TANJONG KATONG GIRLS' SCHOOL
PRELIMINARY EXAMINATION
SECONDARY FOUR EXPRESS
CHEMISTRY

CANDIDATE NAME					
CLASS	4			INDEX NUMBER	

CHEMISTRY

6092/01

Paper 1 Multiple Choice

22 August 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.
Do **NOT** WRITE on ANY BARCODES.

There are **forty** questions in 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.

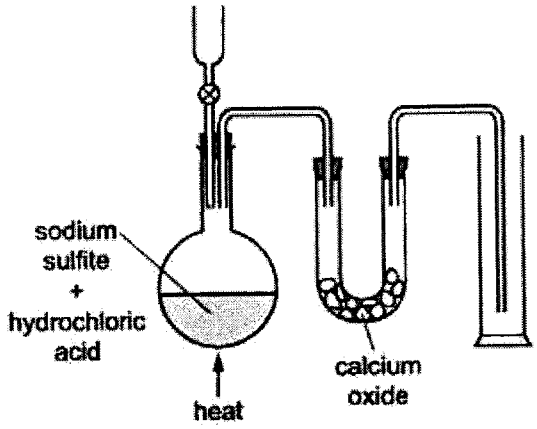
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
A copy of the Periodic Table is printed on page 18.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **18** printed pages.

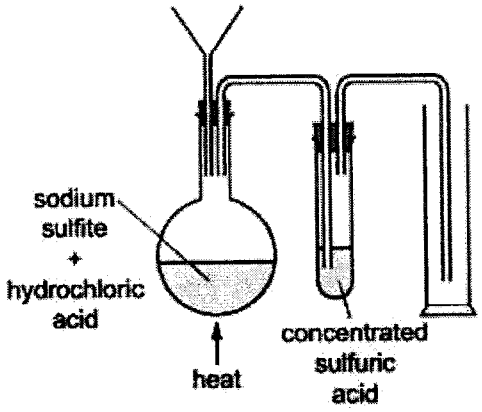
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1 Sulfur dioxide gas can be prepared by heating sodium sulfite with hydrochloric acid. Which set of apparatus is suitable for preparing and collecting a dry sample of sulfur dioxide?

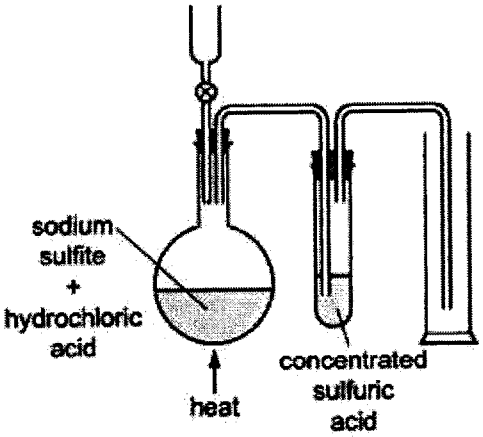
A



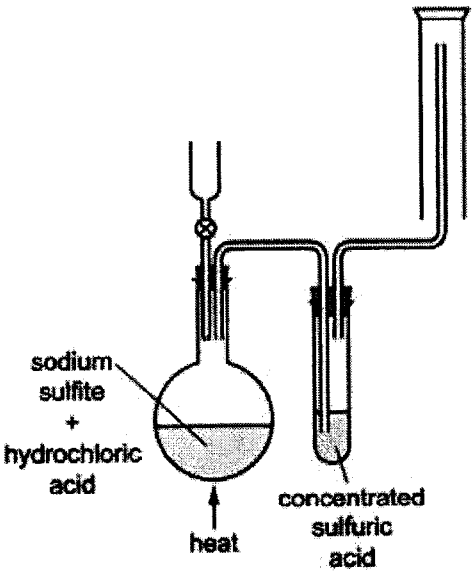
B



C



D



2 A student wants to separate a mixture of iodine and sodium chloride. Which method should she use?

A Crystallisation

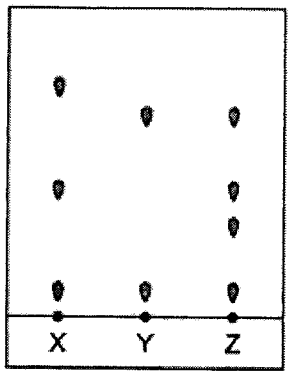
B Sublimation

C Filtration

D Distillation

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3 **X**, **Y** and **Z** are all mixture of alcohols. A paper chromatogram is obtained for samples of **X**, **Y** and **Z**.



Which row is correct?

	statement 1	statement 2
A	**Z** contains no more than four alcohols	**X**, **Y** and **Z** could contain the same alcohol
B	**Z** contains no more than four alcohols	**X**, **Y** and **Z** could not contain the same alcohol
C	**Z** contains at least four alcohols	**X**, **Y** and **Z** could contain the same alcohol
D	**Z** contains at least four alcohols	**X**, **Y** and **Z** could not contain the same alcohol

4 What happens as ice melts at 0°C?

1 Molecules gain kinetic energy and temperature increases.

2 Energy is gained to overcome the intermolecular forces of attraction.

3 Molecules gain sufficient energy to move from fixed positions.

A 1 only

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

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5 Which gas diffuses most rapidly under the same conditions of temperature and pressure?

A Cl_2 **B** CO_2

C CH_4 **D** NO_2

6 Which statement about electrons, neutrons and protons is correct?

A The relative charge of a proton is equal but opposite in sign to the relative charge of an electron.

B The relative charge of a proton is the same as the relative charge of a neutron.

C The relative mass of an electron is about 2000 times the relative mass of a neutron.

D The relative masses of protons and electrons are the same.

7 Which statement about isotopes is correct?

A They have different numbers of electrons and react differently in chemical reactions.

B They have the same number of neutrons and exhibit identical chemical and physical properties.

C They have different mass numbers but undergo the same chemical reactions.

D They have different proton numbers and belong to different elements.

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8 The table shows the number of subatomic particles in different atoms or ions.

	number of neutrons	number of protons	number of electrons
W	12	12	10
X	13	12	12
Y	16	15	18
Z	18	17	18

Which statements about **W**, **X**, **Y** and **Z** are correct?

1 **W** has a charge of 2–.

2 **W** and **Y** form $\mathbf{W_2Y_3}$.

3 $\mathbf{WZ_2}$ has a giant ionic structure.

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

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

9 Which structure corresponds to its description of physical properties?

	structure	physical properties
1	giant covalent	high melting point, conducts electricity when in solution but not when solid
2	simple molecular	low melting point, does not conduct electricity in any state
3	giant metallic	variety of melting points, conducts electricity when solid and when molten

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

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

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10 Nitric acid reacts with a wide range of elements and compounds.

$$P_4 + \mathbf{a}HNO_3 \rightarrow 4H_3PO_4 + 4H_2O + 20NO_2$$

What is the value of **a** in the correctly balanced equation?

A 5 **B** 10

C 15 **D** 20

11 Which **two** pieces of information are most essential to calculate the relative molecular mass of a compound?

A the empirical formula and the relative atomic masses of the elements in the compound

B the empirical formula and the total number of atoms of each element in the compound

C the molecular formula and the percentage by mass of each element in the compound

D the molecular formula and the relative atomic masses of the elements in the compound

12 Copper, in the form of $CuFeS_2$, is extracted from ores in copper mines. The ore contains only 1% by mass of copper.

What percentage of the ore contains $CuFeS_2$, if it is the only copper-containing compound present?

A 1.00% **B** 2.88% **C** 3.47% **D** 34.70%

13 Boron carbide contains boron and carbon. A sample contains 0.78 g of boron and 0.22 g of carbon.

What is the empirical formula of boron carbide?

A BC_2 **B** BC_4 **C** B_2C **D** B_4C

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14 An element forms a diatomic molecule, **Q**, which has a relative molecular mass, x. The Avogadro constant is L.

How many atoms are present in 1.0 g of **Q**?

A $\frac{L}{x}$ **B** $\frac{2L}{x}$ **C** $\frac{L}{2x}$ **D** $2LX$

15 A farmer tests the soil and finds it has a pH of 4.5. Which substance should she add to correct the pH?

A ammonium sulfate

B calcium hydroxide

C sulfur dioxide

D potassium nitrate

16 Which oxides react with aqueous sodium hydroxide?

1 copper(II) oxide
2 carbon dioxide
3 zinc oxide

A 2 only **B** 3 only

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

17 A salt can be prepared by adding an excess of solid **X** to an aqueous solution of **Y**. A solution and some solid **X** remain.

The mixture is filtered. The filtrate is evaporated to form a concentrated solution, which is left to crystallise. Excess solution is poured off, leaving salt **Z**.

Which salt can be safely prepared using this method?

A ammonium chloride

B copper(II) sulfate

C barium sulfate

D potassium chloride

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18 Which statement about the Haber process for the manufacture of ammonia is correct?

A At higher temperatures, the yield increases and the rate of production of ammonia is faster.

B At higher pressure, the yield increases and the rate of production of ammonia is faster.

C In the presence of a catalyst, the yield decreases but the rate of production of ammonia is faster.

D In the presence of a catalyst, the yield increases and the rate of production of ammonia is faster.

19 Filings of an alloy containing zinc and aluminium reacted with dilute hydrochloric acid to form a solution. Excess aqueous ammonia was added to the solution with shaking. The outcome was recorded.

Which statement correctly describes the outcome?

A A white precipitate is seen due to $Al(OH)_3$.

B A white precipitate is seen due to $Zn(OH)_2$.

C A white precipitate is seen due to a mixture of $Al(OH)_3$ and $Zn(OH)_2$.

D A colourless solution with no precipitate is seen as the precipitate dissolved.

20 **J** is an aqueous solution.

On addition of aqueous sodium hydroxide to **J**, a green precipitate is formed. The resulting mixture is heated and no gas is formed.

Aluminium foil is added to the warmed mixture. A gas is formed that turns damp red litmus paper blue.

Which ions could be present in **J**?

A Fe^{2+} and NO_3^- **B** Fe^{2+} and NH_4^+

C Fe^{3+} and NO_3^- **D** Fe^{3+} and NH_4^+

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21 What happens during the purifying of copper by electrolysis?

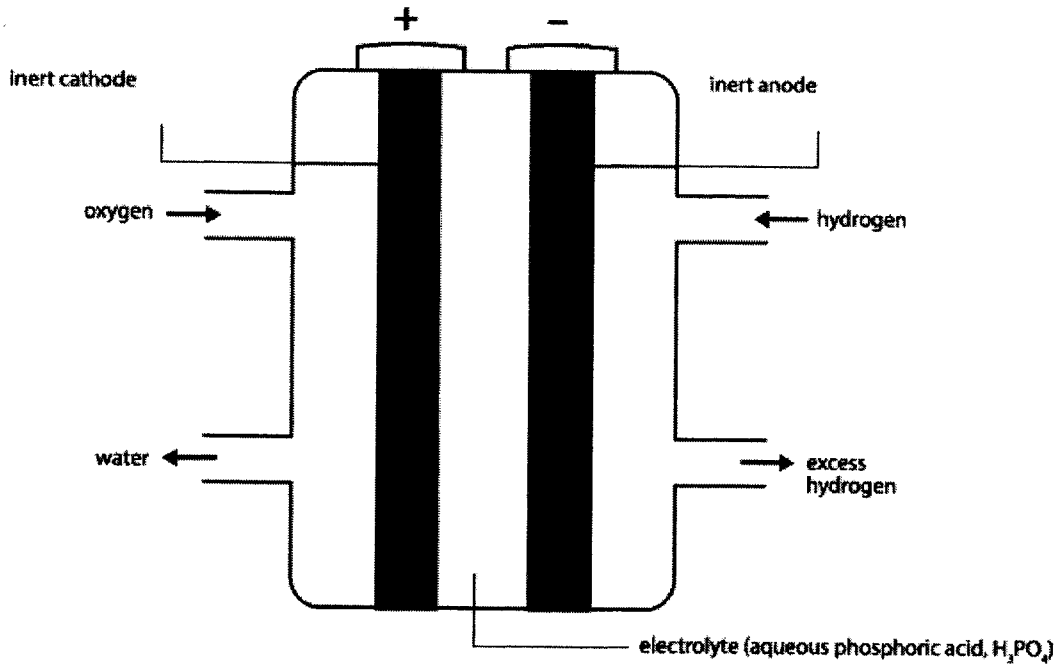
A Copper is removed from the anode and deposited at the cathode. The solution remains blue.

B Copper is deposited on the negative electrode and the solution becomes colourless.

C The solution becomes increasingly blue as more copper ions are formed at the positive electrode.

D Copper is transferred from the solution to the anode and the solution becomes colourless.

22 The diagram shows a hydrogen-oxygen fuel cell.



What are the changes in the pH of the solution around each of the electrode when a current is flowing?

	cathode	anode
A	increase	increase
B	decrease	decrease
C	decrease	increase
D	increase	decrease

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23 Three aqueous solutions are electrolysed using inert electrodes.

1 dilute aqueous sodium chloride

2 concentrated aqueous sodium bromide

3 dilute aqueous sodium sulfate

What are the gases produced at the anode for each solution?

	gas formed at anode for solution 1	gas formed at anode for solution 2	gas formed at anode for solution 3
A	oxygen	bromine	oxygen
B	chlorine	bromine	sulfur dioxide
C	oxygen	oxygen	sulfur dioxide
D	chlorine	oxygen	oxygen

24 Which species are from the same group of the Periodic Table?

1 an atom with the electronic configuration of 2, 3

2 an atom with the electronic configuration of 2, 8, 3

3 an ion with a 3– charge and an electronic configuration of 2, 8, 8

A 1 and 3 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

25 Indium, $^{115}_{49}In$, is used in solar cells and transistors, and to coat high-speed bearings.

From its position in the Periodic Table, which properties will indium be expected to possess?

1 It forms a chloride with the formula $InCl_3$.

2 Its oxide neutralises nitric acid.

3 Its chloride forms coloured solutions.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

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26 Properties of an element and its compounds can be predicted from the position of the element in the Periodic Table.

Which property could **not** be predicted in this way?

A The acidic or basic nature of its oxide.

B The number of valence electrons in its atoms.

C The number of isotopes it has.

D The reactivity of the element.

27 Rubidium is a Group 1 metal located below potassium in the Periodic Table.

Which statement is correct?

A Rubidium is less dense than potassium.

B Rubidium has a higher melting point than potassium.

C Rubidium reacts more explosively with water than potassium.

D Rubidium chloride is insoluble while potassium chloride is soluble.

28 Which deduction about the element astatine, At, can be made from its position in Group 17?

A It is a gas.

B It is more reactive than iodine.

C It forms covalent compounds with sodium.

D It is displaced from aqueous potassium astatide, KAt, by chlorine.

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29 Iron and copper are widely used as industrial catalysts.

Which statement explains why this is so?

A Their compounds have low melting points and are easily decomposed.

B They form ions with variable oxidation states that can participate in redox reactions.

C They are in the same group of the Periodic Table and react readily with acids.

D They are coloured metals that do not form oxides easily.

30 Why is argon commonly used to fill electric light bulbs to prolong the life of the wire filament?

A Argon is a dense air that cools the filament rapidly.

B Argon conducts electricity and increases the efficiency of the filament.

C Argon is chemically unreactive and prevents oxidation of the filament.

D Argon reacts with oxygen, forming a protective oxide coating.

31 A metal oxide cannot be reduced by either carbon or hydrogen.

Which statement is correct?

A The metal is more reactive than carbon and hydrogen and must be extracted by electrolysis.

B The metal is less reactive than carbon and can be extracted by heating with carbon.

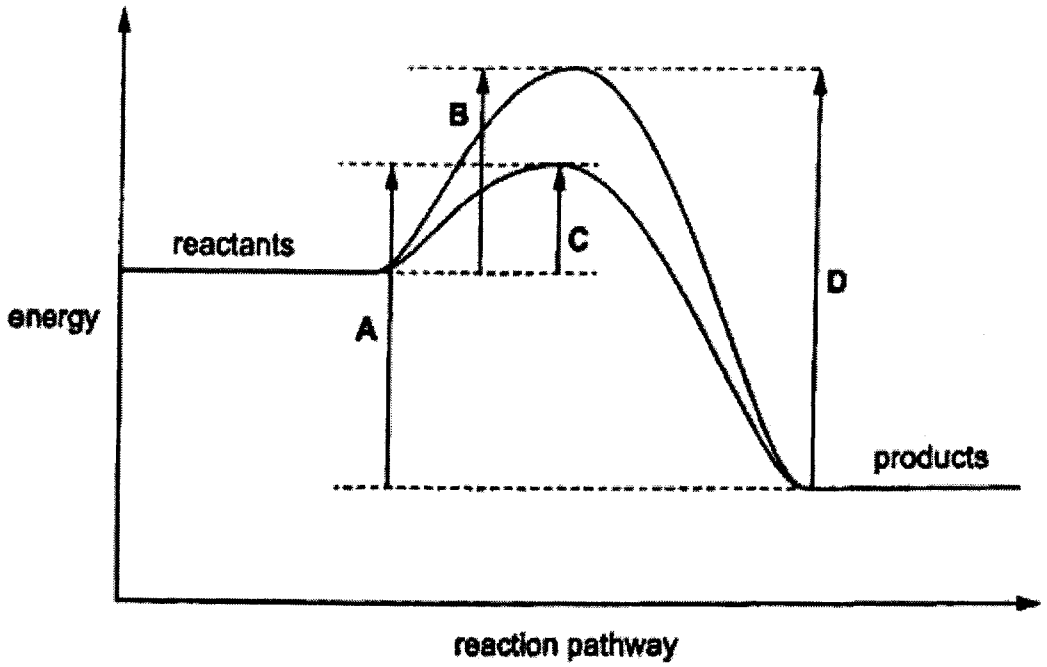
C The metal is less reactive than hydrogen and can be found uncombined in nature.

D The metal is more reactive than hydrogen but less reactive than carbon, so should be reduced using hydrogen.

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32 When 7.0 g of **Q** is added to a mixture of reactants, the rate of reaction increases. At the end of the reaction, 7.0 g of **Q** is still present in the mixture.

Which energy change represents the activation energy of the reaction when **Q** is added?



33 The enthalpy change of the decomposition of nitrogen(II) oxide, NO, is –180kJ/mol.

$$2NO(g) \rightarrow N_2(g) + O_2(g)$$

What is the enthalpy change of the reaction shown?

$$4NO(g) \rightarrow 2N_2(g) + 2O_2(g)$$

A –360kJ **B** –180kJ **C** +180kJ **D** +360kJ

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34 The table shows information about two fractions obtained from the fractional distillation of crude oil.

fraction	average number of carbon atoms	collection point in column
petrol	5 – 9	near the top
diesel	14 – 20	lower than petrol

Which statement explains why petrol is collected nearer the top of the column than diesel?

A Petrol contains smaller molecules, so its intermolecular forces of attraction are weaker, and it condenses at lower temperature.

B Petrol is more flammable than diesel, so it separates at a higher temperature.

C Diesel has stronger covalent bonds, which increases its boiling points.

D Diesel contains more carbon atoms, so it rises higher in the column before condensing.

35 Alkenes can be produced by the cracking of alkanes, such as decane, $C_{10}H_{22}$.

Which equation correctly shows the cracking of decane to produce two different alkenes and at least one other product?

A $C_{10}H_{22} \rightarrow 2C_2H_4 + C_3H_6 + C_4H_{10}$

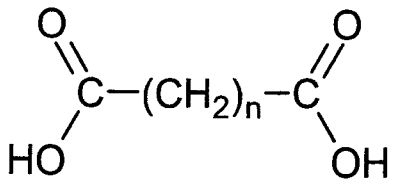
B $C_{10}H_{22} \rightarrow H_2 + 2C_2H_4 + C_3H_6 + C_5H_{10}$

C $C_{10}H_{22} \rightarrow 2C_3H_6 + C_4H_{10}$

D $C_{10}H_{22} \rightarrow H_2 + 2C_2H_4 + 2C_3H_6$

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36 The setting agent used in the manufacture of chocolate mousse is an organic acid. It has a relative molecular mass of 146.



How many carbon atoms are there in one molecule of this organic acid?

A 4 **B** 5 **C** 6 **D** 7

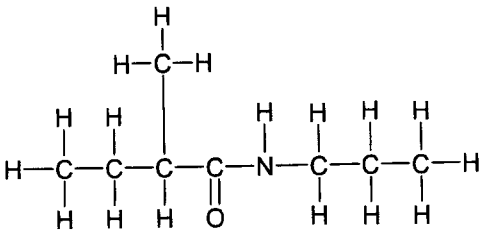
37 In which compounds are the empirical and molecular formulae different?

1 ethanoic acid
2 ethyl ethanoate
3 propane

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

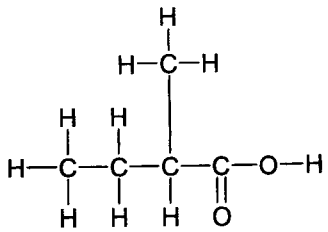
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38 An amide has the following structure.

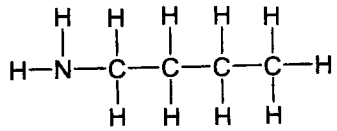


Which two compounds will react to form this amide?

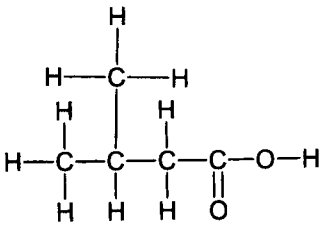
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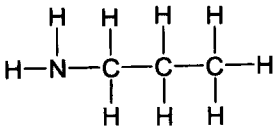
2



3



4



A 1 and 4

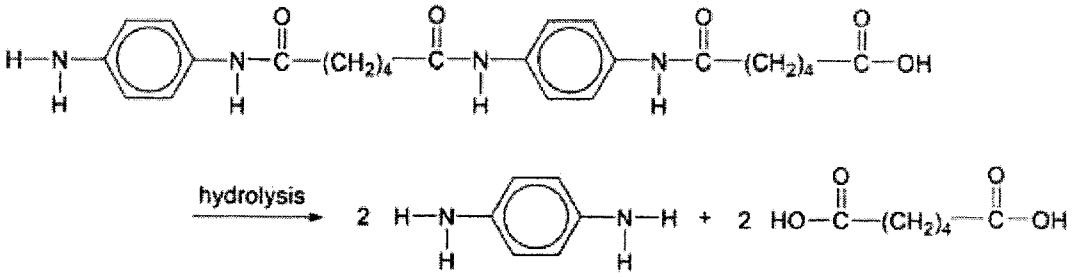
B 2 and 3

C 1 and 2

D 3 and 4

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39 A polyamide **S** is hydrolysed as shown.



Another polyamide **T** is hydrolysed using the same method.

The equation is shown.

$$\mathbf{T} \rightarrow 10\ H_2N(CH_2)_6NH_2 + 10\ HOOC(CH_2)_4COOH$$
$$(M_r = 116) \qquad (M_r = 146)$$

What is the M_r of **T**?

A 2260 **B** 2278 **C** 2440 **D** 2620

40 Which list shows typical uses of man-made fibres?

A cling film, fishing line, parachutes

B cling film, clothing, sleeping bags

C fishing line, plastic bags, sleeping bags

D clothing, fishing line, parachutes

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

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BP~372

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PRELIMINARY EXAMINATION
SECONDARY FOUR EXPRESS
CHEMISTRY

CANDIDATE NAME					
CLASS	4			INDEX NUMBER	

CHEMISTRY

Paper 2

6092/02
15 August 2025
1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in.
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.
DO **NOT** WRITE ON ANY BARCODES.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page 24.

The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Section A	
Section B	
Total	**/ 80**

This document consists of **24** printed pages.

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Section A

Answer **all** questions.

1 The electron arrangement in the outer shells of five elements, **A**, **B**, **C**, **D** and **E** are shown in Fig.1.1. All elements are from Period 3 of the Periodic Table.

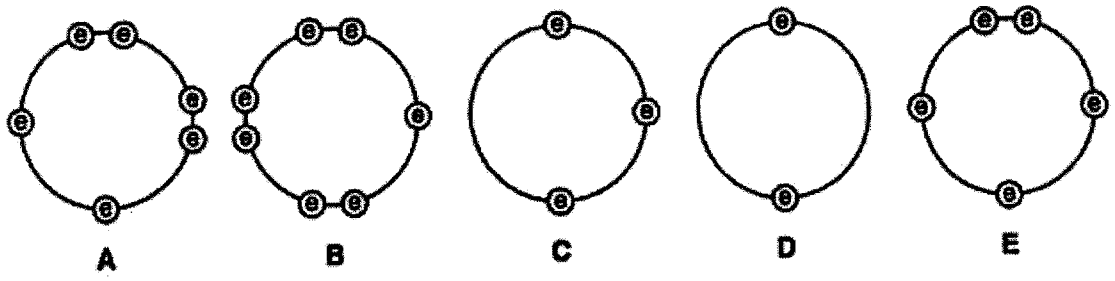


Fig. 1.1

Use the letters **A**, **B**, **C**, **D** and **E** to answer the following questions.

Each letter may be used once, more than once or not at all.

(a) Which **two** elements are most likely to be metals?

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

(b) Which element has an atomic number of 16?

.....[1]

(c) Which element will form double covalent bonds with an oxygen atom?

.....[1]

(d) Which **two** elements will form an ionic compound with the formula type XY?

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

(e) Which element will form an oxide that reacts with both acids and bases?

.....[1]

[Total: 5]

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2 **(a)** Table 2.1 shows information of atoms.

Complete Table 2.1.

Table 2.1

atoms	number of protons	number of neutrons	number of electrons
$^{39}_{19}K$			
		28	24

[2]

(b) The strength of interactions between particles determines whether the substance is a solid, liquid or gas at room temperature.

Potassium oxide, K_2O, is a solid while sulfur trioxide, SO_3, is a liquid at room temperature.

(i) Explain in terms of structure and bonding, why potassium oxide is a solid while sulfur trioxide is a liquid at room temperature.

.....

.....

.....

.....

.....[3]

(ii) State one other difference in the physical properties of potassium oxide and sulfur trioxide.

.....

.....[1]

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(iii) Draw a 'dot-and-cross' diagram to show the bonding in K_2O.

Show all outer shell electrons.

[2]

(c) Potassium oxide, aluminium oxide and sulfur trioxide are each added to separate samples of dilute sulfuric acid and aqueous sodium hydroxide.

Complete Table 2.2 to show whether a reaction occurs in each case.

Put a tick (✓) in the box if a reaction occurs.

Table 2.2

	dilute sulfuric acid	dilute sodium hydroxide
potassium oxide		
aluminium oxide		
sulfur trioxide		

[2]

[Total: 10]

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3 A student performs three experiments. In the first experiment, she adds large pieces of copper(II) carbonate to dilute hydrochloric acid. Copper(II) carbonate added is in excess.

(a) Fig. 3.1 shows how the mass of the reaction mixture changes with time as the reaction proceeds.

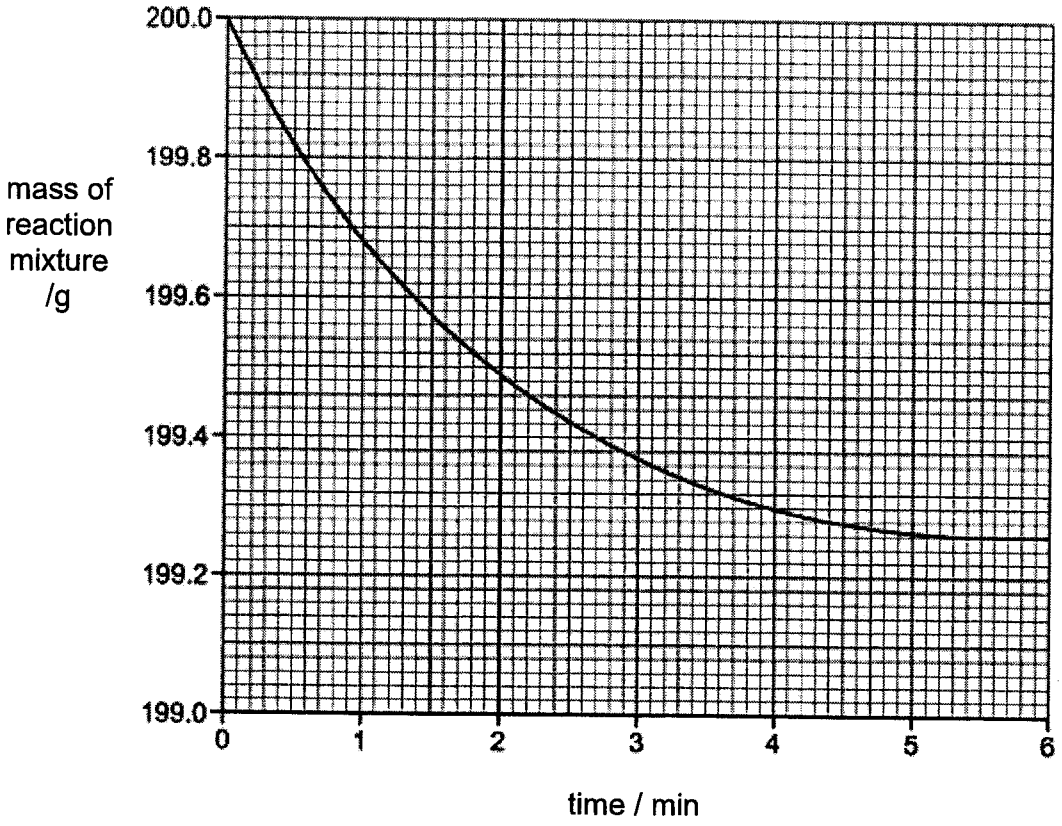


Fig. 3.1

(i) In the second experiment, powdered copper(II) carbonate is used instead of large pieces of copper(II) carbonate. All other conditions and the mass of copper(II) carbonate stay the same.

Draw a line on the grid in Fig. 3.1 to show how the mass of the reaction mixture changes with time when powdered copper(II) carbonate is used.

[1]

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(ii) In the third experiment, the student uses large pieces of copper(II) carbonate and hydrochloric acid of a higher concentration.

All other conditions stay the same.

Describe and explain the difference in the rate of reaction when hydrochloric acid of a higher concentration is used.

.....

.....

.....[2]

(b) After the copper(II) carbonate has reacted completely with hydrochloric acid, the student places a clean strip of zinc metal into the resulting solution.

Suggest and explain the observations.

.....

.....

.....[2]

(c) Describe what you see when:

(i) a few drops of aqueous ammonia are added to an aqueous solution containing copper(II) ions.

.....[1]

(ii) excess aqueous ammonia is added to an aqueous solution containing copper(II) ions.

.....[1]

(d) Describe how to prepare crystals of ammonium chloride by reacting aqueous ammonia with dilute hydrochloric acid.

.....

.....

.....

.....

.....[3]

[Total: 10]

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4 **(a)** Petrol is a mixture of hydrocarbons that includes octane, C_8H_{18}.

(i) Write an equation for the complete combustion of octane.

.....[1]

(ii) Suggest a reason why the fuel in an internal combustion engine is unlikely to undergo complete combustion.

.....[1]

(b) Exhaust gases from petrol engines contain compounds which are harmful to the environment. These includes oxides of carbon and nitrogen.

(i) Write an equation to show the removal of carbon monoxide **and** nitrogen monoxide from the exhaust gases.

.....[1]

(ii) Thiophene, C_4H_4S, is present in crude oil fractions. During combustion, it produces sulfur dioxide. Combustion of fuels also produces nitrogen dioxide.

Explain the effects of sulfur dioxide and nitrogen dioxide being released into the atmosphere.

.....

.....

.....

.....

.....[2]

(c) Explain, in terms of specific processes, how the carbon cycle regulates the amount of carbon dioxide in the atmosphere.

.....

.....[1]

[Total: 6]

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5 **(a)** Fig. 5.1 show some organic compound reactions.

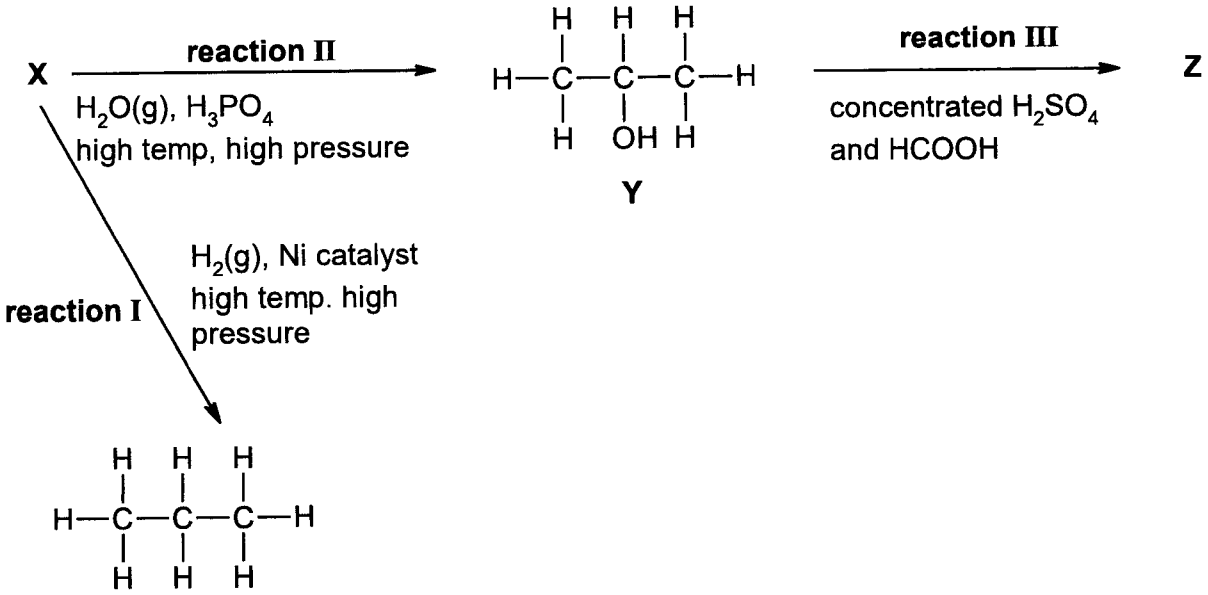


Fig. 5.1

(i) Draw the organic compounds, **X** and **Z** in the spaces provided. [2]

X:

Z:

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(ii) Reaction II produces compound **Y** and one other isomer. Draw the full structural formula of the isomer.

[1]

(b) After the fermentation of sugar from sugarcane to produce ethanol, some ethyl ethanoate is found to be present in the mixture.

Suggest how this ethyl ethanoate may be formed.

.....

.....

.....[2]

(c) A student is given three unlabelled bottles containing colourless liquids.

One of the liquids is ethanol, one is ethanoic acid, and the other is ethyl ethanoate.

Describe the reagents and conditions for a chemical test that gives positive result **only** with ethanol. Describe what would be observed.

reagents and conditions .....

.....[1]

observations .....

.....[1]

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(d) 1.00 g of a powder contains

0.30 g of glucose, $C_6H_{12}O_6$

0.45 g of citric acid, $C_6H_8O_7$

0.25 g of sodium hydrogencarbonate, $NaHCO_3$

In the presence of water, the powder effervescences as citric acid reacts with the sodium hydrogencarbonate to form sodium citrate, $Na_3(C_6H_5O_7)$.

$$3NaHCO_3(s) + C_6H_8O_7(aq) \rightarrow Na_3(C_6H_5O_7)(aq) + 3CO_2(g) + 3H_2O(l)$$

(i) Determine the limiting reactant when 1.00 g of this powder reacts.

[2]

(ii) In an experiment, 0.043 dm^3 of CO_2 is produced in the above reaction from using 1.00 g of the powder.

Calculate the percentage yield obtained in this experiment.

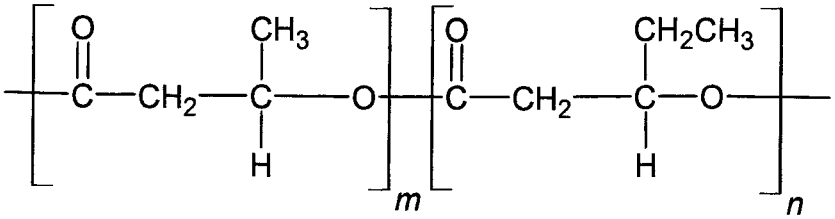
[2]

[Total: 11]

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6 **(a)** Synthetic polymers are macromolecules which have many uses. They are made from monomers which combine in polymerisation reactions.

The synthetic polymer, PHBV, is a polymer which is often used in packaging material.



PHBV

(i) Draw the structural formulae of the two monomers used to make PHBV.

[2]

(ii) State the type of reaction used to make PHBV.

.....[1]

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(b) (i) Poly(ethene) is an example of a poly(alkene) and can be used in food plastic wrapping.

This polymer macromolecule has a relative molecular mass of between 15 000 and 20 000.

Calculate the minimum number of repeating units needed to be present in one macromolecule of poly(ethene).

[2]

(ii) Suggest why people are encouraged to recycle poly(alkenes).

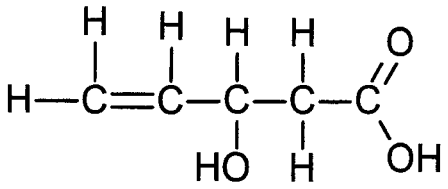
.....

.....

.....[1]

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(c) Compound **X** can be polymerised to form two different polymers.



X

Draw a repeat unit for each of the polymer.

repeat unit for polymer 1

[1]

repeat unit for polymer 2

[1]

[Total: 8]

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7 Role of water chemistry in aquarium health

Water chemistry plays a critical role in the well-being of fishes in an aquarium. Fish waste releases ammonia, NH_3, and ammonium ions, NH_4^+, into water, both of which are toxic to fish. NH_3 is highly toxic to fish, whereas NH_4^+ is significantly less harmful.

Nitrification process

During nitrification, NH_3 and NH_4^+ are broken down by beneficial bacteria into less toxic nitrate ions, NO_3^-, as shown in Fig. 7.1.

ammonia NH_3 → (beneficial bacteria **A**) → nitrite NO_2^- → (beneficial bacteria **B**) → nitrate NO_3^-

$$NH_4^+ + 2O_2 \rightarrow 2H^+ + NO_3^- + H_2O$$

Fig. 7.1

Establishing a new aquarium

Setting up a new aquarium involves establishing colonies of beneficial bacteria in the tank before fish are added. NH_3 and NH_4^+ are added daily, and the concentrations of different water parameters are monitored.

Fig. 7.2 shows a graph of the water parameters over 35 days.

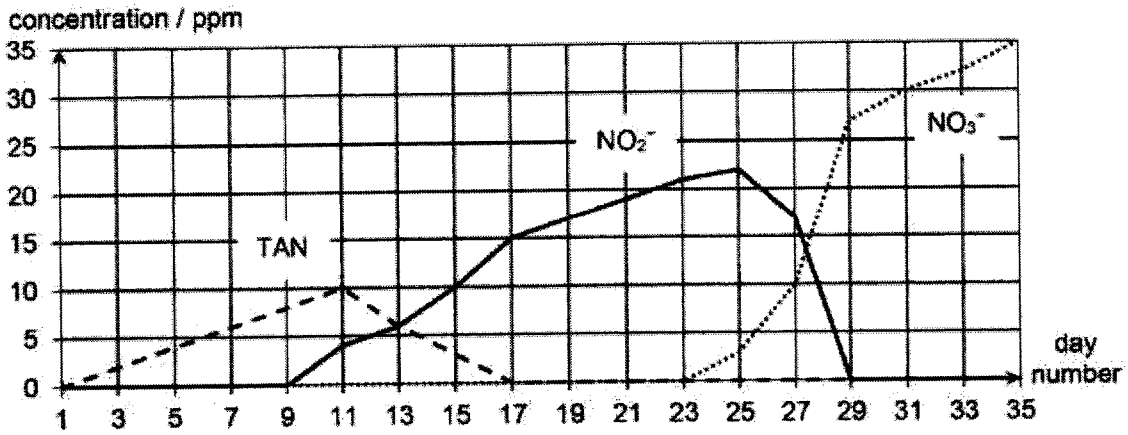


Fig. 7.2

The presence of the respective products in Fig. 7.1 indicates that the beneficial bacteria has been established.

Fish can only be safely added after the concentration of NO_2^- increases then decreases to 0 ppm as NO_2^- is also toxic to fish.

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PPM, or parts per million, indicates how many units of a substance are present for every one million units of the total mixture.

Percentage of NH_3 in total ammonia nitrogen (TAN)

The total ammonia nitrogen, TAN, measured is the sum of the concentrations of NH_3 and NH_4^+ present.

The percentage of TAN present as NH_3 is affected by the pH of the aquarium water.

Table 7.3 shows the approximate percentage of TAN present as NH_3 at different pH values.

Table 7.3

pH	% of TAN present as NH_3
6.0	0.4
6.5	1.0
7.0	2.5
7.5	6.3
8.0	16.0
8.5	26.0
9.0	39.0

Measuring dissolved oxygen

The recommended range for the concentration of dissolved oxygen in aquarium water samples is 0.000150 to 0.000500 mol/dm^3.

Manganese is a transition element. In this experiment, manganese(II) hydroxide, $Mn(OH)_2$, is added to aquarium water. Dissolved oxygen in the water oxidises $Mn(OH)_2$ to $Mn(OH)_3$.

The $Mn(OH)_3$ then reacts to produce iodine, I_2. The I_2 is then titrated with thiosulfate ions, $S_2O_3^{2-}$, solution.

It is known that 1 mole of dissolved oxygen produces 4 moles of thiosulfate ions.

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(a) Despite nitrification takes place readily under the conditions in an aquarium, the presence of beneficial bacteria is necessary for any appreciable breakdown of NH_3 or NH_4^+ to be observed within a short time.

Suggest the role of beneficial bacteria in the nitrification process.

.....[1]

(b) **(i)** State the day number that first indicates that beneficial bacteria **A** is established.

.....[1]

(ii) State the day number that is first safe for the addition of fish.

.....[1]

(iii) On day 35, 25% of the aquarium water is replaced with water that is free of NO_3^-.

Calculate the new concentration of NO_3^-, in ppm.

[1]

(c) The pH of the aquarium water on Day 11 is measured to be 7.5.

(i) State the value of TAN on Day 11.

.....[1]

(ii) Hence, calculate the concentration of NH_3 present, in ppm, on Day 11.

[1]

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(d) A 100 cm^3 of sample of aquarium water containing dissolved oxygen requires 13.40 cm^3 of 0.0100 mol/dm^3 thiosulfate solution to reach the titration end point.

Calculate the concentration of dissolved oxygen in this 100 cm^3 sample and hence determine if it falls within the recommended range.

[3]

(e) State one chemical property of manganese.

.....

.....[1]

(f) A student found iron parts in an aquarium filter starting to rust over time. She decides to attach a strip of zinc metal to the iron to prevent rusting.

(i) Name the method used to protect the iron.

.....[1]

(ii) Explain why this method is effective, based on the reactivity series.

.....

.....[1]

[Total: 12]

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8 **(a)** Aqueous nickel(II) sulfate, a green solution, is electrolysed using inert platinum electrodes.

During electrolysis, the green colour of the solution fades. Bubbles are observed at one of the electrodes.

Nickel(II) ions, Ni^{2+}, are discharged during this process.

(i) Write the ionic equation for the reaction that occurs at the electrode where Ni^{2+} ions are discharged.

.....[1]

(ii) Identify the gas released during this electrolysis and the electrode where it is formed.

gas: .....

electrode: .....[1]

(iii) Explain why the green colour of the solution fades.

.....

.....[1]

(b) A simple cell is then set up using a nickel strip and a cadmium strip in a beaker of aqueous sodium hydroxide.

The reactivity series shows: Cadmium > Nickel > Hydrogen

(i) Identify which metal is the negative electrode in this cell. Explain your answer.

.....

.....[1]

(ii) State one physical property of nickel and cadmium that make them suitable for use as electrodes in batteries.

.....[1]

(iii) State the direction of electron flow in the external circuit in terms of the metals used.

From ..... to ..... [1]

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(iv) State and explain whether the simple cell will continue to function if the sodium hydroxide electrolyte dries up.

.....

.....

.....[1]

(c) The equation below shows a reaction that occurs in some cells:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

Show which substance is oxidised using oxidation states.

.....

.....[1]

[Total: 8]

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Section B

Answer **one** question from this section.

9 Scientists conducted two experiments to study how different acids and heat affect calcium carbonate.

Experiment 1:

Equal-sized pieces of calcium carbonate were added to aqueous hydrochloric acid, and aqueous ethanoic acid of equal concentration and volume.

(a) (i) Write an equation for the reaction of aqueous ethanoic acid with calcium carbonate.

.....[1]

(ii) Explain why the reaction with hydrochloric acid is faster than with ethanoic acid, even though both acids have the same concentration.

.....

.....

.....

.....[2]

(iii) The reaction between calcium carbonate and hydrochloric acid is exothermic.

Explain, in terms of bond breaking and bond forming, why the overall enthalpy change for this reaction is negative.

.....

.....

.....

.....[2]

(b) Experiment 2:

A separate sample of calcium carbonate was heated strongly in a test tube.

(i) Write an equation for the thermal decomposition reaction.

.....[1]

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(ii) Explain how the reactivity of calcium and copper affects the thermal decomposition of their respective carbonates.

.....

.....[1]

(c) Crustaceans such as crabs use calcium carbonate to build their shells.

When carbon dioxide dissolves in water, it forms carbonic acid. The following equilibria are established:

Equilibrium 1: $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equilibrium 2: $H_2CO_3(aq) \rightleftharpoons 2H^+ + CO_3^{2-}(aq)$

Table 9.1 shows the concentration of hydrogen ions and carbonate ions in seawater as the amount of dissolved carbon dioxide increases.

Table 9.1

amount of dissolved CO_2	concentration of H^+ / mol/dm^3	concentration of CO_3^{2-} / mol/dm^3
low	1.0×10^{-6}	2.0×10^{-3}
high	1.0×10^{-5}	0.5×10^{-3}

(i) Using the information in Table 9.1, suggest why an increase in dissolved carbon dioxide makes it more difficult for crustaceans to form their shells.

.....

.....[1]

(ii) State the colour change you would expect when Universal Indicator is added to seawater with high dissolved carbon dioxide.

.....[1]

(iii) A student is given a seawater sample and wants to find out if it contains carbonate ions.

Describe a chemical test the student could carry out to confirm the presence of carbonate ions.

.....

.....[1]

[Total: 10]

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10 Scientists investigated the chemical behaviour and thermal stability of different carbonates.

(a) Experiment 1:

Samples of sodium carbonate and magnesium carbonate were each added to separate beakers containing equal volumes and concentrations of nitric acid. The rate of gas formation was recorded, and pH measurements were taken before and after excess acid was added.

(i) Write an ionic equation for the reaction between carbonate ions and hydrogen ions.

.....[1]

(ii) Sodium carbonate reacts faster than magnesium carbonate.

Explain this observation in terms of solubility and ions availability.

.....

.....

.....[1]

(iii) The pH of sodium carbonate solution was 11 before nitric acid was added. After excess nitric acid was added, the pH dropped to 3.

Explain this change in terms of the ions present in the solution and their concentrations.

.....

.....

.....[1]

(iv) Predict and explain the difference in the total volume of gas produced when equal masses of sodium carbonate and magnesium carbonate are used, assuming complete reaction.

.....

.....

.....

.....[2]

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(b) Experiment 2:

A student heated magnesium carbonate and copper(II) carbonate separately in test tubes and observed the temperature at which decomposition began.

(i) Write an equation for the thermal decomposition of magnesium carbonate.

.....[1]

(ii) The gas produced from the thermal decomposition of magnesium carbonate was passed through limewater for a few minutes. A precipitate was initially formed.

Identify the precipitate and state what happens when the gas is passed through limewater for a longer time.

.....

.....

.....[2]

(iii) The decomposition of magnesium carbonate is an endothermic process.

Explain, in terms of bond breaking and bond forming, why the overall enthalpy change for this reaction is positive.

.....

.....

.....

.....[2]

[Total: 10]

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

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2025 S4 Preliminary Examination
Suggested Solutions

Answer Key

1	2	3	4	5
C	B	C	D	C

6	7	8	9	10
A	C	D	C	D

11	12	13	14	15
D	B	D	B	B

16	17	18	19	20
D	B	B	A	A

21	22	23	24	25
A	D	A	B	A

26	27	28	29	30
C	C	D	B	C

31	32	33	34	35
A	C	A	A	D

36	37	38	39	40
C	B	A	B	D

1 **C**

Why C: To make a dry acidic gas like SO_2 from solid + acid, you need a delivery tube → drying agent that doesn't react with SO_2 (conc. H_2SO_4 or anhydrous $CaCl_2$) → downward delivery (SO_2 is denser than air).

Why not A/B/D:
A: Basic CaO will react with acidic SO_2 gas.

B: Using the filter funnel will allow the SO_2 gas to escape.

D: Upward delivery method is used for gases less dense than air.

2 **B**

Why B: Iodine is a substance that sublimes (changes directly from solid to purple vapour without melting).

Sodium chloride (NaCl) does not sublime; it has a very high melting point and remains solid.

By heating the mixture gently, iodine vapour can be driven off, collected and cooled back into solid iodine crystals. Sodium chloride stays behind as a solid.

Why not A/C/D:
A: Both iodine and sodium chloride are solids, not dissolved in a solution, so crystallisation is not suitable.
C: Works only to separate insoluble solid from liquid, not two solids.
D: Used to separate liquids with different boiling points, not solid mixtures like this.

3 **C**

Step 1: Interpreting statement 1
Z shows four distinct spots on the chromatogram.
That means Z contains at least four different components.
It cannot be "no more than four" because there could be more that did not separate under the given solvent conditions.
So, statement 1 must be "Z contains at least four alcohols".

Step 2: Interpreting statement 2
If spots from X, Y and Z line up at the same R_f values, that suggests those mixtures may contain a common alcohol.
Therefore, it is possible they share the same substance.
So, statement 2 = "X, Y and Z could contain the same alcohol".

4 **D**

Statement 1: Molecules gain kinetic energy and temperature increases.
Wrong. During melting, the temperature stays constant at 0 °C. The particles don't gain kinetic energy; instead, energy goes into overcoming intermolecular forces of attraction.

Statement 2: Energy is gained to overcome the intermolecular forces of attraction.
Correct. Heat energy supplied during melting is used to overcome intermolecular forces of attraction.

Statement 3: Molecules gain sufficient energy to move from fixed positions.
Correct. Solid ice particles are in fixed positions. When melting, they break free and can slide past each other.

5 **C**

The lighter the gas, the faster it diffuses.

Cl_2: $35.5 \times 2 = 71$
CO_2: $12 + (16 \times 2) = 44$
CH_4: $12 + (1 \times 4) = 16$
NO_2: $14 + (16 \times 2) = 46$

The smallest $M_r = 16$ (CH_4). Hence, CH_4 diffuses the fastest.

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6	A	
✓	A	Proton charge = +1 Electron charge = –1 Equal magnitude, opposite signs.
×	B	Neutron has 0 charge, not +1.
×	C	Neutron = 1 (relative mass). Electron = $\frac{1}{1840}$ so it's much lighter, not heavier.
×	D	Proton = 1 and Electron = $\frac{1}{1840}$

7	C	
×	A	Isotopes of an element have the same number of electrons → same electronic configuration → same chemical properties. They may differ in physical properties (e.g. density, boiling point), but not in chemistry reactions.
×	B	Isotopes differ in number of neutrons. They have the same chemical properties but physical properties are different.
✓	C	mass number = protons + neutrons Different isotopes differ in number of neutrons hence, they have different mass numbers. Different isotopes have the same number of electrons hence, they have the same electronic configuration, same chemical properties.
×	D	If the proton numbers are different, they are different elements instead not isotopes.

8	D	
×	1	W is 2+ not 2–.
×	2	Should be W_3Y_2
✓	3	WZ_2 is $MgCl_2$

9	C	
×	1	Giant covalent (e.g. diamond, SiO_2) → high mp but do not conduct electricity at all (except graphite).
✓	2	Example: CO_2, I_2. Weak intermolecular forces → low melting point. No free ions/free delocalised electrons → does not conduct electricity
✓	3	Metals conduct due to delocalised electrons in both states. Different metals have different melting points.

10	D
	Use trial and error method

11	D
	Why right: Molecular formula + Ar values gives Mr directly. Why others wrong: Empirical formula or % by mass alone isn't enough to get molecular mass.

12	B
	% Cu in $CuFeS_2$ = $\frac{64}{64+56+2(32)} \times 100 = 34.782\%$ If ore has 1% Cu, % = (1 ÷ 34.782) x 100% = 2.88%

13	D
	no. mol of B = $\frac{0.78}{11} = 0.070909$ no. mol of C = $\frac{0.22}{12} = 0.018333$ Ratio of B:C ≈ 4:1 B_4C

14	B
	no. mol of Q molecules = $\frac{1}{x}$ no. of Q molecules = $\frac{1}{x} \times L = \frac{L}{x}$ no. of Q atoms = $2 \times \frac{L}{x} = \frac{2L}{x}$

15	B
	To neutralise acidic soil, add a base (alkali). Reasoning: • Calcium hydroxide is a strong base used in agriculture ("liming"). • Neutralisation increases pH value towards neutral.

16	D
	Acidic oxides (e.g. CO_2) react with alkalis Amphoteric oxides (e.g. ZnO) react with both acids and alkalis. Basic oxides (e.g. CuO) do not react with alkali.

17	B
	Insoluble base/carbonate + acid → filter off excess solid → evaporate filtrate → crystallise salt. • $CuSO_4$ can be made by reacting an insoluble copper(II) oxide/carbonate with dilute sulfuric acid. • Ammonium chloride is prepared by titration method. • Barium sulfate is insoluble; it forms via precipitation, not crystallisation. • Potassium chloride is prepared by titration method.

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18 **B**

Higher pressure → higher yield of NH_3; also increases reaction rate.
Higher temperature increases reaction rate but reduces yield.
Catalyst increases reaction rate only; no change to yield.

19 **A**

Reaction of metal ions with $NH_3(aq)$ vs excess $NH_3(aq)$:
Zn^{2+}: white $Zn(OH)_2$ ppt with few drops; dissolves in excess NH_3 to give colourless solution.

Al^{3+}: white $Al(OH)_3$ ppt with few drops; does not dissolve in excess NH_3 (unlike in excess NaOH)

After dissolving alloy in HCl you have $Zn^{2+}(aq)$ and $Al^{3+}(aq)$. Adding excess NH_3: Zn ppt dissolves, $Al(OH)_3$ remains→ white ppt observed.

20 **A**

$Fe^{2+} + OH^- \rightarrow$ green $Fe(OH)_2(s)$. Fe^{3+} would give brown $Fe(OH)_3$ ppt.

NH_4^+ + warm NaOH → NH_3 gas (alkaline, turns red litmus blue).

Nitrate test (Al foil in warm alkali): forms NH_3→ turns red litmus blue.

Green ppt ⇒ Fe^{2+}, not Fe^{3+}.
Heating with NaOH produced no gas ⇒ no NH_4^+.
After adding Al foil and warming, a gas formed that turned red litmus blue ⇒ NO_3^- present.

21 **A**

Electrorefining of copper, electrolyte: $CuSO_4(aq)$.

Anode (impure copper): $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ (anode loses mass).

Cathode (pure copper): $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (cathode gains mass).

Electrolyte colour: remains blue (Cu^{2+} continually replenished at anode as it is removed at cathode).

✗	B / D	Solution does not become colourless; Cu^{2+} stays present.
✗	C	Solution does not get increasingly blue overall; $[Cu^{2+}]$ is maintained.

22 **D**

Cathode (reduction of O_2): $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
⇒ $[OH^-]$ increases → pH value increases.

Anode (oxidation of H_2): $H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$
⇒ OH^- consumed → pH value decreases.

23 **A**

Concept to recall: At inert anodes in dilute solutions, OH^- tends to be oxidised to O_2 unless the halide is concentrated and lower in the discharge series.
Reasoning:
Dilute NaCl: OH^- oxidised → O_2 (Cl_2 is favoured only when concentrated).
Concentrated NaBr: Br^- oxidised → Br_2.
Dilute Na_2SO_4: sulfate is hard to oxidise; OH^- oxidised → O_2.

24 **B**

Concept to recall:
Group number equals number of valence electrons in the atom.

Reasoning:
1: 2,3 ⇒ Group 13.
2: 2,8,3 ⇒ Group 13.
3: $(2,8,8)^{3-}$ corresponds to P^{3-} (came from 2,8,5; Group 15 as an atom).
Thus not same group as 1 & 2.

25 **A**

Group 13 metals often form MCl_3 and their oxides are basic to neutralise acids.

✓	1	$InCl_3$ is expected ($In^{3+} + 3Cl^-$).
✓	2	Its oxide neutralises nitric acid." Basic behaviour.
✗	3	Its chloride forms coloured solutions." Most In(III) salts are colourless in solution.

26 **C**

Group number → number of valence electrons.
Period number → number of electron shells.
Position across the Period/Group → whether oxides are acidic/basic/amphoteric, and reactivity trends.

BUT the number of isotopes is determined by the nucleus (neutrons), and this does not follow a periodic pattern. You cannot look at an element's place in the table and know how many isotopes it has.

✗	A	Oxide nature → Predictable. Across Period 3 for example: Na_2O, MgO (basic); Al_2O_3 (amphoteric); SiO_2, P_4O_{10}, SO_3 (acidic).
✗	B	Valence electrons→ Predictable. Group 1 all have 1 outer electron, Group 17 all have 7,
✓	C	Number of isotopes → Not predictable. Chlorine has 2 stable isotopes, carbon has 2 common stable isotopes, while fluorine has only 1. This pattern does not follow groups or periods.
✗	D	Reactivity→ Predictable E.g. reactivity of alkali metals increases down Group 1; reactivity of halogens decreases down Group 17.

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27	C Density increases down Group 1. Melting point decreases down Group 1. Reactivity increases down Group 1 (lower ionisation energy). All Group 1 chlorides are soluble.	
×	A	Wrong. Rubidium is denser.
×	B	Wrong. Rubidium has a lower melting point.
✓	C	Rubidium is more reactive than K, so it reacts more explosively with water.
×	D	Both RbCl and KCl are soluble.

28	D Physical state: fluorine and chlorine = gases, bromine = liquid, iodine = solid. Astatine, below iodine, is a solid at room temp. Reactivity decreases down the group. Sodium halides are ionic, not covalent. More reactive halogens (above) displace less reactive halogens (below).	
×	A	Wrong. Astatine is a solid.
×	B	Wrong. It is less reactive than iodine.
×	C	Wrong. Sodium–halogen compounds are ionic (e.g. NaCl).
✓	D	Correct. Chlorine, being more reactive, displaces At.

29	B Properties of transition metals • variable oxidation states. • forms coloured compounds. • catalysts • high melting points • A: Wrong. They have high melting points. B: Correct. They form ions with variable oxidation states hence, they participate in redox reactions. C: Wrong. Fe and Cu are not in the same group. D: Wrong. They form oxides readily.

30	C Argon is a noble gas: inert, does not react, prevents oxidation. Does not conduct electricity, nor form oxides.

31	A Metals that are more reactive than carbon or hydrogen must be extracted by electrolysis.	
✓	A	Correct. More reactive than both, so electrolysis needed.
×	B	Wrong. If less reactive than carbon, it could be reduced by carbon.
×	C	Wrong. Metals below H can exist uncombined. But if a metal is less reactive than H, then hydrogen can reduce its oxide. But the question says the oxide cannot be reduced by H or C, so this contradicts.
×	D	Wrong. If it were between H and C, it could be reduced by H.

32	C A catalyst lowers activation energy (Ea). ΔH (enthalpy change) of reaction remains the same. Mass of catalyst remains unchanged. Thus the correct diagram is the one with lower forward Ea but same overall ΔH.

33	A Reaction: $2NO \rightarrow N_2 + O_2$, $\Delta H = -180$ kJ Asked: $4NO \rightarrow 2N_2 + 2O_2$ Doubling stoichiometric coefficients doubles ΔH. $\Delta H = 2 \times (-180) = -360$ kJ.

34	A Smaller hydrocarbons → weaker intermolecular forces → lower boiling point → condense higher up (cooler). Diesel has larger molecules, higher boiling points, condenses lower.	
✓	A	Petrol smaller molecules, weaker forces, condenses higher.
×	B	Flammability irrelevant to separation.
×	C	All hydrocarbons have similar covalent bonds; difference lies in intermolecular forces, not covalent bonds.
×	D	Larger molecules condense lower, not higher.

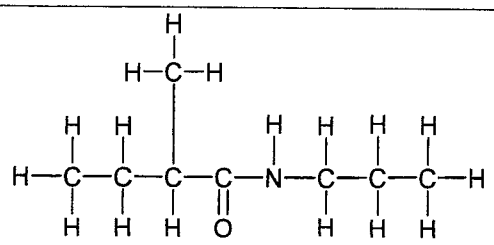
35	D Check each option for balance and conditions: A: C balance (10 C), but only 1 alkene repeated (C_2H_4) + 1 alkene (C_3H_6) + 1 alkane → not 2 different alkenes + extra. B: Carbons = 12 > 10 → unbalanced. C: Gives 2 alkenes + 1 alkane, but not 2 different alkenes. D: $C_{10}H_{22} \rightarrow H_2 + 2C_2H_4 + 2C_3H_6$ → Carbons: 10, Hydrogens: 22. Balanced. Two different alkenes present.

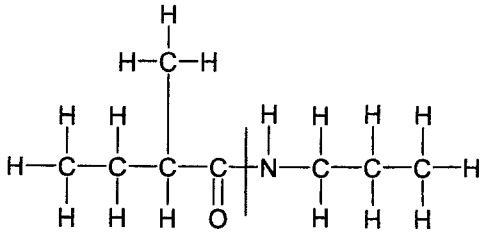
36	C Mr = (6×12) + (10×1) + (4×16) = 72 + 10 + 64 = 146. Hence contains 6 carbon atoms.

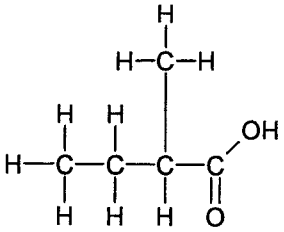
37	B Ethanoic acid: Molecular $C_2H_4O_2$, Empirical CH_2O → different. Ethyl ethanoate: Molecular $C_4H_8O_2$, Empirical C_2H_4O → different. Propane: Molecular C_3H_8, Empirical C_3H_8 (already simplest).

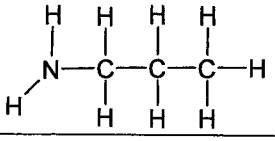
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38	A









39	B
	Total monomers = (10×116) + (10×146) = 2620. Polymer chain of 20 monomers has 19 amide bonds. Each bond formation eliminates 1 H_2O (Mr 18). So Mr = 2620 – (19×18) = 2620 – 342 = 2278.

40	D
	Clothing (polyester/nylon) ✓ Fishing line (nylon) ✓ Parachutes (nylon) ✓

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TANJONG KATONG GIRLS' SCHOOL
PRELIMINARY EXAMINATION
SECONDARY FOUR EXPRESS
CHEMISTRY

CANDIDATE NAME	ANSWERS				
CLASS	4			INDEX NUMBER	

CHEMISTRY
Paper 2

6092/02
15 August 2025
1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in.
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.
DO **NOT** WRITE ON ANY BARCODES.

Section A
Answer **all** questions.
Write your answers in the spaces provided.

Section B
Answer **one** question.
Write your answers in the spaces provided.

The number of marks is given in brackets [ ] at the end of each question or part question.
A copy of the Periodic Table is printed on page 24.

The use of an approved scientific calculator is expected, where appropriate.

For Examiner's Use	
Section A	
Section B	
Total	**/ 80**

This document consists of **24** printed pages.

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Section A

Answer **all** questions.

1 The electron arrangement in the outer shells of five elements, **A**, **B**, **C**, **D** and **E** are shown in Fig.1.1. All elements are from Period 3 of the Periodic Table.

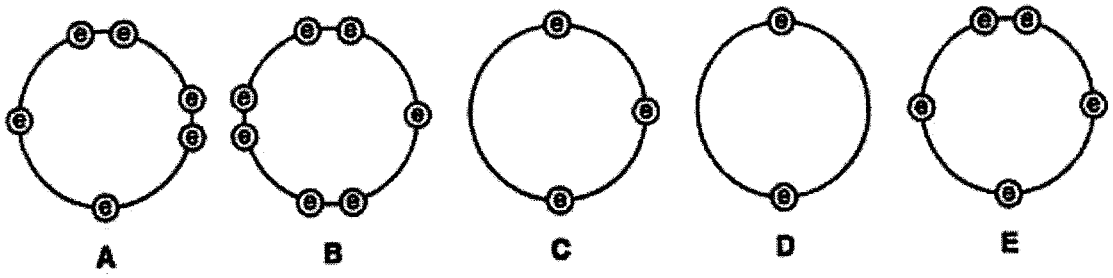


Fig. 1.1

Use the letters **A**, **B**, **C**, **D** and **E** to answer the following questions.
Minus **[1]** from Q1 if they use name of elements.

Each letter may be used once, more than once or not at all.

(a) Which **two** elements are most likely to be metals?

C and D [1]

(b) Which element has an atomic number of 16?

A [1]

(c) Which element will form double covalent bonds with an oxygen atom?

A [1]

(d) Which **two** elements will form an ionic compound with the formula type XY?

C and E OR **D & A [1]**

(e) Which element will form an oxide that reacts with both acids and bases?

C [1]

[Total: 5]

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2 **(a)** Table 2.1 shows information of atoms.

Complete Table 2.1.

Table 2.1

atoms	number of protons	number of neutrons	number of electrons
$^{39}_{19}K$	**19**	**20**	**19**
$^{52}_{24}Cr$	**24**	28	24

[2]

[1] for each correct row

(b) The strength of interactions between particles determines whether the substance is a solid, liquid or gas at room temperature.

Potassium oxide, K_2O, is a solid while sulfur trioxide, SO_3, is a liquid at room temperature.

(i) Explain in terms of structure and bonding, why potassium oxide is a solid while sulfur trioxide is a liquid at room temperature.

K_2O has a **giant ionic structure** with **strong electrostatic forces of attraction between oppositely charged ions**. This requires **large amount of energy** to weaken, hence, K_2O exists as a solid.
accept if students wrote "ionic bonds" instead of "electrostatic forces of attraction between oppositely charged ions"

SO_3 has a **simple molecular / simple covalent structure** with **weak intermolecular forces of attraction.** This requires **small amount of energy** to weaken, hence, SO_3 exists as a liquid.

[1] correct structure for both K_2O and SO_3
[1] correct bonding for both K_2O and SO_3
[1] compare strength / energy required
OR **[1]** correct structure + bonding for either K_2O and SO_3

Candidates who did not gain full credits due to the following
- Failure to mention the "giant ionic structure" and "simple covalent structure".
- Give **contradicting statements** such as "strong electrostatic forces of attraction between atoms" for K_2O and "weak intermolecular forces of attraction between atoms/ions"

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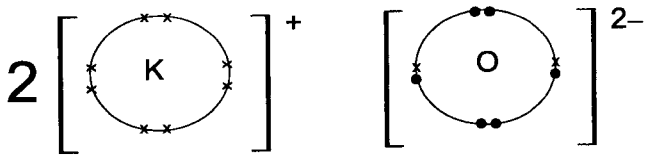
(ii) State one other difference in the physical properties of potassium oxide and sulfur trioxide.

K_2O **conducts electricity in the molten and aqueous state** while SO_3 **does not conduct electricity**.**[1]**

Candidates did not gain credit miss out the point that ionic compound only conduct electricity "in molten and in aqueous" state. Some candidates give melting and boiling point as an answer despite the question indicating to state other difference.

(iii) Draw a 'dot-and-cross' diagram to show the bonding in K_2O.

Show all outer shell electrons.



[1] for cation and **[1]** for anion

Candidates need to follow instructions and show only the **outer** shells electrons.

[2]

(c) Potassium oxide, aluminium oxide and sulfur trioxide are each added to separate samples of dilute sulfuric acid and aqueous sodium hydroxide.

Complete Table 2.2 to show whether a reaction occurs in each case.

Put a tick (✓) in the box if a reaction occurs.

Table 2.2

	dilute sulfuric acid	dilute sodium hydroxide
potassium oxide	✓	
aluminium oxide	✓	✓
sulfur trioxide		✓

[2]

[2] for all correct oxides
[1] for two correct oxides

[Total: 10]

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3 A student performs three experiments. In the first experiment, she adds large pieces of copper(II) carbonate to dilute hydrochloric acid. Copper(II) carbonate added is in excess.

(a) Fig. 3.1 shows how the mass of the reaction mixture changes with time as the reaction proceeds.

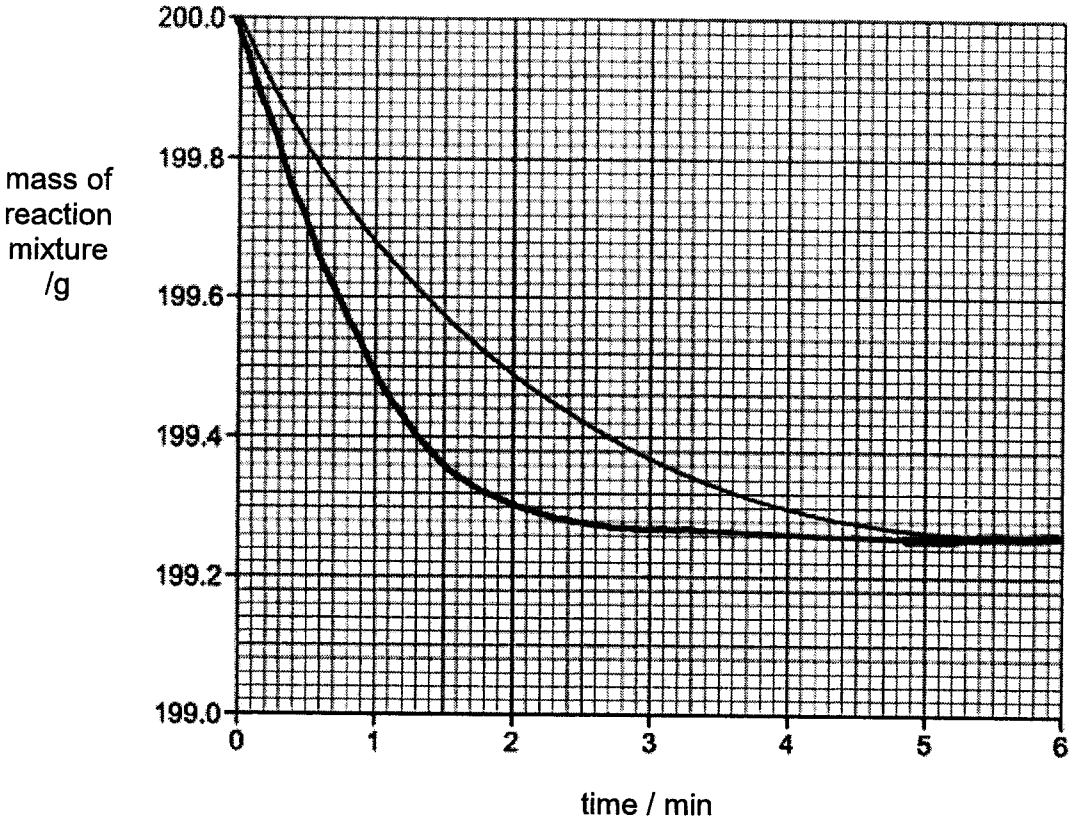


Fig. 3.1

(i) In the second experiment, powdered copper(II) carbonate is used instead of large pieces of copper(II) carbonate. All other conditions and the mass of copper(II) carbonate stay the same.

Draw a line on the grid in Fig. 3.1 to show how the mass of the reaction mixture changes with time when powdered copper(II) carbonate is used.

[1]

[1] initial gradient steeper and line starts at 200.0 + line is curved and ends at the same final mass + line end at earlier time.

(ii) In the third experiment, the student uses large pieces of copper(II) carbonate and hydrochloric acid of a higher concentration.

All other conditions stay the same.

Describe and explain the difference in the rate of reaction when hydrochloric acid of a higher concentration is used.

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When hydrochloric acid of a higher concentration is used, the **rate of reaction increases.** **[no marks]**

There are **more reactant particles per unit volume**.**[1]** Hence, **frequency of effective collision increases** **[1]** resulting in increased reaction rate.

Common mistakes
- Candidates mentioned "*HCl molecules*" , showing that they have forgotten acids dissociates in aqueous solutions to form H^+ ions.
- "Rate of effective collisions", "more effective collisions", "chances of effective collisions" are not accepted.

Better candidates recognise that H^+ ions are responsible for acidic reactions and wrote "more H^+ ions per unit volume" to explain the increase in concentration of acid.

(b) After the copper(II) carbonate has reacted completely with hydrochloric acid, the student places a clean strip of zinc metal into the resulting solution.

Suggest and explain the observations.

A **reddish-brown / brown solid** is formed. / **Blue solution fades**. **[1]**

Zinc displaces copper from copper(II) ions as **zinc is more reactive**.**[1]**

Accept observations of $CuCO_3$ reacting with HCl: Effervescence [1]
Acid + metal carbonate forms CO_2 [1]

Reject "zinc displace Cu^{2+}", "Cu^{2+} is discharged"

Common mistakes:
- Some candidates assumed that the HC*l* is in excess. The HC*l* could be reacting in good ratio with the $CuCO_3$ and hence be used up as well. Suggestions of zinc reacting with excess acid left are not accepted.
- Some candidates assumed that zinc reacted with the water produced from the acid and carbonate reaction. However, the reactivity of zinc does not allow it to react with cold water. Zinc reacts with steam instead.

(c) Describe what you see when:

(i) a few drops of aqueous ammonia are added to an aqueous solution containing copper(II) ions.

light blue precipitate **[1]** accept blue precipitate

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(ii) excess aqueous ammonia is added to an aqueous solution containing copper(II) ions.

light blue **precipitate soluble** in excess aqueous ammonia giving a **dark blue solution**. **[1]**

Part C is not well answered. Candidates must memorise the cation and anion test table for Chemistry Papers 1 and 2 as well.

(d) Describe how to prepare crystals of ammonium chloride by reacting aqueous ammonia with dilute hydrochloric acid.

[Total: 10]

First, carry out a **titration** by slowly adding hydrochloric acid from a burette to 25.0 cm^3 of aqueous ammonia in a conical flask, using **methyl orange** indicator to determine the exact volume of hydrochloric acid needed for neutralisation.**[1]**

Next, **repeat the titration without using an indicator**, **[1]** using the exact volumes of aqueous ammonia and hydrochloric acid to avoid contamination of the salt. The product solution will contain only the salt and water.

Then, **heat** the product solution **to obtain a saturated solution.** **[1]**

Cool the solution so that crystals form.

Filter the mixture to collect the crystals as residue.

Dry the crystals between sheets of filter paper. **[1]** for cool + filter + dry steps

A lot of candidates were not able to decide on the correct salt preparation method. Universal indicator cannot used in titration as it is very difficult to judge a sharp colour change at the end point.

A lot of candidates forgot to repeat the titration without the indicator. Without this step, the crystals formed from the first titration would be contaminated with the indicator and will be coloured.

Heating the ammonium chloride solution to dryness will not yield crystals as ammonium chloride solution upon exposure to heat will dissociate into ammonia and HC*l* gas.

max [3]

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4 **(a)** Petrol is a mixture of hydrocarbons that includes octane, C_8H_{18}.

(i) Write an equation for the complete combustion of octane.

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ [1] no need state symbols

(ii) Suggest a reason why the fuel in an internal combustion engine is unlikely to undergo complete combustion.

There is **insufficient oxygen [1]** in the internal combustion engine hence, incomplete combustion occurs.

Some candidates focus on the large amount of oxygen needed rather than the lack of oxygen, the answer should indicate that there is **insufficient oxygen.**

(b) Exhaust gases from petrol engines contain compounds which are harmful to the environment. These includes oxides of carbon and nitrogen.

(i) Write an equation to show the removal of carbon monoxide **and** nitrogen monoxide from the exhaust gases.

$2CO + 2NO \rightarrow 2CO_2 + N_2$ [1]

(ii) Thiophene, C_4H_4S, is present in crude oil fractions. During combustion, it produces sulfur dioxide. Combustion of fuels also produces nitrogen dioxide.

Explain the effects of sulfur dioxide and nitrogen dioxide being released into the atmosphere.

Sulfur dioxide and nitrogen dioxide dissolve in rainwater to **form acid rain**.**[1]**

Or SO_2 + NO_2 causes respiratory irritation in humans.

1 mark – *Effect of acid rain (any one) WTTE:*

- Acid rain leaches essential nutrients from soil, harming plant growth.
- Acid rain lowers soil pH, making it unsuitable for many plants.
- Acid rain lowers the pH of lakes or ponds, harming or killing aquatic life.
- Acid rain reduces biodiversity in forests or water bodies.
- Acid rain corrodes limestone buildings/statues & metal structures.

Candidates need to indicate the impact of acid rain and not stop at the formation of acid rain. Candidates also need to know that acid rain only affects limestone buildings and metal structures (not all buildings/statues – limestone is often missed out)

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(c) Explain, in terms of specific processes, how the carbon cycle regulates the amount of carbon dioxide in the atmosphere.

Carbon dioxide **released by combustion, decomposition and respiration** (any two) is **removed by photosynthesis.**[1]

Candidates who were not awarded the credit often only mentioned about how CO_2 is removed and missed out how CO_2 is produced.

[Total: 6]

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5 **(a)** Fig. 5.1 show some organic compound reactions.

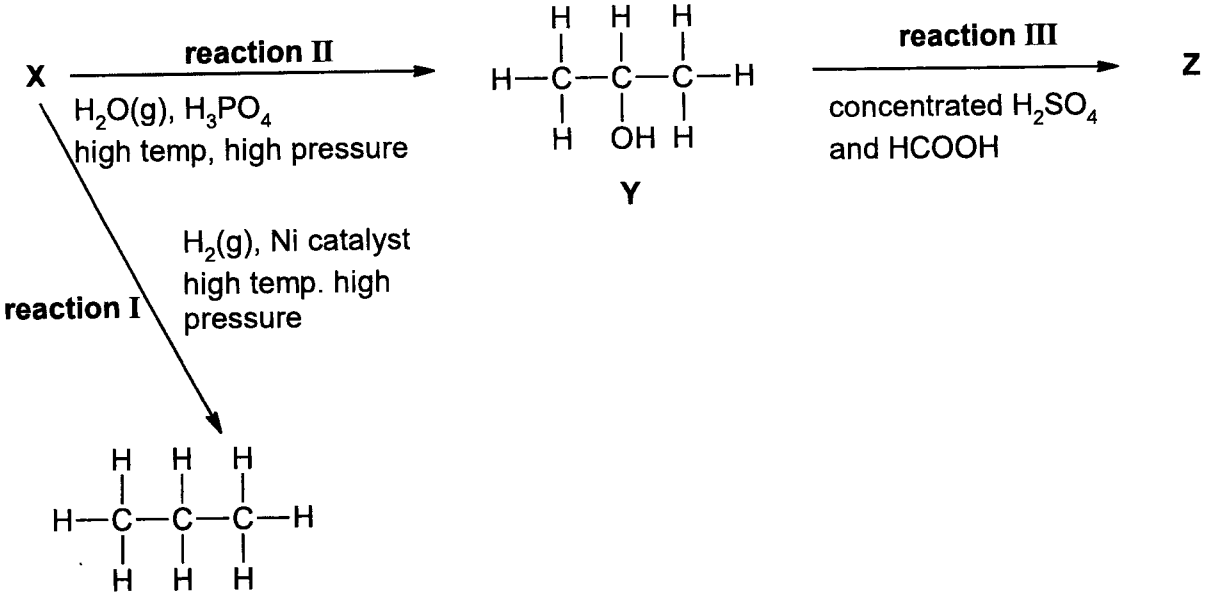
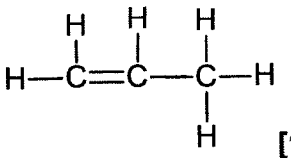


Fig. 5.1

(i) Draw the organic compounds, **X** and **Z** in the spaces provided. [2]

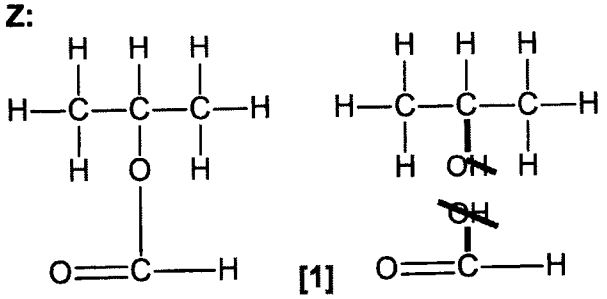
X:



[1]

Most common mistake is drawing more than 4 bonds for carbon atoms especially the double-bonded ones.

Z:

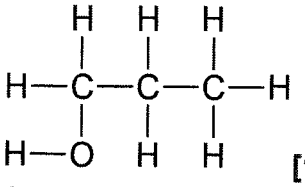


[1]

The reagents involved are concentrated sulfuric acid, carboxylic acid and alcohol. Therefore, Z should be an ester formed.

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(ii) Reaction II produces compound **Y** and one other isomer. Draw the full structural formula of the isomer.



[1]

Since the question asked for **full** structural formula, all bonds should be shown, including the bond between H and O within the hydroxyl functional group.

[1]

(b) After the fermentation of sugar from sugarcane to produce ethanol, some ethyl ethanoate is found to be present in the mixture.

Suggest how this ethyl ethanoate may be formed.

Ethanol **oxidises** in air to form **ethanoic acid**. **[1]**

Both ethanol and ethanoic acid **react** to form ethyl ethanoate. **[1]**

Ethyl ethanoate formed suggests that the reaction is between ethanol which is formed through fermentation and ethanoic acid. Candidates need to explain how ethanoic acid is formed. In esterification, concentrated sulfuric acid is a catalyst and helps to speed up the reaction. During fermentation, concentrated sulfuric acid was not added and candidates should not assume so.

(c) A student is given three unlabelled bottles containing colourless liquids.

One of the liquids is ethanol, one is ethanoic acid, and the other is ethyl ethanoate.

Describe the reagents and conditions for a chemical test that gives positive result **only** with ethanol. Describe what would be observed.

Heat with acidified $KMnO_4$ (aq) or acidified potassium manganate (VII) [1]
Candidates should provide the reagents and conditions in full as any one missing will not produce the intended observations.

Purple $KMnO_4$ solution **decolourised**. **[1]**
As colour change is expected, candidates need to provide the original colour and the final colour. Since the colour change is due to $KMnO_4$ solution, candidates should specific that it is $KMnO_4$ solution that has changed colour.

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(d) 1.00 g of a powder contains

0.30 g of glucose, $C_6H_{12}O_6$

0.45 g of citric acid, $C_6H_8O_7$

0.25 g of sodium hydrogencarbonate, $NaHCO_3$

In the presence of water, the powder effervescences as citric acid reacts with the sodium hydrogencarbonate to form sodium citrate, $Na_3(C_6H_5O_7)$.

$$3NaHCO_3(s) + C_6H_8O_7(aq) \rightarrow Na_3(C_6H_5O_7)(aq) + 3CO_2(g) + 3H_2O(l)$$

(i) Determine the limiting reactant when 1.00 g of this powder reacts.

no. of moles of $NaHCO_3$ available = $\frac{0.25}{23+1+12+(3\times16)}$ = 0.002976 mol

no. of moles of $C_6H_8O_7$ available = $\frac{0.45}{(6\times12)+8+(7\times16)}$ = 0.002344 mol

*no. of moles of $NaHCO_3$ required to react with 0.002344 moles of $C_6H_8O_7$ = 3 x 0.002344 = 0.007031

***Since the no. of moles of $NaHCO_3$ available are less than the no. of moles of $NaHCO_3$ required, $NaHCO_3$ is the limiting reactant.**

Several candidates saw that the number of moles of citric acid is less than that of sodium hydrogen carbonate and mistakenly concluded that citric acid is the limiting reagent. Instead, students should use the mole ratio and check if there is enough moles of reactants. See * .

For calculations, candidates should not express their numerical answers in fractions.

[2]

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(ii) In an experiment, 0.043 dm^3 of CO_2 is produced in the above reaction from using 1.00 g of the powder.

Calculate the percentage yield obtained in this experiment.

no. of moles of $NaHCO_3 = \frac{0.25}{23+1+12+3(16)}$

$= 0.002976$ mol

no. of moles of CO_2 = 0.002976 mol
expected volume of CO_2 = 0.002976 x 24
$= 0.071429\ dm^3$ **[1]**

percentage yield $= \frac{0.043}{0.071429} \times 100$

$=$ **60.2%** **[1]**

Student must use the named limiting reagent in (i) to calculate expected number of moles of CO_2. e.g. if student concludes that citric acid is the limiting reagent in (i), she needs to calculate the expected number of moles of CO_2 based on the number of moles of citric acid not sodium hydrogen carbonate. ECF will apply. Hence, it would be conceptually wrong when the student uses number of moles of $NaHCO_3$ if it was not named as the limiting reagent in the earlier part.

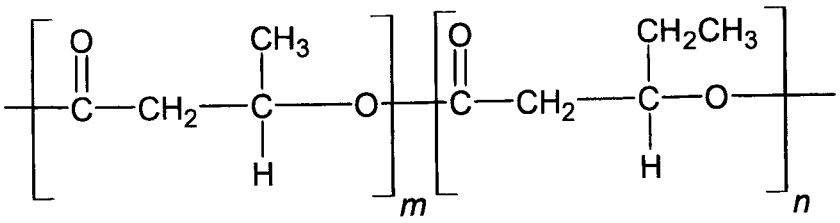
[2]

[Total: 11]

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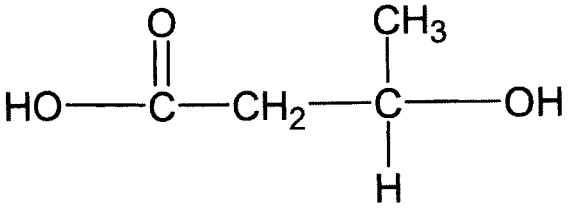
6 **(a)** Synthetic polymers are macromolecules which have many uses. They are made from monomers which combine in polymerisation reactions.

The synthetic polymer, PHBV, is a polymer which is often used in packaging material.

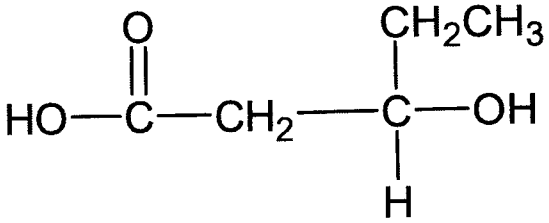


PHBV

(i) Draw the structural formulae of the two monomers used to make PHBV.



[2]



[1] for each monomer
Reject brackets and n

(ii) State the type of reaction used to make PHBV.

condensation[1] polymerisation

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(b) **(i)** Poly(ethene) is an example of a poly(alkene) and can be used in food plastic wrapping.

This polymer macromolecule has a relative molecular mass of between 15 000 and 20 000.

Calculate the minimum number of repeating units needed to be present in one macromolecule of poly(ethene).

relative molecular mass of one ethene unit = 28 **[1]**

minimum molecular mass of poly(ethene) = 15 000

minimum no. of repeating units = 15 000 ÷ 28

= 535.7

= **536** **[1]**

[2]

(ii) Suggest why people are encouraged to recycle poly(alkenes).

Either one of these:

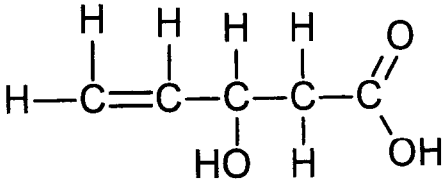
- poly(alkenes) are non-biodegradable / do not break down easily
- reduce pollution / amount of plastic waste
- conserve non-renewable resources
- saves energy compared to making new plastics
- any other valid reasons

[1] identify either environmental reason or resource-based reason

Weaker answers do not explain the impact of poly(alkenes) being non-biodegradable. Some candidates are also not able to use the term "non-biodegradable"

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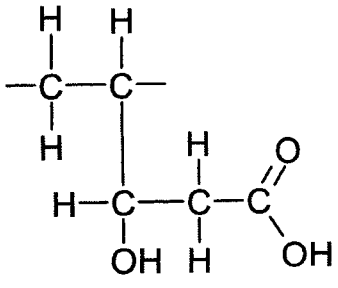
(c) Compound **X** can be polymerised to form two different polymers.



X

Draw a repeat unit for each of the polymer.

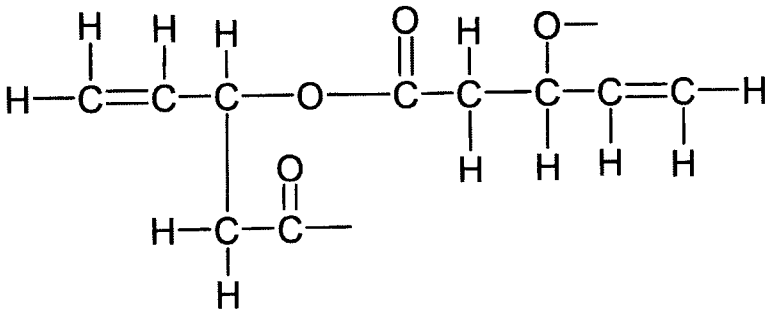
repeat unit for polymer 1



[1]

[1]

repeat unit for polymer 2



[1]

Mark for ester functional group in middle + OH removed from COOH + H removed from OH

Most candidates got partial credit for this question and were able to draw polymer 1. Polymer 2 seems to be a challenge for many.

A handful of candidates were able to draw the structure of the polymer but unfortunately missed out that the question asked for "repeat unit".

[1]

[Total: 8]

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7 Role of water chemistry in aquarium health

Water chemistry plays a critical role in the well-being of fishes in an aquarium. Fish waste releases ammonia, NH_3, and ammonium ions, NH_4^+, into water, both of which are toxic to fish. NH_3 is highly toxic to fish, whereas NH_4^+ is significantly less harmful.

Nitrification process

During nitrification, NH_3 and NH_4^+ are broken down by beneficial bacteria into less toxic nitrate ions, NO_3^-, as shown in Fig. 7.1.

ammonia NH_3 → (beneficial bacteria **A**) → nitrite NO_2^- → (beneficial bacteria **B**) → nitrate NO_3^-

$$NH_4^+ + 2O_2 \rightarrow 2H^+ + NO_3^- + H_2O$$

Fig. 7.1

Establishing a new aquarium

Setting up a new aquarium involves establishing colonies of beneficial bacteria in the tank before fish are added. NH_3 and NH_4^+ are added daily, and the concentrations of different water parameters are monitored.

Fig. 7.2 shows a graph of the water parameters over 35 days.

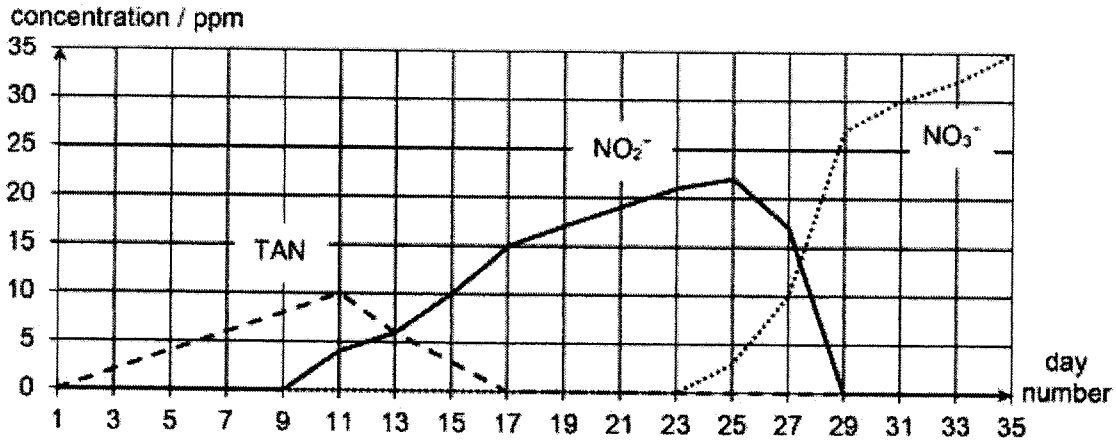


Fig. 7.2

The presence of the respective products in Fig. 7.1 indicates that the beneficial bacteria has been established.

Fish can only be safely added after the concentration of NO_2^- increases then decreases to 0 ppm as NO_2^- is also toxic to fish.

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PPM, or parts per million, indicates how many units of a substance are present for every one million units of the total mixture.

Percentage of NH_3 in total ammonia nitrogen (TAN)

The total ammonia nitrogen, TAN, measured is the sum of the concentrations of NH_3 and NH_4^+ present.

The percentage of TAN present as NH_3 is affected by the pH of the aquarium water.

Table 7.3 shows the approximate percentage of TAN present as NH_3 at different pH values.

Table 7.3

pH	% of TAN present as NH_3
6.0	0.4
6.5	1.0
7.0	2.5
7.5	6.3
8.0	16.0
8.5	26.0
9.0	39.0

Measuring dissolved oxygen

The recommended range for the concentration of dissolved oxygen in aquarium water samples is 0.000150 to 0.000500 mol/dm^3.

Manganese is a transition element. In this experiment, manganese(II) hydroxide, $Mn(OH)_2$, is added to aquarium water. Dissolved oxygen in the water oxidises $Mn(OH)_2$ to $Mn(OH)_3$.

The $Mn(OH)_3$ then reacts to produce iodine, I_2. The I_2 is then titrated with thiosulfate ions, $S_2O_3^{2-}$, solution.

It is known that 1 mole of dissolved oxygen produces 4 moles of thiosulfate ions.

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(a) Despite nitrification takes place readily under the conditions in an aquarium, the presence of beneficial bacteria is necessary for any appreciable breakdown of NH_3 or NH_4^+ to be observed within a short time.

Suggest the role of beneficial bacteria in the nitrification process.

Catalyst [1]

Many candidates lifted phrases directly from the passage but failed to identify that bacteria act as a *catalyst*. The role of bacteria is not just to break down ammonia but to speed up the process within a short time.

(b) **(i)** State the day number that first indicates that beneficial bacteria **A** is established.

Day **9/10** **[1]**

A common weakness was the inability to read Fig. 7.2 correctly. Some candidates did not identify the correct day when beneficial bacteria were established or when it was safe to add fish. Careful interpretation of the graph was required.

(ii) State the day number that is first safe for the addition of fish.

Day **29** **[1]**

A common weakness was the inability to read Fig. 7.2 correctly. Some candidates did not identify the correct day when beneficial bacteria were established or when it was safe to add fish. Careful interpretation of the graph was required.

(iii) On day 35, 25% of the aquarium water is replaced with water that is free of NO_3^-.

Calculate the new concentration of NO_3^-, in ppm.

concentration of NO_3^- before water change = 35 ppm

concentration of NO_3^- after water change = (100% – 25%) x 35

$$= \frac{75}{100} \times 35$$

= **26.3 ppm** **[1]**

A frequent error was incorrect or missing units (ppm). Several candidates did not know how to begin the calculation, showing uncertainty in applying dilution to concentration problems.

[1]

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(c) The pH of the aquarium water on Day 11 is measured to be 7.5.

(i) State the value of TAN on Day 11.

10 [1]

Many candidates gave 6.3% instead of the correct TAN value of 10. They misread the table by copying the percentage rather than checking what the table header represented.

(ii) Hence, calculate the concentration of NH_3 present, in ppm, on Day 11.

At pH 7.5, 6.3% of TAN is present as NH_3

$TAN = [NH_3] + [NH_4^+] = 10$ ppm

$[NH_3] = \frac{6.3}{100} \times 10$

$= \mathbf{0.63}$ ppm **[1]**

Many candidates were unsure how to start. Candidates often quoted the percentage directly instead of applying it to the TAN value to calculate the concentration of NH_3.

(d) A 100 cm^3 of sample of aquarium water containing dissolved oxygen requires 13.40 cm^3 of 0.0100 mol/dm^3 thiosulfate solution to reach the titration end point.

Calculate the concentration of dissolved oxygen in this 100 cm^3 sample and hence determine if it falls within the recommended range.

no. of moles of $S_2O_3^{2-} = \frac{13.40}{1000} \times 0.0100$

$= 0.000134$ mol **[1]**

1 mole of dissolved oxygen produces 4 moles of thiosulfate ions

no. of moles of $O_2 = \frac{1}{4} \times 0.000134$ **[1]**

$= 0.0000335$ mol

concentration of $O_2 = 0.0000335 \div \frac{100}{1000}$

$= \mathbf{0.000335}$ mol/dm^3 (**within** recommended range) **[1]**

This calculation was poorly attempted. A common misconception was that candidates treated oxygen as a gas rather than dissolved oxygen. Candidates also struggled with mole ratio reasoning in the titration.

[3]

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(e) State one chemical property of manganese.

Manganese is a transition metal that has **variable oxidation states** [1] OR **forms coloured compounds**. OR **catalyst**

Many candidates did not recognise manganese as a transition metal and so could not state a correct chemical property.

(f) A student found iron parts in an aquarium filter starting to rust over time. She decides to attach a strip of zinc metal to the iron to prevent rusting.

(i) Name the method used to protect the iron.

Sacrificial protection [1]

Many candidates confused sacrificial protection with galvanising. Candidates should be aware that galvanising involves coating with zinc, while sacrificial protection involves attaching a more reactive metal.

(ii) Explain why this method is effective, based on the reactivity series.

Zinc is **more reactive** than iron, so it **corrodes in place** of iron.**[1]**
OR
Zinc **loses electrons more readily** than iron, so it **corrodes in place** of iron.

Many incomplete responses were seen. Candidates often stated only that "zinc is more reactive" without explaining that zinc corrodes in place of iron, or that zinc loses electrons more readily.
Many candidates also stated "zinc rusts" instead of realising that term "rust" is only applicable to iron.

[Total: 12]

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8 **(a)** Aqueous nickel(II) sulfate, a green solution, is electrolysed using inert platinum electrodes.

During electrolysis, the green colour of the solution fades. Bubbles are observed at one of the electrodes.

Nickel(II) ions, Ni^{2+}, are discharged during this process.

(i) Write the ionic equation for the reaction that occurs at the electrode where Ni^{2+} ions are discharged.

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ [1]

Many candidates were able to write the half-equation correctly. Common error includes missing or incorrect electron (e.g. writing $Ni^{2+} \rightarrow Ni + 2e^-$).

(ii) Identify the gas released during this electrolysis and the electrode where it is formed.

gas: **oxygen**
electrode: **anode / positive electrode**
[1] for correct gas + electrode

Many candidates correctly identified oxygen as the gas at the anode. Weaker candidates wrongly suggested hydrogen or gave the wrong electrode. Some candidates are confused which electrode is positive or negative.

(iii) Explain why the green colour of the solution fades.

Green colour fades because **concentration of Ni^{2+} decreases**. **[1]**
OR
Ni^{2+}ions are removed / **Ni^{2+}ions discharged / reduced.**

Many candidates were able to explain the fading of the green colour in terms of the decrease in Ni^{2+} concentration. Weaker answers stated vaguely that the colour "disappears" without linking to the removal/discharge of Ni^{2+} ions.

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(b) A simple cell is then set up using a nickel strip and a cadmium strip in a beaker of aqueous sodium hydroxide.

The reactivity series shows: Cadmium > Nickel > Hydrogen

(i) Identify which metal is the negative electrode in this cell. Explain your answer.

Cadmium as it is **more reactive** / **loses electrons more readily** than nickel.**[1]**

Many candidates knew cadmium forms the negative electrode, as it is more reactive. A common incomplete answer was to state only "cadmium" without explaining in terms of reactivity or electron loss.

(ii) State one physical property of nickel and cadmium that make them suitable for use as electrodes in batteries.

One of the following **[1]**:

Good conductor of electricity
High melting point
Malleable

Many candidates gave "good conductor of electricity". Few candidates gave properties unrelated to electrode suitability (e.g. "strong", "shiny"), which were not credited any marks.

(iii) State the direction of electron flow in the external circuit in terms of the metals used.

From cadmium to nickel [1]

Many candidates gave the correct direction of electron flow from cadmium to nickel. Some candidates reversed the flow or stated "from negative to positive" without naming the metals, which was insufficient.

(iv) State and explain whether the simple cell will continue to function if the sodium hydroxide electrolyte dries up.

The cell **will stop working**.
Because **ions cannot move** to complete the circuit.
[1] for both

Many candidates recognised that the cell stops working without electrolyte. Common errors included incomplete reasoning (e.g. "ions are not present" without realising that ions are present, but they are not mobile.

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(c) The equation below shows a reaction that occurs in some cells:

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

Show which substance is oxidised using oxidation states.

Mg
Oxidation state of magnesium increases **from 0** in Mg **to +2** in Mg^{2+}.**[1]**

Most candidates correctly identified magnesium as the substance oxidised and showed the increase in oxidation state from 0 to +2.

[Total: 8]

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Section B

Answer **one** question from this section.

9 Scientists conducted two experiments to study how different acids and heat affect calcium carbonate.

Experiment 1:

Equal-sized pieces of calcium carbonate were added to aqueous hydrochloric acid, and aqueous ethanoic acid of equal concentration and volume.

(a) (i) Write an equation for the reaction of aqueous ethanoic acid with calcium carbonate.

$$2CH_3COOH + CaCO_3 \rightarrow (CH_3COO)_2Ca + H_2O + CO_2$$ **[1]**

accept $Ca(CH_3COO)_2$

Many candidates are unable to write the correct formula for calcium ethanoate and ethanoic acid (2-carbon organic compound) and mistakenly wrote the formula for propanoic acid (3-carbon organic compound) instead.

(ii) Explain why the reaction with hydrochloric acid is faster than with ethanoic acid, even though both acids have the same concentration.

HC*l* is a strong acid that is **completely/fully ionised** in solution to form **high concentration of H^+ ions.**

CH_3COOH is a weak acid that is **partially ionised** in solution to form **low concentration of H^+ ions.**

Candidates should describe the acids as strong/weak acid (not stronger or weaker) to illustrate the different concentrations of H^+ and not number of H^+.

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(iii) The reaction between calcium carbonate and hydrochloric acid is exothermic.

Explain, in terms of bond breaking and bond forming, why the overall enthalpy change for this reaction is negative.

Bonds are **broken in the reactants**- calcium carbonate and hydrochloric acid, which **absorb energy / endothermic**.

Bonds are **formed in the products**- carbon dioxide, water, and calcium chloride, which **releases energy / exothermic**.

The **energy released** during bond forming is **greater** **[1]** than energy absorbed during bond breaking. Therefore, the overall enthalpy change is negative.

Candidates need to be clear that energy is released (not "required") during bond forming and absorbed during bond breaking. Any mixed up is a contradictory statement which will yield no marks.

(b) Experiment 2:

A separate sample of calcium carbonate was heated strongly in a test tube.

(i) Write an equation for the thermal decomposition reaction.

$CaCO_3 \rightarrow CaO + CO_2$ [1]

Many candidates often confuse burning (reaction with O_2) with decomposition (involving only one reactant).

(ii) Explain how the reactivity of calcium and copper affects the thermal decomposition of their respective carbonates.

Copper is **less reactive** than calcium, so copper(II) carbonate **decomposes more easily / at a lower temperature / less thermally stable** than calcium carbonate.

Candidates need to be clear that reactivity refers to metals (i.e. calcium and copper) and thermally stability refers to the metal compounds (i.e. calcium carbonate and copper(II) carbonate). Weak responses refer to the carbonates as 'it'.

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(c) Crustaceans such as crabs use calcium carbonate to build their shells.

When carbon dioxide dissolves in water, it forms carbonic acid. The following equilibria are established:

Equilibrium 1: $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equilibrium 2: $H_2CO_3(aq) \rightleftharpoons 2H^+ + CO_3^{2-}(aq)$

Table 9.1 shows the concentration of hydrogen ions and carbonate ions in seawater as the amount of dissolved carbon dioxide increases.

Table 9.1

amount of dissolved CO_2	concentration of H^+ / mol/dm^3	concentration of CO_3^{2-} / mol/dm^3
low	1.0×10^{-6}	2.0×10^{-3}
high	1.0×10^{-5}	0.5×10^{-3}

(i) Using the information in Table 9.1, suggest why an increase in dissolved carbon dioxide makes it more difficult for crustaceans to form their shells.

As the amount of dissolved CO_2 increases, concentration of CO_3^{2-} decreases.
There are **less CO_3^{2-} available [1]** for calcium carbonate to be formed.

(ii) State the colour change you would expect when Universal Indicator is added to seawater with high dissolved carbon dioxide.

green to yellow / orange[1]

As the question requires candidates to state the colour change, the colour before and after reaction should be stated. Since carbonic acid is a weak acid, it is unlikely that the Universal Indicator will turn from green to **red**.

(iii) A student is given a seawater sample and wants to find out if it contains carbonate ions.

Describe a chemical test the student could carry out to confirm the presence of carbonate ions.

Add dilute **acid** to the solution. If CO_3^{2-} is present, there will be **effervescence**. **[1]**

Candidates should state clearly which acid is to be added and the expected observations.

[Total: 10]

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10 Scientists investigated the chemical behaviour and thermal stability of different carbonates.

(a) Experiment 1:

Samples of sodium carbonate and magnesium carbonate were each added to separate beakers containing equal volumes and concentrations of nitric acid. The rate of gas formation was recorded, and pH measurements were taken before and after excess acid was added.

(i) Write an ionic equation for the reaction between carbonate ions and hydrogen ions.

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$ [1] ignore state symbols

(ii) Sodium carbonate reacts faster than magnesium carbonate.

Explain this observation in terms of solubility and ions availability.

Sodium carbonate is more soluble.

More carbonate ions available [1] in solution to react with acid.

From (a) (i), candidates should be able to see that it is the carbonate ions that are involved in the reaction not the cations. Many candidates mistakenly apply the reactivity rule here which is conceptually incorrect.

(iii) The pH of sodium carbonate solution was 11 before nitric acid was added. After excess nitric acid was added, the pH dropped to 3.

Explain this change in terms of the ions present in the solution and their concentrations.

Initially: **High concentration of OH^- ions** from carbonate results in pH 11

After excess acid: **High concentration of H^+ ions [1]** lowers the pH to 3

Student must identify the ions and their respective concentration initially and after as the question asked for change.

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(iv) Predict and explain the difference in the total volume of gas produced when equal masses of sodium carbonate and magnesium carbonate are used, assuming complete reaction.

Sodium carbonate produces lesser gas. **[1]**

Na_2CO_3 has a higher molar mass (Mr = 106) compared to $MgCO_3$ (Mr = 84), **lesser moles / lesser number of moles** **[1]** are present in equal mass compared to $MgCO_3$.

$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$
$MgCO_3 + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2O + CO_2$

Likewise, many candidates incorrectly related the yield with the reactivity of the metals. The reactants here involve the compounds not the metals.

(b) Experiment 2:

A student heated magnesium carbonate and copper(II) carbonate separately in test tubes and observed the temperature at which decomposition began.

(i) Write an equation for the thermal decomposition of magnesium carbonate.

$MgCO_3 \rightarrow MgO + CO_2$ [1]

(ii) The gas produced from the thermal decomposition of magnesium carbonate was passed through limewater for a few minutes. A precipitate was initially formed.

Identify the precipitate and state what happens when the gas is passed through limewater for a longer time.

The precipitate is **calcium carbonate**. **[1]**

The **precipitate dissolves**. **[1]**

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(iii) The decomposition of magnesium carbonate is an endothermic process.

Explain, in terms of bond breaking and bond forming, why the overall enthalpy change for this reaction is positive.

Bonds are **broken in the reactants**- magnesium carbonate, which **absorb energy / endothermic**.

Bonds are **formed in the products**- magnesium oxide, carbon dioxide and water, which **releases energy / exothermic**.

[1] for both bond forming and bond breaking.

The **energy absorbed** during bond breaking is **greater** **[1]** than energy released during bond forming. Therefore, the overall enthalpy change is positive.

Candidates need to be clear that energy is released (not "required") during bond forming and absorbed during bond breaking. Any mixed up is a contradictory statement which will yield no marks.

[Total: 10]

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The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

Key

proton (atomic) number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).
The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-}

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