Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY

Paper 1 Multiple Choice

9729/01

25 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D.**
Choose the one you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

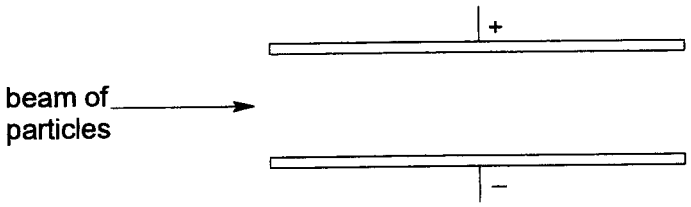
Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **12** printed pages.

[Turn over

1 In two separate experiments, a beam of alpha particles ($^4He^{2+}$) and a beam of charged particles **X** were fired with equal velocities into an electric field.



The angle of deflection of the charged particles, $^4He^{2+}$ and **X**, was found to be +1° and +6° respectively.

Which statement is correct?

A **X** is negatively charged.

B **X** travels in a straight path towards one of the charged plates.

C **X** could be a $^{12}C^+$ ion.

D None of the above.

2 *Use of the Data Booklet is relevant to this question.*

W is an isotope of an element. An isotope of strontium has a nucleon number of 84 and the same number of neutrons in the nucleus as the isotope **W**.

The species Sr^{2+} and **W** contain the same number of electrons.

What is the nucleon number of **W** and how many orbitals are occupied in its valence shell?

	W	number of orbitals occupied in valence shell
A	80	3
B	82	4
C	82	3
D	84	4

3 The molecules CO_2, CS_2 and COS have the same shape.

Which statements are correct?

1 The molecules all contain polar covalent bonds.

2 The molecules each contain two sigma and two pi bonds.

3 Only COS has permanent dipole–permanent dipole interactions.

4 COS has stronger instantaneous dipole–induced dipole interactions than CS_2.

A 1, 2 and 3 only

B 2 and 4 only

C 2 and 3 only

D 1 and 4 only

4 Which row correctly describes the structure and bonding present in the solid lattice of the given substance?

	substance	structure	bonding
A	ice	giant molecular	covalent and hydrogen bonding
B	iodine	simple molecular	covalent bonding and permanent dipoles
C	sodium nitrate	giant ionic	ionic and covalent bonding
D	manganese	giant metallic	ionic bonding

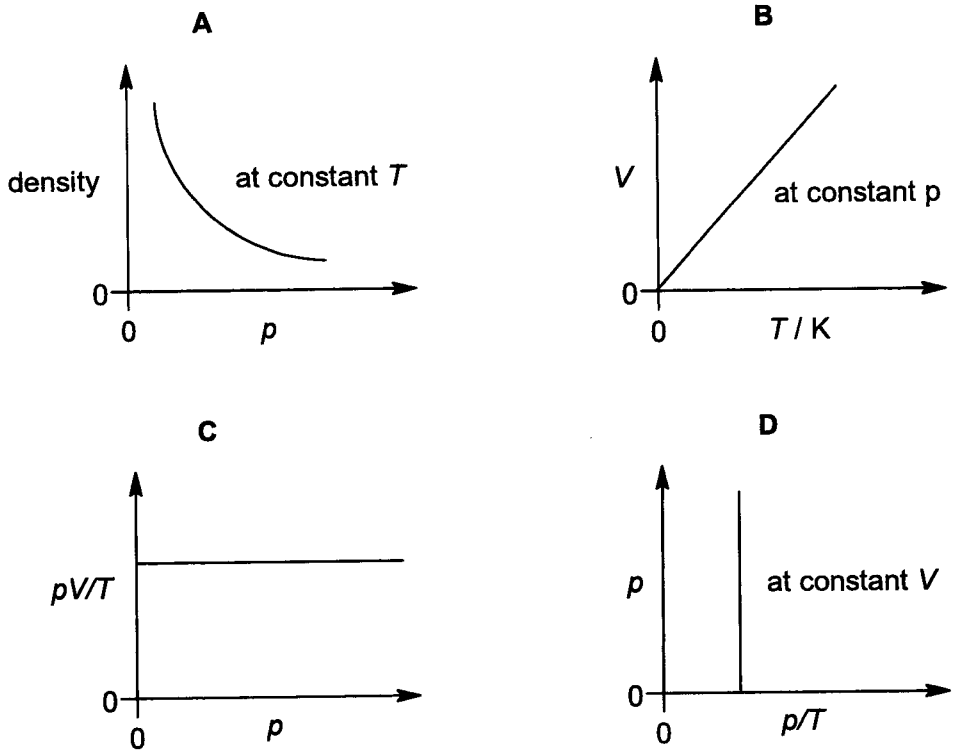
5 Analysis of a mixture of sulfur–containing gases shows that hydrogen sulfide, H_2S, and carbon disulfide, CS_2, are present in a 2 : 1 mole ratio.

60 cm^3 of the gaseous mixture is burned in excess oxygen. The resulting gases are bubbled through aqueous sodium hydroxide. All volumes are measured under the same temperature and pressure.

Which row correctly describes
- the SO_2 : CO_2 mole ratio in the gaseous mixture obtained after complete combustion and
- the reduction in volume of the gaseous mixture when bubbled through NaOH(aq)?

	SO_2 : CO_2 mole ratio	reduction in volume
A	3 : 1	80 cm^3
B	4 : 1	80 cm^3
C	3 : 1	100 cm^3
D	4 : 1	100 cm^3

6 Which graph does **not** represent the behaviour of a fixed mass of an ideal gas?



7 0.00200 mol of nitrate ions was reduced by 30.0 cm^3 of 0.200 mol dm^{-3} iron(II) sulfate to form a brown iron(III) complex.

What is a possible identity of the nitrogen–containing product?

A N_2 **B** NO

C NO_2^- **D** NO_2

8 **K**, **L** and **M** are elements with atomic numbers between 11 and 18. They have the following properties compared to other elements in Period 3.

- **K** has the largest ionic radii.
- **L** has the highest melting point.
- **M** has the second highest electrical conductivity at room temperature.

Arrange the elements in order of increasing atomic number.

A **K, L, M** **B** **L, M, K**

C **K, M, L** **D** **M, L, K**

9 Which trends down a Group in the Periodic Table are correct?

1 Electronegativity of Group 1 elements decreases

2 Reducing power of Group 2 elements increases

3 Volatility of Group 17 elements increases

A 1 and 2 only **B** 2 and 3 only

C 1 and 3 only **D** 1, 2 and 3

10 The standard entropy change of formation, $\Delta S_f^{\ominus}$, of a substance is similarly defined as the standard enthalpy change of formation, $\Delta H_f^{\ominus}$.

Which Period 3 oxide has the most negative $\Delta S_f^{\ominus}$?

A sodium oxide **B** magnesium oxide

C silicon dioxide **D** sulfur dioxide

11 *Use of the Data Booklet is relevant to this question.*

Which solid has the most exothermic lattice energy?
[Assume the lattice structure of the following compounds are identical.]

A TiF_3 **B** FeF_3

C TiO **D** FeO

12 0.70 g of fuel undergoes complete combustion to heat up 500 cm^3 of water by 7.5 °C. The system is known to be 70% efficient.

What is the energy released per gram, in kJ g^{-1}, of the fuel burnt?

A 15.7 **B** 22.4

C 32.0 **D** 1196

13 The rate of removal of aspirin, a pain–killer drug, from the body follows a first–order reaction. It takes 6.0 hours for 87.5% of aspirin to be removed from the body.

What is the value of the rate constant for this reaction?

A 0.462 h^{-1} **B** 0.347 h^{-1}

C 0.116 h^{-1} **D** 0.0385 h^{-1}

14 Consider the following reaction:

$$3P + Q \rightarrow P_3Q$$

The proposed mechanism for the reaction involves the following steps:

$2P \rightleftharpoons P_2$	fast
$P_2 + Q \rightarrow P_2Q$	slow
$P_2Q + P \rightarrow P_3Q$	fast

Based on the given information, what is the rate equation for the reaction?

A rate = $k[P]^2[Q]$

B rate = $k[P_2][Q]$

C rate = $k[P]^2$

D rate = $k[P]^3[Q]$

15 Which statement is correct for the equilibrium below?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

	change	effect on position of equilibrium	effect on K_c
A	addition of catalyst	shifts right	no change
B	addition of argon gas at constant volume	shifts left	decreases
C	decrease in temperature	shifts right	increases
D	decrease in volume of vessel	shifts left	no change

16 Solutions **E**, **F**, **G** and **H** contain HC*l*(aq), CH_3COOH(aq), NaOH(aq) and NH_4Cl(aq) but not necessarily in the same order. The concentration and pH for each solution are shown below.

solution	concentration / mol dm^{-3}	pH
E	1.0	4.0
F	1.0	5.8
G	0.01	12.0
H	0.01	2.0

Which statements are correct?

1 **E** contains a weak acid while **H** contains a strong acid.

2 Mixing 10 cm^3 of **E** and 500 cm^3 of **G** produces a buffer solution.

3 Mixing 10 cm^3 of **F** and 50 cm^3 of **H** produces a buffer solution

A 1, 2 and 3 **B** 1 and 2 only

C 1 and 3 only **D** 2 and 3 only

17 At a body temperature of 37 °C, K_w has a value of 2.4×10^{-14}.

What is the concentration of OH^- if the pH of blood is 7.4 under these conditions?

A 3.98×10^{-8} mol dm^{-3} **B** 6.03×10^{-7} mol dm^{-3}

C 2.51×10^{-7} mol dm^{-3} **D** 7.00×10^{-7} mol dm^{-3}

18 The solubilities of $BaSO_4$ and $PbSO_4$ are x and y mol dm^{-3} respectively at 298 K.

A solution saturated with both $BaSO_4$ and $PbSO_4$ was prepared by dissolving $BaSO_4$(s) and $PbSO_4$(s) in water at 298 K.

Which statements about the saturated solution are correct?

1 $[SO_4^{2-}] = (x + y)$ mol dm^{-3}

2 $[Ba^{2+}] < x$ mol dm^{-3}

3 $[SO_4^{2-}] = [Ba^{2+}] + [Pb^{2+}]$

A 1, 2 and 3 **B** 1 and 2 only

C 1 and 3 only **D** 2 and 3 only

19 A mixture of propyne and propadiene is produced as side products during the cracking of propane. Propyne exists in equilibrium with propadiene.

$$\underset{\text{propyne}}{H\text{–}C{\equiv}C\text{–}CH_3} \rightleftharpoons \underset{\text{propadiene}}{H_2C{=}C{=}CH_2}$$

Which statement is **incorrect**?

A Propyne contains a σ bond formed by 1s–2sp overlap.

B Propadiene contains a π bond formed by 2p–2p overlap.

C Both propyne and propadiene contain sp hydridised carbons.

D Propyne has a longer C—C single bond compared to propane.

20 Ethers have the general structure R_1–O–R_2 where R_1 and R_2 are hydrocarbon groups.

What is the lowest number of carbon atoms an ether molecule must contain to have a chiral carbon atom?

A 5 **B** 6

C 7 **D** 8

21 Which reactions will give a product mixture that rotates plane polarised light?

1 1–bromohexane heated with alcoholic NaCN

2 3–bromo–3–methylhexane heated with aqueous NaOH

3 Butanone reacted with HCN, trace amount of NaOH

4 Cyclohexene with Br_2 in CCl_4

A 4 only **B** 1 and 3 only

C 2 and 3 only **D** None of the above

22 Compounds **P** to **S** have the same molecular formula C_7H_7X, where X can be C*l*, Br or I.

Each compound was separately heated with ethanolic $AgNO_3$ and the observations were recorded.

compound	observations
P	precipitate formed after 2 minutes
Q	no precipitate formed
R	precipitate formed instantaneously
S	precipitate formed after 10 minutes

Which statement about the compounds **P** to **S** is correct?

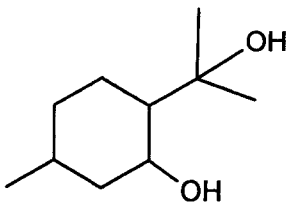
A The C—X bond length increases in the order **R** < **P** < **S** < **Q**.

B **R** can be formed by reacting Cl_2 with methylbenzene in the presence of UV light.

C **Q** can be formed by reacting Br_2 with methylbenzene in the presence of $AlBr_3$.

D Heating of each compound **P**, **Q**, **R** and **S** in acidified $KMnO_4$ produces $C_6H_5CO_2H$.

23 Citriodiol is an active ingredient in insect repellent extracted from the lemon eucalyptus tree.



citriodiol

Citriodiol is heated under reflux with acidified potassium dichromate(VI) to form compound **E**.

Which reagent reacts with **both** citriodiol and compound **E**?

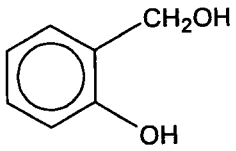
A alcoholic sodium hydroxide

B 2,4–dinitrophenylhydrazine

C warm alkaline aqueous iodine

D hot alumina

24 The structure of saligenin is shown.



saligenin

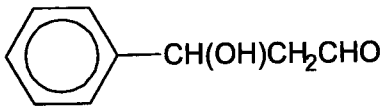
One mole of saligenin is separately reacted with an excess of sodium hydroxide and sodium.

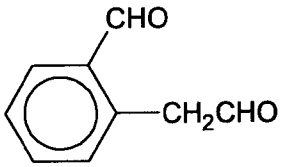
Which row is correct?

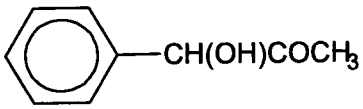
	moles of NaOH(aq) that react with one mole of saligenin	moles of H_2 produced when one mole of saligenin reacts with Na
A	0	1
B	1	2
C	1	1
D	2	2

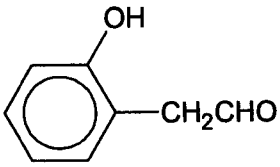
25 When phosphorus pentachloride was added to an organic compound **P**, fumes of hydrogen chloride was evolved. When **P** was warmed with Fehling's solution, a red–brown precipitate was obtained.

Which of the following is likely to be compound **P**?

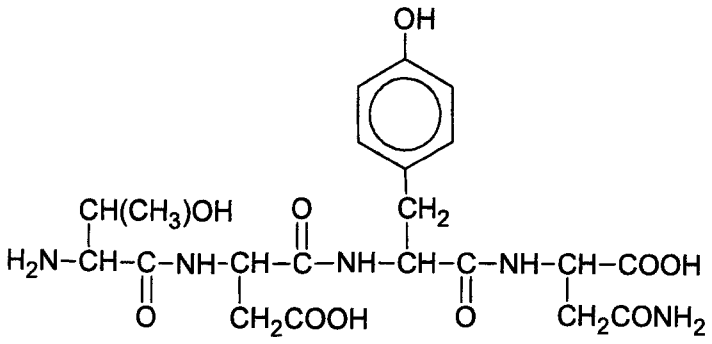
A 

B 

C 

D 

26 Compound **Z** is formed from the partial hydrolysis of a hormone molecule.



compound **Z**

Which statement is **incorrect**?

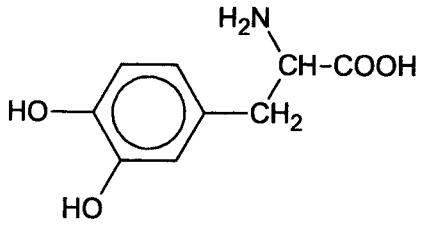
A Prolonged heating of **Z** with dilute NaOH produces three different carbon–containing products.

B Prolonged heating of **Z** with dilute NaOH liberates an alkaline gas.

C Two moles of CH_3COCl are needed for complete reaction with one mole of **Z**.

D One mole of Na_2CO_3 is needed for complete reaction with one mole of **Z**.

27 Listening to music you enjoy releases the mood-enhancing chemical dopamine in your brain.



dopamine

Which of the following statements about dopamine are **false**?

1 It is soluble in water due to zwitterion formation.

2 It migrates to the cathode of an electrolytic cell at pH 14.

3 The acidity of dopamine will decrease when aqueous bromine is added.

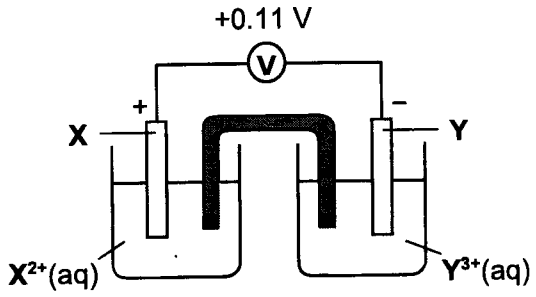
A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

28 An electrochemical cell is shown below.



Which is the strongest reducing agent?

A X **B** Y

C X^{2+} **D** Y^{3+}

29 *Use of the Data Booklet is relevant to this question.*

When a current of 2.0 A was passed through a molten aluminium salt for 9.0 hours, what is the maximum mass of aluminium formed at the cathode?

A 6.04 g **B** 18.1 g

C 48.6 g **D** 54.4 g

30 A reaction scheme starting from aqueous copper(II) sulfate is shown below. Both **G** and **H** are copper–containing species.

$$CuSO_4(aq) \xrightarrow[I]{NH_3(aq)} \mathbf{G} \xrightarrow[II]{\text{excess } NH_3(aq)} \mathbf{H} \xrightarrow[III]{EDTA^{4-}(aq)} [Cu(EDTA)]^{2-}(aq)$$

Which statement is correct?

A NH_3 is a ligand in reaction I.

B Reaction II is a redox reaction.

C **H** is a deep blue solution containing $[Cu(NH_3)_4(H_2O)_2]SO_4$.

D The entropy of the system decreases when reaction III occurs.

Name:		Centre/Index Number:		Class:	

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.

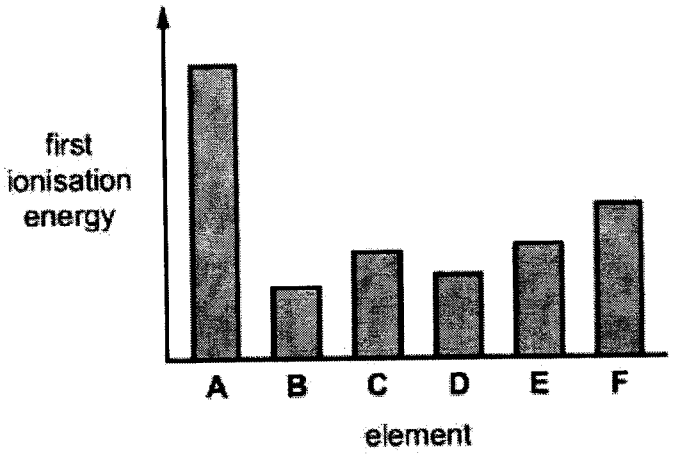


Fig. 1.1

(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.

equation 1 $\quad Cl_2 + H_2S \rightarrow 2HCl + S$

(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.

$$Br_2(l) + 3F_2(g) \rightarrow 2BrF_3(l)$$

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.

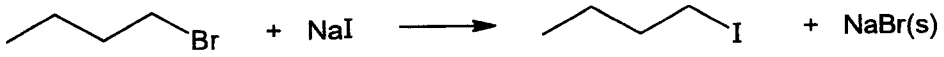
Table 1.1

	$\Delta H^{\ominus}$ / 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 cm^3 of 0.10 mol dm^{-3} bromobutane and 15.0 cm^3 of 1.0 mol dm^{-3} sodium iodide were mixed.

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

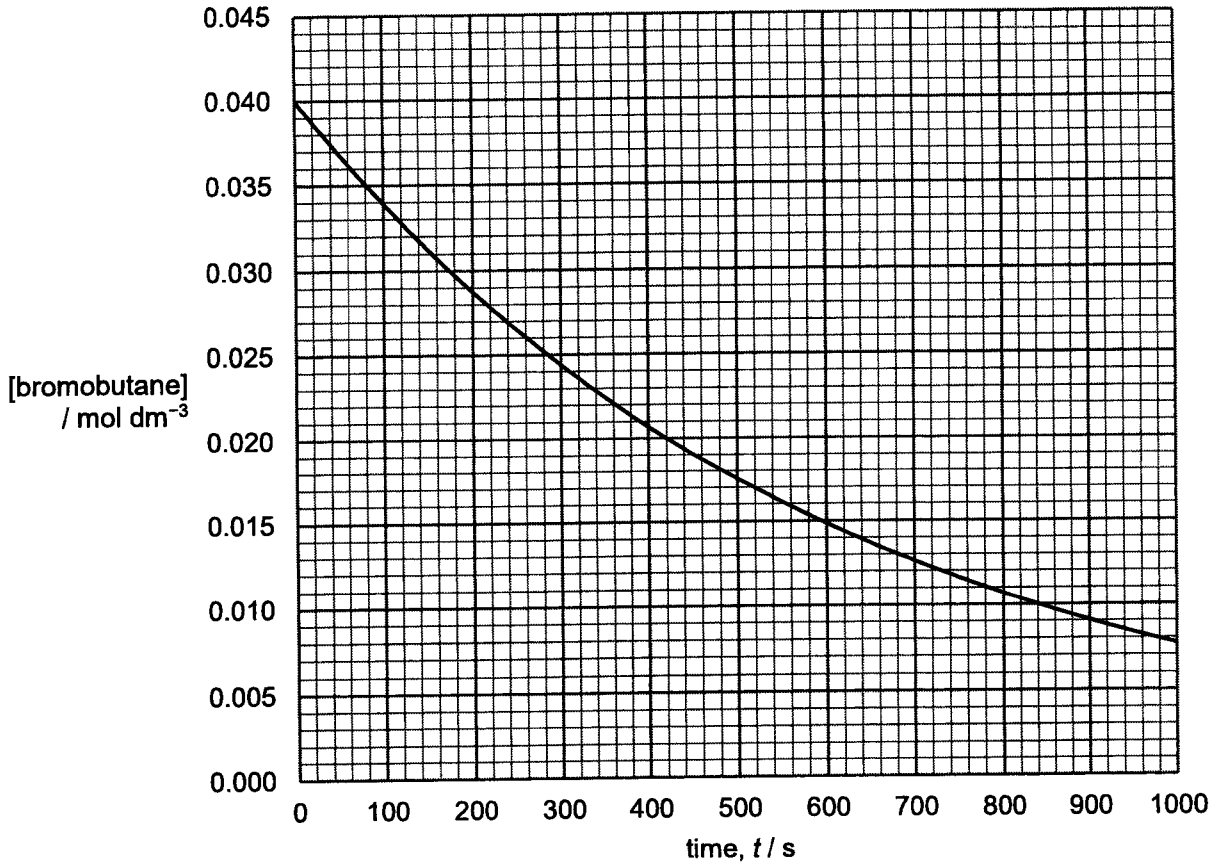


Fig. 2.1

(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.

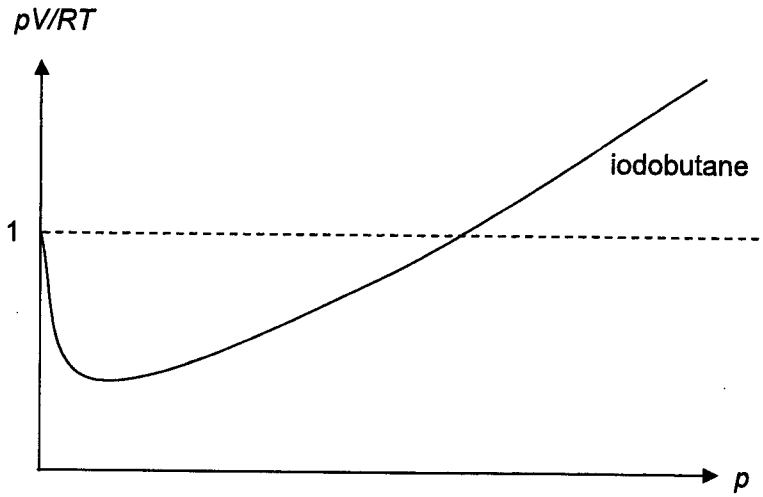


Fig. 2.2

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

.....

.....

.....

.....

..... [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.

.....

.....

..... [1]

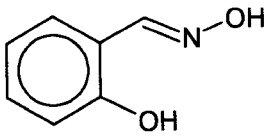
(ii) Explain why the densities of iron and copper are significantly greater than that of calcium.

.....

.....

..... [1]

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



M

(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.

.....

.....

.....

..... [2]

[Total: 12]

BLANK PAGE

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.

.....

.....

..... [1]

(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]

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

.....

.....

..... [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.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [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, $Ca(HCO_3)_2$, 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]

(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]

Some enthalpy changes relating to magnesium chloride are found in Table 5.2.

Table 5.2

	value / 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) Define the term *lattice energy of magnesium chloride*.

.....

.....

..... [1]

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

.....

.....

..... [1]

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

.....

.....

.....

..... [2]

[Total: 21]

BLANK PAGE

BLANK PAGE

BLANK PAGE

Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 CHEMISTRY

9729/03

Paper 3 Free Response Questions

25 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. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A
Answer **all** questions.

Section B
Answer **one** question.

A Data Booklet is provided.
The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	20
2	20
3	20
Section B	
4 / 5	20
Total	80

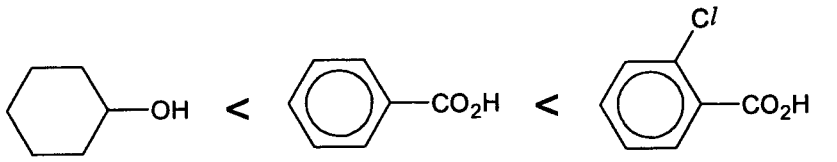
This document consists of **31** printed pages and **1** blank page.

[Turn over

Section A

Answer **all** the questions in this section.

1 **(a)** The order of increasing Brønsted-Lowry acidity of cyclohexanol, benzoic acid and 2–chlorobenzoic acid is shown. Explain this order. [3]



cyclohexanol benzoic acid 2-chlorobenzoic acid

(b) BF_3 acts as a Lewis acid in its reaction with dimethylether, CH_3OCH_3, to form product **P**.

(i) Describe how BF_3 acts as a Lewis acid in this reaction. [1]

(ii) Draw a structure for **P** to show the bonding present. [1]

(c) Dimethylether, CH_3OCH_3, can be formed from the reaction between carbon monoxide, CO, and hydrogen, H_2, as shown by equation 1.

equation 1 $\quad 3CO(g) + 3H_2(g) \rightleftharpoons CH_3OCH_3(g) + CO_2(g)$

A mixture of CO and H_2 was introduced into a 10 m^3 sealed vessel at 500 K. The initial total pressure was 40 atm.

After dynamic equilibrium was established at 500 K, the total pressure in the vessel decreased to 28 atm.

(i) Write an expression for the equilibrium constant, K_p, for this reaction, and state its units. [1]

(ii) *Use of the Data Booklet is relevant to this question.*

The amount of CH_3OCH_3 at equilibrium was found to be 732 mol. Show that the equilibrium partial pressure of CH_3OCH_3 in the sealed vessel is 3 atm. [1]

(iii) At equilibrium, it was found that 60% of the CO had been converted to the products. Calculate the equilibrium partial pressures of CO and H_2 in atm. Hence, determine the value of K_p for the reaction. [3]

(iv) The volume of the vessel is reduced from 10 m^3 to 5 m^3 and the system is allowed to reach equilibrium.

Explain the effect this will have on the partial pressures of the individual gases and the composition of the reaction mixture. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) NH_3 is commonly used as a nucleophile in organic chemistry. In some instances, it adds to the C=C bond as shown in Fig. 1.1.

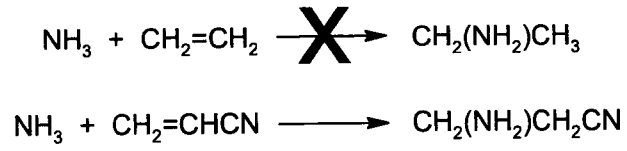


Fig. 1.1

Suggest reasons to explain Fig. 1.1.

Use concepts of electronegativity and electronic effects in your answer. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(e) Ammonia or primary amines react with aldehydes and ketones to produce imines as shown in Fig. 1.2. R_1, R_2 and R_3 represent alkyl groups or hydrogen atoms.

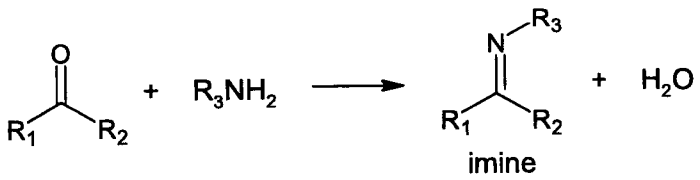
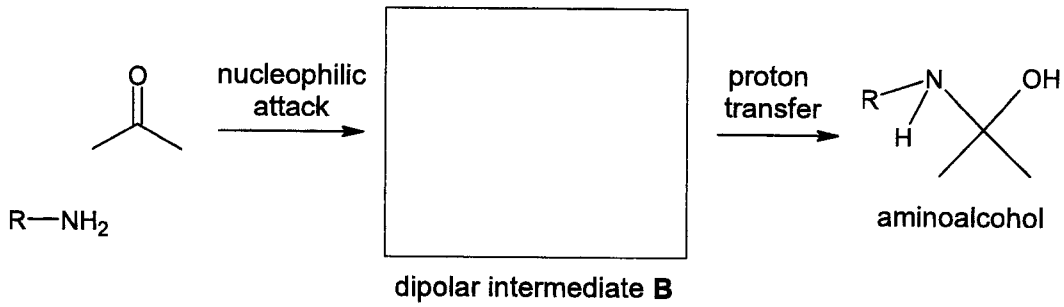


Fig. 1.2

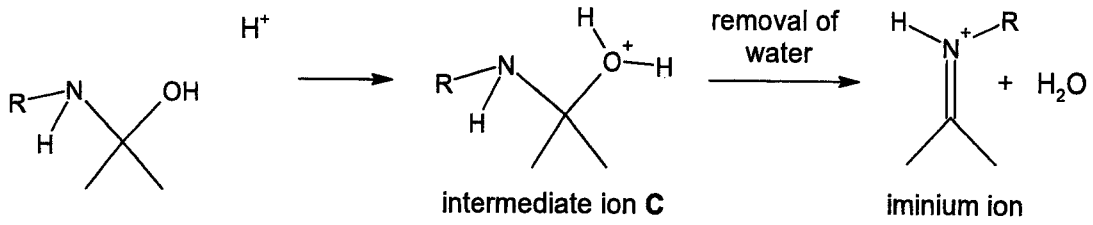
The reaction is carried out at carefully controlled pH of between 4 and 5.

The mechanism for the formation of an imine between a primary amine and propanone is shown in Fig. 1.3.

Stage 1: Formation of aminoalcohol



Stage 2: Formation of iminium ion intermediate



Stage 3: Formation of imine via deprotonation

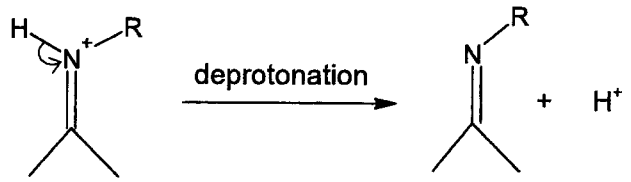


Fig. 1.3

(i) Complete the mechanism for the formation of **B** in Fig. 1.3 by

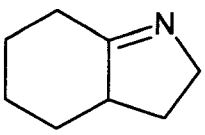
- adding curly arrows, a lone pair and a dipole to show how the nucleophilic attack occurs between the primary amine and propanone.
- drawing the structure of the dipolar intermediate **B** in the box provided. [2]

(ii) Complete the mechanism for stage 2 in Fig. 1.3 by

- adding a curly arrow and a lone pair to show protonation of the aminoalcohol.
- adding a lone pair and curly arrows on intermediate ion **C** to show how the iminium ion is formed. [2]

(iii) By considering stage 1, suggest why the reaction is slower at pH lower than 4. [1]

(iv) Suggest the reactant used to form the following product by a similar reaction to that shown in Fig. 1.2. [1]



[Total: 20]

BLANK PAGE

2 (a) Phenylamine can be made in the laboratory using the method given below.

Nitrobenzene is heated under reflux with a mixture of tin and concentrated hydrochloric acid.

Once the reaction mixture has cooled, concentrated sodium hydroxide solution is added until the mixture is alkaline. Pure phenylamine can be obtained from this mixture.

The reaction between tin and concentrated hydrochloric acid produces $SnCl_2$ and H_2 gas. Nitrobenzene then reacts with $SnCl_2$, in the presence of concentrated hydrochloric, to form $C_6H_5NH_3^+$ and $[SnCl_6]^{2-}$ ions.

(i) Describe the roles of tin and concentrated hydrochloric acid when they are added together to form $SnCl_2$ and H_2 gas. Explain your answer in terms of electron transfer. [2]

(ii) Construct a half–equation for the formation of $C_6H_5NH_3^+$ from nitrobenzene. State symbols are **not** required. [1]

(iii) Using the relevant theory of acids and bases, explain how the phenylamine can be recovered from the mixture by adding concentrated sodium hydroxide solution. [1]

(iv) Describe a simple chemical test you could carry out to confirm the presence of phenylamine in the product. State what you would observe. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) **(i)** Table 2.1 gives the pK_b values of some nitrogen-containing compounds at 25 °C.

Table 2.1

name	structure	pK_b
phenylamine	$C_6H_5NH_2$	9.40
phenylalanine	$C_6H_5CH_2CH(NH_2)CO_2H$	4.87 (α-amino group)
propylamine	$CH_3CH_2CH_2NH_2$	3.46

Explain the relative basicities of the compounds in Table 2.1 in terms of their structures. [3]

(ii) Use Table 2.2 to draw the predominant species of phenylalanine at pH 8. [1]

Table 2.2

name	structure	pK_a at 25 °C	
		α-carboxyl group	α-amino group
phenylalanine	$C_6H_5CH_2CH(NH_2)CO_2H$	1.83	9.13

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Arecoline, $C_8H_{13}NO_2$, is a compound found in the Taiwanese betel nut.

Arecoline has three different functional groups, does not display cis-trans isomerism and does not contain a chiral centre. It contains a six-membered ring comprising one nitrogen and five carbon atoms.

Table 2.3 shows the organic products formed, and other information, when arecoline and compound **F**, $C_8H_{15}NO_2$, are added to different reagents under specific conditions.

Table 2.3

test	reactant	reagents and conditions	organic products formed	other information
1	arecoline	excess H_2 / Ni	**F**, $C_8H_{15}NO_2$	**F** contains one chiral centre.
2	arecoline	2,4-DNPH	no reaction	[redacted]
3	arecoline	Na_2CO_3(aq)	no reaction	
4	arecoline	ethanoyl chloride	no reaction	
5	arecoline	excess CH_3Cl in ethanol, heat	**G**, $C_9H_{16}NO_2Cl$	**G** is an ionic compound.
6	**F**	excess HCl(aq), heat	**H**, $C_7H_{14}NO_2^+$, and **J**	[redacted]
7	**F**	excess acidified $KMnO_4$, heat	**H** only	effervescence observed.

For each of the seven tests, state the type of reaction occurring, if any. For each compound, state what the information in Table 2.3 tells you about the functional groups it contains. Include your reasoning.

Suggest possible structures for **F**, **G**, **H** and **J**. Hence deduce a possible structure for arecoline. [10]

.....

.....

.....

.....

.....

.....

.....

.....

[Total: 20]

3 **(a)** Aqua regia (a mixture of 25% nitric acid and 75% hydrochloric acid by volume) is highly corrosive. Only noble metals like iridium are inert to this solution. A 5 g sample of platinum–iridium alloy required 24.6 cm^3 of aqua regia for complete reaction. Platinum was completely oxidised to platinum(IV) ions by nitric acid and 0.5 g of the remaining metal was recovered.

(i) Find the percentage of each metal in the alloy. [1]

(ii) Aqua regia was prepared using 5.0 mol dm^{-3} nitric acid. Assuming that the reaction between the sample and aqua regia is complete, calculate the number of moles of nitric acid reacted per mole of platinum. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) Gold is typically an inert metal and it does not dissolve in either hydrochloric acid or nitric acid alone. It will dissolve in aqua regia because of the unique combined action of the two acids.

In aqua regia, nitric acid converts gold to its ionic form, Au^{3+}, and hydrochloric acid provides a source of chloride which reacts with the gold cations to form stable tetrachloroaurate(III) complex, $AuCl_4^-$.

The standard reduction potential of Au^{3+} to Au is given below.

$$Au^{3+} + 3e^- \rightleftharpoons Au \qquad E^\ominus = +1.50\ V$$

(i) With the use of relevant data from the *Data Booklet*, explain why hydrochloric acid alone cannot dissolve gold. [1]

(ii) Gold has the chemical properties of a typical transition element.
Explain why gold can be considered a transition element. [1]

(iii) Another method of extracting gold from low–grade ore involves converting the gold to a water–soluble dicyanoaurate(I) anionic complex, $[Au(CN)_2]^-$.

Explain why the gold complex ion, $AuCl_4^-$ in **(b)**, is coloured while the dicyanoaurate(I) complex ion, $[Au(CN)_2]^-$, is colourless. [4]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Freshly prepared aqua regia decomposes quickly and one of the decomposition products, nitrosyl chloride, NOC*l*, is a yellow gas.

Nitrosyl chloride can further decompose into nitrogen, chlorine and oxygen, as shown in the equation below.

$$2NOCl(g) \rightarrow N_2(g) + Cl_2(g) + O_2(g) \qquad \Delta H = +258 \text{ kJ mol}^{-1}$$

(i) Define the term *bond energy of N=O bond*. [1]

(ii) Using data from the *Data Booklet*, calculate the bond energy of N=O bond in NOC*l*. [2]

(iii) The boiling points of NOC*l* and NOF are –5.6 °C and –72.4 °C respectively. Suggest a reason for the difference in their boiling points. [2]

(iv) Copper(II) oxide, CuO, is a common catalyst used for the decomposition of NOC*l*. Suggest the type of catalyst CuO acts as and describe its mode of action. [3]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) *Use of the Data Booklet is relevant to this question.*

A student wanted to study the following reaction.

$$2Au^{3+} + 3Ni \rightleftharpoons 2Au + 3Ni^{2+}$$

He first sets up an electrochemical cell which comprises of Au^{3+}/Au and Ni^{2+}/Ni half–cells prepared under standard conditions.

When the reaction begins, $[Au^{3+}]$ starts to decrease while $[Ni^{2+}]$ increases. In the study of electrochemical cells, the *Nernst equation*, given below, can be applied to determine the cell potential under non–standard conditions.

$$E_{cell} = E^{\ominus}_{cell} - \frac{0.0592}{n} \log_{10} Q$$

where n is the number of moles of electrons transferred, Q is the reaction quotient given by $\frac{[Ni^{2+}]^3}{[Au^{3+}]^2}$ and $E^{\ominus}_{cell}$ is the standard cell potential.

(i) Using the $E^{\ominus}(Au^{3+}/Au)$ given in **(b)**, calculate the new E_{cell} using the Nernst equation, when $[Au^{3+}]$ and $[Ni^{2+}]$ are 0.02 mol dm^{-3} and 2.47 mol dm^{-3} respectively. [2]

(ii) Suggest and explain what happens to E_{cell} value of the electrochemical cell when the mass of nickel electrode is increased. [1]

.....

.....

.....

.....

.....

.....

.....

.....

.....

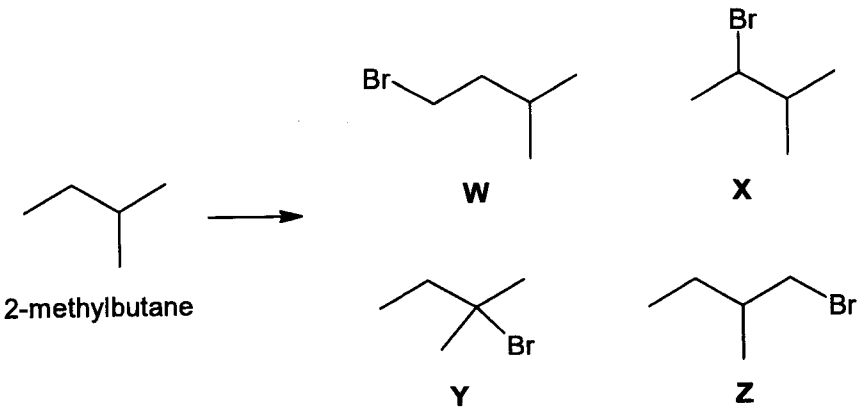
.....

[Total: 20]

Section B

Answer **one** question from this section.

4 2-methylbutane reacts with bromine in the presence of UV light to give a mixture of products. There are four possible monobromoalkanes, **W** to **Z**, that can be formed.



(a) **(i)** Draw both stereoisomers of **Z**. [1]

(ii) Name and draw the mechanism for the formation of **W** from 2-methylbutane using curly arrows. [3]

Empirical evidence has shown that different types of carbons have a different relative probability of being substituted by bromine. These probabilities can be found in Table 4.1.

Table 4.1

type of carbon	relative probability of substitution
primary	1
secondary	62
tertiary	1640

(iii) By considering the number of H atoms on each carbon, and information in Table 4.1, predict the relative proportions of **W**, **X**, **Y** and **Z** in the product mixture. [1]

The reaction of 2-methylbutane and bromine gas also forms a mixture of side-products with a molecular formula of $C_{10}H_{22}$.

(iv) Use Table 4.1 to deduce the identity of the most stable alkyl radical present in the reaction mixture. Draw its structure using skeletal formula. [1]

(v) Hence name the $C_{10}H_{22}$ product that is formed in the highest proportion. [1]

.....

.....

.....

(b) Fig. 4.1 shows a 2-step synthesis to obtain 2-methylbutan-2-ol from **X**.

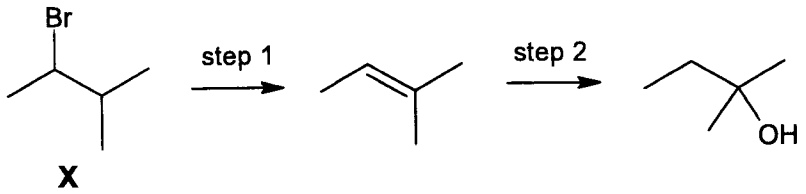


Fig. 4.1

(i) State the reagents and conditions required for each step. [2]

Each step in the synthesis forms a mixture of products as there is more than one possible region for each reaction to occur. The term *regioselectivity* refers to the preference for a chemical reaction to occur at a specific region of a molecule to give the major product.

(ii) Explain if each step in Fig. 4.1 is regioselective for the intended product. Your answer should refer to the relative stability of relevant products or intermediates.

Hence conclude if the synthesis will give a good yield of 2-methylbutan-2-ol. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

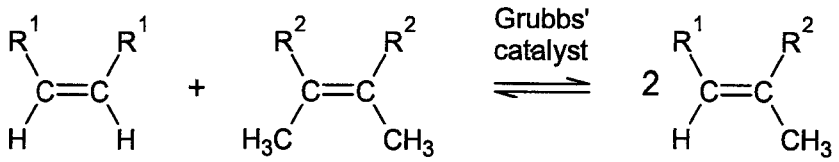
.....

.....

.....

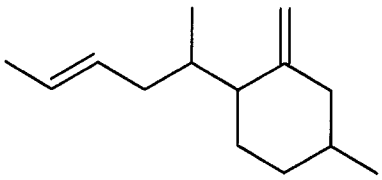
.....

(c) Alkene metathesis allows the redistribution of alkene fragments.



The reaction only involves the breaking and forming of C=C bonds.

Compound **T** is shown. When compound **T** undergoes alkene metathesis, an intramolecular reaction occurs to form a small hydrocarbon and a product containing two rings.



T

Predict the small hydrocarbon and the product formed in this reaction. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) Sodium bisulfite, $NaHSO_3$, is commonly used as a food preservative.

(i) Given that the bisulfite ion contains a O–H covalent bond, draw a dot-and-cross diagram to show the bonding in a bisulfite ion, HSO_3^-. [1]

(ii) Hence state the shape and bond angle around the sulfur atom within the bisulfite ion. Explain your answer using the Valence Shell Electron Pair Repulsion Theory. [2]

The bisulfite ion is a weak acid with a pK_a value of 6.97.

$$HSO_3^- \rightleftharpoons SO_3^{2-} + H^+$$

An aqueous mixture containing bisulfite ions, $HSO_3^-(aq)$, and sulfite ions, $SO_3^{2-}(aq)$, can act as a buffer.

(iii) Write two equations to describe how a HSO_3^-/SO_3^{2-} mixture resists pH change when a small amount of acid or base is added. [1]

A buffer with pH 7.5 was prepared by mixing 30.0 cm^3 of 0.500 mol dm^{-3} sodium bisulfite with 20.0 cm^3 of aqueous sodium hydroxide.

(iv) Calculate the $[SO_3^{2-}]:[HSO_3^-]$ ratio of the buffer. [1]

(v) Hence calculate the concentration of sodium hydroxide used in the preparation of the buffer. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[Total: 20]

5 (a) (i) Explain the difference in pH in Table 5.1. [2]

Table 5.1

compound	pH of a 1.0 mol dm^{-3} solution in water
NaCl	7.0
$AlCl_3$	3.0

(ii) With the aid of relevant equation(s), describe what happens when Na_2O, SiO_2 and P_4O_{10} are separately added to water. [3]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(b) Strontium metal can be obtained by the electrolysis of molten strontium chloride, $SrCl_2$, using the apparatus shown in Fig. 5.1.

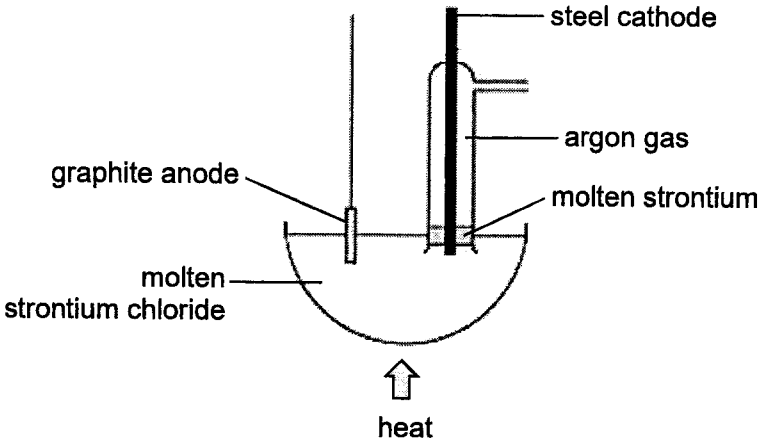


Fig. 5.1

Strontium ions are reduced at the cathode to form molten strontium metal, which is then removed from the set up.

(i) Write the half–equations, including state symbols, for the reactions at the anode and cathode. [2]

(ii) A current of 5.0 A was passed through molten strontium chloride for 45 min.

Calculate the mass of strontium metal formed at the cathode. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Cyclohexylamine can be produced from benzene in a three–step synthesis as shown in Fig. 5.2.

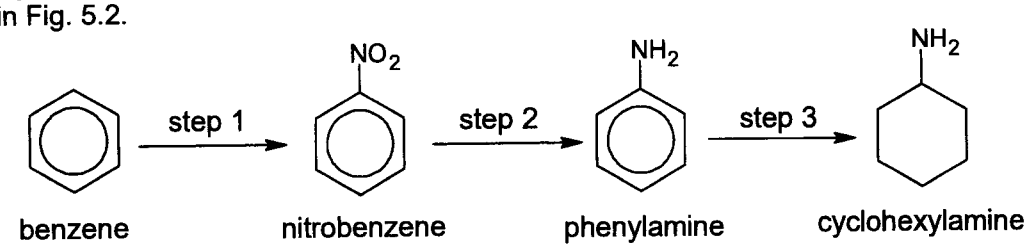


Fig. 5.2

(i) Name and draw the mechanism for step 1. Include all relevant lone pairs, curly arrows and charges. Include the structure of the organic intermediate. [3]

In step 3, phenylamine is converted to cyclohexylamine using hydrogen gas dissolved in supercritical carbon dioxide in the presence of rhodium catalyst supported on alumina. This was carried out at high temperature and pressure.

(ii) By considering the structure of phenylamine, suggest why its conversion to cyclohexylamine requires the use of a catalyst. [1]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(d) Glycine, $H_2NCH_2CO_2H$, is a naturally occurring α–amino acid.

It can be synthesised using bromomethane as shown in Fig. 5.3.

$$CH_3Br \xrightarrow{\text{step 1}} CH_3CN \xrightarrow{\text{step 2}} ClCH_2CN \xrightarrow{\text{step 3}} \underset{\textbf{A}}{\text{intermediate}} \xrightarrow{\text{step 4}} H_2NCH_2CO_2H$$

Fig. 5.3

(i) State the reagents and conditions required for step 1. [1]

(ii) Draw the **displayed** structural formula of intermediate **A** and state the reagents and conditions required for step 3. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

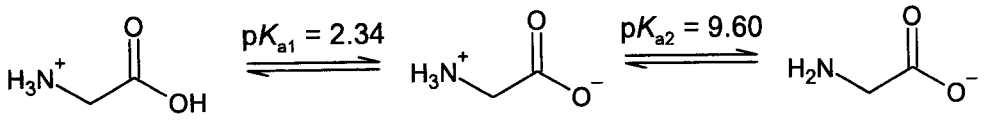
.....

.....

.....

.....

(e) Protonated glycine acts as a dibasic weak acid.



A student adds small portions of 0.125 mol dm^{-3} NaOH(aq) to 25.0 cm^3 of 0.100 mol dm^{-3} protonated glycine. The student uses a pH meter to measure the pH of the mixture.

(i) Calculate the pH of 0.100 mol dm^{-3} protonated glycine. You may ignore the effect of pK_{a2} on the pH. [1]

(ii) Calculate the volume of NaOH required to reach the first equivalence point. [1]

(iii) Sketch the pH-volume added curve you would expect to obtain when a total of 50 cm^3 of 0.125 mol dm^{-3} NaOH(aq) is added.

Label the following points on the curve.

- initial pH
- volume required for each equivalence point
- pH and volume at each point of maximum buffering capacity

You may assume that the pH of the solution is 12.2 upon addition of 50 cm^3 of NaOH. [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[Total: 20]

Additional answer space

If you use the following page to complete the answer to any question, the question number must be clearly shown.