



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 **16** printed 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.

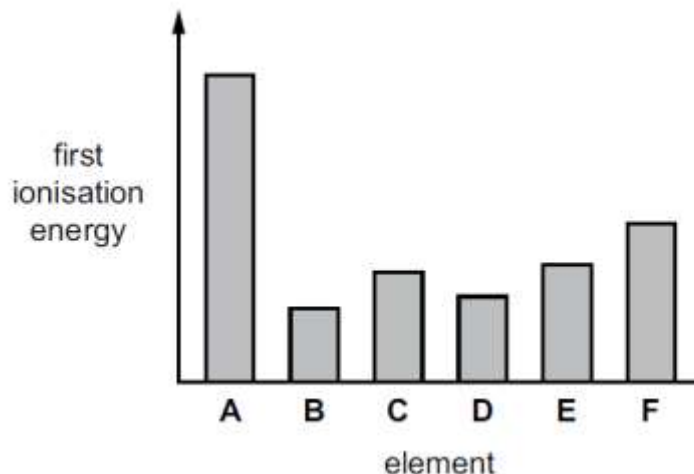
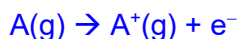


Fig. 1.1

- (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]

Both elements have similar shielding effect. However, F has a greater nuclear charge. Hence, F has a greater effective nuclear charge than E. The attraction between the nucleus and the outermost electron is stronger in F.

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

[1]

Element D. It is in Group 13 with outermost shell electronic configuration of $ns^2 np^1$. The 4th ionisation energy involves removal of an electron from an inner electron shell. Or 4th valence electron is removed from an inner electron shell.

- (iv) Element **E** is in Period 3.

Identify element **E** and state the number of electron pairs in an atom of **E**.

[1]

element E is silicon

number of electron pairs in an atom of E is 6

- (b) 10.0 cm³ of 0.10 mol dm⁻³ aqueous bromine was added to 50.00 cm³ 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 cm³ 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]

$$\text{Initial amount of NaOH} = \frac{50.00}{1000} \times 0.10 = 5.00 \times 10^{-3} \text{ mol}$$

$$\text{amount of NaOH reacted with HCl(aq)} = \frac{15.00}{1000} \times 0.20 = 3.00 \times 10^{-3} \text{ mol}$$

$$\begin{aligned} \text{amount of NaOH reacted with aqueous Br}_2 &= (5.00 \times 10^{-3}) - (3.00 \times 10^{-3}) \\ &= 2.00 \times 10^{-3} \text{ mol} \end{aligned}$$

$$\text{amount of Br}_2 \text{ used} = \frac{10.00}{1000} \times 0.10 = 1.00 \times 10^{-3} \text{ mol}$$

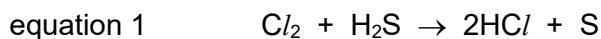
$$\text{mole ratio of Br}_2 : \text{NaOH} = 1 : 2$$

Balanced ionic equation:



$$x = 1$$

- (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]

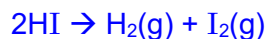
Cl_2 has a greater reactivity than I_2 as Cl_2 is a stronger oxidising agent than I_2 .

- (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]

Purple fumes observed is iodine vapour when HI thermally decomposed



Bond energy of $\text{H-I} < \text{H-Cl}$ the covalent bond length of $\text{H-I} > \text{H-Cl}$.

A lower amount of energy is required to overcome the weaker H-I covalent bond.

Thermal stability of $\text{HI} < \text{HCl}$, HI decomposes readily in the presence of a red-hot wire to give purple iodine vapour. However, insufficient energy is provided to overcome H-Cl bond. HCl does not decompose.

- (iii) Both $\text{HI}(\text{g})$ and $\text{HCl}(\text{g})$ 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]

Add $\text{Cl}_2(\text{aq})$ or Cl_2 gas into $\text{HCl}(\text{aq})$ and $\text{HI}(\text{aq})$ separately.

With $\text{HCl}(\text{aq})$, solution remains colourless.

With $\text{HI}(\text{aq})$, solution turns brown due to the formation of $\text{I}_2(\text{aq})$.

OR

Add $\text{Br}_2(\text{aq})$ into $\text{HCl}(\text{aq})$ and $\text{HI}(\text{aq})$ separately.

With $\text{HCl}(\text{aq})$, solution turns orange.

With $\text{HI}(\text{aq})$, solution turns brown due to the formation of $\text{I}_2(\text{aq})$.

Also accept:

Add $\text{Pb}(\text{NO}_3)_2(\text{aq})$ into $\text{HCl}(\text{aq})$ and $\text{HI}(\text{aq})$ separately.

With $\text{HCl}(\text{aq})$, white ppt of PbCl_2 .

With $\text{HI}(\text{aq})$, yellow ppt of PbI_2 .

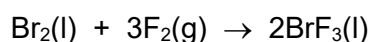
OR

Add $\text{Cu}(\text{NO}_3)_2(\text{aq})$ into $\text{HCl}(\text{aq})$ and $\text{HI}(\text{aq})$ separately.

With $\text{HCl}(\text{aq})$, solution turns blue (due to Cu^{2+} present).

With $\text{HI}(\text{aq})$, white ppt (due to CuI) in brown solution (due to I_2)

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

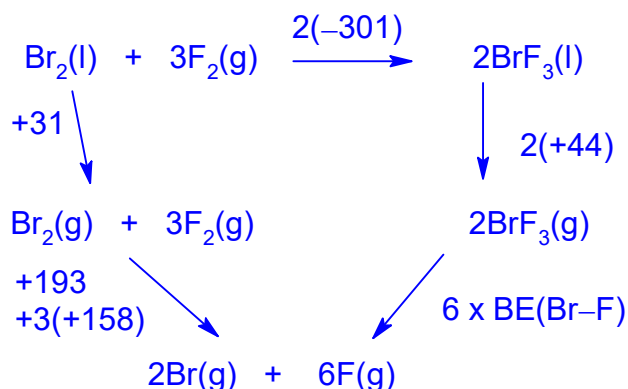


Using the data in Table 1.1, together with data from the *Data Booklet*, construct a fully labelled energy cycle to calculate the average bond energy of the Br–F bond in BrF_3 .

Table 1.1

process	$\Delta H^\ominus / \text{kJ mol}^{-1}$
Standard enthalpy change of formation of $\text{BrF}_3(\text{l})$	–301
Enthalpy change of vaporisation of $\text{Br}_2(\text{l})$	+31
Enthalpy change of vaporisation of $\text{BrF}_3(\text{l})$	+44

[3]



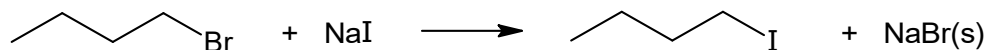
By Hess' Law,

$$2(-301) = (+31) + (+193) + 3(+158) - 6\text{BE}(\text{Br}-\text{F}) - 2(+44)$$

$$\text{average BE}(\text{Br}-\text{F}) = +202 \text{ kJ mol}^{-1}$$

[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.

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

[2]

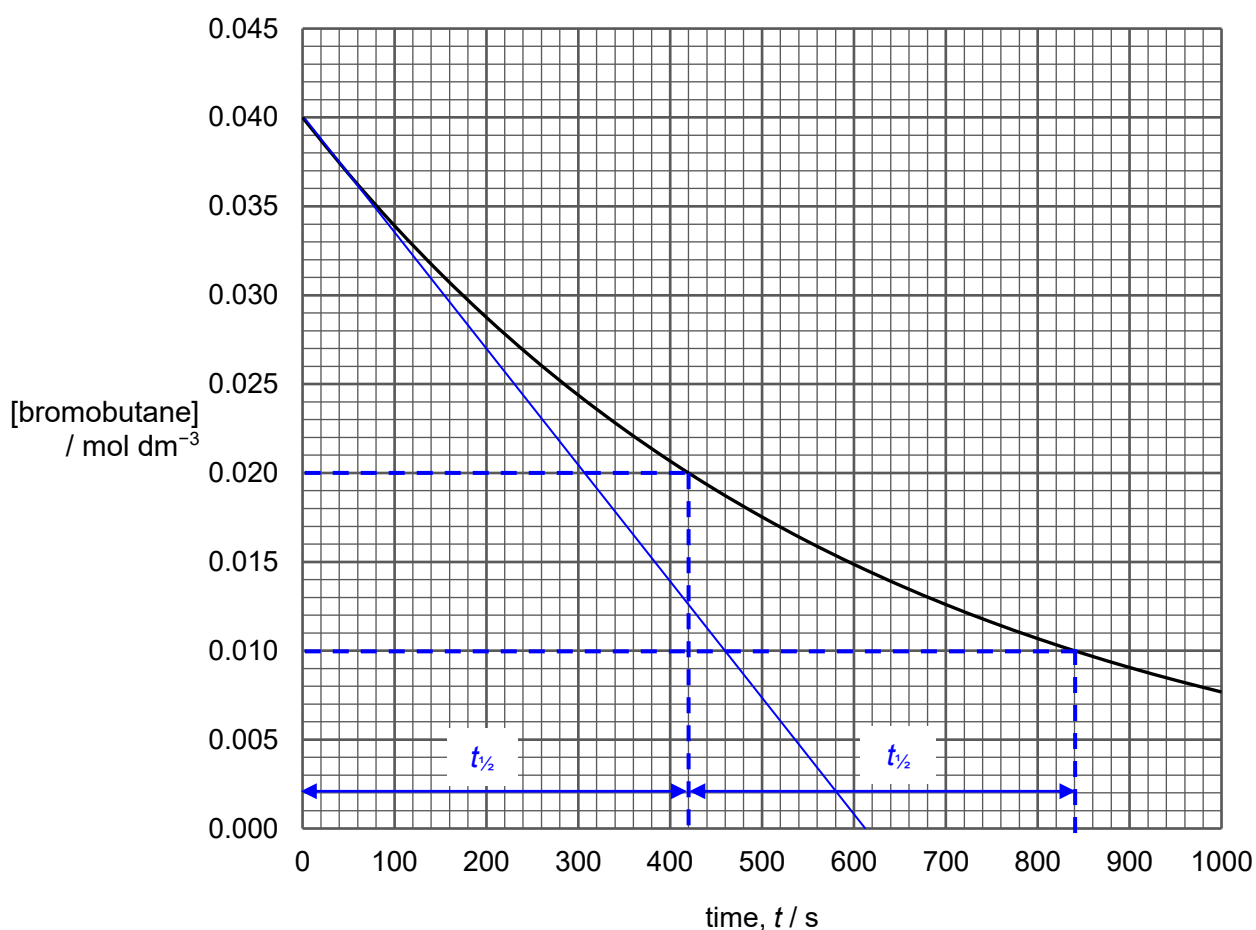


Fig. 2.1

Since $t_{1/2}$ is constant at 420 s, the reaction is first order wrt bromobutane.

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

[2]

$$\text{rate of reaction} = \frac{0.04}{610} = 6.56 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$$

- (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]

Since the extent of reaction is kept constant, relative rate $\propto \frac{1}{t}$.

Let the order of reaction w.r.t. NaI be x .
Comparing the rate of experiments 2 and 3,

$$\frac{\text{rate}_2}{\text{rate}_3} = \frac{k[\text{bromobutane}][\text{NaI}]^x}{k[\text{bromobutane}][\text{NaI}]^x}$$

$$\frac{1/21}{1/47} = \frac{k \times 0.60 \times (0.60)^x}{k \times 0.40 \times (0.40)^x}$$

$$1.49 = \left(\frac{0.60}{0.40}\right)^x$$

$x = 1$ (to nearest whole number)

- (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]

rate = $k[\text{bromobutane}][\text{NaI}]$
units of $k = \text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$

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

[2]

For experiment 1,

$$\text{initial } [\text{NaI}] = \frac{15.0 \times 1.0}{25.0} = 0.60 \text{ mol dm}^{-3}$$

$$\text{rate} = k[\text{bromobutane}][\text{NaI}]$$

$$6.56 \times 10^{-5} = k \times 0.040 \times 0.60$$

$$k = 2.73 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

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

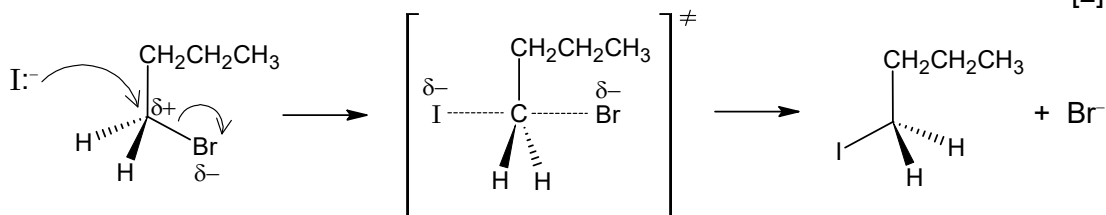
- (i) Using your answer to (b)(ii), identify the mechanism for the reaction between bromobutane and sodium iodide. Suggest a reason why this is the predominant mechanism.

[1]

The reaction goes by S_N2 mechanism. Bromobutane is a primary alkyl halide with little steric hindrance around the electrophilic (δ^+) C, hence the I^- nucleophile is able to approach the relatively-unhindered electrophilic (δ^+) C easily.

- (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.

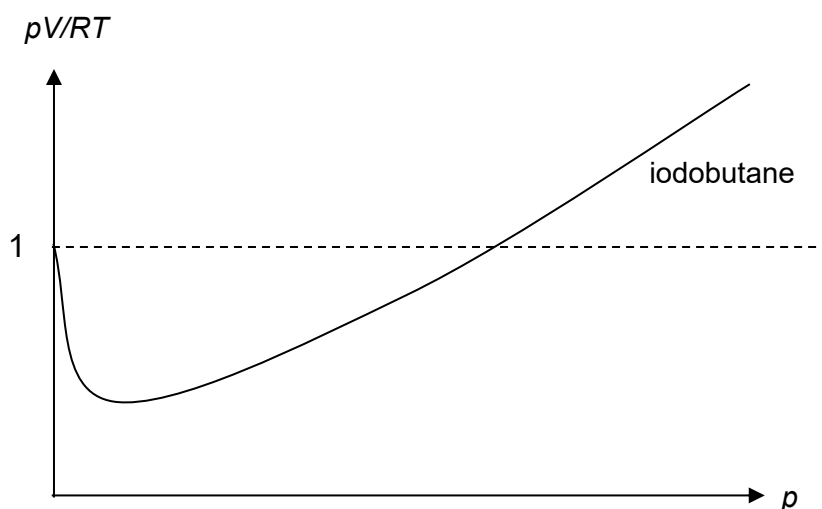


Fig. 2.2

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

[2]

The gas particles have negligible volume compared to that of the container.
There are negligible intermolecular forces of attraction between gas particles.

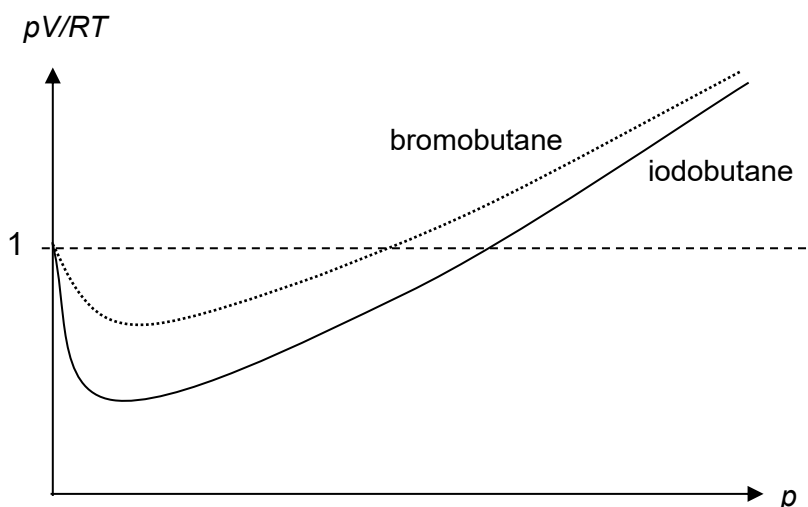
The boiling points of bromobutane and iodobutane are given in Table 2.2.

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 cm³ 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]

$$\begin{aligned}
 pV &= nRT \\
 pV &= \frac{m}{M}RT \\
 M &= \frac{mRT}{pV} \\
 &= \frac{1.868 \times 8.31 \times (200+273)}{(1.5 \times 10^5) \times (356 \times 10^{-6})} \\
 &= 137.5 \text{ g mol}^{-1} \text{ (to 1 d.p.)}
 \end{aligned}$$

By trial and error, the molecular formula of freon-11 is CCl₃F.

$$12.0 + (3 \times 35.5) + 19.0 = 137.5$$

[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.

[1]

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

V atom has 23 electrons.

Electronic configuration of V is 1s²2s²2p⁶3s²3p⁶3d³4s²

Since only one electron remains in the 3d subshell, hence 4 outermost electrons are lost. The oxidation state of V is +4.

- (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.

[1]

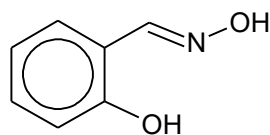
Atomic radius of Fe < Ca due to its higher nuclear charge and poor shielding by 3d electrons. Hence higher effective nuclear charge for Fe, resulting in smaller radius.

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

[1]

Both iron and copper have greater atomic mass packed into a smaller volume as the atomic radii of Fe and Cu are smaller than Ca.

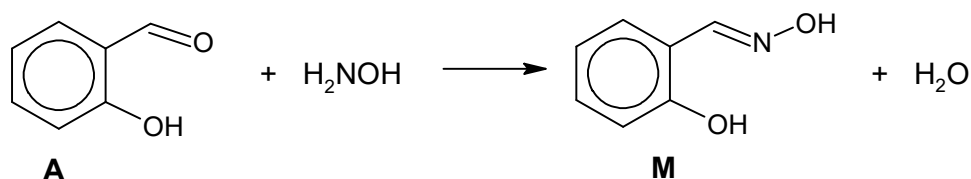
- (c) Compound **M** is formed through the condensation reaction between a suitable aldehyde **A** and hydroxylamine, H₂NOH.



M

- (i) Write an equation to show the formation of **M** from **A** and H₂NOH.

[1]

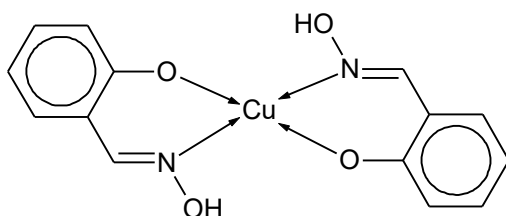


The phenolic group in **M** can be deprotonated to form a bidentate ligand. Copper can be extracted by forming an uncharged square planar complex with deprotonated **M**.

- (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. [1]

Oxidation number: +2

Coordination number: 4

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. [2]

Table 3.2

reagent	observations	structure of organic product
aqueous bromine	orange $\text{Br}_2(\text{aq})$ decolourised + white ppt	
aqueous sodium carbonate	no effervescence of CO_2	nil

- (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.

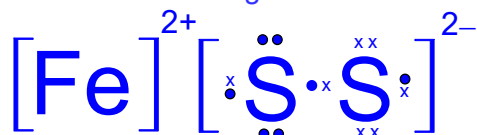
Draw a 'dot-and-cross' diagram to show the type(s) of bonding present within a formula unit of pyrite. [2]

Anion in pyrite has an approximate M_r of 64.

\Rightarrow anion is S_2^{2-}

Hence ionic bonding is present within a formula unit of pyrite, FeS_2 .

Dot-and-cross diagram:



- (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.

[2]

Oxidation.

SO₂ can be dissolved in water to give sulfurous acid. This increases the acidity level that endanger aquatic lives. Or other environmental concerns such as

- 'acid rain', which can damage limestone buildings and monuments
- acidification of soil, decreasing its pH and making it less suitable for plant growth.
- Pyrite contains other heavy metals ions that can be released and these ions can contaminate water sources, enter the food chain, and pose health risks to humans and animals.

[Total: 12]

- 4 (a) Compound **P** is an intermediate formed in the synthesis of Vitamin A. It has molecular formula C₁₅H₂₂O and it reacts with Fehling's reagent to form a brick red precipitate.

When **P** is treated with excess hot concentrated KMnO₄, three organic molecules are formed:

- CH₃CO(CH₂)₃C(CH₃)₂COCO₂H
- **Q**, C₃H₄O₃
- **R**, HOOC–COOH

R is further oxidised to form CO₂.

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

[1]

aliphatic aldehyde and alkene

P is reduced to C₁₅H₂₄O by excess reagent **S**.

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

[1]

NaBH₄ OR LiAlH₄

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]

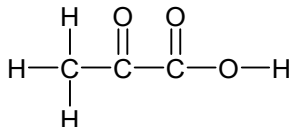
Restricted rotation due to C=C or rigid ring

Two different atoms or groups of atoms attached to each carbon of the C=C bond

- (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.

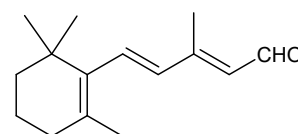
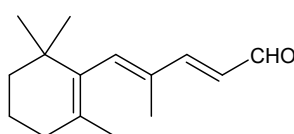
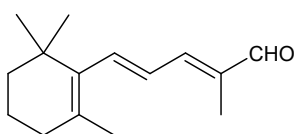
- (i) Draw the displayed formula of **Q**.

[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]



any one possible structure

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

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

[1]

Nucleophilic addition

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

[1]

The $-COO^-$ group is larger than the methyl group, exerting greater steric hindrance to the approaching CN^- nucleophile.

OR

The carboxylic acid group is deprotonated under basic conditions, hence the carboxylate anion repels the negatively charged CN^- nucleophile.

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

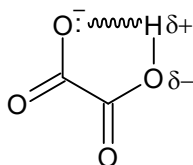
Table 4.1

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

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

[1]

hydrogen bonding



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

[1]

The removal of an H^+ from $\text{HO}_2\text{CCO}_2^-$ that already carries a negative charge would be unfavourable.

OR

The stabilisation of the mono-anion by hydrogen bonding would be destroyed when the second $-\text{CO}_2\text{H}$ group ionises. Hence pK_{a2} of $\text{HOOC}-\text{COOH}$ is higher than its pK_{a1} value.

[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.

[3]

Decomposition temperature increases from MgCO_3 to BaCO_3
 Ionic radius of metal cation increases from Mg^{2+} to Ba^{2+} / down the group
 Charge density / polarising power of metal cation decreases from Mg^{2+} to Ba^{2+}
 / down the group

Extent of polarisation / distortion of electron cloud of CO_3^{2-} by metal cation decreases from Mg^{2+} to Ba^{2+} / down the group
 Extent of weakening of covalent bonds in CO_3^{2-} decreases from Mg^{2+} to Ba^{2+} / down the group
 More energy is required for the decomposition of Group 2 carbonates from MgCO_3 to BaCO_3

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

[1]

+235 (kJ mol^{-1})

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

[1]

$$K_{\text{sp}} = [\text{Ba}^{2+}][\text{CO}_3^{2-}]$$

$$\text{mol}^2 \text{ dm}^{-6}$$

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

[2]

$$\begin{aligned} \text{solubility of BaCO}_3 &= 0.014 \div 197.3 \\ &= 7.0958 \times 10^{-5} \text{ mol dm}^{-3} \\ K_{\text{sp}} \text{ of BaCO}_3 &= (7.0958 \times 10^{-5})^2 \\ &= 5.04 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6} \end{aligned}$$

- (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]

$$\begin{aligned} \text{Solubility of Ca(OH)}_2 &= 1.03 \div 74.1 \\ &= 0.013900 \\ &= 0.0139 \text{ mol dm}^{-3} \end{aligned}$$

$$[\text{Ca}^{2+}] = 0.0139 \text{ mol dm}^{-3}$$

- (ii) Hence, calculate the pH of a saturated solution of calcium hydroxide at 25°C .

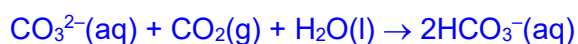
[2]

$$\begin{aligned} [\text{OH}^-] &= 2 \times 0.0139 \\ &= 0.0278 \text{ mol dm}^{-3} \\ \text{pOH} &= -\lg 0.0278 \\ &= 1.5556 \\ \text{pH} &= 14 - 1.5556 \\ &= 12.4 \end{aligned}$$

- (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.

[1]

By Le Chatelier's Principle, the decrease in $[\text{CO}_3^{2-}]$ results in the position of equilibrium of " $\text{CaCO}_3 \rightleftharpoons \text{Ca}^{2+} + \text{CO}_3^{2-}$ " to shift to the right (to increase $[\text{CO}_3^{2-}]$). Hence, the white precipitate dissolves.

- (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.

[2]

MgCl_2 dissolves in water and undergoes partial hydrolysis to give a slightly acidic solution with pH 6.5.



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*.

[1]

It is the energy evolved when one mole of solid magnesium chloride is formed from its constituent gaseous ions, Mg^{2+} and Cl^- , under standard conditions.

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

[1]

Energy is released upon formation of ion-dipole interactions between Mg^{2+} ions and water molecules.

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

[1]

$$\begin{aligned}\Delta H_{\text{sol}}^\ominus (\text{MgCl}_2) &= -\text{L.E.} (\text{MgCl}_2) + \Delta H_{\text{hyd}}^\ominus (\text{Mg}^{2+}) + 2\Delta H_{\text{hyd}}^\ominus (\text{Cl}^-) \\ &= -(-2540) + (-1980) + 2(-364) \\ &= -168 \text{ kJ mol}^{-1}\end{aligned}$$

- (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]

$$\begin{aligned}\Delta G_{\text{sol}}^\ominus &= \Delta H_{\text{sol}}^\ominus - T\Delta S_{\text{sol}}^\ominus \\ -126 &= -168 - [298 \times \Delta S_{\text{sol}}^\ominus (\text{MgCl}_2)]\end{aligned}$$

$$\begin{aligned}\Delta S_{\text{sol}}^{\ominus}(\text{MgCl}_2) &= -0.14094 \text{ kJ mol}^{-1} \text{ K}^{-1} \\ &= -141 \text{ J mol}^{-1} \text{ K}^{-1}\end{aligned}$$

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

[2]

When temperature increases, $-T\Delta S_{\text{sol}}$ becomes more positive.

Since $\Delta G_{\text{sol}} = \Delta H_{\text{sol}} - T\Delta S_{\text{sol}}$, ΔG_{sol} will become less negative / more positive with increasing temperature. Hence, the dissolution is less spontaneous at higher temperatures.

[Total: 21]