



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	

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

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]

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(b) (i) A solution containing the $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ complex ion is green.

When 1,2-diaminoethane, *en*, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, is added, the colour of the solution changes to purple. This is due to the formation of the $[\text{Ni}(\text{en})_2(\text{H}_2\text{O})_2]^{2+}$ complex ion.

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

(ii) $[\text{Ni}(\text{en})_2(\text{H}_2\text{O})_2]^{2+}$ 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.

The diagram shows the chemical structure of the nickel(II) complex [Ni(EDTA)]²⁺. A central nickel atom (Ni) is coordinated by four nitrogen atoms of an ethylenediaminetetraacetate (EDTA) ligand. The EDTA ligand consists of two ethylenediamine groups (H₂N-CH₂-CH₂-NH₂) and two acetate groups (CH₂-COO⁻). The nickel atom is also coordinated by two water molecules (H₂O). The entire complex is enclosed in square brackets with a 2+ charge indicated outside the top right corner.

Fig 1.1

Draw another isomer and state the type of isomerism.

[2]

[illegible]

(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]

[Turn over

- (d) Ruthenium can form complexes with ligands like $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ (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	$[\text{Ru}(\text{H}_2\text{O})_6]^{3+} + \text{e}^- \rightleftharpoons [\text{Ru}(\text{H}_2\text{O})_6]^{2+}$
B	$[\text{Ru}(\text{NH}_3)_6]^{3+} + \text{e}^- \rightleftharpoons [\text{Ru}(\text{NH}_3)_6]^{2+}$
C	$[\text{Ru}(\text{en})_3]^{3+} + \text{e}^- \rightleftharpoons [\text{Ru}(\text{en})_3]^{2+}$

- (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.

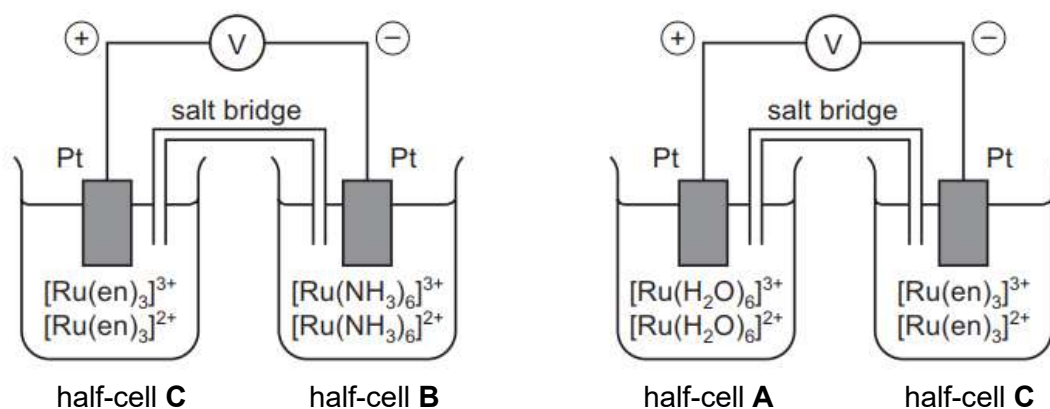


Fig 1.2

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 $[\text{Cu}(\text{NH}_3)_4]^{2+}/\text{Cu}$ 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 ΔG^\ominus for the cell reaction represented by your overall equation. [2]

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

			
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	nitrobenzene	acetanilide	phenylamine
reactivity with Br ₂ (aq) at room temperature	no reaction	mono-substitution of benzene ring	tri-substitution of benzene ring

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|-------|---|-----|
| (i) | Explain the difference in the reactivity of the three compounds with $\text{Br}_2(\text{aq})$. | [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 $\text{p}K_{\text{b}}$ of phenylamine at 25°C is 9.38, calculate the pH of the resultant mixture when 25 cm^3 of 0.25 mol dm^{-3} phenylamine is titrated with 25 cm^3 of 0.25 mol dm^{-3} of hydrochloric acid. | [2] |

[illegible]

NC(=O)[C@H](N)CCCCN

The pK_a values of lysine are given in Table 2.2.

Table 2.2

functional group on lysine	pK_a value
α -carboxyl group	2.2
α -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 α -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 cm^3 sample of the fully protonated lysine is titrated against $0.100 \text{ mol dm}^{-3} \text{ NaOH}$, the following titration curve is obtained.

pH ↑

(i) Calculate the concentration of lysine in the 10.0 cm^3 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]

This image shows a full page of white paper with horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and run across the entire width of the page. There are no margins, text, or other markings present.

9729/03/H2

- 3 (a) (i) Describe and explain the trend in the thermal stability of HCl , HBr and HI . [2]
- (ii) Explain why the volatility of Group 17 hydrides decreases from HCl , 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.
- $\text{Br}_2(\text{aq})$ and $\text{KI}(\text{aq})$
 - $\text{I}_2(\text{aq})$ and $\text{KBr}(\text{aq})$ [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:

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

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 x 10 ⁻⁷
2	0.20	0.40	1.4 x 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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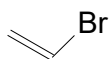
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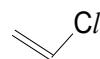
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- 3 (c) Vinyl bromide and vinyl chloride are common monomers used in manufacture of addition polymers.



Vinyl bromide



Vinyl chloride

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

Step 1: $\text{H}_2(\text{g})$ 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 $\text{NH}_3(\text{aq})$ and concentrated $\text{NH}_3(\text{aq})$ 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. $\text{NH}_3(\text{aq})$	in conc. $\text{NH}_3(\text{aq})$
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 $\text{C}=\text{C}$ bond in an alkene and $\text{C}=\text{O}$ bond in an aldehyde.

Explain why $\text{C}=\text{C}$ bond in an alkene is weaker than $\text{C}=\text{O}$ bond in an aldehyde.

[2]

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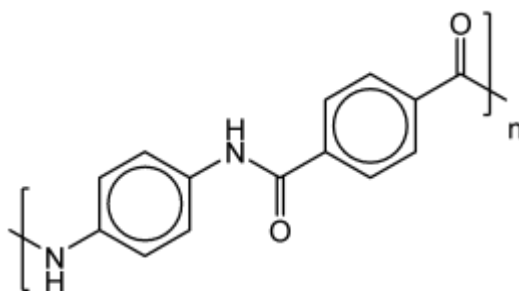
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- 3 (d) Kevlar is a lightweight and strong material, used to make tyres and bulletproof vests. Its structure is given below.



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 phosphorous 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) NCI_3 and PCl_3 are both chlorides of Group 15 elements. Predict and explain the difference in bond angles between NCI_3 and PCl_3 . [2]

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- (b) D-glucose exists in two forms. The α -form has an optical rotation of $+113.4^\circ$ and the β -form which has an optical rotation of $+19.0^\circ$.

The following equilibrium exists in aqueous solution.



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

- (i) Show that the equilibrium mixture contains 35.2% of the α -form. [1]
- (ii) Calculate the K_c value at 298 K. [1]
- (iii) Given that $\Delta G^\circ = -RT \ln K_c$, using your answer from (b)(ii), calculate the value of ΔG° and ΔS° 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.



(X = Cl, 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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- hot aqueous KOH to form organic compound **V**, $\text{C}_2\text{H}_6\text{O}$, and salt **W**, $\text{C}_4\text{O}_4\text{H}_2\text{K}_2$,
- hot acidic KMnO_4 to form **U**, $\text{C}_2\text{H}_4\text{O}_2$, as the only organic product.

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]

[illegible]

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[Total: 20]

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



- (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 $\text{Fe}^{2+}(\text{aq})$ catalyst.

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

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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.

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This image shows a full page of a handwriting practice worksheet. It consists of multiple sets of three horizontal dashed lines, providing a guide for letter height and placement. The lines are evenly spaced across the entire page, which is otherwise blank.

- (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 $\text{C}_2\text{H}_5\text{CH}(\text{CH}_3)\text{MgBr}$ 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 manganate(VII) is added, **X** is formed. **X** forms a yellow precipitate when reacted with alkaline aqueous iodine.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

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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