NATIONAL JUNIOR COLLEGE
SH2 MID YEAR TIMED PRACTICE
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY

9476/02
Paper 2 Structured Questions
7 July 2026
2 hours

Candidates answer on Question Paper.
Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft 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	**/7**
2	**/19**
3	**/15**
4	**/18**
5	**/12**
6	**/9**
Paper 2 Total	**/80**

This document consists of **24** printed pages including 1 blank page.

1 **(a)** Two organic compounds, **A** and **B,** can co-polymerise to produce a polyester. On treatment with hot acidified sodium dichromate(VI), compound **A**, $C_4H_{10}O_2$, is converted into compound **B**. Compound **B** can also be formed from fumaric acid, $HO_2CCH=CHCO_2H$, upon treatment with hydrogen over a nickel catalyst

(i) Draw the structures for compounds **A** and **B**.

A	**B**

[2]

(ii) Draw the structural formula of **one** repeat unit of the polymer formed from compounds **A** and **B**.

[1]

Poly(A-B) is a biodegradable plastic and can be used for food packaging like disposable tablewares and paper cups.

(iii) Suggest why poly(A-B) is biodegradable.

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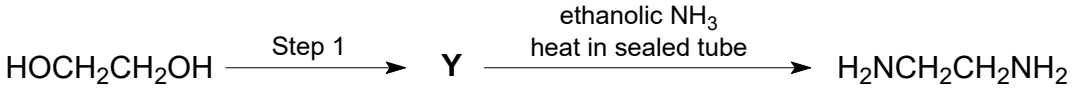
[1]

(b) Ethane-1,2-diol, $HOCH_2CH_2OH$, has a wide variety of uses including in antifreeze in cars. Ethane-1,2-diol undergo a series of steps to form $NH_2CH_2CH_2NH_2$.



(i) Suggest the structure of **Y** and state the reagents and conditions for step 1.

Y: ……..

Step 1: ……..

[2]

(ii) Deduce which compound, $HOCH_2CH_2OH$ or $NH_2CH_2CH_2NH_2$ has a higher boiling point.

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……... [1]

[Total: 7]

2 Bromine can form several compounds under suitable conditions as shown in Table 2.1.

Table 2.1

Bromine containing species	Oxidation number of Br
Br^-	–1
BrO^-	+1
BrF_4^-	+3
BrO_3^-	+5
BrO_4^-	+7

(a) **(i)** Draw the dot-and-cross diagram for BrO_3^-.

[1]

(ii) State and explain the bond angle in BrO_3^-.

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[2]

(b) When a sample of 9.909 g of $Br_2(l)$ was reacted with an excess of aqueous NaOH, two different bromine containing ions, **X** and **Y**, are formed. The identities of **X** and **Y** can be found in Table 2.1. The resulting mixture was then made up to 250 cm^3 with deionised water to form solution **Q**.

The following procedures were carried out on solution **Q**.

1. When 25.0 cm^3 of solution **Q** was acidified with an excess of acid, followed by the addition of $AgNO_3(aq)$, a cream precipitate was formed.
2. This precipitate was insoluble in excess $NH_3(aq)$, and its mass was found to be 1.942 g.
3. To a separate 25.0 cm^3 portion of solution **Q**, excess KI solution was added. The I_2 liberated required 24.80 cm^3 of 0.500 mol dm^{-3} $Na_2S_2O_3$ for complete reaction as shown.

$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2\,I^-$$

(i) Given that ion **X** is responsible for the formation of the cream precipitate, state the identity of **X**.

Ion **X**: …… [1]

(ii) Calculate the amount of **X** in 25.0 cm^3 of solution **Q**.

[1]

(iii) Calculate the amount of bromine atoms in 9.909 g of $Br_2(l)$.
Hence, show that there are 0.00206 mol of **Y** in 25.0 cm^3 of solution **Q**.

[2]

(iv) In step 3, **Y** reacts with KI to form **X**. Deduce the oxidation state of Br in **Y**.

[2]

(v) Using Table 2.1 and your answers in **(iii)** and **(iv)**, construct the balanced equation for reaction between Br_2 and NaOH.

……..……[1]

(c) Br^- reacts with BrO_3^- in acidified medium as shown.

$$BrO_3^- + Br^- + 6H^+ \rightarrow 3Br_2 + 3H_2O$$

A series of kinetic experiments were conducted on this reaction and the data collected were tabulated in Table 2.2.

Table 2.2

Expt	$[BrO_3^-]$ / mol dm^{-3}	$[Br^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	1.20	0.100	1.50	1.00×10^{-2}
2	2.40	0.100	1.50	2.00×10^{-2}
3	1.80	0.200	1.50	3.00×10^{-2}

(i) Use Table 2.2, deduce the order of reaction with respect to $[BrO_3^-]$ and $[Br^-]$.

[2]

(ii) Given that the reaction is 2nd order with respect to $[H^+]$, calculate the value of rate constant, *k*, for experiment 1. Include its units.

[1]

(iii) The initial rate of experiment 1 is determined from the gradient of tangent at time, $t = 0$ when concentration of Br^- is monitored with time.

Given that the concentrations of BrO_3^- and H^+ remain unchanged during the course of reaction, calculate the half-life of this reaction.

Hence sketch the graph of $[Br^-]$ against time.

[2]

(d) A bromine compound, BrC*l* reacts with benzene, in the presence of A*l*C*l*$_3$, to form a monohalogenobenzene, C_6H_5X.

(i) Suggest whether the product C_6H_5X is chlorobenzene or bromobenzene. Explain your answer.

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(ii) Draw the mechanism of the reaction. Include all the relevant dipoles, curly arrows and charges.

Include the structure of the organic intermediate.

[3]

[Total: 19]

3 **(a)** Chloroform, $CHCl_3$ is commonly used as a solvent for paints, lacquers, adhesives, and floor polishes. It can undergo hydrolysis in basic conditions as follows.

$$CHCl_3(aq) + 4OH^-(aq) \rightleftharpoons HCO_2^-(aq) + 3Cl^-(aq) + 2H_2O(l)$$

At 60 °C, 0.20 mol of $CHCl_3$ is mixed with 0.80 mol of NaOH in 2.0 dm^3 of solution and allowed to reach equilibrium. The final concentration of HCO_2^- was found to be 0.098 mol dm^{-3}.

(i) Explain what is meant by the term *dynamic equilibrium*.

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(ii) Write the expression for the equilibrium constant, K_c, for this reaction and state its units.

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(iii) Use these data to calculate the value of K_c.

[2]

(iv) Predict and explain the effect on the equilibrium position when the reaction is repeated at a higher pH.

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…… [1]

(b) A chemical plant has groundwater with contaminated $CHCl_3$ and two other halogenated solvents:

- Methyl iodide, CH_3I
- Benzyl chloride, $C_6H_5CH_2Cl$

The half-lives, $t_{1/2}$, for hydrolysis of the contaminant and solvents in the groundwater at 25°C obtained from environmental monitoring are provided in Table 3.1.

Table 3.1

Compound	$t_{1/2}$
$CHCl_3$	1.4 years
CH_3I	7 days
$C_6H_5CH_2Cl$	15 hrs

(i) Suggest two reasons for the large difference in hydrolysis rates between $CHCl_3$ and CH_3I.

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……[2]

(ii) Benzyl chloride, $C_6H_5CH_2Cl$, hydrolyses rapidly via S_N1 mechanism.
Suggest why benzyl chloride is able to undergo S_N1 mechanism despite being a primary halide.

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…… [1]

(c) **(i)** Compound **X,** $CH_3CH_2CH_2OCH_2CH_3$, is made by reacting 1-chloropropane with ethanol.

Suggest why the yield of this synthesis is improved significantly with the addition of sodium.

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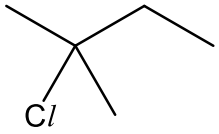
…… [2]

(ii) When 2-chloro-2-methylbutane is treated with CH_3CH_2ONa in ethanol at 80°C, a mixture of three organic products is formed from both substitution and elimination reactions.



2-chloro-2-methylbutane

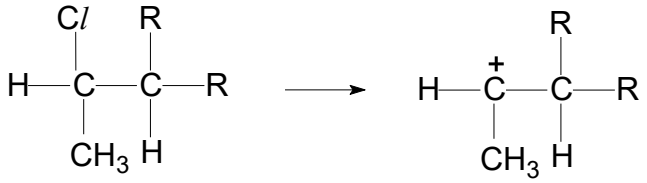
Draw the **skeletal formula** of all the organic products.

[2]

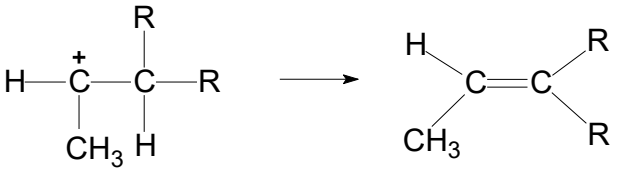
(iii) When 2-chloro-2-methylbutane undergoes elimination, the $CH_3CH_2O^-$ acts as a base and abstracts a proton from the reactive intermediate

Complete the diagram below to show how elimination takes place. Use curly arrows to show movement of electrons. Include all the relevant dipoles, lone pairs and charges.

Step 1:



Step 2:



$CH_3CH_2O^-$ + CH_3CH_2OH

[2]

[Total: 15]

4 This question is about the chemistry of Group 2 elements and their compounds.

(a) The carbonates of Group 2 elements are sparingly soluble in water. The carbonates also decompose upon strong heating. Some of the properties of Group 2 carbonates are given in Table 4.1.

Table 4.1

compound	molar mass / g mol^{-1}	solubility at 25 °C / g dm^{-3}	enthalpy change of thermal decomposition / kJ mol^{-1}
magnesium carbonate	84.3	0.18	+117
calcium carbonate	100.1	0.0066	+178
strontium carbonate	147.6	0.0034	+235
barium carbonate	197.3	0.014	+267

(i) Write the equation, including state symbols, for the thermal decomposition of calcium carbonate.

……..[1]

(ii) Describe and explain the trend of the decomposition temperatures of the Group 2 carbonates.

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(iii) Write the solubility product expression for barium carbonate, including the units.

……..[1]

(iv) Using the data in Table 4.1 and your answer in **(a)(iii)**, calculate the solubility product for barium carbonate.

[2]

(b) The hydroxides of Group 2 elements are also sparingly soluble in water. Given that the solubility of calcium hydroxide is 0.0139 mol dm^{-3} at 25 °C, calculate the pH of a saturated solution of calcium hydroxide at 25 °C.

[2]

(c) When carbon dioxide was bubbled into a saturated solution of calcium hydroxide, a white precipitate of calcium carbonate was formed. However, upon further bubbling of carbon dioxide into the mixture, the precipitate dissolved and a colourless solution of calcium hydrogencarbonate, $Ca(HCO_3)_2$, was obtained.

(i) Write an ionic equation for the formation of hydrogencarbonate ions.

……[1]

(ii) State and explain, using Le Chatelier's Principle, why calcium carbonate dissolves when excess carbon dioxide was bubbled into the mixture.

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……..[2]

(d) Magnesium chloride is a supplement used to increase dietary magnesium intake.

(i) Describe the reaction of magnesium chloride with water. Write an equation for the reaction and state the pH of the resultant solution.

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……..[2]

Some enthalpy changes relating to magnesium chloride are found in Table 4.2.

Table 4.2

	ΔH / kJ mol^{-1}
lattice energy of $MgCl_2$(s)	–2540
standard enthalpy change of hydration of Mg^{2+}(g)	–1980
standard enthalpy change of hydration of Cl^-(g)	–364

(ii) Using data from Table 4.2, calculate the standard enthalpy change of solution, $\Delta H_{sol}^{\ominus}$, of magnesium chloride, $MgCl_2$(s).

[1]

(iii) Given that the standard Gibbs free energy change of solution of magnesium chloride is –126 kJ mol^{-1}, use your answer in **(d)(ii)** to calculate the standard entropy change of solution, $\Delta S_{sol}^{\ominus}$, of $MgCl_2$(s) at 298 K.

[1]

(iv) Predict how the spontaneity of the dissolution of magnesium chloride will change with increasing temperature.

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……[2]

[Total: 18]

5 Fluorine was historically difficult to isolate because it is extremely reactive. It was finally isolated in 1886 by Henri Moissan, who electrolysed a cooled solution of potassium bifluoride (KHF_2) dissolved in anhydrous HF using platinum–iridium electrodes.

(a) (i) Use the data in Table 5.1, together with data from the *Data Booklet*, to calculate a value for the lattice energy of potassium bifluoride, $KHF_2(s)$. Show your working.

Table 5.1

	ΔH / kJ mol^{-1}
enthalpy change for the reaction, $HF(g) + F(g) + e^- \rightarrow HF_2^-(g)$	–568
standard enthalpy change of atomisation of K(s)	+89
standard enthalpy change of formation of $KHF_2(s)$	–928

[4]

(ii) Compare the magnitude of the lattice energy of KHF_2 to that of KF. Explain the difference.

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……[1]

(b) The strength of a carboxylic acid depends on its structure. An example of this is the comparison of ethanoic acid and 2-fluoroethanoic acid.

Acid	pK_a
CH_3CO_2H	4.76
FCH_2CO_2H	2.60

(i) Explain the difference in pK_a values in the above table.

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……... [2]

(ii) Calculate the pH of a solution containing 0.200 mol dm^{-3} of FCH_2CO_2H.

[1]

(iii) Calculate the ratio of $\frac{[CH_3CO_2^-]}{[CH_3CO_2H]}$ when CH_3CO_2H is placed in a buffer solution kept at pH 3.8. Give your answer to three significant figures.

[1]

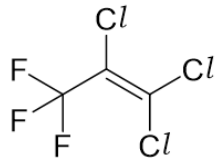
(c) Trifluoroethanoic acid, CF_3CO_2H, is a colourless liquid with a vinegar-like smell. It is produced industrially by electrofluorination of ethanoyl chloride to first give trifluoroethanoyl fluoride, CF_3COF.

(i) State the type of reaction involved for the conversion of CF_3COF into CF_3CO_2H.

……[1]

(ii) An older route to CF_3CO_2H commences from compound **A**.

The synthesis of compound **A** to CF_3CO_2H produces two side products, one of which is a pale-yellow gas.



compound **A**

Suggest the reagents and conditions for the one-step conversion of compound **A** into CF_3CO_2H, and state the identities of the two by-products.

Reagents and conditions	By-products

[2]

[Total: 12]

6 Three compounds, **A**, **B**, and **C**, each containing only carbon, hydrogen, and oxygen, have the same molecular mass of 164. All three compounds are 1,4-disubstituted benzenes and each compound contains exactly one carboxylic acid functional group.

Table 6.1 shows the observations made when separate samples of **A**, **B** and **C** were treated with different reagents under specified conditions.

Table 6.1

Test	Reagents and conditions	Observations with **A**	Observations with **B**	Observations with **C**
1	warm with alkaline aqueous iodine	no change	pale yellow precipitate, **D**, forms	no change
2	add aqueous bromine	no change	no change	orange solution decolourises and white precipitate, **E**, $C_9H_6O_3Br_4$, forms
3	warm with Fehling's solution	brick red precipitate forms	no change	no change
4	add cold alkaline potassium permanganate(VII)	no change	no change	purple solution decolourises
5	add 2,4-dinitrophenylhydrazine	orange precipitate, **F**, forms	orange precipitate forms	no change

(i) For each compound **A**, **B** and **C**, use the information in **Table 6.1** to deduce the functional groups present.

Compound	Functional groups present
A	
B	
C	

[3]

(ii) Suggest the structures for compounds **A**, **B**, **C, D**, **E** and **F**.

[6]

[Total: 9]

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