ANDERSON SERANGOON JUNIOR COLLEGE

2025 JC2 PRELIMINARY EXAMINATION

NAME:_____ (   )   CLASS: 25 /____

CHEMISTRY

Paper 1 Multiple Choice

9729/01

2 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 register number on the Answer Sheet.

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.

Multiple Choice Answer Sheet

Write your name, class and NRIC / FIN number, **including** the reference letter.

Shade the NRIC / FIN number.

Exam Title: JC2 PRELIM

Exam Details: H2 Chemistry / Paper 1

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

1   Sodium azide, NaN_3 is an explosive used to inflate airbags in cars when they crash. It consists of positive sodium ions and negative azide ions.

What are the number of electrons in the sodium ion and the azide ion?

	sodium ion	azide ion
A	10	20
B	10	22
C	12	20
D	12	22

2   The graph shows the variation of the first ionisation energy with proton number for some elements. The letters used are not the actual symbols for the elements.

first ionisation
energy / kJ mol⁻¹

proton number
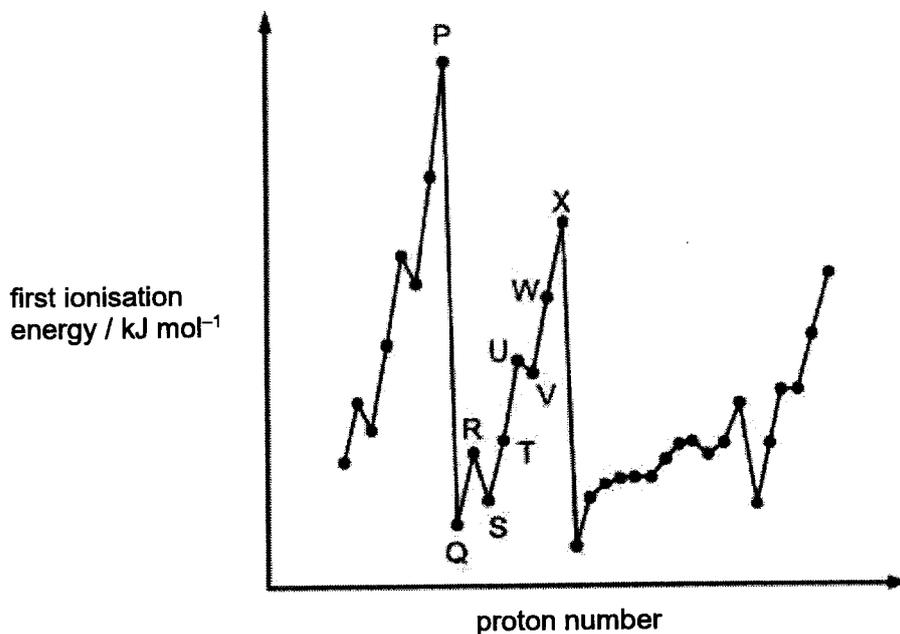
Which statement about the elements is correct?

A   P and X are in the same period in the Periodic Table.

B   The general increase from Q to X is due to increasing atomic radius.

C   The small decrease from R to S is due to decreased shielding.

D   The small decrease from U to V is due to repulsion between paired electrons.

3   The table identifies the shape and polarity of four molecules.

Which row is correct?

	molecule	molecular shape	polarity
A	boron trichloride	trigonal pyramidal	polar
B	nitrogen trichloride	trigonal planar	non-polar
C	sulfur dioxide	bent	polar
D	trichloromethane	tetrahedral	non-polar

4   The element tin exists in two forms, grey tin and white tin.

Some properties of grey tin and white tin are shown.

	grey tin	white tin
boiling point	2543 °C	2533 °C
electricial conductivity	none in solid or liquid	good in solid and liquid
malleability	brittle	malleable

Which structural change might take place when grey tin changes to white tin?

A   giant covalent to giant ionic

B   giant covalent to giant metallic

C   giant ionic to giant covalent

D   giant ionic to giant metallic

4

5   0.01 mol of KIO_n reacts with 0.05 mol of KI stoichiometrically to produce I_2 under acidic conditions. In this reaction, all the iodine containing reactants were converted to I_2.

What is the value of n?

A   1

B   2

C   3

D   4

6   X and Y are two different samples of the same ideal gas.

Given that X contains a higher mass than Y, which graph shows the correct ideal gas relationship for the two samples of gas? (T is measured in K.)
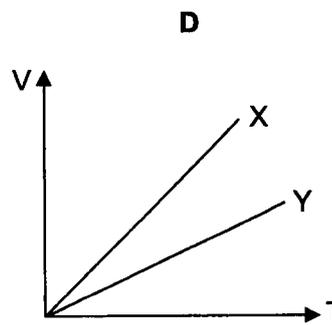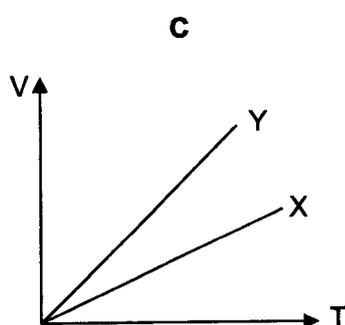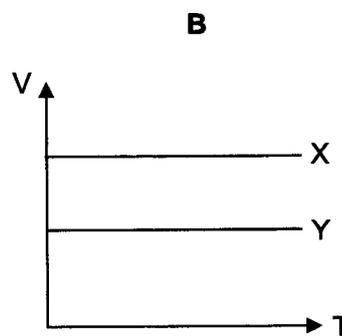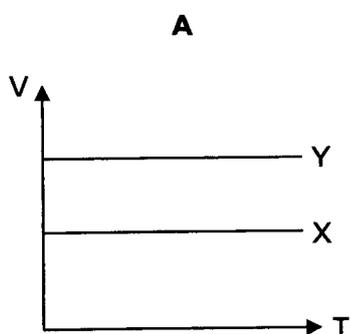
7   A student mixes 25.0 cm³ of 0.350 mol dm⁻³ sodium hydroxide solution with 25.0 cm³ of 0.350 mol dm⁻³ hydrochloric acid. The temperature increases by 2.5 °C. No heat is lost to the surroundings.

The final mixture has a specific heat capacity of 4.2 J g⁻¹ K⁻¹.

What is the molar enthalpy change for the reaction?

A   −150 kJ mol⁻¹

B   −60 kJ mol⁻¹

C   −30 kJ mol⁻¹

D   −0.15 kJ mol⁻¹

8   Silane, SiH_4, exists as a gas at standard temperature and pressure. Hess' Law can be used to calculate the average Si–H bond energy in gaseous SiH_4. Which information is needed to perform the calculation?

A $\Delta H^\ominus_{atomisation}(Si)$, $\Delta H^\ominus_{combustion}(H_2)$, $\Delta H^\ominus_{formation}(SiH_4)$

B $\Delta H^\ominus_{atomisation}(Si)$, $\Delta H^\ominus_{atomisation}(H)$, $\Delta H^\ominus_{formation}(SiH_4)$

C $\Delta H^\ominus_{atomisation}(H)$, $\Delta H^\ominus_{combustion}(Si)$, $\Delta H^\ominus_{combustion}(SiH_4)$

D $\Delta H^\ominus_{combustion}(Si)$, $\Delta H^\ominus_{combustion}(H_2)$, $\Delta H^\ominus_{formation}(SiH_4)$

9   Group 2 hydroxides undergo thermal decomposition in a similar fashion to Group 2 carbonates.

Barium hydroxide undergoes decomposition as shown in the equation below:

$$Ba(OH)_2(s) \rightarrow BaO(s) + H_2O(g) \qquad \Delta H > 0$$
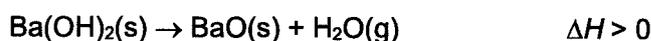
Which statements about this reaction are correct?

1   The Gibbs free energy change can be positive or negative depending on the temperature.

2   The decomposition is spontaneous only at high temperature.

3   The entropy change is negative.

A   1 and 2 only

B   1 and 3 only

C   2 and 3 only

D   1, 2 and 3

6

10 The reaction between NO and Br_2 is proposed to proceed via the following mechanism:

Step 1: $NO + Br_2 \rightleftharpoons NOBr_2$ (fast)

Step 2: $NOBr_2 + NO \longrightarrow 2NOBr$ (slow)
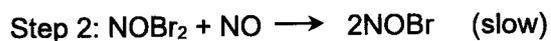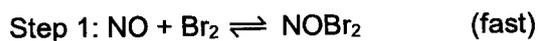
Which statements are correct?

1 $NOBr_2$ is a radical.

2 The rate equation for this reaction is rate = $k[Br_2][NO]^2$.

3 $NOBr_2$ is formed at the transition state.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

11 The kinetics of the following reaction is investigated, and the experimental data is given in the table below.

$$2R + 2S \longrightarrow T + U$$

[R] / mol dm^{-3}	[S] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
0.015	0.010	5.10×10^{-4}
0.030	0.020	4.08×10^{-3}
0.045	0.010	1.53×10^{-3}

What is the numerical value of the rate constant for this reaction?

A 0.00294 B 3.40 C 227 D 340

12 Ethanol is produced industrially by reacting ethene and steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \quad \Delta H = -50.3 \text{ kJ mol}^{-1}$$

K_p has a value of 1.8×10^{-5} and the partial pressures of the reactants at equilibrium are shown.

reactant	partial pressure / x 10^6 Pa
ethene	4.8
steam	2.8

Which statement is correct?

A Adding a catalyst increases the value of K_p for the reaction at equilibrium.

B The overall process is a nucleophilic addition reaction.

C Increasing the temperature will increase the K_p for the reaction.

D Partial pressure of ethanol at equilibrium is 242 x 10^6 Pa.

13 Lithium reacts with nitrogen at room temperature to form solid Li_3N.

Three vessels of equal volume are connected by taps 1 and 2 as shown.
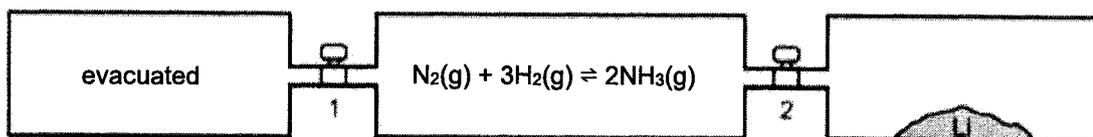
At the start, taps 1 and 2 are closed, the left-hand vessel is evacuated, the middle vessel has the indicated reaction at equilibrium and the right-hand vessel contains lithium only.

Which action would allow the equilibrium mixture to contain the **most** ammonia?

A Keep both taps 1 and 2 closed.

B Open both taps 1 and 2.

C Open tap 1 only.

D Open tap 2 only.

8

14 The table below describes some indicators.

indicator	colour in acid	colour in alkali	pK_a	range of pH for colour change
methyl orange	red	yellow	3.7	3.2 – 4.4
thymol blue	yellow	blue	8.9	8.0 – 9.6

For the titration of NaOH(aq) against HCOOH(aq), which row shows the most suitable indicator and the corresponding colour change?

	indicator	colour change
A	methyl orange	red to orange
B	methyl orange	yellow to orange
C	thymol blue	yellow to green
D	thymol blue	blue to green

15 In this question, Q represents an atom of chlorine, bromine or iodine.

Which statement about their atoms, molecules or halide ions is correct?

A Down the Group, permanent dipole–permanent dipole forces between halogen molecules become stronger.

B The first ionisation energy $Q(g) \rightarrow Q^+(g) + e^-$ decreases.

C Q_2 reactivity as oxidising agent increases down the group.

D The enthalpy change of formation of hydrogen halides becomes more exothermic.

16 Magnesium, aluminium, silicon and phosphorus are consecutive elements in Period 3 of the Periodic Table.

Which of the following properties generally decreases from magnesium to phosphorus?

A   electrical conductivity

B   ionic radius

C   melting point of their oxides

D   electronegativity

17 A hydrogen-oxygen fuel cell is constructed using 1.00 mol dm^{-3} sodium hydroxide as the electrolyte. What is the change in pH of the solution around each electrode when the current is flowing?

porous electrodes
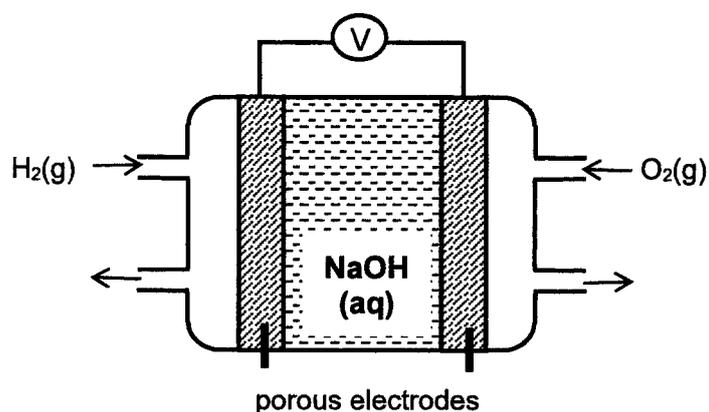
	Cathode	Anode
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

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

In the electrolysis of molten aluminium oxide. 0.27 g of aluminium is liberated when 2904 coulombs of electricity is passed through molten aluminium oxide.

Which value of Avogadro's constant do **these figures** give?

A 6.02×10^{23}

B 6.05×10^{23}

C 1.82×10^{24}

D 2.02×10^{23}

19 10 cm^3 of an organic substance Z burns completely with exactly 75 cm^3 of oxygen to produce 50 cm^3 of carbon dioxide. All the volume are measured at the same temperature and pressure.

Which statements about the organic substance are correct?

    1   Z may be an alcohol.

    2   Z may be cycloalkane.

    3   Z may decolorise aqueous bromine in the dark

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 3 only

20 Which compound has the greatest number of stereoisomers?

A 2-methylhex-2-ene

B 3-methylhex-2-ene

C 4-methylhex-2-ene

D 5-methylhex-2-ene

21 Which statement about methylbenzene and its properties is correct?

A   Methylbenzene undergoes nucleophilic substitution and free radical substitution reactions with Br_2 in the presence of A/Br_3.

B   The methylbenzene molecule is planar so hydrogen can easily undergo addition reactions with it without the use of a catalyst.

C   The π electrons in the benzene ring are able to donate an electron pair to attack a carbocation to form a bond.

D   The sideways overlap of p orbitals in benzene means the C–C bonds alternate between long, single bonds and short, double bonds.

22 Which pair of reagents react together in a redox reaction?

A CH_3CHCH_2 + Br_2

B $CH_3CH_2CH_2OH$ + concentrated H_3PO_4

C CH_3COCH_3 + HCN

D $HCO_2C_2H_5$ + dilute H_2SO_4

23 Methylcyclopentane can react with chlorine via free radical substitution to produce compound A and B as shown.

A   B
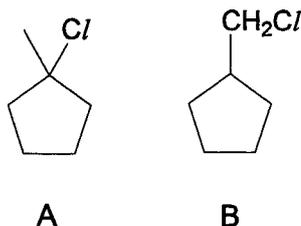
Given the relative rate of substitution of tertiary and primary hydrogen atoms follows a 5 : 1 ratio.

What is the likely ratio of compound A and B formed?

A   1 : 15

B   1 : 3

C   3 : 5

D   5 : 3

24 K_a values for two acids are given.

acid	K_a
$CH_3CH_2CO_2H$	1.34×10^{-5}
$C_6H_5CO_2H$	6.46×10^{-5}

Which statement is correct?

A The K_a of $CH_3C_6H_4OH$ is larger than 1.34×10^{-5}.

B The K_a of $CH_3CH(Cl)CO_2H$ is larger than 1.34×10^{-5}, but smaller than the K_a of $CH_2(Cl)CH_2CO_2H$.

C In a mixture containing equal concentrations of $CH_3CH_2CO_2H$ and $C_6H_5CO_2H$, $[CH_3CH_2CO_2^-] = [C_6H_5CO_2^-]$.

D In two separate solutions of $Cl-\bigcirc-CO_2H$ and $C_6H_5CO_2H$, which have the same pH, there is a greater concentration of $C_6H_5CO_2H$ in mol dm^{-3}.

25 Esters can be reduced by LiAlH$_4$ in dry ether to give two alcohols as shown below.
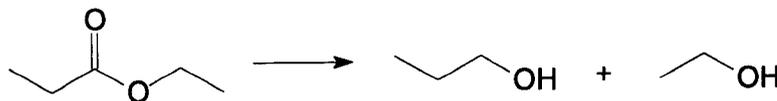
What are the possible products formed when the following compound is reacted with LiAlH$_4$ in dry ether?

1

2

3
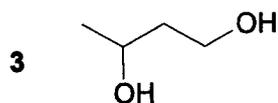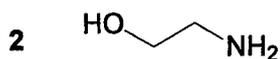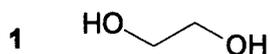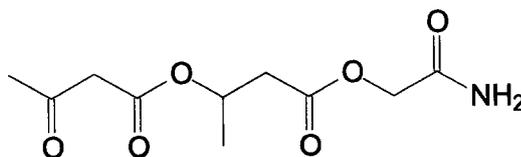
A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

26 Which of the following shows the most likely first step in the mechanism of a reaction?

A

$$\underset{}{\underset{\delta^+ \quad \delta^-}{C=C}} \quad Br-I$$

B

C

$$CN^- \quad \overset{\delta^+ \quad \delta^-}{C-Br}$$

D

$$CN^- \quad \overset{\delta^+ \quad \delta^-}{C=O}$$
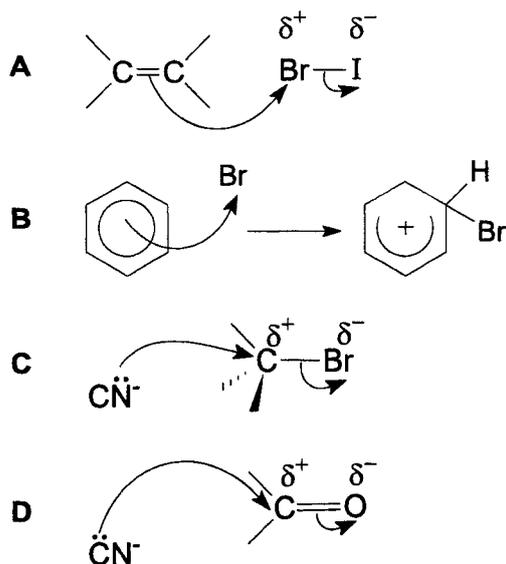
27 Morphine and codeine are both effective painkillers.
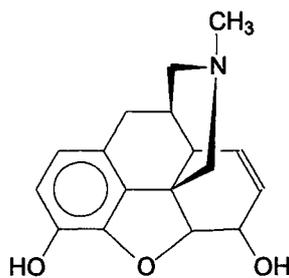
morphine

Which observation will be given by morphine?

1   the decolourisation of liquid bromine

2   the evolution of hydrogen with metallic sodium

3   the formation of green Cr^{3+} ions from an acidified solution of $Cr_2O_7^{2-}$

A   3 only

B   1 and 2 only

C   2 and 3 only

D   1, 2 and 3

28 Etomidate is an anaesthetic agent that has been found in e-vaporisers. It will soon be listed by Singapore as a Class C drug under the Misuse of Drugs Act.
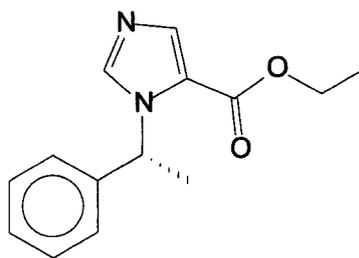
etomidate

What are the products when etomidate is hydrolysed by heating with a dilute acid?

A

B

C

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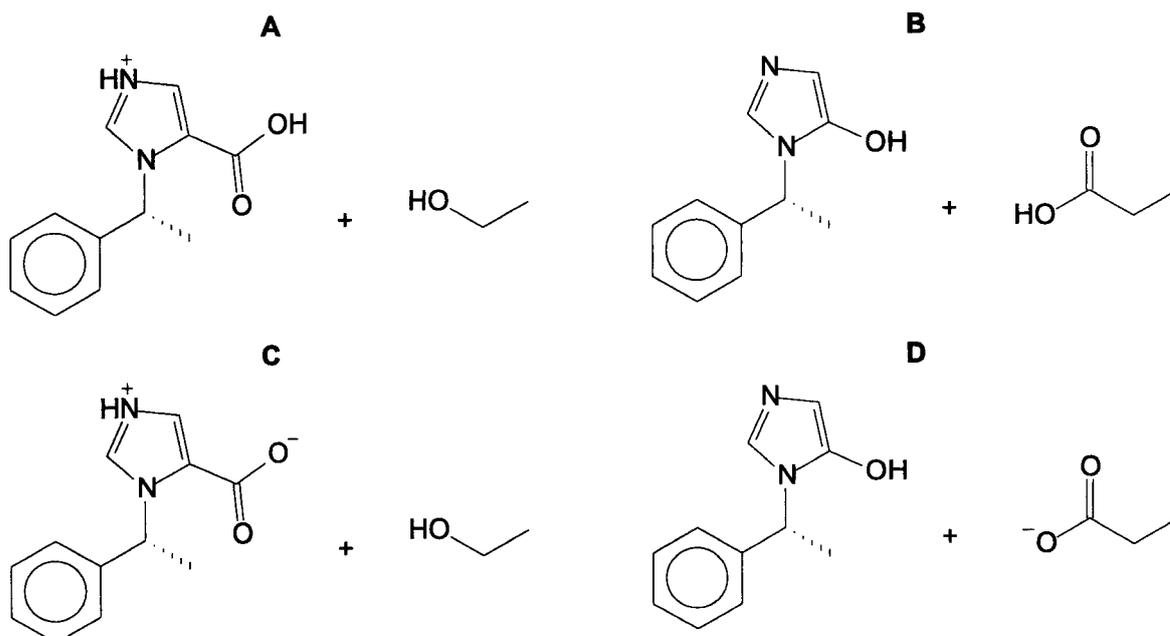
29 In a 'high spin' state, the electrons occupy all the d–orbitals singly, before starting to pair up in the lower energy d–orbitals.

Which energy diagram shows the electron arrangement in the 3d orbitals for a nickel in the +2 oxidation state in an octahedral complex in a 'high spin' state.

A

B

C

D
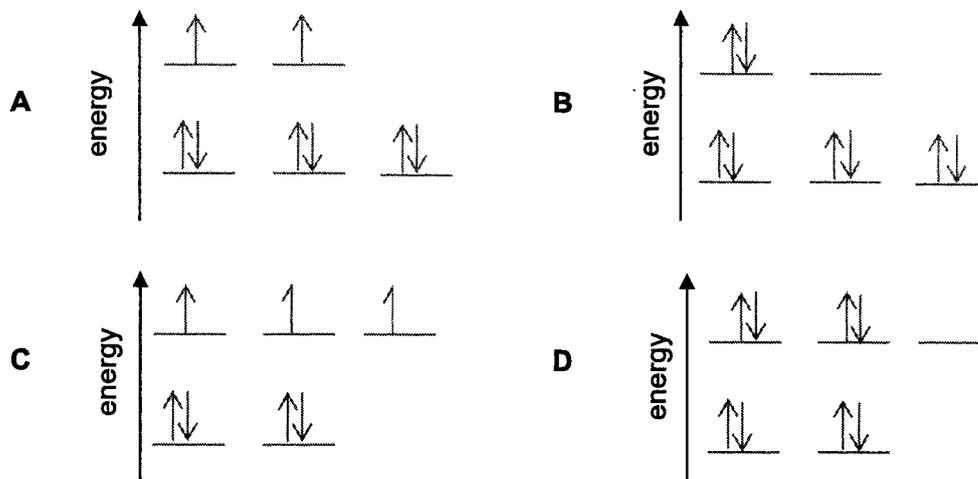
30 The rate of reaction between peroxodisulfate(VI) and iodide ions is increased by the presence of small concentrations of $Fe^{2+}(aq)$.

$$S_2O_8^{2-}(aq) + 2I^-(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq)$$
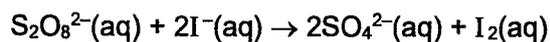
Which property of iron allows it to act as a homogeneous catalyst?

A partially filled d subshell

B variable oxidation states

C low activation energy

D high charge density

16

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ANDERSON SERANGOON JUNIOR COLLEGE

2025 JC 2 PRELIMINARY EXAMINATION

NAME:_____ (   )   CLASS: 25 / ____

CHEMISTRY   **9729/02**

Paper 2 Structured Questions   **27 August 2025**

                                                                2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number on all the work 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.

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	/8
	2	/16
Paper 2	3	/25
	4	/14
	5	/12
Total		/ 75

This document consists of **22** printed pages and **2** blank pages.

2

Answer **all** the questions.

1 **(a)** Mild steel is an alloy that contains iron and carbon. A sample of mild steel was analysed, and four different types of atoms were identified; **A**, **B**, **C** and **D**. Table 1.1 shows information about the four types of atoms found in the sample.

Table 1.1

atom	relative mass	relative % abundance
A	12.00	0.238
B	13.00	0.012
C	53.94	5.79
D	55.93	93.96

(i) Calculate the relative atomic mass of carbon in this sample to four significant figures. Show your working.

[1]

(ii) In an experimental set-up, beams of particles travelling at the same speed from different sources are subjected to an electric field as shown in Fig. 1.1. A beam of protons with an angle of deflection of 60° has already been drawn.
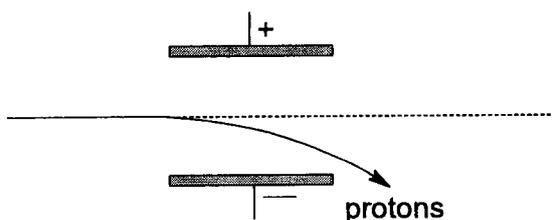
Fig. 1.1

Under identical conditions, beams of particles $^{12}C^{2+}$ and $^{56}Fe^{2+}$ were subjected to the same electric field.

Calculate the angle of deflection of $^{12}C^{2+}$ and $^{56}Fe^{2+}$ particles under the electric field and sketch the beams of $^{12}C^{2+}$ and $^{56}Fe^{2+}$ on Fig. 1.1. Label the beams clearly.

[2]

(b) The compound C_6H_6 has many possible structural isomers. Three suggested structures of C_6H_6 are shown in Fig. 1.2.

Kekulé benzene   Dewar benzene   Ladenburg benzene
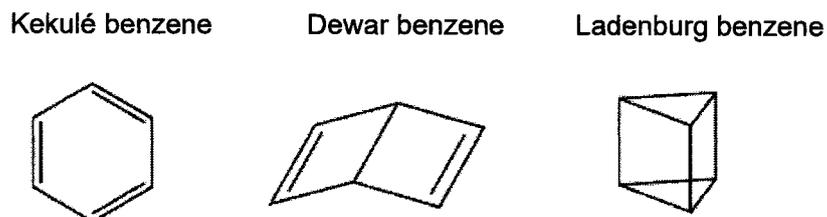
Fig. 1.2

(i) Using Fig. 1.2, complete Table 1.2 to predict the number of carbon atoms that have sp, sp^2 and sp^3 hybridisation in Kekulé benzene, Dewar benzene and Ladenburg benzene.

Table 1.2

C_6H_6 structure	sp hybridised	sp^2 hybridised	sp^3 hybridised
Kekulé benzene			
Dewar benzene			
Ladenburg benzene			

[2]

4

(ii) Dewar benzene contains both σ bonds and π bonds.
By reference to the hybridisation of the carbon atoms and orbital overlap, describe the covalent bonding in Dewar benzene.

....

....

....

....

....

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....

.... [2]

(iii) Suggest why Dewar benzene and Ladenburg benzene are unstable isomers of C_6H_6.

....

.... [1]

[Total: 8]

2 Aluminum is the most abundant metal in the earth's crust and has been produced commercially since 1888. It is now the second most used metal in the world after iron.

Approximately 75% of aluminum ever produced is still in use today, as it can be recycled endlessly without compromising any of its unique properties or quality.

(a) Aluminum objects that have had the aluminum oxide layer removed may be anodised.

(i) Complete Table 2.1 to show the relevant half-equations, during the anodisation of an aluminum object.

Table 2.1

	half-equation
anode	..... Al + ... H_2O → ..... Al_2O_3 + ... H^+ + ...e
cathode	

[2]

(ii) During the anodisation of an aluminum object, 3.50 g of a protective layer aluminum oxide is formed in 2 hours.

Calculate the value of the current used.

[2]

(b) Fig. 2.1 shows an **incomplete** energy cycle involving aluminium oxide, Al_2O_3.

line C: ....

process 3

line B: $2Al(g) + 3O(g)$

process 2: enthalpy change of atomisation of Al and O

process 4:
lattice energy of $Al_2O_3(s)$

line A: $2Al(s) + \frac{3}{2}O_2(g)$

process 1: enthalpy change of formation of $Al_2O_3(s)$

line D: $Al_2O_3(s)$
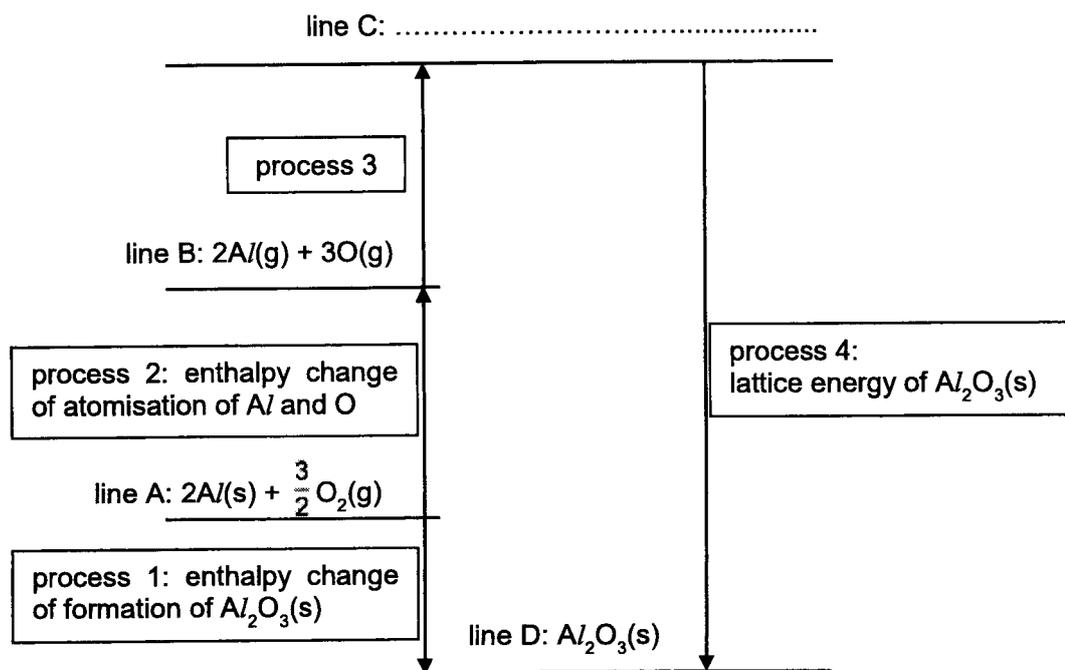
Fig. 2.1

(i) Complete line C. Include state symbols. [1]

(ii) Using Fig 2.1, the data in Table 2.2, together with data from the *Data Booklet*, to calculate the lattice energy of $Al_2O_3(s)$.

Table 2.2

	$\Delta H^{\ominus}$ / kJ mol^{-1}
1st electron affinity of oxygen, $O(g) + e^- \rightarrow O^-(g)$	−141
2nd electron affinity of oxygen, $O^-(g) + e^- \rightarrow O^{2-}(g)$	+790
standard enthalpy change of atomisation of $Al(s)$	+326
standard enthalpy change of formation of $Al_2O_3(s)$	−1676

[2]

(iii) Explain why the first electron affinity of oxygen is exothermic, but the second electron affinity is endothermic.

....

....

....

....

....

.... [2]

8

(c) When aluminum reacts with dry chlorine, aluminum chloride, $AlCl_3$, is formed.

(i) $AlCl_3$ can undergo dimerisation to form Al_2Cl_6.

With the aid of a diagram, name the type of bond formed during dimerisation and explain why this bond is formed.

....

.... [2]

(ii) When $AlCl_3$ is dissolved in water, a solution of pH 3.0 is formed.

Explain with the aid of a balanced equation why the solution has a pH of 3.0.

....

....

....

.... [2]

(iii) $AlCl_3$ can be used as a catalyst in the reaction of methylbenzene with chloroethane to form 4-ethylmethylbenzene.

Describe the mechanism of this reaction.

[3]

[Total: 16]

3 (a) The acid strength of a carboxylic acid is measured by its pK_a value.
Table 3.1 shows pK_a of ethanoic acid, chloroethanoic acid and fluoroethanoic acid.

Table 3.1

carboxylic acid	pK_a
ethanoic acid, CH_3CO_2H	4.76
chloroethanoic acid, $ClCH_2CO_2H$	2.87
fluoroethanoic acid, FCH_2COOH	2.60

(i) Explain the difference in pK_a values for ethanoic acid, chloroethanoic acid and fluoroethanoic acid.

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.... [3]

(ii) Calculate the $\dfrac{[anion]}{[acid]}$ ratio for each of the following acids when it is placed in a buffer solution kept at pH 3.8. Give your answer to **three** significant figures.

For CH_3CO_2H:	For $ClCH_2CO_2H$:

[1]

 [Turn over

(iii) Hence, using your answer from **(a)(ii)**, explain if ethanoic acid or chloroethanoic acid, and its conjugate base forms a more effective buffer in removing the small amount of H^+ added at pH 3.8.

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....[1]

(b) Both ethanoic acid, CH_3COOH, and lactic acid, $CH_3CH(OH)CO_2H$, can be synthesised from ethanol, CH_3CH_2OH, in the laboratory via different routes, as shown in Fig. 3.1.

$$CH_3CO_2H$$

$$CH_3CH_2OH$$

$$I$$

$$G \xrightarrow{\text{II}} H \xrightarrow{\text{III}} CH_3CH(OH)CO_2H$$
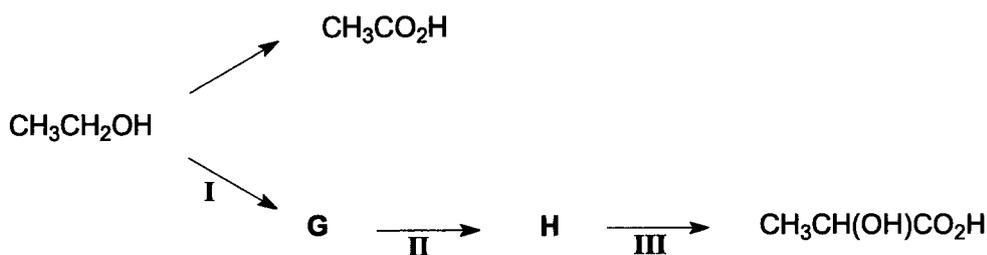
Fig. 3.1

(i) Suggest structures for compounds **G** and **H**.

G	H
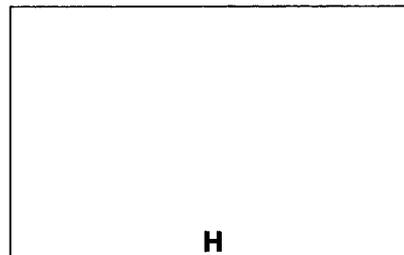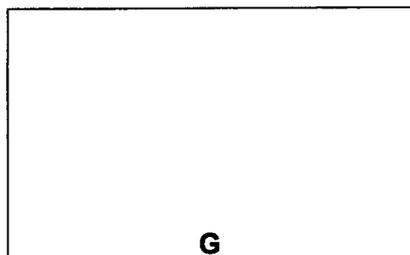
[2]

(ii) Suggest reagents and conditions for each of the steps **I** and **II**.

step **I** ....

step **II** ....

[2]

(iii) It is found that lactic acid synthesised in the lab do not rotate plane polarised light while naturally occurring lactic acid found in goat milk exhibits optical activity. Explain why such observation is made.

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.... [2]

(c) Lactic acid reacts in the presence of hot, concentrated sulfuric acid to form two different compounds, **J** and **K**.

- **J** has a molecular mass 72.0 g mol^{-1}
- **K** is a cyclic compound and has a molecular formula $C_6H_8O_4$.

Draw the skeletal formula of **J** and **K**.

J	**K**

[2]

(d) Table 3.2 shows the solubility of various calcium salts in water.

Table 3.2

calcium salt	solubility / mol dm^{-3}	colour
CaC_2O_4	4.8×10^{-5}	white
$Ca_3(PO_4)_2$	1.6×10^{-7}	white
$CaCrO_4$	2.7×10^{-2}	bright yellow

(i) Write an expression for the solubility product of $Ca_3(PO_4)_2$.

.... [1]

(ii) Calculate the solubility product, K_{sp}, for $Ca_3(PO_4)_2$, giving its units.

[1]

(iii) Describe what you would observe if equal volumes of saturated solutions of CaC_2O_4 and $CaCrO_4$ were mixed. Explain your answer using calculations.

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.... [3]

(e) An iodometric titration can be used to determine the percentage purity of calcium oxalate crystals, CaC_2O_4.

A 3.20 g impure sample of CaC_2O_4 is shaken with 100.0 cm^3 of 0.10 mol dm^{-3} aqueous acidified MnO_4^- ions. One of the products of this reaction is CO_2.

The remaining MnO_4^- is reacted with an excess of iodide solution to liberate $I_2(aq)$.

$$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5I_2(aq) + 8H_2O(l)$$
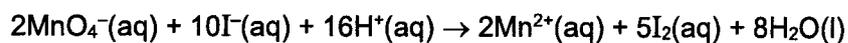
A 25.0 cm^3 aliquot requires 24.50 cm^3 of 0.2 mol dm^{-3} $S_2O_3^{2-}$ for this titration.

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$
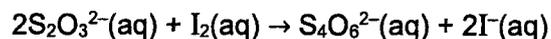
(i) Construct an equation for the reaction between MnO_4^- ions and $C_2O_4^{2-}$ ions.

.... [1]

(ii) Calculate the percentage purity of the sample of CaC_2O_4.

[3]

14

(f) The trend in the thermal stability of Group 2 oxalates, MC_2O_4, is similar to that of Group 2 carbonates.

Suggest if MgC_2O_4 or CaC_2O_4 undergoes thermal decomposition at a lower temperature. Explain your answer.

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.... [3]

[Total: 25]

4 **(a)** 4-hydroxybutanal can undergo an esterification reaction with a carboxylic acid. In a controlled experiment, 4-hydroxybutanal and ethanoic acid were heated under reflux with a small amount of concentrated sulfuric acid as a catalyst.
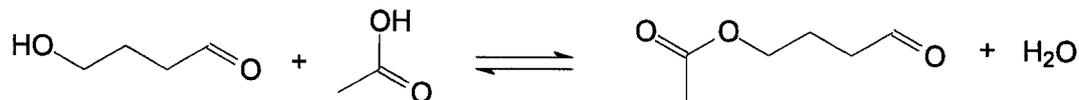
The following information was recorded from the experiment at 298 K.
- initial amount of 4-hydroxybutanal: 0.500 mol
- initial amount of ethanoic acid: 0.400 mol
- total volume of solution: 2.00 dm³
- at equilibrium, 60% of 4-hydroxybutanal has reacted

(i) Write the expression for the equilibrium constant, K_c, for this reaction. Use your expression to calculate the value of K_c for this reaction.

[3]

(ii) Aqueous potassium hydroxide was added to the equilibrium mixture at 298 K.

Suggest how the position of equilibrium might change and if the K_c will be affected.

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.... [2]

(b) 4-hydroxybutanal can form a cyclic hemiacetal in the presence of an acid catalyst as shown in Fig. 4.1.

4-hydroxybutanal   cyclic hemiacetal

Fig. 4.1

(i) The mechanism for the reaction in Fig. 4.1 is shown in Table 4.1.
Draw **four** curly arrows to complete the mechanism shown in Table 4.1.

Table 4.1

Step 1: The aldehyde is protonated by the acid catalyst to form a non-cyclic intermediate.	
Step 2: Nucleophilic attack by the alcohol to form a cyclic intermediate.	
Step 3: Deprotonation of the cyclic intermediate to form the product.	

[2]

(ii) The reaction to form cyclic hemiacetal is completed when all the 4-hydroxybutanal is used up. Describe a chemical test to check the completion of the reaction.

Include the reagents and conditions for the test. Explain how the observations will be used to determine if the reaction has been completed.

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.... [3]

(c) Koch reaction uses carbon monoxide to manufacture tertiary carboxylic acids as shown in Fig. 4.2.

$$RCH_2CH{=}CH_2 \; \underset{I}{\rightleftharpoons}^{\;H^+} \; RCH_2\overset{+}{C}H{-}CH_3 \; \underset{II}{\rightleftharpoons} \; R{-}\overset{+}{\underset{CH_3}{C}}{-}CH_3$$

$$\text{III} \mid CO \downarrow$$

R—C—CH₃ with O=C⁺ and CH₃ (structure IV) ; H₂O, −H⁺ → tertiary carboxylic acid

Fig. 4.2

(i) Step **II** is known as a rearrangement reaction. With reference to the stability of the species involved, suggest a reason why such a reaction occurs.

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....[1]

(ii) Draw the "dot–and–cross" diagram for carbon monoxide, CO.

[1]

(iii) Hence, state the role of carbon monoxide, CO, in the mechanism of step **III**.

....[1]

(iv) Acidic hydrolysis of an ester can be explained in terms of nucleophilic acyl substitution.

Besides electronic effect, suggest another reason why esters synthesised from tertiary carboxylic acids are stable when heated in the presence of acids.

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....[1]

[Total: 14]

5 **(a)** Volatile Organic Compounds (VOCs) are a group of organic chemicals that easily vaporise at room temperature. They are released by a wide range of products and processes, both indoors and outdoors.

Some VOCs can contribute to the formation of secondary pollutants like ozone and have adverse health effects. They are usually released from sources like vehicle exhaust, paint and solvents.

In the presence of sunlight, photochemical reaction is triggered between nitrogen oxides (NO and NO_2) and VOCs. The five stages of the reaction between formaldehyde, one of the common VOCs, with NO in the presence of sunlight leading to the formation of ozone, O_3, are described in Table 5.1.

Table 5.1

stage	description of stage	equation
1	*photolysis of formaldehyde	$HCHO \rightarrow \bullet H + \bullet CHO$
2	oxidation of formyl radical	$\bullet CHO + O_2 \rightarrow CO + \bullet HO_2$
3	oxidation of NO(g)	$\bullet HO_2 + NO \rightarrow NO_2 + \bullet OH$
4	photolysis of $NO_2(g)$	
5	formation of $O_3(g)$	

* photolysis is the decomposition of a molecule by the action of light.

After stage 3, NO_2 is photolysed by sunlight to generate NO and O atoms. The O atom formed then reacts with the oxygen gas in the air to form ozone.

(i) Explain why the hydrogen atom produced in step 1 is described as a *free radical*.

....

.... [1]

(ii) Complete Table 5.1 by adding the two equations to represent stages 4 and 5. [1]

(iii) Propanone, CH_3COCH_3, undergoes a similar reaction to that shown for stage 1 to 3 in Table 5.1.

Complete Table 5.2 by adding the equations to represent stage 1 and 3.

Table 5.2

stage	description of stage	equation
1	photolysis of CH_3COCH_3 to generate two radicals, $CH_3CO\bullet$ being one of them	
2	oxidation of $CH_3CO\bullet$ radical to form peroxyacetyl radical	(structural equation: $CH_3CO\bullet$ + O_2 ⟶ $CH_3C(O)OO\bullet$)
3	oxidation of NO(g) by peroxyacetyl radical to form brown gas	

[2]

(b) In recent years, there is an increasing concern about the post renovation air quality in buildings. In 2018, the death of a flat-dweller in Beijing has been attributed to formaldehyde, a carcinogenic substance widely used in wood products due to its strong adhesive, preservative and binding properties. Similarly, homeowners in Singapore have also been seeking help as they experienced stinging sensation in their nose and eyes due to VOCs released from furniture in their newly-renovated houses.

The air quality of a newly renovated office with limited ventilation was studied over the course of one week. Table 5.3 shows the average concentrations, in parts per billion (ppb), of selected VOCs detected.

Table 5.3

VOCs detected in the air of the office	molar mass (g mol^{-1})	concentration (ppb)
Formaldehyde, HCHO	30.0	0.0692
Toluene, $C_6H_5CH_3$	92.0	38.5
Xylene $C_6H_4(CH_3)_2$	106.0	12.7

(i) State two basic assumptions of the kinetic theory as applied to an ideal gas.

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.... [2]

(ii) Explain, with reference to intermolecular forces, which VOC vapour in Table 5.3 will have the greatest deviation from ideal gas behaviour.

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.... [2]

(iii) The concentration of VOC in the air is often represented in parts per billion (ppb). 1ppb VOC means there should be 1 mole of VOC for every 1 000 000 000 moles of air.
Calculate the concentration, in mol dm^{-3}, of toluene in the sample of office air.

[Assume the sample of air is at room temperature and pressure conditions.]

[1]

(iv) The indoor air quality is often measured by TVOC (Total Volatile Organic Compounds) levels. It is calculated as the sum of the concentrations of all measured VOCs, expressed in ppb.

Using Table 5.3, determine the TVOC level of the office.

[1]

(v) The World Health Organisation (WHO) recommends a target level of under 50 ppb for TVOC.

Explain if the TVOC level of the office is of concern and suggest a measure that can be taken to keep TVOC low in indoor spaces.

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....[2]

[Total: 12]

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ANDERSON SERANGOON JUNIOR COLLEGE
2025 JC 2 PRELIMINARY EXAMINATION

NAME:_____ (   )   CLASS: 25 / _____

CHEMISTRY
Paper 3 Free Response Questions

9729/03
29 August 2025
2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number on all the work 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.

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				
Pa pe r 3	A1	/ 19	Paper 1 (15%)	/ 30
	A2	/ 18	Paper 2 (30%)	/ 75
	A3	/ 23	Paper 3 (35%)	/ 80
	B4*	/ 20	Paper 4 (20%)	/ 55
	B5*	/ 20	Percentage	
	*Circle the question you have attempted		Grade	

2

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

9729/03/H2

3

Section A

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

1 **(a)** Transition elements have characteristic physical and chemical properties.

    (i) Explain what is meant by the term *transition element.* [1]

    (ii) Explain why the melting point and density of nickel is higher than that of calcium. [3]

(b) **(i)** A solution containing the $[Ni(H_2O)_6]^{2+}$ complex ion is green.

    When 1,2-diaminoethane, *en* , $H_2NCH_2CH_2NH_2$, is added, the colour of the solution changes to purple. This is due to the formation of the $[Ni(en)_2(H_2O)_2]^{2+}$ complex ion.

    Explain why the two solutions are coloured, and why the colours are different. [3]

    (ii) $[Ni(en)_2(H_2O)_2]^{2+}$ complex ion can exist in three different forms where the ions differ in the spatial arrangement of the ligands around the central metal ion.

    Fig. 1.1 shows one of the isomers.

4

Fig 1.1

Draw another isomer and state the type of isomerism. [2]

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(c) When a sample of aqueous copper(II) sulfate was added to a small amount of aqueous ammonia, a blue precipitate **A** was formed. Upon adding excess aqueous ammonia, **A** dissolved, and a deep blue solution containing a complex ion, **B**, was formed.

When another sample of aqueous copper(II) sulfate was added to concentrated hydrochloric acid, a yellow-green solution was formed.

(i) Identify **A** and **B** and explain their formation. Include relevant equations. [4]

(ii) Write an equation to explain the observation of the yellow-green solution. [1]

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(d) Ruthenium can form complexes with ligands like $H_2NCH_2CH_2NH_2$ (represented as *en*) and NH_3.

Three redox systems involving ruthenium complex ions are shown in Table 1.1.

Table 1.1

half-cell	half equation
A	$[Ru(H_2O)_6]^{3+} + e^- \rightleftharpoons [Ru(H_2O)_6]^{2+}$
B	$[Ru(NH_3)_6]^{3+} + e^- \rightleftharpoons [Ru(NH_3)_6]^{2+}$
C	$[Ru(en)_3]^{3+} + e^- \rightleftharpoons [Ru(en)_3]^{2+}$

(i) Two electrochemical cells are set up to compare the standard electrode potential, $E^\ominus$, of the three half-cells. Fig 1.2 shows the relative potential of each electrode.
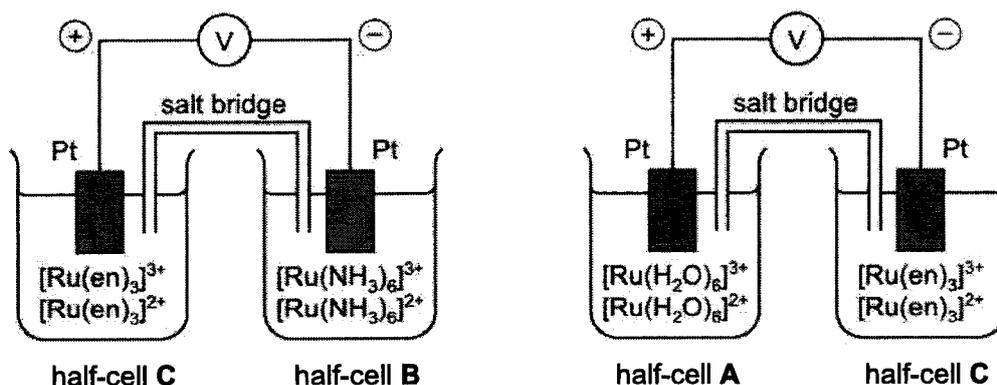
Fig 1.2

Using this information, state and explain the order of standard reduction potential, $E^\ominus$, for the three half-cells from the least negative to the most negative. [2]

(ii) The standard electrode potential of the half-cell **A** is +0.25 V.

An electrochemical cell was set up using half-cell **A** and a $[Cu(NH_3)_4]^{2+}/Cu$ half cell.

Use data from the *Data Booklet* to calculate the $E^\ominus$ cell for this cell. [1]

(iii) Write the overall equation for the reaction that occurs in the cell in **(d)(ii)**.

Using the $E^\ominus_{cell}$ you have calculated in **(d)(ii)**, calculate a value of $\Delta G^\ominus$ for the cell reaction represented by your overall equation. [2]

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[Total: 19]

2 **(a)** The reactivity of three nitrogen-containing compounds with aqueous bromine is shown in the Table 2.1.

Table 2.1

	NO_2	$NHCOCH_3$	NH_2
	⬡	⬡	⬡

8

	nitrobenzene	acetanilide	phenylamine
reactivity with $Br_2(aq)$ at room temperature	no reaction	mono-substitution of benzene ring	tri-substitution of benzene ring

(i) Explain the difference in the reactivity of the three compounds with $Br_2(aq)$. [3]

(ii) State the reagents and conditions to form acetanilide from nitrobenzene. [2]

(iii) Explain why acetanilide is effectively neutral.
[1]

(iv) Phenylamine can react with hydrochloric acid to form phenylammonium chloride.
Given the pK_b of phenylamine at 25 °C is 9.38, calculate the pH of the resultant mixture when 25 cm³ of 0.25 mol dm⁻³ phenylamine is titrated with 25 cm³ of 0.25 mol dm⁻³ of hydrochloric acid. [2]

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(b) Lysine is an ⟨-amino acid that is used in the biosynthesis of proteins.

10

lysine

The pK_a values of lysine are given in Table 2.2.

Table 2.2

functional group on lysine	pK_a value
⟨-carboxyl group	2.2
⟨-amino group	9.0
side chain	10.5

(i) Draw the structures of the major species present in solution of lysine at pH 5 and pH 12.

[2]

(ii) Suggest a reason why the ⟨-amino group of protonated lysine has a lower pK_a than the amino group on the side chain.

[1]

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(c) When a 10.0 cm³ sample of the fully protonated lysine is titrated against 0.100 mol dm⁻³ NaOH, the following titration curve is obtained.

pH ▲

9729/03/H2

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Figure 2.1

(i) Calculate the concentration of lysine in the 10.0 cm³ sample.
Hence, calculate the pH of the solution at point **W** (ignore the effects of the second and third acid dissociations on the pH). [3]

(ii) Determine the pH at point **Y** and **Z** [2]

(iii) Suggest the structure of the zwitterion of lysine and indicate the point of the titration curve where only the zwitterion is found. Mark it with an "X". [2]

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[Total: 18]

3 (a) (i) Describe and explain the trend in the thermal stability of HC*l*, HBr and HI. [2]

(ii) Explain why the volatility of Group 17 hydrides decreases from HC*l*, HBr and HI. [2]

(iii) Predict the colour of the solutions that would be observed when the following pairs of solution are mixed. Give equations for any reactions that occurs.

  • $Br_2(aq)$ and $KI(aq)$
  • $I_2(aq)$ and $KBr(aq)$ [2]

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(b) S_N1 and S_N2 are two different mechanisms for the nucleophilic substitution of halogenoalkanes.

(i) Draw a mechanism for the reaction between 2-bromobutane and OH^- via S_N1. Show relevant lone pairs of electrons, dipoles and use curly arrows to indicate the movement of electron pairs. [2]

(ii) Write the rate equation for the reaction in **(b)(i)**.
Suggest if the value of the rate constant, k, will change when concentration of 2-bromobutane is doubled. [2]

(iii) An investigation of the kinetics of the nucleophilic substitution of 2-bromobutane with OH^- is carried out. The overall rate equation of this nucleophilic substitution is found to be:

$$\text{rate} = y\,[\text{2-bromobutane}] + z\,[\text{2-bromobutane}][OH^-]$$

where y and z are rate constants.

The results of two such experiments are recorded in Table 3.2

Table 3.2

Experiment	[2-bromobutane]/ mol dm^{-3}	[OH$^-$]/ mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.20	0.20	8.0×10^{-7}
2	0.20	0.40	1.4×10^{-6}

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Use the results to calculate the values of *y* and *z* for the rate equation shown, stating their units. [3]

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3 **(c)** Vinyl bromide and vinyl chloride are common monomers used in manufacture of addition polymers.

| Br | Cl |
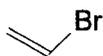
Vinyl bromide   Vinyl chloride

In order to differentiate vinyl bromide and vinyl chloride, the following steps are observed.

Step 1: $H_2(g)$ in the presence of solid platinum was introduced into the respective vinyl halides.

Step 2: Hot aqueous sodium hydroxide is added followed by nitric acid. The samples are then cooled before silver nitrate is added. Precipitate will be observed.

Step 3: To confirm the identity the of the precipitate, dilute $NH_3(aq)$ and concentrated $NH_3(aq)$ are added to fresh sample of the precipitate.

(i) Complete Table 3.3 by stating the relevant observations for each step.

Table 3.3

compound	name of organic substance after step 1	colour of ppt after step 2	solubility of precipitate	
			in dil. $NH_3(aq)$	in conc. $NH_3(aq)$
Vinyl bromide			Insoluble	
Vinyl chloride			Soluble	

[2]

(ii) Step 1 is conducted before step 2 as vinyl halides do not undergo nucleophilic substitution.
Explain the unreactivity of vinyl halides towards nucleophiles. [1]

(iii) Explain why it is necessary to add nitric acid in step 2. [1]

(iv) H_2 gas with platinum can be used to reduce C=C bond in an alkene and C=O bond in an aldehyde.
Explain why C=C bond in an alkene is weaker than C=O bond in an aldehyde. [2]

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3 **(d)** Kevlar is a lightweight and strong material, used to make tyres and bulletproof vests. Its structure is given below.

Kevlar

Upon undergoing hydrolysis, two monomers **A** and **B** are formed.

monomer **A**	$C_6H_8N_2$
monomer **B**	$C_8H_6O_4$

(i) Draw the structures of **A** and **B**. [1]

(ii) Suggest reagents and conditions required to differentiate the monomers **A** and **B**. [2]

(iii) Kevlar can withstand a large amount of pulling force before breaking. Explain why Kevlar has such property. [1]

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[Total: 23]

Section B

Answer **one** question from this section.

4 **(a)** **(i)** Sodium, magnesium and phosphrous are elements from Period 3.

Describe what you would observe when water is added to separate samples of the chlorides of these three elements. Suggest the pH of the resulting solutions, and write equations where appropriate. [3]

(ii) Carbon tetrachloride, CCl_4, and silicon tetrachloride, $SiCl_4$, are both tetrachlorides of Group 14 elements. Explain why CCl_4 does not hydrolyse in water but $SiCl_4$ does. [2]

(iii) NCl_3 and PCl_3 are both chlorides of Group 15 elements. Predict and explain the difference in bond angles between NCl_3 and PCl_3. [2]

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(b) D-glucose exists in two forms. The ⟨-form has an optical rotation of +113.4° and the ®-form which has an optical rotation of +19.0°.

The following equilibrium exists in aqueous solution.

$$⟨\text{-glucose(aq)} \rightleftharpoons ®\text{-glucose(aq)} \qquad \otimes H^\oplus = -2.10 \text{ kJ mol}^{-1}$$

If an aqueous solution of either form is allowed to stand, the optical rotation changes until it reaches +52.2°.

(i) Show that the equilibrium mixture contains 35.2% of the ⟨-form. [1]

(ii) Calculate the K_c value at 298 K. [1]

(iii) Given that $\otimes G^\oplus = -RT \ln K_c$, using your answer from **(b)(ii)**, calculate the value of $\otimes G^\oplus$ and $\otimes S^\oplus$ at 298 K. [2]

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(c) The Corey–House reaction is an organic reaction that involves the reaction of a lithium dialkyl cuprate, R_2CuLi, with a halogenoalkane, R'X, to form a new alkane, an organocopper compound and a lithium halide.

The reaction is as shown.

$$R_2CuLi + R'X \square R\text{-}R' + RCu + LiX$$

(X = C*l*, Br or I)

(i) Suggest the lithium dialkyl cuprate and a secondary halogenoalkane to form $CH_3CH(CH_3)CH_2CH_2CH_3$. [1]

(ii) Suggest the type of reaction for the Corey–House reaction. [1]

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(d) Compound **T**, $C_8H_{12}O_4$, is a neutral, sweet-smelling liquid. It does not give any orange precipitate with 2,4-DNPH. One mole of compound **T** decolourised one mole of liquid Br_2.

Samples of compound **T** are reacted separately with

- hot aqueous KOH to form organic compound **V**, C_2H_6O, and salt **W**, $C_4O_4H_2K_2$,
- hot acidic $KMnO_4$ to form **U**, $C_2H_4O_2$, as the only organic product.

Compound **V** gives a yellow precipitate with alkaline aqueous iodine.

Suggest possible structures for **T**, **U**, **V** and **W**. For each reaction, state the type of reaction described and explain what the information tells you about the functional group present in each compound. [7]

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[Total: 20]

5 In aqueous solution, chlorine dioxide, ClO_2, reacts with hydroxide ions as shown.

$$2ClO_2 + 2OH^- \rightarrow ClO_3^- + ClO_2^- + H_2O$$

(a) **(i)** Suggest how the shape and bond angle of a ClO_3^- ion is different from those of ClO_2^- ion.
[2]

(ii) Determine the oxidation number of chlorine in ClO_2, ClO_3^- and ClO_2^-. Hence, suggest what is so special about this reaction.
[2]

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(b) The reaction between chlorine dioxide and hydroxide ions can be influenced by the presence of $Fe^{2+}(aq)$ catalyst.

Explain, with the aid of a labelled Boltzmann distribution diagram, the effect of the use of $Fe^{2+}(aq)$ on the rate constant. [3]

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(c) **R, S** and **T** are oxides of Period 3 elements which are solids at room temperature.

R, S, and **T** are added to excess cold water, HCl(aq) and NaOH(aq) separately at room temperature. Table 5.1 shows the observation and reactions.

Table 5.1

	Observation on addition to water	Reaction with HCl(aq)	Reaction with NaOH(aq)
R	White solid did not dissolve.	Reacts to form salt.	Reacts to form complex ions.
S	Some white solid remain undissolved.	Reacts to form salt.	No reaction.
T	All white solid dissolved.	No salt formed.	Reacts to form salt.

Using Table 5.1, identify **R, S** and **T**. State the pH of the solution when each of the oxide is added to water. [3]

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(d) The evaporation of one mole of pure water has a standard entropy change of $\Delta S^{\ominus} = +110$ J mol^{-1} at 298 K.

(i) Given that the standard enthalpy change for the evaporation of one mole of pure water, $\otimes H^{\ominus} = +41.0$ kJ mol^{-1}, calculate the $\otimes G^{\ominus}$ in kJ mol^{-1} at 298 K. [1]

(ii) State the ΔG of water at 373 K and sketch a clearly labelled graph of ΔG, on the y-axis, against temperature measured in Kelvin, on the x-axis, to show how $\otimes G$ changes for the evaporation process when temperature increases from 298 K to 373 K. [1]

(iii) Comment on the gradient of your graph and explain how temperature affects the spontaneity of the evaporation process. [2]

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(e) Grignard reagents, RMgBr, are excellent carbon-based nucleophiles as well as strong bases. They can add to aldehydes and ketones to form alcohols. A typical example of the use of Grignard reagent is the two-step reaction of RMgBr with a carbonyl compound to form an alcohol.

$$RMgBr + R'COR'' \xrightarrow{\text{step 1}} R'\!-\!\overset{\overset{\displaystyle OMgBr}{|}}{\underset{\underset{\displaystyle R}{|}}{C}}\!-\!R'' \xrightarrow{\text{step 2}} R'\!-\!\overset{\overset{\displaystyle OH}{|}}{\underset{\underset{\displaystyle R}{|}}{C}}\!-\!R'' + Mg(OH)Br$$

where R = alkyl, R' and R" = alkyl group or H.

(i) State the type of reaction in step 1. [1]

(ii) Suggest the identity of the Grignard reagent and an aldehyde that is needed to form pentan-2-ol. [1]

(iii) The Grignard reagent $C_2H_5CH(CH_3)MgBr$ can be converted into carboxylic acid **U** by using carbon dioxide. When **U** reacted with $LiAlH_4$, **V** is produced. **W** is produced when **V** reacts with hot concentrated sulfuric acid. When hot acidified potassium managnate(VII) is added, **X** is formed. **X** forms a yellow precipitate when reacted with alkaline aqueous iodine.

Suggest the structural formulae of **U**, **V**, **W** and **X**. [4]

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Additional answer space

If you use the following pages to complete the answer to any questions, the question number must be clearly shown.

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