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 **23** 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.*

Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons.

[1]

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

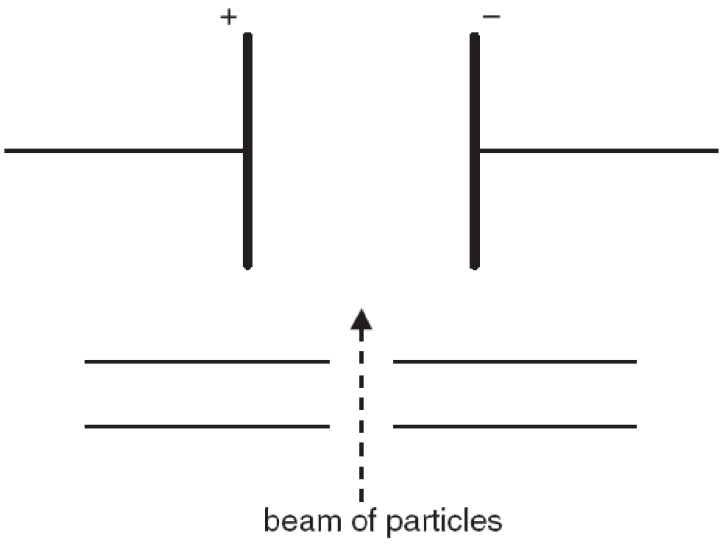
number of protons	
number of neutrons	
number of electrons	

Protons: 10 (8 from O, 1 from each D)
- Neutrons: 12 (8 from O, 2 from each D)
- Electrons: 10 (8 from O, 1 from each D)

[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.



 1 mark: $^{14}C^{2-}$ deflects toward positive plate, curved path labelled (angle = 7°)
 1 mark: $^{7}Li^{+}$ deflects toward negative plate, with **greater** curvature than $^{14}C^{2-}$
(Opposite directions, and lighter ion deflects more.)

[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.

Ar = $\frac{(32.0\ x\ 94.93)+(33.0\ x\ 0.76)+(34\ x\ 4.29)+(36\ x\ 0.02)}{100}$ [1]

= 32.07 [1]

(accept values within ± 0.01 if correct method is shown

(c) Calculate relative atomic mass of sulfur to 4 s.f.

[2 marks]

- **1 mark**: Correct application of formula:

$$A_r = \frac{(32 \times 94.93) + (33 \times 0.76) + (34 \times 4.29) + (36 \times 0.02)}{100}$$

- **1 mark**: Final answer = **32.07** (to 4 s.f.)

  (Accept values within ±0.01 of correct answer if method shown.)

[2]

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

- Electronic configuration of Cu: **[Ar] $3d^{10}$ $4s^{1}$ [1]**
- Explanation: full d-subshell ($3d^{10}$) is more stable than partially-filled $3d^{9}$ $4s^{2}$ configuration due to exchange energy/stability of half or full subshell **[1]**

[2]

(e) Predict and explain the order of first IE of Al, Mg, and S.

 Correct order: **S > Mg > Al [1]**
 Explanation:
- S has higher nuclear charge and same shielding, hence greatest nuclear attraction for most loosely held electron.

- Al has electron in 3p orbital → easier to remove due to higher energy level from repulsion from pair electrons in p orbital. Hence most loosely held electron is easier to remove than that of Mg.

[2]

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

Correct bonding with P in centre forming **five** single bonds with Cl atoms [1]

[1]

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

 P can expand its octet by using empty 3d orbitals → forms 5 bonds [1]
 N cannot expand its octet as it has only 2s and 2p orbitals → limited to a maximum of 4 electron pairs (8 electrons) [1]

[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

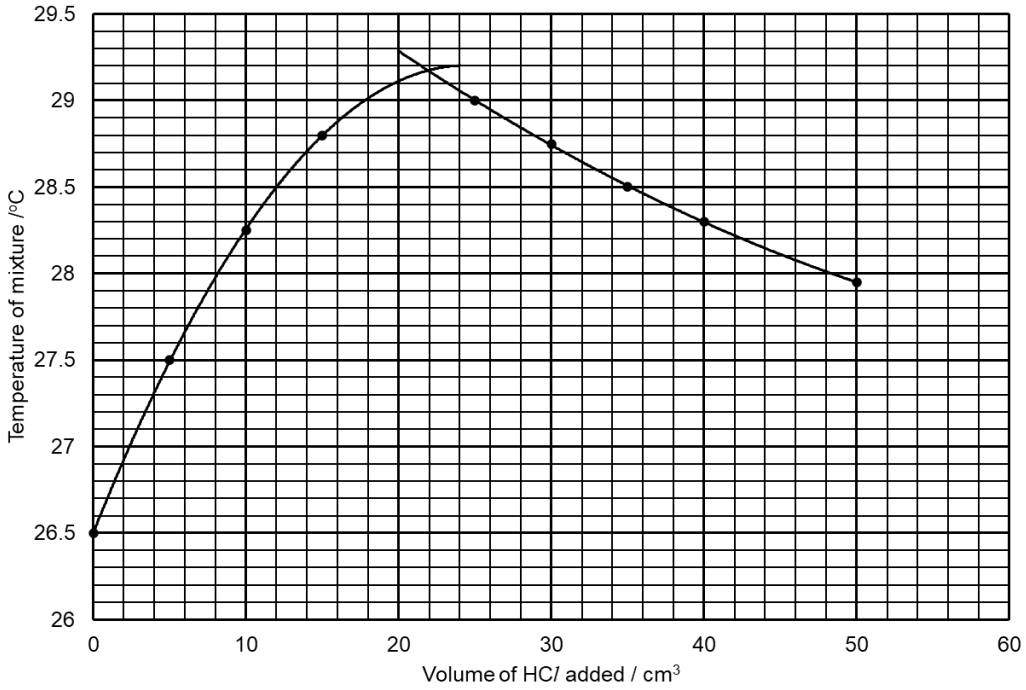


Fig 2.1

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

The energy released when 1 mole of water is formed from the neutralisation of an acid by a base under standard conditions (1 bar, 298 K, solutions at 1 mol dm^{-3}).

[1]

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

Correctly identifies **ΔT = 2.7 °C** from the graph.

[1]

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

Given:

- Volume of HCl used = 22.0 cm^3 = 0.0220 dm^3
- Volume of NH_3 = 60.0 cm^3 = 0.0600 dm^3
- Concentration of NH_3 = 0.370 mol dm^{-3}

•

Step 1: Calculate moles of NH_3 added
mol NH_3=0.0600×0.370=0.0222 mol
Step 2: At equivalence, mol NH_3 = mol HCl
mol HCl=0.0222 mol [1]
Step 3: Calculate concentration of HCl
[HCl]=mol HCl/volume in dm^3=0.0222/0.0220=1.01 mol dm^{-3} [1]

[2]

(iv) Calculate the enthalpy change of neutralisation, $\Delta H_n^{\ominus}$, 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}.

Given:
- Total volume = 60.0 cm^3 (NH_3) + 22.0 cm^3 (HCl) = 82.0 cm^3
- Assume **density = 1.00 g cm^{-3}**, so **mass = 82.0 g**
- Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
- Temperature rise (ΔT) = 2.7 °C
- Moles of water formed = moles of NH_3 = 0.0222 mol

Step 1: Calculate heat evolved (q)
q=mcΔT=82.0×4.18×2.7=925.6J [1]
Step 2: Convert to kJ
q=0.9256 kJ
Step 3: Calculate $\Delta H^{\ominus}_{neut}$
ΔH=−q/n=−0.9256/0.0222=−41.7 kJ mol^{-1} [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)**.

1 mark: Heat loss to surroundings / incomplete reaction / inaccurate measurement of temperature / polystyrene cup not perfectly insulated / evaporation or delay in mixing

[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.

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$

[1]

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

Calculate mol $KMnO_4$ used:
$0.0231 \times 18.801000 = 4.35 \times 10^{-4}$
1 mark: Use mol ratio 2 MnO_4^- : 5 $C_2O_4^{2-}$
mol $C_2O_4^{2-} = 52 \times 4.35 \times 10^{-4} = 1.09 \times 10^{-3}$ mol
1 mark: Multiply by 10 to find mol in 250 cm^3 (since 25.0 cm^3 taken)
$[C_2O_4^{2-}] = 1.09 \times 10^{-2} / 0.250 = 0.0436$ mol dm^{-3}

[2]

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

- Use mol from full 250 cm^3 = 1.09×10^{-2} mol
- **1 mark**: Multiply by molar mass of $H_2C_2O_4 \cdot 2H_2O$ = 126.07 g mol^{-1}

mass $= 1.09 \times 10^{-2} \times 126.07 = 1.37$ g

[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.

- **1 mark**: Assume toxicity limit is approx. 600 mg per kg body weight:

65 kg × 600 = 39,000 mg = 39g

- **1 mark**:

Servings = 39/1.37 ≈ 29 servings

[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.

- **1 mark** for correct structure of **NCl_3**:
  - Nitrogen in the center with 3 single bonds to Cl atoms
  - One lone pair on nitrogen
  - Valence electrons shown using dots and crosses
- **1 mark** for correct structure of **HOCl**:
  - O atom bonded to H and Cl
  - Two lone pairs on O
  - Single bonds to both H and Cl, with appropriate electron count

[2]

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

- **1 mark** for **NCl_3**:
  - Bond angle ≈ **107°**
  - Explanation: Trigonal pyramidal shape due to 3 bonding pairs and 1 lone pair → lone pair repulsion reduces angle from tetrahedral (109.5°)
- **1 mark** for **HOCl**:
  - Bond angle ≈ **104–105°**
  - Explanation: Bent/angular shape around oxygen due to 2 bonding pairs and 2 lone pairs → strong lone pair repulsion

[2]

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

- **1/2 mark**: NCl_3 is a **simple covalent molecule** with instantaneous **dipole–induced dipole** only
- **1/2 mark**: HOCl has a **polar O–H bond** → forms **hydrogen bonds** between molecules
- **1 mark**: More energy is available at room temperature to overcome the stronger hydrogen bonding between the NCl_3 molecules than the weaker id-id between the HOCl molecules.→ **HOCl is a liquid**, NCl_3 is a gas.

[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.

1 mark for correct ionic or balanced molecular equation:

$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

(Accept ionic version: $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$)

[1]

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

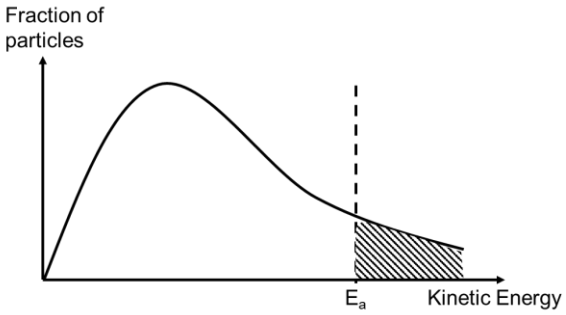
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$

(Accept molecular: $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na[Al(OH)_4]$)

[1]

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

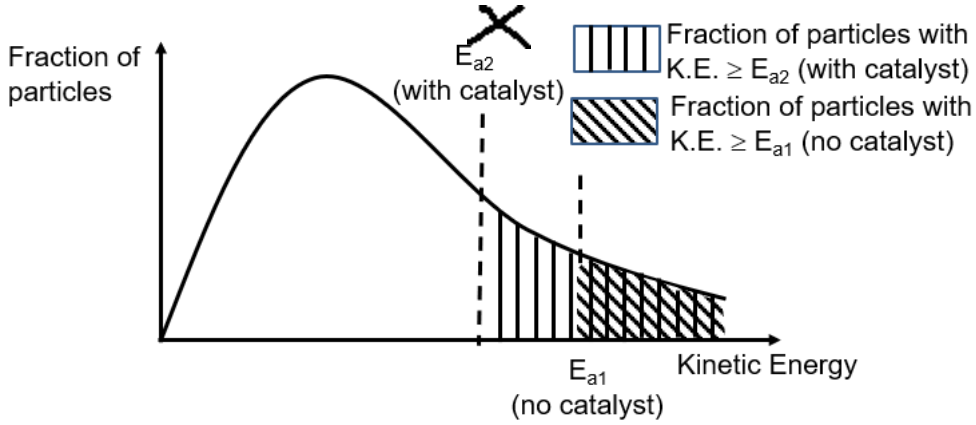
(i) Draw and label a Boltzmann distribution curve for a sample containing 1 mol of ethanol at a particular temperature.



[1]

(ii) On the Boltzmann distribution curve in **(d)(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 **(d)(i)** to explain your answer.

1 mark: Catalyst provides **alternative pathway with lower activation energy**

- Hence, **more molecules** have energy ≥ Ea → **more frequent successful collisions**

1 mark: Leads to an increase in the rate of reaction.

[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

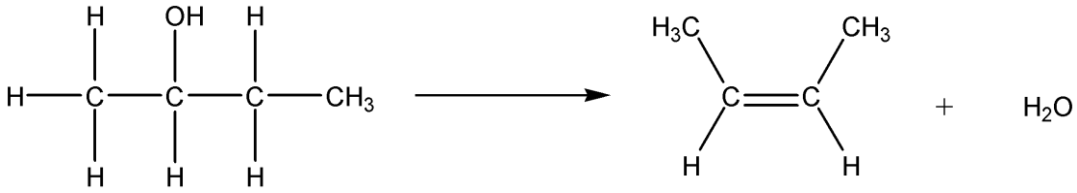
② the number of ethanol molecules that possesses the most probable energy value.

① No change in activation energy (Ea is a property of the reaction)

② Decreases; more particles have lower energy → peak of curve shifts left

[2]

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

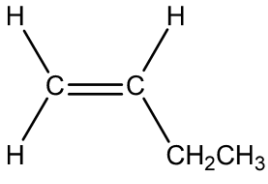


(i) State the isomerism exhibited by the example above.

Cis-trans isomerism

[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.



[1]

The adjacent carbons do not have 2 different groups. [1]

[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 **CuL_4^{2+}** is the copper–ligand complex.

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

1 mark: A dynamic equilibrium is established when the **forward and reverse reactions occur at the same rate**, and the **concentrations of reactants and products remain constant** in a closed system.

[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.

- **1 mark:**

$$K_c = \frac{[CuL_4^{2+}][H^+]^4}{[Cu^{2+}][LH]^4}$$

Units:

$$\frac{(mol\ dm^{-3})(mol\ dm^{-3})^4}{(mol\ dm^{-3})(mol\ dm^{-3})^4} = mol^0\ dm^0 \Rightarrow \text{no units}$$

[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 $[H^+]$ and $[CuL_4^{2+}]$=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.

	Cu^{2+} (aq)	+ 4 LH (org)	⇌ CuL_4^{2+} (org)	+ 4 H^+ (aq)
Initial/ mol dm^{-3}	0.0100	0.0500	-	-
Change / mol dm^{-3}	–0.0010	–0.0040	+0.0010	+0.0040
Equilibrium/ mol dm^{-3}	0.0090	0.0460	0.0010	0.0040

ICE Table [1m], Correct $[Cu^{2+}]$ [1m]

[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.

- **1 mark**: Buffer contains a **weak acid and its conjugate base** (or vice versa)
- **1 mark**: Example equation:

$CH_3COO^- + H^+ \rightarrow CH_3COOH$(removes added acid)
or
$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$(removes added base)

[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.

 1 mark: Buffer maintains a **stable pH** → prevents drastic pH changes due to H^+ release
 1 mark: Without buffer, increasing $[H^+]$ would **shift equilibrium left**, reducing extraction efficiency or causing Cu^{2+} to remain in aqueous layer

[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)

Phenolphthalein will be the more suitable indicator. [1] The working range of phenolphthalein coincides with the equivalence point pH.

[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.

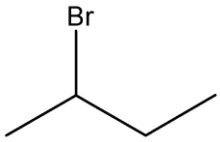
1 mark: Correct condition stated as:
- **UV light** or **sunlight**

[1]

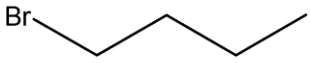
(b) When butane is treated with a small quantity of chlorine under appropriate condition, two mono-substituted isomers, **A** and **B** are produced. When **A** is heated with aqueous sodium hydroxide, **C** is produced which can be oxidised to **D. D does not** react with sodium carbonate.

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

- **Step 1**: Identification of mono-substituted isomers:
  - Butane gives two mono-substituted isomers:

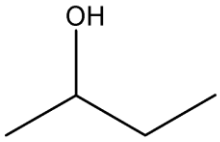


A

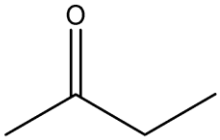


B

    - **1-chlorobutane** and **2-chlorobutane** (B and A)
- **Step 2**: A (e.g., 1-chlorobutane) + NaOH(aq) → **C = Butan-2-ol**
  - **Reaction**: **Nucleophilic substitution**
- **Step 3**: Butan-2-ol + [O] (oxidation) → **D = Butanone**
  - **Reaction**: **Oxidation**
- **Step 4**: Butanone is unable to react with **sodium carbonate** as it is neutral.



C

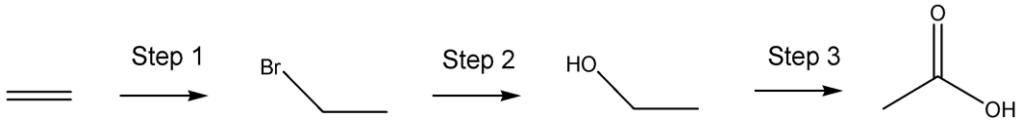


D

Awarding:
- **1 mark**: Correct identification of C (butan-2-ol) and type of reaction (substitution)
- **1 mark**: Correct identification of D (butanone) and type of reaction (oxidation)
- **1 mark**: Explanation of not able to react with sodium carbonate indicating presence of ketone group

[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

Step	Reagents & Conditions	Reaction Type
1. Ethene → Bromoethane	HBr (g), room temperature	Addition
2. Bromoethane → Ethanol	Aqueous NaOH, heat	Substitution
3. Ethanol → Ethanoic acid	$K_2Cr_2O_7$((aq), H_2SO_4 (aq), heat	Oxidation

- 1 mark for correct reagents and conditions (must be mostly accurate)
- 1 mark for correct classification of all three reaction types
- 1 mark for correct sequence/identification of intermediates

[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.

- **1 mark**: Formula used correctly:
  For cube,
  $SA=6x^2, Volume=x^3, SA/V=6/x$
  - 1 μm cube: $SA/V = 6 / (1 \times 10^{-6}\ m) = 6 \times 10^{6}\ m^{-1}$
  - 1 nm cube: $SA/V = 6 / (1 \times 10^{-9}\ m) = 6 \times 10^{9}\ m^{-1}$
- **1 mark**: Clear comparison showing **nanoparticle has 1000× larger SA/V ratio** than microcube

[2]

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

 1 mark: Higher surface area to volume ratio provides **more active sites** for reaction
 1 mark: **Greater catalytic efficiency** with smaller amounts of material, improving cost-effectiveness

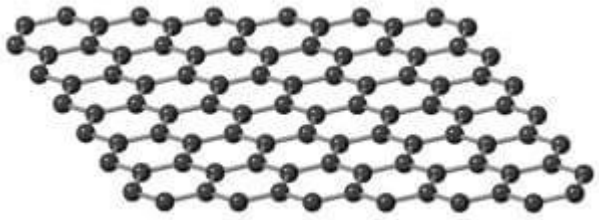
[2]

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

 1 mark: Gecko toes have **nanoscale hairs or structures** (setae)
 1 mark: These increase surface contact → more **van der Waals interactions**, enhancing adhesion

[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

 1 mark: **High tensile strength** due to **strong covalent bonds** in hexagonal carbon lattice
 1 mark: **Electrical conductivity** due to **delocalised π-electrons**
 1 mark: Logical link between structure and property for both cases

[3]

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

1 mark: Valid example e.g. **flexible electronics**, **wearable sensors**, or **conductive, strong composite materials**

[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

1 mark: Small nanoparticles can **pass through cell membranes** or **enter bloodstream via pores**

[1]

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

1 mark each for two valid risks, e.g.:
- Accumulation in tissues → **toxicity or inflammation**
- Unknown **long-term environmental impact**
- Can **cross blood–brain barrier**, causing potential neurological effects

[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.

 1 mark: **Increased surface area** allows faster/more efficient reactions
 1 mark: Better **absorption or interaction** with biological/chemical targets

[2]

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

1 mark: Due to **unknown health/environmental risks** or **unintended side effects** from long-term exposure

[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.

1 mark: Graphene is **has high electrical conductivity** and is thus sensitive to pH changes.

[1]

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

1 mark:

$pH = -\lg(3.2 \times 10^{-5}) \approx 4.49$

[1]

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

- **1 mark**: Balanced argument on **performance vs cost/recyclability** (e.g. nanomaterials offer better strength/performance but are more expensive and less recyclable)
- **1 mark**: Discussion on **environmental and health impacts** (e.g. uncertainty may limit widespread replacement in packaging)

[2]
[Total : 20]

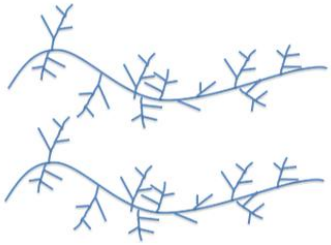
8 A manufacturer is studying the use of different polymers for everyday products. The table shows data on four polymers:

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

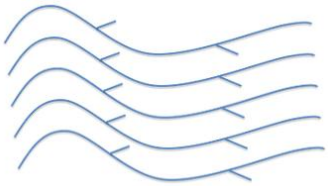
(a) Explain why LDPE is more flexible than HDPE, illustrating your explanation with drawings.

 1 mark: LDPE has **long branched chains** that prevent close packing. This results in **weaker intermolecular forces** → more flexibility

 1 mark: HDPE has **less branching chains/linear chains** that allows close packing. This results in **stronger intermolecular forces** → less flexibility



LDPE



HDPE

1 mark: 2 Diagrams

[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?

 1 mark: Recommend **PP** because of its **high resistance to hydrolysis**
 1 mark: PET is prone to **alkaline hydrolysis** due to ester groups

[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.

1 mark: PP can be **melted** and **reshaped** many times as there are no cross-links between chains

 1 mark: Upon cooling, **new intermolecular interactions** can form, which allows PP to be recycled.

[2]

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

 1 mark: PVA has **–OH groups** that form **hydrogen bonds with water**, allowing solubility
 1 mark: PVC lacks polar groups → mostly hydrophobic → **insoluble in water**

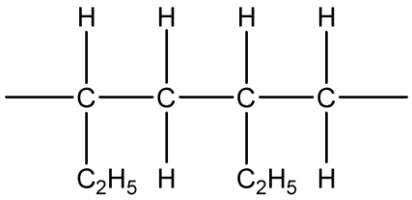
[2]

(ii) Hence suggest a use for PVA

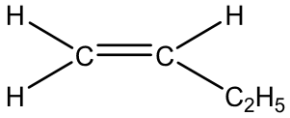
As a water soluble polymer for eye drop/ packaging material for dishwasher detergent pods.

[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.

Additional Polymerisation

[1]

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

Polybutene will have a higher tensile strength due to having longer chains that give rise to stronger instantaneous dipole-induced dipoles between the polymer chains.

[2]

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

 1 mark: **High tensile strength** or rigidity due to aromatic rings

 1 mark: **Low solubility / hydrophobicity / non-polar** due to lack of polar groups

[2]

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

 1 mark: Reduces **waste accumulation** and **environmental pollution**
 1 mark: Conserves **petrochemical resources** / **lowers production cost**

[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.

 1 mark: **Lack of hydrolysable groups** (e.g. no esters) → increased acid stability
 1 mark: **Hydrophobic / non-polar chains** → repel water-based acids, improve resistance

[2]
[Total : 20]