NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY
8873/02
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 name, registration number and subject class on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** the questions.

Section B
Answer **one** question.
At the end of the examination, fasten all your work securely together.

A1	**/13**
A2	**/13**
A3	**/6**
A4	**/11**
A5	**/10**
A6	**/7**
B6 / B7	**/20**

Paper 2	**/80**
Paper 1	**/30**
Weightage	
Paper 1 (33%)	**/33**
Paper 2 (67%)	**/67**
Overall	

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

This document consists of **21** printed pages and **1** blank page.

Section A

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

1 Boron, carbon, and lithium play critical roles in nuclear, organic, and battery chemistry. Their atomic structure and periodic behaviour provide important insights into chemical properties and bonding patterns.

(a) (i) About 0.005% of water molecules consist of an oxygen atom bonded to two atoms of the *isotope* of hydrogen, deuterium, $^{2}_{1}D$. The compound formed is deuterium oxide, D_2O, and is also known as 'heavy water'.

Define the term *isotope.*

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……

[1]

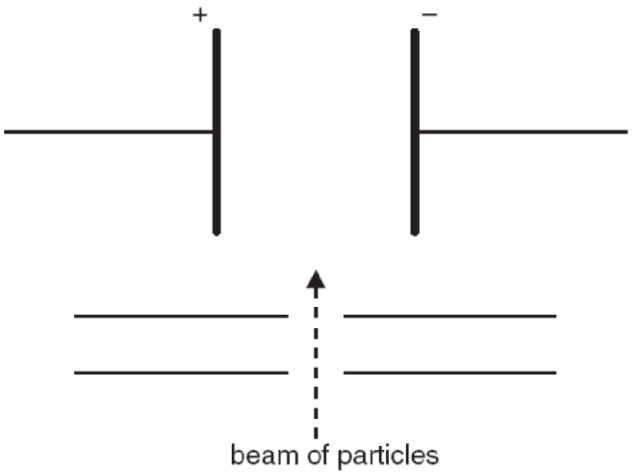
(ii) State the number of subatomic particles present in one molecule of D_2O.

number of protons	
number of neutrons	
number of electrons	

[1]

(b) Separate beams of $^{14}C^{2-}$ and $^{7}Li^{+}$ ions are passed through an electric field in the set-up below. The angle of deflection of the $^{14}C^{2-}$ beam is 7.0 °.

Sketch on the diagram below, the paths taken by beams of $^{7}Li^{+}$ and $^{14}C^{2-}$ ions in the presence of an electric field. Label your sketch clearly.



[2]

(c) The element sulfur has four naturally occurring isotopes as shown in Table 1.2.

Table 1.2

isotope	relative abundance / %
^{32}S	94.93
^{33}S	0.76
^{34}S	4.29
^{36}S	0.02

Use the relative abundance data to calculate the relative atomic mass of sulfur to 4 significant figures. Show your working.

[2]

(d) Write the electronic configuration of Cu and explain its anomaly

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[2]

(e) Predict and explain the order of first IE of A*l*, Mg, and S.

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[2]

(f) **(i)** Draw the dot-and-cross diagram for PCl_5.

[1]

(ii) Explain why PCl_5 exists but NCl_5 does not, in terms of electronic structure.

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[2]
[Total : 13]

2 Oxalic acid, found in many leafy vegetables, can be analysed via redox titration using potassium manganate(VII). This question explores thermochemistry and redox stoichiometry in food and materials chemistry.

(a) To determine the standard enthalpy change of neutralisation, 60 cm^3 of 0.370 mol dm^{-3} aqueous ammonia was placed in a polystyrene cup. Constant volume of dilute HC*l* was added. The mixture was stirred after each addition and the maximum temperature was recorded.

The following graph was obtained in Figure 2.1

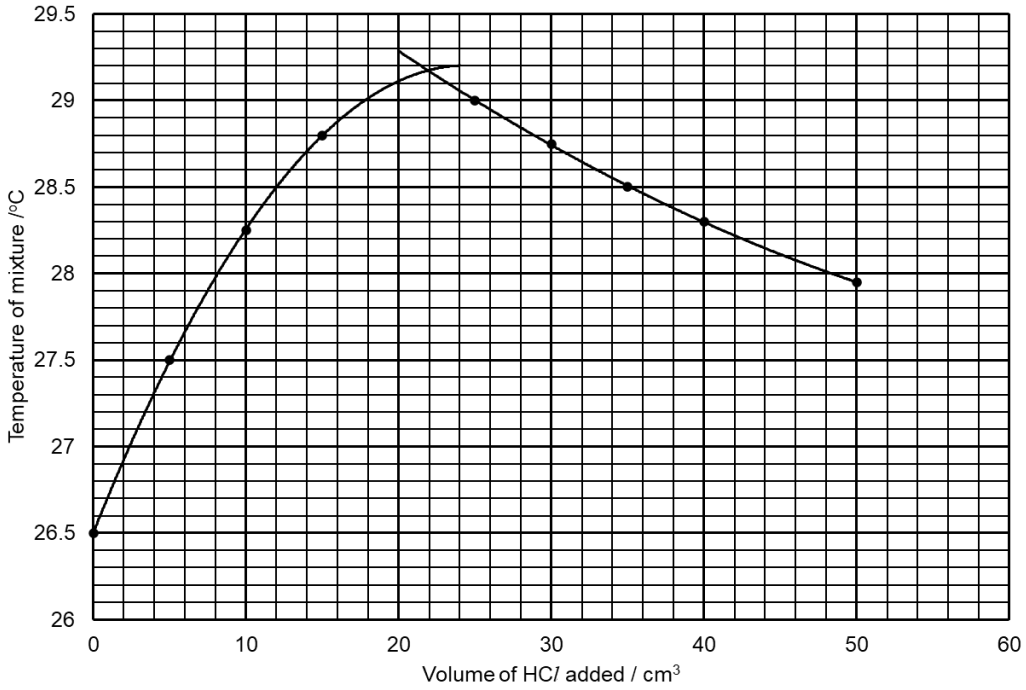

Fig 2.1

(i) Define the term *standard enthalpy change of neutralisation*.

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[1]

(ii) Determine the maximum temperature change from Figure 2.1.

[1]

(iii) Calculate the concentration of HC*l* used in the experiment.

[2]

(iv) Calculate the enthalpy change of neutralisation, ΔH_n^e, for the reaction between HC*l* and ammonia.

Assuming that the density of all aqueous solution is constant at 1.00 g cm^{-3} and specific heat capacity of the solution is 4.18 J g^{-1} $°C^{-1}$.

[2]

(v) The theoretical *standard enthalpy change of neutralisation* is −57.0 kJ mol^{-1}. Account for the discrepancy in the value calculated in **(a)(iv)**.

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[1]

(b) The following investigation was carried out on a sample of oxalic acid, $H_2C_2O_4$, extracted from 100 g of spinach (about one serving) using 50.0 cm^3 of an inert organic solvent. The solution is then titrated with acidified potassium manganate(VII), $KMnO_4$.

$$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$

Solutions used in the experiment:	
FA 1	The given inert organic solvent containing the oxalic acid was diluted with deionised water to a total volume of 250 cm^3 in a volumetric flask.
FA 2	1.0 mol dm^{-3} sulfuric acid, H_2SO_4
FA 3	0.0231 mol dm^{-3} potassium manganate(VII), $KMnO_4$.

Procedures:

1) 25.0 cm^3 of **FA 1** was first pipetted into a conical flask.
2) 25.0 cm^3 of **FA 2** and 40.0 cm^3 of deionised water were then added to the same flask.
3) The resultant mixture was heated to a temperature of 65 °C over a Bunsen burner before being titrated with **FA 3** from the burette.
4) 18.80 cm^3 of **FA 3** was required to react completely with the hot mixture.

(i) The reaction between oxalate ion, $C_2O_4^{2-}$ and MnO_4^- ion can be described by two half–equations.
Write the two half-equations for this reaction.

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[1]

(ii) Determine the concentration, in mol dm^{-3}, of $C_2O_4^{2-}$ in **FA 1**.

[2]

(iii) Calculate the mass of oxalic acid in one serving of spinach.

[1]

(iv) Assuming that spinach is the only dietary source of oxalic acid on a particular day, calculate the minimum number of servings of spinach must a healthy person, with a body weight of 65 kg, consume in a meal before he suffers from oxalic acid toxicity. You may assume toxicity limit is approx. 600 mg per kg body weight.

[2]
[Total: 13]

3 Nitrogen-containing compounds and small polyatomic species such as nitrogen trichloride (NCl_3) and hypochlorous acid ($HOCl$) exhibit a wide range of bonding arrangements, shapes, and physical properties. Understanding their electron configurations, molecular geometries, and intermolecular interactions is essential to predicting their chemical behaviour and physical states under standard conditions.

(a) Draw the dot-and-cross diagrams for NCl_3 and $HOCl$.

[2]

(b) State and explain the bond angles using VSEPR theory.

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[2]

(c) Suggest in terms of intermolecular bonding why NCl_3 is a gas and $HOCl$ is a liquid at room temperature.

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[2]
[Total: 6]

4 **(a)** Aluminium oxide, Al_2O_3, is amphoteric and reacts separately with both acids and alkalis to form colourless solutions..

(i) Write an equation for the reaction of aluminium oxide with excess aqueous hydrochloric acid.

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[1]

(ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

……

[1]

(b) Al_2O_3 can be used as a catalyst in the dehydration of alcohols.

(i) Draw and label a Boltzmann distribution curve for a sample containing 1 mol of ethanol at a particular temperature.

[1]

(ii) On the Boltzmann distribution curve in **(b)(i)**, show the change that would happen when Al_2O_3 is used as the catalyst at the same temperature.

Label the change '**X**'.

[1]

(iii) State the effect of using Al_2O_3 as the catalyst on the rate of the dehydration reaction. Use your Boltzmann distribution curve in **(b)(i)** to explain your answer.

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[2]

(iv) A sample containing 1 mol of ethanol has its temperature decreased.

By considering the Boltzmann distribution curve, state the effect, if any, of decreasing temperature on

① the activation energy of the dehydration reaction and

② the number of ethanol molecules that possesses the most probable energy value.

①……
…

②……
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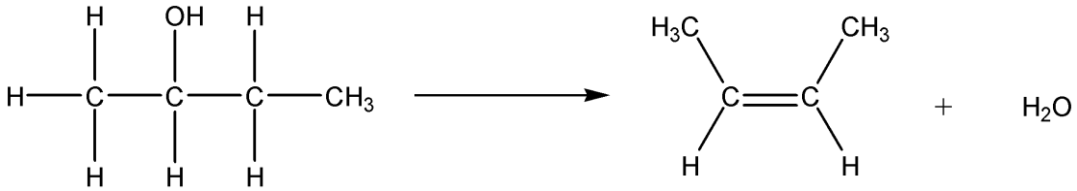
[2]

(c) In the dehydration of alcohols by Al_2O_3, alkenes can be formed. One example such example is shown below:



(i) State the isomerism exhibited by the example above.

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[1]

(ii) Draw the other possible structural isomers of the product of the dehydration reaction example in (c) and explain why it does not undergo cis-trans isomerism.

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[2]
[Total : 11]

5 The Grasberg mine in Indonesia is one of the largest copper-producing sites in the world. During processing, copper(II) ions (Cu^{2+}) dissolve in the water pumped from the mine. These ions can be recovered via liquid–liquid extraction, using an organic compound that selectively binds Cu^{2+} ions to form a copper–ligand complex.
The equilibrium between aqueous and organic layers can be represented by the following reaction:

$$Cu^{2+}\ (aq) + 4\ LH\ (org) \rightleftharpoons CuL_4^{2+}\ (org) + 4\ H^+\ (aq)$$

where **LH** is a neutral ligand in the organic solvent, and $\mathbf{CuL_4^{2+}}$ is the copper–ligand complex.

(a) **(i)** Define the term dynamic equilibrium.

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[1]

(ii) Write an expression for the equilibrium constant K_c for the reaction above which includes all the reagents in the different phases . State the units of K_c.

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[1]

(b) In an experiment, the following initial concentrations were prepared in a 1.00 dm^3 aqueous phase:

- $[Cu^{2+}]$=0.0100 mol dm^{-3}
- [LH]=0.0500 mol dm^{-3}
- Assume $[H^+]$=0 initially

At equilibrium, the concentration of H^+ in the aqueous layer was found to be 0.0040 mol dm^{-3}.

Calculate the equilibrium concentration of Cu^{2+} in the aqueous layer. Show all working clearly.

[2]

(c) The extraction process affects the **pH of the aqueous phase** due to the release of H^+ ions. A buffer solution is added to maintain a stable pH.

(i) Explain, with the aid of an equation, how a buffer solution resists changes in pH when small amounts of acid or base are added.

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[2]

(ii) Suggest why adding a buffer during the copper extraction process is important, and explain the effect on the equilibrium if no buffer were present.

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[2]

(d) 25.0 cm^3 of 0.100 mol dm^{-3} ethanoic acid was titrated with 0.100 mol dm^{-3} sodium hydroxide. The equivalence pH is above 7.

With reference to the table below, suggest and explain which indicator will be suitable for the above titration.

Indicator	**pH working range (simplified)**	**Colour**		
		Colour 1 H*In*	**at end point**	**Colour 2 In^-**
Methyl Orange	3 − 5	Red (pH < 3)	Orange (pH 3−5)	Yellow (pH > 5)
Phenolphthalein *	8 − 10	Colourless (pH < 8)	Pale pink (pH < 8−10)	Pink (pH > 10)

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[2]

[Total: 10]

6 Organic compounds can be transformed from one class to another through well-defined reactions involving suitable reagents and conditions. Such transformations allow simple hydrocarbons to be converted into more useful functional groups such as halogenoalkanes, alcohols, and alkenes.

(a) State the condition needed for alkane to react with a halogen.

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[1]

(b) When butane is treated with a small quantity of chlorine under appropriate condition, two mono-substituted isomers, **A** and **B** are produced. When **A** is heated with aqueous sodium hydroxide, **C** is produced which can be oxidised to **D. D does not** react with sodium carbonate.

Suggest structures for **C** and **D** and explain the reaction involved in the reaction of **C** with sodium hydroxide.

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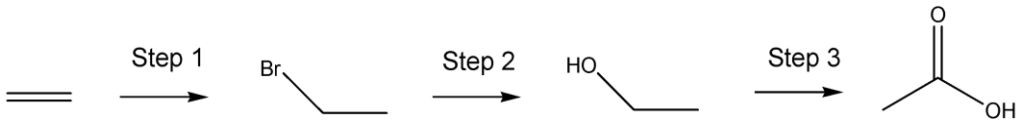
[3]

(c) A synthetic route is shown below:



For each step in the above sequence:

- State the reagents and conditions used
- Classify the type of reaction involved

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[3]
[Total: 7]

Section B

Answer **one** question from this section in the spaces provided.

7 Nanomaterials have particle sizes typically below 100 nanometres, giving them a large surface area to volume ratio and unique properties such as high reactivity, strength, and conductivity. These features make them useful in applications like catalysis, drug delivery, and electronics. This question explores the structure, properties, and uses of nanomaterials, as well as potential risks associated with their increasing use.

(a) **(i)** A platinum cube has edge length 1 μm, and a platinum nanoparticle has edge length 1 nm. Calculate and compare the surface area to volume ratio of both. Show all working.

[2]

(ii) Explain why platinum nanoparticles are preferred in catalytic converters.

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[2]

(b) Geckos can climb vertical walls using van der Waals forces. Explain how nanoscale structures on their toes contribute to this adhesion.

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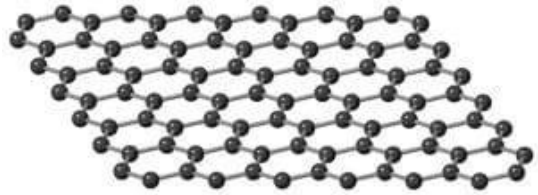
[2]

(c) Graphene is a single layer of carbon atoms arranged in a hexagonal lattice.



(i) Explain how the structure of graphene contributes to:
– its high tensile strength
– its electrical conductivity

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[3]

(ii) Suggest one practical application of graphene that uses both properties.

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[1]

(d) Nanoparticles are small enough to behave differently from larger particles.

(i) Explain how their small size allows them to enter the human body more easily

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[1]

(ii) Suggest two potential risks associated with widespread nanoparticle use.

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[2]

(e) Nanoparticles are used in cosmetics, sunscreens, and drug delivery systems.

(i) Explain how the large surface area to volume ratio of nanoparticles enhances their performance.

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[2]

(ii) Suggest one reason why rigorous testing is important before using them in consumer products.

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[1]

(f) Graphene sensors are being developed to detect pH changes in biological systems due to their high sensitivity to detect electrical changes.

(i) Suggest which feature from **c(i)** of graphene is suitable for this role.

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[1]

(ii) The $[H^+]$ in a sample is 3.2×10^{-5} mol dm^{-3}. Calculate the pH.

[1]

(g) Evaluate whether nanomaterials will eventually replace traditional plastics in packaging and consumer products. Consider performance, cost, recyclability, and health/environmental impact.

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[2]
[Total : 20]

8 A manufacturer is studying the use of different polymers for everyday products. The table shows data on four polymers:

Polymer	Structure Description	Melting Point (°C)	Water Solubility	Flexibility	Resistance to Hydrolysis
LDPE	Long branched chains	110	Insoluble	High	High
HDPE	Linear chains	135	Insoluble	Low	High
PET (polyester)	Contains ester linkages	260	Insoluble	Medium	Low
PP (polypropene)	Methyl-substituted hydrocarbon backbone	160	Insoluble	Medium	High

(a) Explain why LDPE is more flexible than HDPE, illustrating your explanation with drawings.

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[3]

(b) PP and PET are both used to make bottles. A cleaner with pH = 13 is stored in one of them.

Which bottle would you recommend and why?

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[2]

(c) PP can be used across a wide variety of applications from construction pipes to packaging for food and can be recycled. Explain why PP can take different shape and why it can be recycled.

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[2]

(d) **(i)** Explain how the structure of PVA allows it to dissolve in water, and contrast this with PVC used in raincoats.

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[2]

(ii) Hence suggest a use for PVA.

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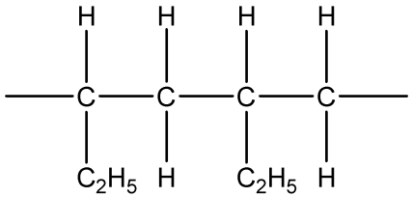
[1]

(e) A polymer structure of polybutene is given in the diagram below:



(i) Draw the structure of the monomer that makes up the polybutene.

[1]

(ii) State the type of isomerism that forms polybutene from its monomer.

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[1]

(iii) Suggest and explain how the tensile strength of polybutene differs from polypropene (PP).

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[2]

(f) Predict two physical properties of a new polymer that contains rigid aromatic rings and no polar groups.

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[2]

(g) Describe two economic or environmental reasons for recycling plastics.

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[2]

(h) The manufacturer is considering designing a new polymer to package acidic food items (pH ~3.5). Suggest two structural features the polymer should have, and explain how each feature contributes to acid resistance.

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[2]
[Total : 20]

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