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DUNMAN HIGH SCHOOL

Preliminary Examination

Year 6

H2 CHEMISTRY

Paper 2 Structured Questions

9729/02

18 September 2025

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	15
2	17
3	12
4	10
5	21
Total	75

This document consists of **20** printed pages and **4** blank pages.

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

- 1 (a) Fig. 1.1 shows the relative first ionisation energies of six consecutive elements, **A** to **F**, in the Periodic Table with atomic number less than 20.

The letters are **not** the symbols of the elements.

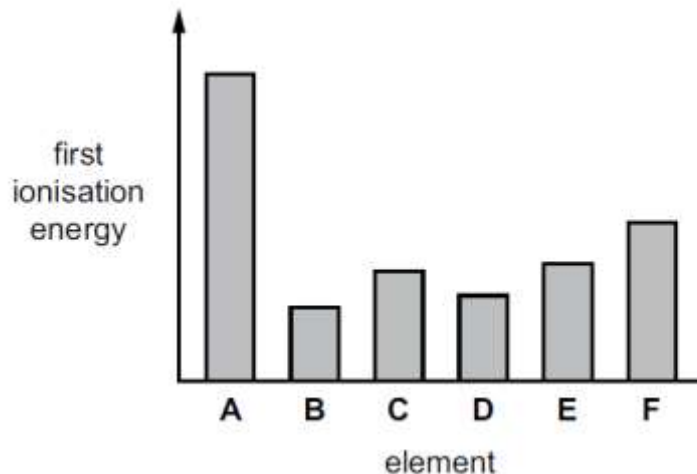


Fig. 1.1

- (i) Write an equation to represent the first ionisation energy of **A**.

..... [1]

- (ii) Explain why the first ionisation energy of **F** is more than that of **E**.

.....

 [1]

- (iii) Which element has the highest 4th ionisation energy? Explain your answer.

.....

 [1]

- (iv) Element **E** is in Period 3.
 Identify element **E** and state the number of electron pairs in an atom of **E**.

.....
 [1]

- (b) 10.0 cm^3 of 0.10 mol dm^{-3} aqueous bromine was added to 50.00 cm^3 of a 0.10 mol dm^{-3} sodium hydroxide solution. The products formed were Br^- and BrO_x^- .

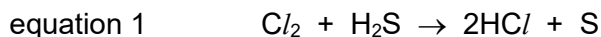
The excess sodium hydroxide required 15.00 cm^3 of 0.20 mol dm^{-3} hydrochloric acid for complete neutralisation.

Calculate the mole ratio between aqueous bromine and sodium hydroxide in the redox reaction.

Hence write a balanced equation for the reaction and deduce the value of x .

[3]

- (c) The halogens Cl_2 and I_2 both react similarly with H_2S . The reaction of Cl_2 with H_2S is shown in equation 1.



- (i) Predict which halogen, Cl_2 or I_2 , has a greater reactivity when added to H_2S . Explain your answer in terms of the role of the halogen in these reactions.

.....
 [1]

- (ii) The white fuming gaseous products, HCl and HI , were collected in separate jars. A piece of red-hot wire was plunged into each jar and purple fumes were observed in one of them.

Explain the observation.

.....

 [2]

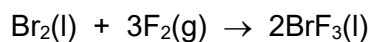
- (iii) Both HI(g) and HCl(g) dissolve readily in water.

Suggest a reagent, other than aqueous silver nitrate, that could be used to distinguish between the aqueous solutions of these two gases. Describe the expected observations.

.....

 [2]

- (d) Bromine and fluorine react together to give bromine trifluoride.



Using the data in Table 1.1, together with data from the *Data Booklet*, construct a fully labelled energy cycle to calculate the average bond energy of the Br–F bond in BrF₃.

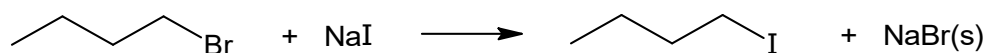
Table 1.1

	$\Delta H^\ominus / \text{kJ mol}^{-1}$
standard enthalpy change of formation of BrF ₃ (l)	–301
enthalpy change of vaporisation of Br ₂ (l)	+31
enthalpy change of vaporisation of BrF ₃ (l)	+44

[3]

[Total: 15]

- 2 The kinetics of the Finkelstein reaction between bromobutane and sodium iodide in propanone forming solid sodium bromide was studied in a series of experiments.



- (a) In experiment 1, 10.0 cm³ of 0.10 mol dm⁻³ bromobutane and 15.0 cm³ of 1.0 mol dm⁻³ sodium iodide were mixed.

Fig. 2.1 shows the concentration of bromobutane against time, t , for this experiment.

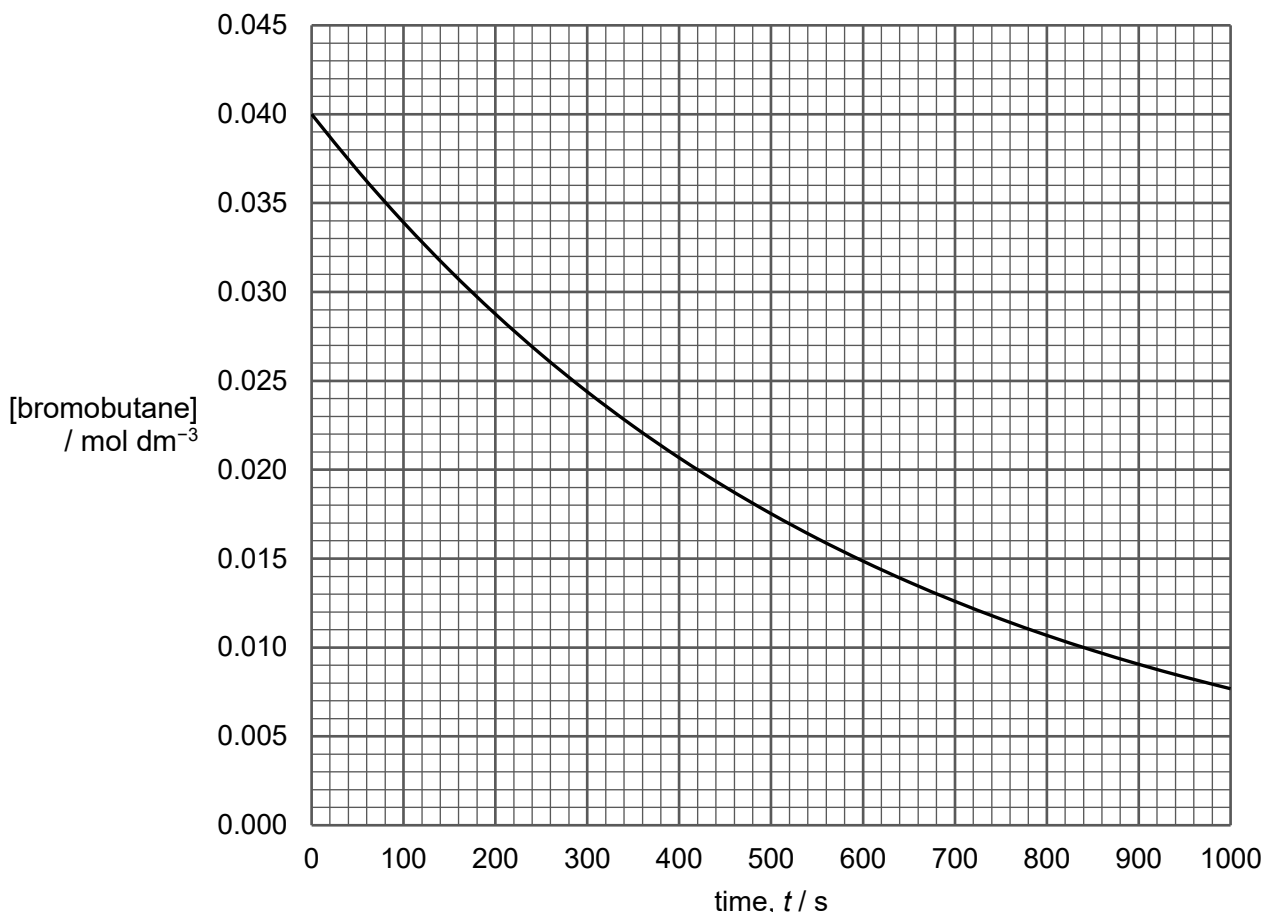


Fig. 2.1

- (i) Use the graph in Fig. 2.1 to determine the order of reaction with respect to bromobutane. Show your working clearly.

.....
 [2]

- (ii) By drawing a tangent at $t = 0$ s, determine the initial rate of reaction. Include its units.

[2]

- (b) In experiments 2 and 3, the time taken for a small and fixed amount of NaBr(s) to be formed was measured. The results obtained are found in Table 2.1.

Table 2.1

experiment	initial [bromobutane] / mol dm ⁻³	initial [sodium iodide] / mol dm ⁻³	time / s
2	0.60	0.60	21
3	0.40	0.40	47

- (i) Use Table 2.1 to determine the order of reaction with respect to sodium iodide. Show your working clearly.

[1]

- (ii) Use your answers to (a)(i) and (b)(i) to write the rate equation for the reaction between bromobutane and sodium iodide. State the units of the rate constant, k .

.....

..... [1]

- (iii) Hence use the initial rate of reaction from (a)(ii) to calculate the value of the rate constant, k .

[2]

(c) The Finkelstein reaction is a nucleophilic substitution reaction that can occur via the S_N1 or S_N2 mechanism.

- (i) Using your answer to (b)(ii), identify the mechanism for the reaction between bromobutane and sodium iodide. Suggest a reason why this is the predominant mechanism.

.....
.....
..... [1]

- (ii) Hence draw the mechanism for the reaction between bromobutane and sodium iodide. Use curly arrows to show the movement of electrons, and include relevant dipoles and lone pair of electrons.

[2]

- (d) The graph of pV/RT against p for one mole of iodobutane gas at 200 °C is shown in Fig. 2.2.

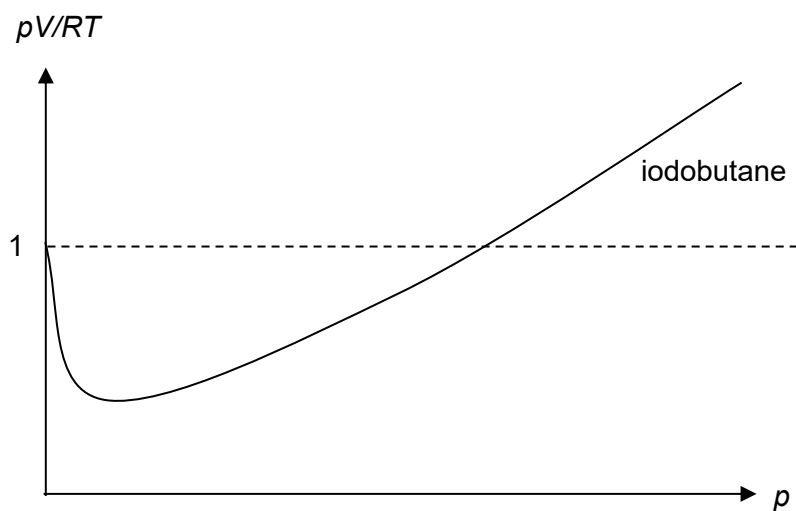


Fig. 2.2

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

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.....

..... [2]

The boiling points of bromobutane and iodobutane are given in Table 2.2.

Table 2.2

	boiling point / °C
bromobutane	101
iodobutane	131

- (ii) Hence show in Fig. 2.2 how one mole of bromobutane will behave at the same temperature. [1]

Freon-11 was one of the most widely used chlorofluorocarbon (CFC) before its use was phased out by the Montreal Protocol.

- (e) 1.868 g of freon-11 gas occupied 356 cm^3 at 200°C and 1.5 bar. Assuming freon-11 gas behaves ideally, calculate its molar mass.

Hence deduce the molecular formula of freon-11, given that each molecule of freon-11 contains one carbon atom only. Show your working clearly.

[3]

[Total: 17]

3 Transition elements show typical properties that distinguish them from s-block elements, such as calcium. These include variable oxidation states in their compounds, and the formation of coloured complexes.

- (a) An ion of vanadium has one electron in its 3d subshell. Deduce the oxidation state of this vanadium ion.

..... [1]

- (b) Table 3.1 gives data about some physical properties of the elements calcium, iron and copper.

Table 3.1

property	calcium	iron	copper
relative atomic mass	40.1	55.8	63.5
atomic radius (metallic) / nm	0.197	0.126	0.128
ionic radius (2+) / nm	0.099	0.076	0.069
density / g cm ⁻³	1.54	7.86	8.92

- (i) Suggest why the atomic radius of iron is smaller than that of calcium.

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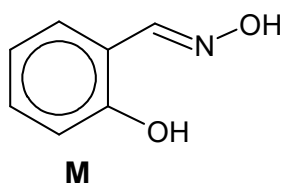
 [1]

- (ii) Explain why the densities of iron and copper are significantly greater than that of calcium.

.....

 [1]

- (c) Compound **M** is formed through the condensation reaction between a suitable aldehyde **A** and hydroxylamine, H_2NOH .



- (i) Write an equation to show the formation of **M** from **A** and H_2NOH .

[1]

The phenolic group in **M** can be deprotonated to form a bidentate ligand. Copper can be extracted by forming an uncharged square planar complex with deprotonated **M**.

- (ii) The oxygen atom of the phenoxide group and the nitrogen atom in deprotonated **M** act as donor sites in the formation of the copper complex.

Draw a structure of the complex, clearly showing the geometry around the copper centre.

[1]

- (iii) State the oxidation number and coordination number of copper in the complex.

oxidation number.....

coordination number.....

[1]

Compound **M** was reacted separately with aqueous bromine and aqueous sodium carbonate.

- (iv) Complete Table 3.2 by predicting the observations that could be obtained with these reagents, and the structure of the organic product (if any) formed. You can assume that the -C=NOH group in **M** is inert.

Table 3.2

reagent	observations	structure of organic product
aqueous bromine		
aqueous sodium carbonate		

[2]

- (d) (i) The yellowish mineral pyrite mainly contains iron and sulfur. Table 3.3 gives the oxidation numbers of the elements in pyrite.

Table 3.3

element in pyrite	oxidation number of element in pyrite
Fe	+2
S	-1

The anion in pyrite has an approximate M_r of 64.

Draw a 'dot-and-cross' diagram to show the type(s) of bonding present within a formula unit of pyrite.

[2]

- (ii) Pyrite ore contains impurities such as copper, arsenic, nickel, cadmium and cobalt. It tends to form iron(III) hydroxide along with other sulfur containing products such as sulfur dioxide when exposed to air and water.

State the type of reaction pyrite undergoes in the presence of air and water and suggest the impact on the environment when water moves through a pyrite-bearing rock.

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 [2]

[Total: 12]

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- 4 (a) Compound **P** is an intermediate formed in the synthesis of Vitamin A. It has molecular formula $C_{15}H_{22}O$ and it reacts with Fehling's reagent to form a brick red precipitate.

When **P** is treated with excess hot concentrated $KMnO_4$, three organic molecules are formed:

- $CH_3CO(CH_2)_3C(CH_3)_2COCO_2H$
- **Q**, $C_3H_4O_3$
- **R**, $HOOC-COOH$

R is further oxidised to form CO_2 .

- (i) State two functional groups present in **P**.

..... [1]

P is reduced to $C_{15}H_{24}O$ by excess reagent **S**.

- (ii) Suggest a possible identity of **S**.

..... [1]

P exists as a mixture of cis-trans isomers.

- (iii) Describe two features in the molecule of **P** that allows it to exhibit cis-trans isomerism.

.....

 [2]

- (b) When **Q** is added to alkaline aqueous iodine, a pale yellow precipitate forms. When **Q** is added to aqueous sodium carbonate, effervescence is observed.

- (i) Draw the displayed formula of **Q**.

[1]

- (ii) Given that the molecule of **P**, $C_{15}H_{22}O$, contains a 6-membered ring, suggest a possible structure of **P**.

[1]

(c) Similar to propanone, **Q** reacts with HCN at pH 10.

(i) Name the type of reaction occurring when **Q** reacts with HCN.

..... [1]

(ii) Suggest a reason why **Q** reacts slower than propanone under the same reaction conditions.

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..... [1]

(d) The pK_a values of ethanoic acid and **R**, $\text{HOOC}-\text{COOH}$, are found in Table 4.1.

Table 4.1

	pK_{a1}	pK_{a2}
ethanoic acid	4.76	-
$\text{HOOC}-\text{COOH}$	1.27	4.28

(i) The pK_{a1} value of $\text{HOOC}-\text{COOH}$ is lower than that of ethanoic acid due to an intramolecular interaction. Draw a labelled diagram to show this intramolecular interaction.

[1]

(ii) Suggest a reason why the pK_{a2} value of $\text{HOOC}-\text{COOH}$ is higher than its pK_{a1} value.

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..... [1]

[Total: 10]

5 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 5.1.

Table 5.1

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	?
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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..... [3]

- (iii) Hence suggest a value for the enthalpy change of thermal decomposition of strontium carbonate.

..... [1]

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

..... [1]

- (v) Using the data in Table 5.1 and your answer in (a)(iv), calculate the solubility product for barium carbonate.

[2]

- (b) The hydroxides of Group 2 elements are also sparingly soluble in water. The solubility of calcium hydroxide is 1.03 g dm^{-3} at 25°C .

- (i) Calculate the concentration of calcium ions, in mol dm^{-3} , in a saturated solution of calcium hydroxide at 25°C .

[1]

- (ii) Hence, 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, $\text{Ca}(\text{HCO}_3)_2$, was obtained.

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

..... [1]

(ii) Use Le Chatelier's Principle to explain why calcium carbonate dissolves when excess carbon dioxide was bubbled into the mixture.

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..... [1]

(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 5.2.

Table 5.2

	value / kJ mol^{-1}
lattice energy of $\text{MgCl}_2(\text{s})$	-2540
standard enthalpy change of hydration of $\text{Mg}^{2+}(\text{g})$	-1980
standard enthalpy change of hydration of $\text{Cl}^{-}(\text{g})$	-364

(ii) Define the term *lattice energy of magnesium chloride*.

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..... [1]

- (iii) Suggest a reason for the sign of the standard enthalpy change of hydration of $\text{Mg}^{2+}(\text{g})$.

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..... [1]

- (iv) Using data from Table 5.2, calculate the standard enthalpy change of solution, $\Delta H_{\text{sol}}^{\ominus}$, of magnesium chloride.

[1]

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

[1]

- (vi) Predict, with reasoning, how the spontaneity of the dissolution of magnesium chloride will change with increasing temperature.

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..... [2]

[Total: 21]

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