Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY — 9729/02

Paper 2 Structured Questions

11 September 2024

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
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.
You may lose marks if you do not show your working or if you do not use appropriate units.

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	11
2	12
3	11
4	16
5	25
Total	75

This document consists of **20** printed pages.

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

1 **(a)** The concentration of aluminium ions in a water sample can be determined accurately by titrating it with a solution of $EDTA^{4-}$. The representative balanced equation for the reaction between aluminium ions and $EDTA^{4-}$ is shown below.

$$Al^{3+}(aq) + EDTA^{4-}(aq) \rightarrow [Al(EDTA)]^{-}(aq)$$

A 10.0 cm^3 water sample is transferred to a 250 cm^3 volumetric flask and made up to the mark with deionised water.

An aliquot of 25.0 cm^3 is pipetted and titrated with 0.0200 mol dm^{-3} $EDTA^{4-}$. 35.45 cm^3 of this $EDTA^{4-}$ solution is required for complete reaction with the aluminium ions.

(i) Calculate the amount of $EDTA^{4-}$ that reacted with the aluminium ions.

[1]

(ii) Calculate the amount of aluminium ions in the water sample.

[1]

(b) The process of anodising aluminium increases its resistance to wear and corrosion.

(i) State the two half-equations in the anodising of aluminium and the overall equation to form the protective layer.

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(ii) Draw a labelled diagram to show the cell set-up used to anodise aluminium. Include details of the cathode, anode and electrolyte.

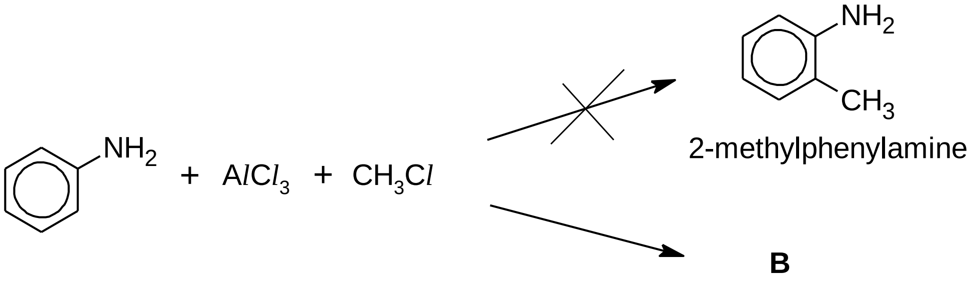
[1]

(c) Aluminium chloride is used extensively as a Lewis acid catalyst in organic reactions with the notable example of *Friedel–Crafts alkylation* of arenes.

(i) State the type of reaction occurring in *Friedel–Crafts alkylation*.

....[1]

(ii) In the presence of aluminium chloride, phenylamine does **not** form 2–methylphenylamine but forms neutral compound **B** instead. Suggest the structure of **B** and hence, explain why 2–methylphenylamine is not formed as expected.



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....[3]

(d) Using relevant data from the *Data Booklet*, explain whether fluorine or chlorine will have greater reactivity with aluminium.

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[Total: 11]

2 Carbon, nitrogen and oxygen are pivotal elements that form a vast array of organic compounds.

(a) Explain the following observations.
- Nitrogen has a smaller atomic radius than carbon.
- Oxygen has a lower first ionisation energy than nitrogen.

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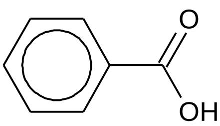
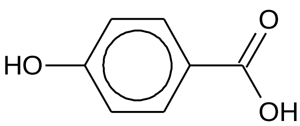
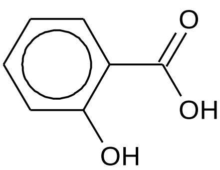
…………………………………………………………………………………………………[3]

Carboxylic acids, esters and ketones are examples of organic compounds containing carbon and oxygen atoms.

(b) Table 2.1 shows a list of organic compounds and the pK_a values of their carboxylic acid group.

Table 2.1

name	structure	pK_a value
benzoic acid		4.2
4–hydroxybenzoic acid		4.6
2–hydroxybenzoic acid		4.1

(i) With reference to the carboxylate anion, explain why carboxylic acids are generally stronger acids than alcohols.

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…………………………………………………………………………………………[1]

(ii) Suggest a reason why

- 4–hydroxybenzoic acid has a higher pK_a value than benzoic acid,
- 2–hydroxybenzoic acid has a lower pK_a value than 4–hydroxybenzoic acid.

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....[3]

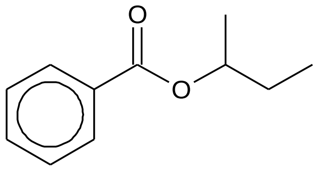
(iii) Carboxylic acids react with Group 2 elements to give an effervescence of hydrogen gas.

State the role of the Group 2 elements in this reaction and describe how the reactivity of the Group 2 elements in this reaction will vary down the group.

....

....[1]

(c) Compound **W** contains an ester functional group.



W

W was heated in an aqueous solution containing $KMnO_4$ and H_2SO_4. Two organic products, compounds **X** and **Y**, were isolated. Table 2.2 contains information about these two products.

Table 2.2

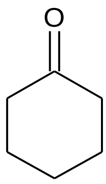
X	Has poor solubility in dilute NaOH.
Y	Dissolves readily in dilute NaOH to give a crystalline solid, compound **Z**, after removing the solvent.

Draw the structures of **X**, **Y** and **Z**.

X	Y	Z

[2]

(d) State a reagent that can be used to distinguish cyclohexanone from ethanoic acid. This reagent should give a positive observation for cyclohexanone.



cyclohexanone

Write the equation for the reaction occurring in this chemical test.

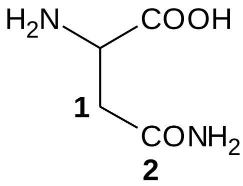
reagent ……………………..………………………………………………………….........

equation ….……………………………………………………………………………..........

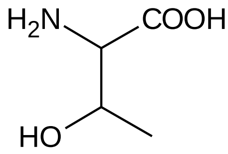
[2]

[Total: 12]

3 **(a)** Asparagine and threonine are essential amino acids vital for protein synthesis.



asparagine



threonine

(i) Draw a dipeptide structure that can be formed from asparagine and threonine.

[1]

(ii) Explain why the side chain of asparagine is neutral.

....

....[1]

(iii) State the oxidation state of carbon atoms labelled **1** and **2** in asparagine.

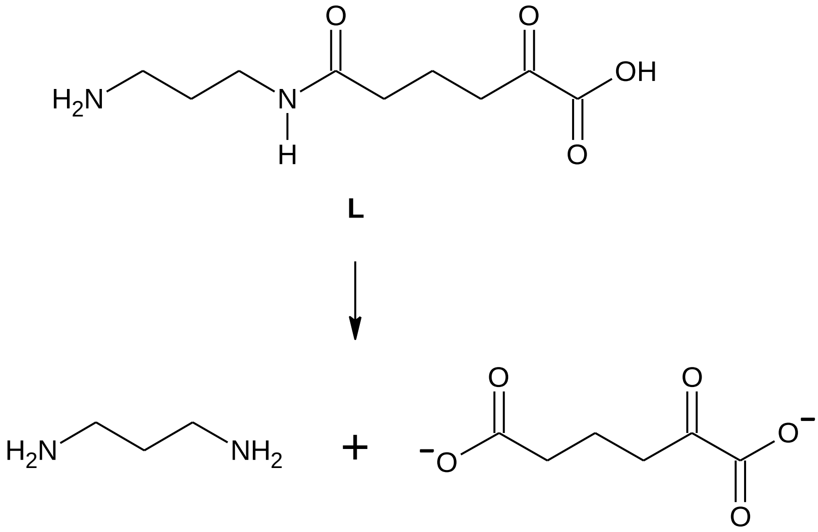
carbon **1** ....   carbon **2** ....

[1]

(iv) Threonine exists as a mixture of stereoisomers. Draw the structure of each stereoisomer of threonine.

[2]

(b) **L** can react to form **M** and **N** as shown below.



L

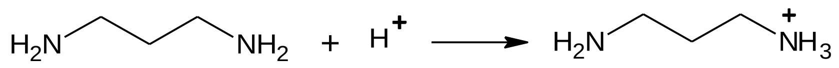
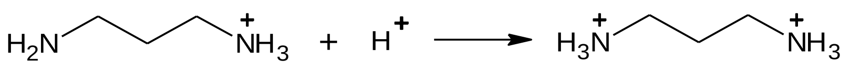
M **N**

(i) State the reagents and conditions required for the reaction to occur.

....[1]

M is a weak diacidic base. Table 3.1 shows the pK_b values of **M**.

Table 3.1

	pK_{b1} = 3.45
	pK_{b2} = 5.12

A 25 cm^3 sample of 0.125 mol dm^{-3} **M** was titrated against 50 cm^3 of 0.125 mol dm^{-3} HC*l*. The pH of the solution was monitored using a pH meter.

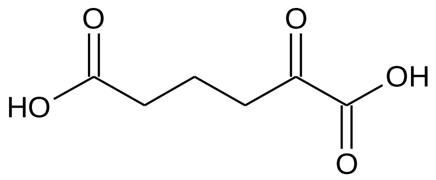
(ii) Calculate the initial pH of the 25 cm^3 sample. Ignore the effects of pK_{b2} on the pH.

[2]

(iii) Calculate the pH of the resulting solution after adding a total of 50 cm^3 of 0.125 mol dm^{-3} HC*l*.

[2]

(iv) **N** can be protonated under acidic conditions to form compound **P**.



P

A hydrocarbon, C_7H_{10}, can be heated with acidified potassium manganate(VII) to form **P**.

Suggest the structure of the hydrocarbon.

[1]

[Total: 11]

4 **(a)** Silver chloride, $AgCl$, is sparingly soluble in water.

$K_{sp}(AgCl) = 1.6 \times 10^{-10}$ at 298 K.

(i) Write the K_{sp} expression for $AgCl$ and state its units.

....[1]

(ii) Describe what you would observe if 20 cm^3 of 0.01 mol dm^{-3} silver nitrate was mixed with 30 cm^3 of 0.10 mol dm^{-3} sodium chloride.

Explain your answer using appropriate calculations.

[2]

(b) White solid of Ag*Cl* dissolves upon the addition of aqueous sodium thiosulfate, $Na_2S_2O_3$, due to the formation of compounds **A** and **B**.

Table 4.1 shows the percentage composition of each of the elements present in **A**. **A** has a formula mass of 401.3.

Table 4.1

element	% composition
Ag	26.9
Na	17.2
O	23.9
S	32.0

Separate samples of **A** and **B** are dissolved in separate samples of deionised water. Neither solution has water ligands present in their complex.

Table 4.2 shows some information about **A**(aq) and **B**(aq).

Table 4.2

	A(aq)	**B**(aq)
oxidation number of metal centre in complex ion	+1	+1
number of different types of ligands in complex ion	1	1
number of ligands in complex ion	2	3

(i) Show that the formula of compound **A** is $AgNa_3O_6S_4$.

[2]

(ii) Deduce the structural formula of the complex ion in **A**(aq).

....[1]

(iii) The ligands in the complex ion in **A**(aq) behave as monodentate ligands.

Name the shape and state the bond angle of the complex ion formed.

shape ………………………………………………………….

bond angle …………………………………………………

[1]

(iv) Write an equation to illustrate the dissolution of AgC*l* due to the formation of the complex ion in **B**.

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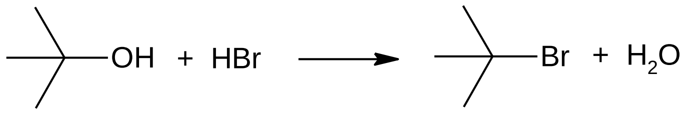
(c) Bromoalkane **X** is made by reacting alcohol **Y** with concentrated hydrobromic acid.

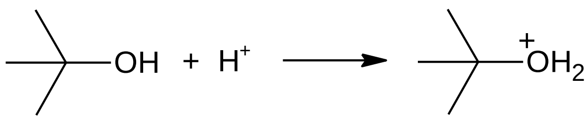


Y **X**

The three steps of the mechanism are described in Table 4.3.

(i) Complete Table 4.3 by
- writing the equations to represent steps 2 and 3,
- drawing mechanisms for steps 2 and 3. Show all charges, curly arrows and relevant lone pair of electrons.

Table 4.3

step	description of step	equation
1	protonation of alcohol **Y** to form **Z**	 **Y** **Z**
2	formation of carbocation intermediate from **Z**	
3	reaction of carbocation intermediate with Br^- to form **X**	

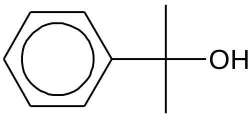
[3]

Step 2 is the rate-determining step of the mechanism described in Table 4.3.

(ii) Suggest the rate equation for the reaction between alcohol **Y** with hydrobromic acid.

……………………………………………………………………………………………[1]

(iii) Alcohol **W** has the following structure.



W

Suggest how the rate of reaction between alcohol **W** and hydrobromic acid would compare with that between alcohol **Y** and hydrobromic acid. Explain your reasoning.

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(iv) Complete the energy profile diagram in Fig. 4.1, for steps 2 and 3 described in Table 4.3. Include labels to show the enthalpy change and the activation energy for each step.

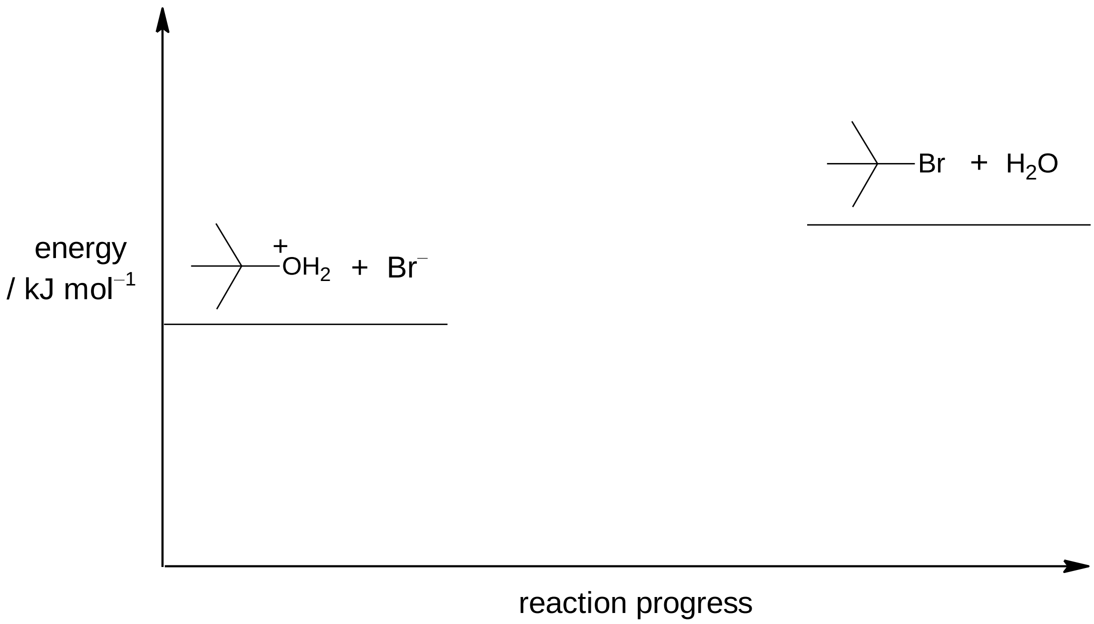

Fig. 4.1

[2]

[Total: 16]

5 **(a)** Table 5.1 shows the standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, for some common fuels and compares the energy released on combustion of these fuels.

Table 5.1

fuel	density at 25 °C and 1 bar / g dm^{-3}	$\Delta H_c^{\ominus}$ / kJ mol^{-1}	energy per gram / kJ g^{-1}	energy per dm^3 at 25 °C and 1 bar / MJ dm^{-3}
diesel	780 – 860	–	45.6	35.6 – 39.2
methane	0.645	−891	55.5	0.0358
ethane	0.784	−1560	52.0	0.0408
propane	1.81	−2219	50.4	0.0912
butane	2.48	−2877	49.6	0.123
ethanol	780	−1367	29.7	23.2

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

....

....[1]

(ii) Suggest why there is no value quoted for the $\Delta H_c^{\ominus}$ of diesel in Table 5.1.

....

....[1]

(iii) Suggest what the regular increase in the numerical values of $\Delta H_c^{\ominus}$ from methane to butane represents.

....

....[1]

(iv) Although each gram of methane releases a large amount of energy on combustion, the large volume needed to store the gas limits its use in vehicles. One possible solution is to store the gas in a pressurised cylinder operating at 25.0 MPa. [1 MPa = 10^6 Pa]

Use the data in Table 5.1 to calculate the energy released per dm^3 of methane at 25 °C and 25.0 MPa.

[1]

(v) Suggest a reason why methane produces the most energy per gram of fuel despite having the least exothermic $\Delta H_c^\ominus$.

....

....[1]

(vi) Explain how the standard entropy change of formation of methane would compare with that of carbon dioxide.

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....

....[2]

(vii) Ethanol exists as a liquid at 25 °C, so it can be stored in conventional fuel tanks.

Explain, in terms of the intermolecular forces involved, two reasons why ethanol has a significantly higher boiling point than ethane.

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....[2]

(b) The global supplies of methane are depleting. Methods are being developed to produce methane from the fermentation of waste organic matter.

(i) Aqueous propanoic acid disproportionates to produce methane and carbon dioxide.

$$4CH_3CH_2COOH(aq) + 2H_2O(l) \rightarrow 5CO_2(g) + 7CH_4(g) \qquad \Delta H$$

Construct the relevant half-equations for this reaction.

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....[2]

(ii) Suggest a method for removing the CO_2 from the gaseous product mixture in **(b)(i)**.

....[1]

(iii) Table 5.2 shows enthalpy change of formation values, ΔH_f, of the reactants and products for the reaction in **(b)(i)**.

Table 5.2

compound	ΔH_f / kJ mol^{-1}
CH_3CH_2COOH	−510
H_2O	−286
CH_4	−75
CO_2	−394

Using the data in Table 5.2, calculate the enthalpy change of the reaction, ΔH.

[2]

(c) Propane and chloroethene are gases at room temperature.

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

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....[2]

(ii) Propane can be liquefied by applying pressure. Explain why the application of pressure causes the gas to liquefy.

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(iii) The plots of $\frac{pV}{RT}$ against p for one mole of an ideal gas and one mole of propane at 273 K are given in Fig. 5.1.

On the same diagram, sketch a curve for the behaviour of 1 mol of chloroethene at 273 K. Explain your answer with reference to significant features of your plot.

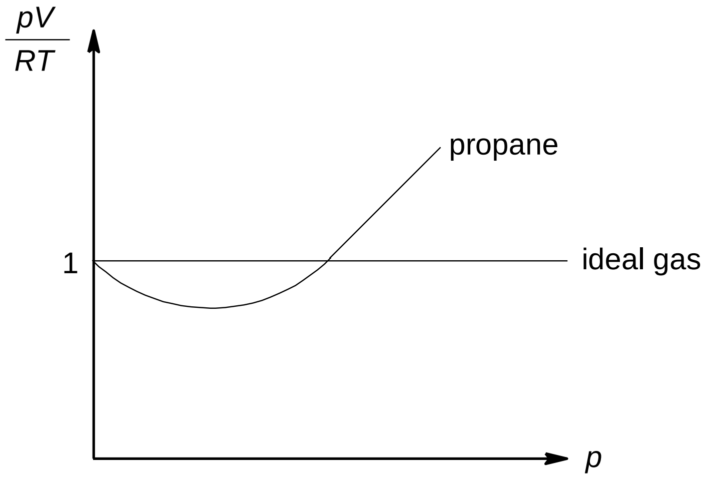

Fig. 5.1

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…………………………………………………………………………………………………[2]

(d) A mixture of CO and H_2 was introduced into a sealed vessel and heated to 1000 K.

$$3CO(g) + 7H_2(g) \rightleftharpoons C_3H_8(g) + 3H_2O(g)$$

At equilibrium, it was found that the total pressure was 28 atm, and the mole fractions of CO and C_3H_8 were 0.44 and 0.10 respectively.

(i) Write an expression for the equilibrium constant, K_p, for this reaction, stating its units.

....[1]

(ii) Calculate the equilibrium partial pressures of all gases. Hence, calculate the value of K_p.

[3]

(iii) A catalyst was added to the sealed vessel. State and explain how the addition of a catalyst will affect the value of K_p.

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....[2]

[Total: 25]