
Question Number	1	2	3	4	5	units	s.f.	Total
Marks	21	18	21	20	20			80

This document consists of **31** printed pages and **1** blank page.





- (c) Explain why benzene undergoes substitution reactions rather than addition reactions. [1]

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- (d) In the Gattermann–Koch reaction, benzene is used to produce benzaldehyde. An example is provided below in Fig. 1.1.

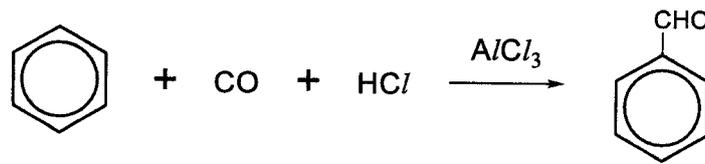


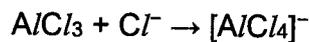
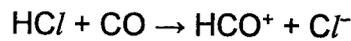
Fig. 1.1

The mechanism of this reaction occurs in 2 steps.

Step 1: Generation of electrophile,  $\text{HCO}^+$

Step 2: Reaction of benzene with electrophile,  $\text{HCO}^+$ , to obtain benzaldehyde

- (i) Define the term *electrophile*. [1]
- (ii) In Step 1, CO reacts with HCl in the presence of  $\text{AlCl}_3$  to form  $\text{HCO}^+$ .



State the roles of CO and  $\text{AlCl}_3$  respectively in Step 1. [2]

- (iii) Name and draw the mechanism in Step 2. Use the displayed formula of  $\text{HCO}^+$ , and show relevant curly arrows, charges and the structure of the intermediate. [3]

- (iv) The synthesis of compound Z shown in Fig. 1.2 involves the Gattermann-Koch reaction.

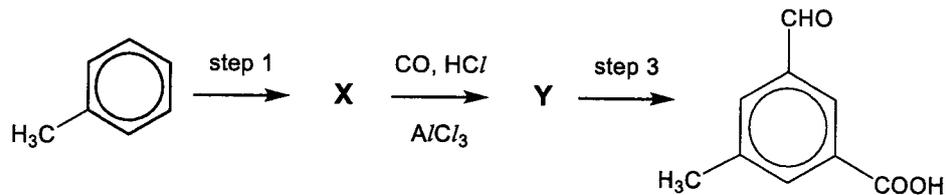


Fig. 1.2

State the reagents and conditions required of Step 1 and Step 3 in Fig. 1.2. Draw the structures of X and Y. [4]







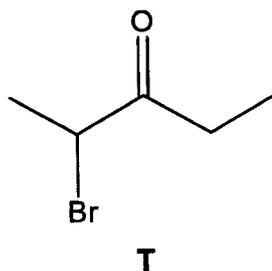




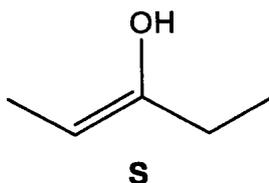




- 3 (a) Pentan-3-one reacts with bromine to undergo acid-catalysed alpha halogenation to form product T.



- (i) Explain what is meant by the term *acid-catalysed* reaction. [1]
- (ii) The first step of this mechanism involves the reaction of pentan-3-one with  $\text{H}_3\text{O}^+$  to give S.



- S has a stereoisomer. Suggest the structure of this stereoisomer and explain how it arises. [2]
- (iii) Suggest the type of reaction for pentan-3-one reaction with bromine to give T. [1]
- (iv) The reaction of S to form T involves an oxygen cation intermediate.
- The first step involves the formation of  $\pi$  bond between oxygen and carbon using a lone pair of electrons from oxygen. Simultaneously, the  $\pi$  electrons from C=C attack the bromine atom to form the oxygen cation intermediate.
  - This intermediate is deprotonated by a bromide ion to generate T.

Suggest the mechanism for this reaction. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. [2]

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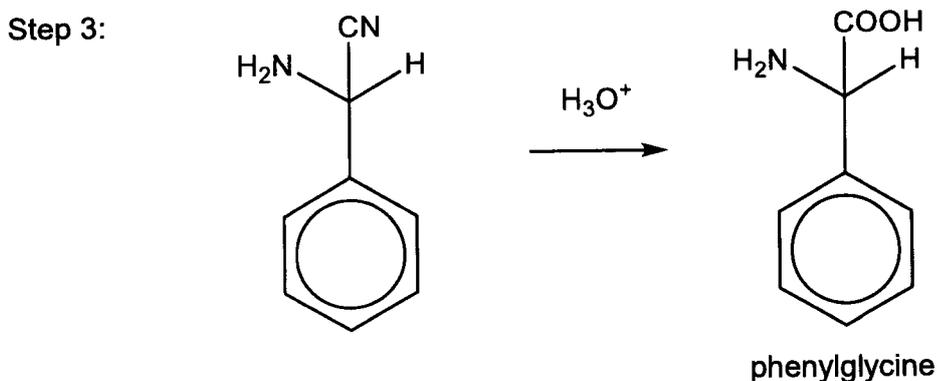
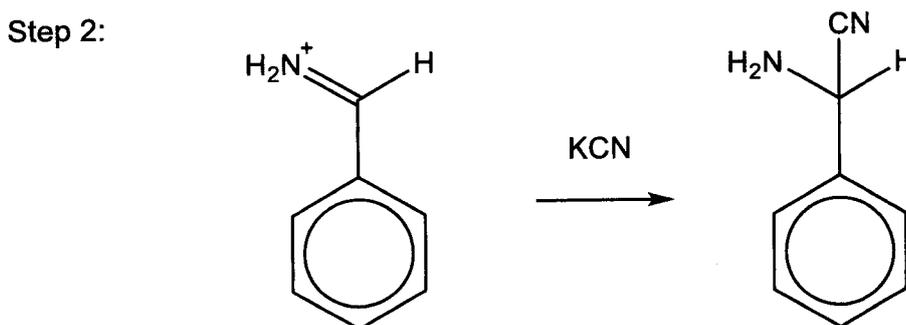
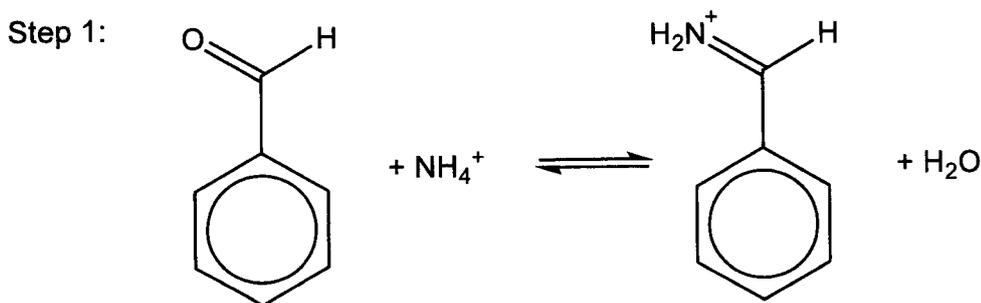
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RVHS Chemistry

- (b) Benzaldehyde undergoes Strecker synthesis to form amino acid in a 3-step mechanism. The first step is shown below.



- (i) 0.212 g of benzaldehyde and 10.7 g of ammonium chloride are dissolved in 200 cm<sup>3</sup> of solution. The solution is allowed to reach equilibrium and the concentration of benzylimine is found to be  $8.80 \times 10^{-3}$  mol dm<sup>-3</sup>.

Show that the initial concentration of benzaldehyde is 0.0100 mol dm<sup>-3</sup> and the initial concentration of ammonium chloride is 1.00 mol dm<sup>-3</sup>. [1]

- (ii) Write an expression and unit of  $K_c$  for the equilibrium in Step 1, and use the data given to calculate its value. Show your working. [3]
- (iii) Suggest why the yield of benzylimine decreases when pH of the solution increases in Step 1. Explain your answer fully. [1]

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(c) The 3-step Strecker synthesis between benzaldehyde, ammonium chloride and potassium cyanide follow the reaction mechanism shown in (b).

The rate equation of this reaction is as follows.

$$\text{Rate} = k [\text{C}_6\text{H}_5\text{CHO}]^w [\text{NH}_4^+]^x [\text{CN}^-]^y [\text{H}_3\text{O}^+]^z$$

The rate of reaction can be followed by measuring the amount of benzaldehyde. Experiments were carried out by changing the initial  $[\text{H}_3\text{O}^+]$  and  $[\text{C}_6\text{H}_5\text{CHO}]$ , but keeping the initial  $[\text{NH}_4^+]$  and  $[\text{CN}^-]$  constant at large excess.

experiment	initial $[\text{H}_3\text{O}^+]$ / $\text{mol dm}^{-3}$	initial $[\text{C}_6\text{H}_5\text{CHO}]$ / $\text{mol dm}^{-3}$	initial rate/ $\text{mol dm}^{-3} \text{ s}^{-1}$
1	0.200	0.400	$8.40 \times 10^{-5}$
2	0.200	0.300	$6.30 \times 10^{-5}$
3	0.100	0.100	$2.10 \times 10^{-5}$

(i) Determine the orders of reaction with respect to  $[\text{C}_6\text{H}_5\text{CHO}]$  and  $[\text{H}_3\text{O}^+]$ . Explain your reasoning. [2]

(ii) Experiment 4 was carried out by measuring the amount of phenylglycine produced after various times.

Species	Initial concentration/ $\text{mol dm}^{-3}$
$\text{C}_6\text{H}_5\text{CHO}$	0.600
$\text{NH}_4^+$	0.0600
$\text{CN}^-$	0.600
$\text{H}_3\text{O}^+$	0.600

The following graph in Fig. 3.1 was obtained.

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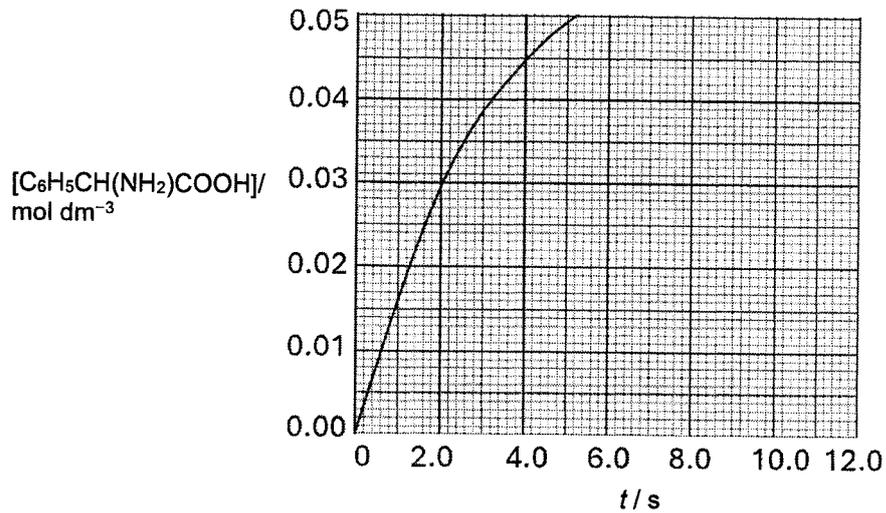
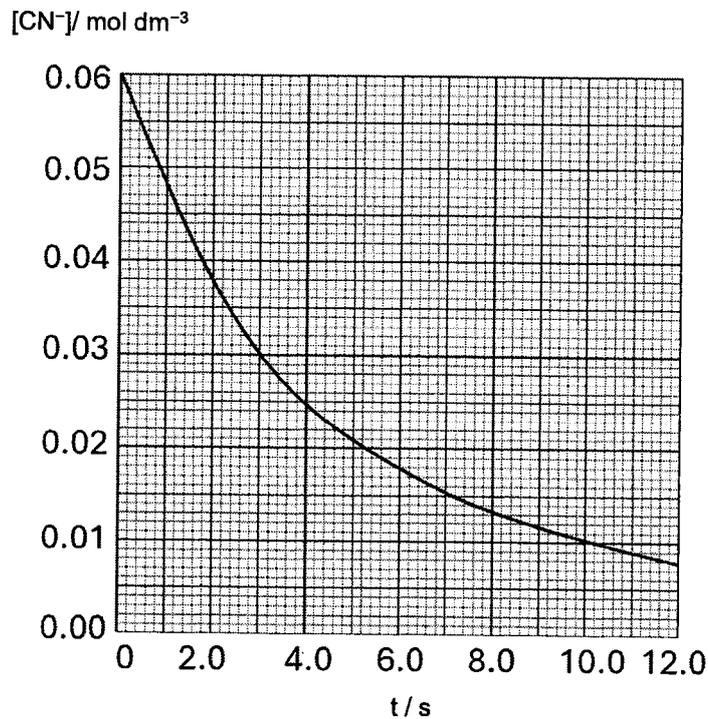


Fig. 3.1

Determine the maximum concentration of phenylglycine at the end of the reaction. Hence, show the reaction is first order with respect to  $[\text{NH}_4^+]$  on Fig. 3.1. Show your working clearly. [2]

- (iii) Further experiment, experiment 5, was carried out by changing initial  $[\text{CN}^-]$  to  $0.0600 \text{ mol dm}^{-3}$  with all the other initial concentrations kept the same as experiment 4. The following graph was obtained.



With reference to (c)(ii), explain why  $t_{1/2}$  is not constant although the reaction is first order with respect to  $[\text{CN}^-]$ . [1]





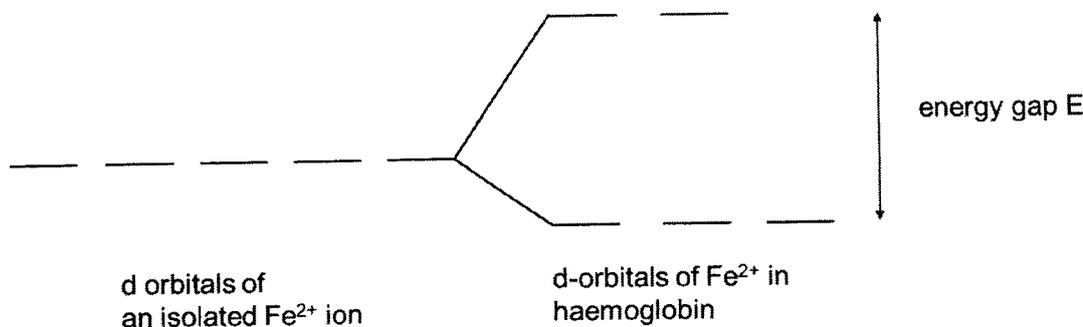


## Section B

Answer **one** question from this section.

- 4 (a) The iron atoms in haemoglobin are in the oxidation state +2 and are in an octahedral environment. Each iron atom is surrounded by five nitrogen-containing ligands, and one oxygen-containing ligand, which is  $\text{H}_2\text{O}$  in deoxyhaemoglobin and  $\text{O}_2$  in oxyhaemoglobin.

The following diagram shows how the d-orbitals are split in an octahedral environment.



- (i) Use this diagram to outline the origin of the red colour of haemoglobin. [2]

When the  $\text{H}_2\text{O}$  ligand in haemoglobin is changed to an  $\text{O}_2$  ligand, the  $\text{Fe}^{2+}$  ion changes its electronic configuration from a 'high spin' state to a 'low spin' state.

In a 'high spin' state, the electrons occupy all the d-orbitals singly, before starting to pair up in the lower energy d-orbitals.

In a 'low spin' state, the lower energy d-orbitals are filled first, by pairing up if necessary, before the higher energy d-orbitals are used.

- (ii) Suggest why electrons usually prefer to occupy orbitals singly, rather than in pairs. [1]
- (iii) Using this explanation, together with the information given above concerning the spin states of deoxyhaemoglobin and oxyhaemoglobin, state and explain which of the two haemoglobins will contain the larger energy gap,  $\Delta E$ , between its d-orbitals. [2]
- (iv) Draw a suitable diagram to show the electron distribution in the 3d subshell of a  $\text{Fe}^{2+}$  ion in oxyhaemoglobin in the **excited** state, where an electron from a lower energy d-orbital has been promoted to a higher energy d-orbital by absorbing light of a certain wavelength. [1]

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- (e) (i) Alkenes do not undergo free radical substitution but alkanes do.

The table below contains information about bond dissociation energies of C-H bonds.

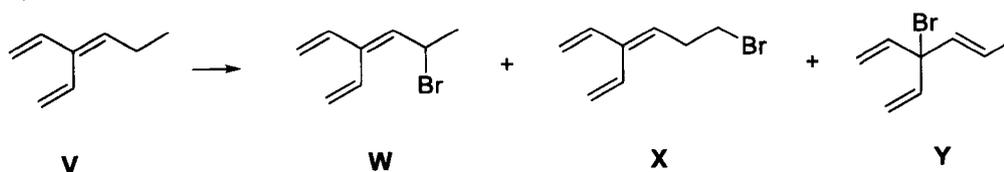
bonds	intermediate formed in the first step of propagation	energy/ kJ mol <sup>-1</sup>
		410
		451

The electronegativity of carbon is proportional to the s-character in the hybridised orbital. In addition, you may assume that the hybridisation states remain unchanged during the reaction.

Using this information, explain the difference in reactivity by reference to bond energies.

Hence, deduce the stability of the intermediates formed in the first step of propagation. Explain your answer. [2]

Three possible monobromoalkanes that can be formed from the reaction of compound **V** with bromine in the presence of ultra-violet light are shown below.



- (ii) Explain why the reaction only starts when it is exposed to ultra-violet light. [1]
- (iii) Describe the mechanism of the propagation steps for the reaction of **V** with bromine in the presence of ultra-violet light to form **W**. [1]
- (iv) When bromination is carried out and the products are analysed, it is found that **Y** is formed as the major product. It is proposed that the intermediate can rearrange from one radical to another.

Draw three curly arrows on Fig. 5.2 to show the formation of the free radical intermediate used in the first propagation step to form **Y**.

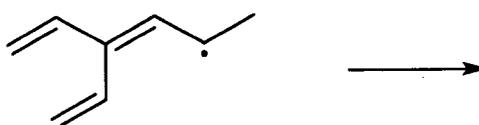


Fig. 5.2

[1]

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