



**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

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.

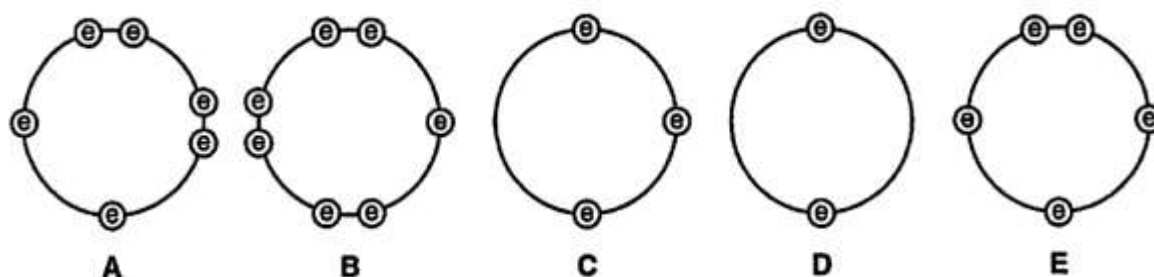


Fig. 1.1

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]

- 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
${}^{39}_{19}\text{K}$	19	20	19
${}^{52}_{24}\text{Cr}$	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”

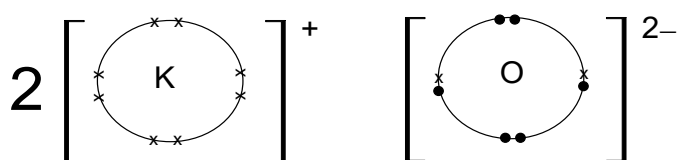
- (ii) State one other difference in the physical properties of potassium oxide and sulfur trioxide.

K₂O conducts electricity in the molten and aqueous state while SO₃ 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 K₂O.

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]

- 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.

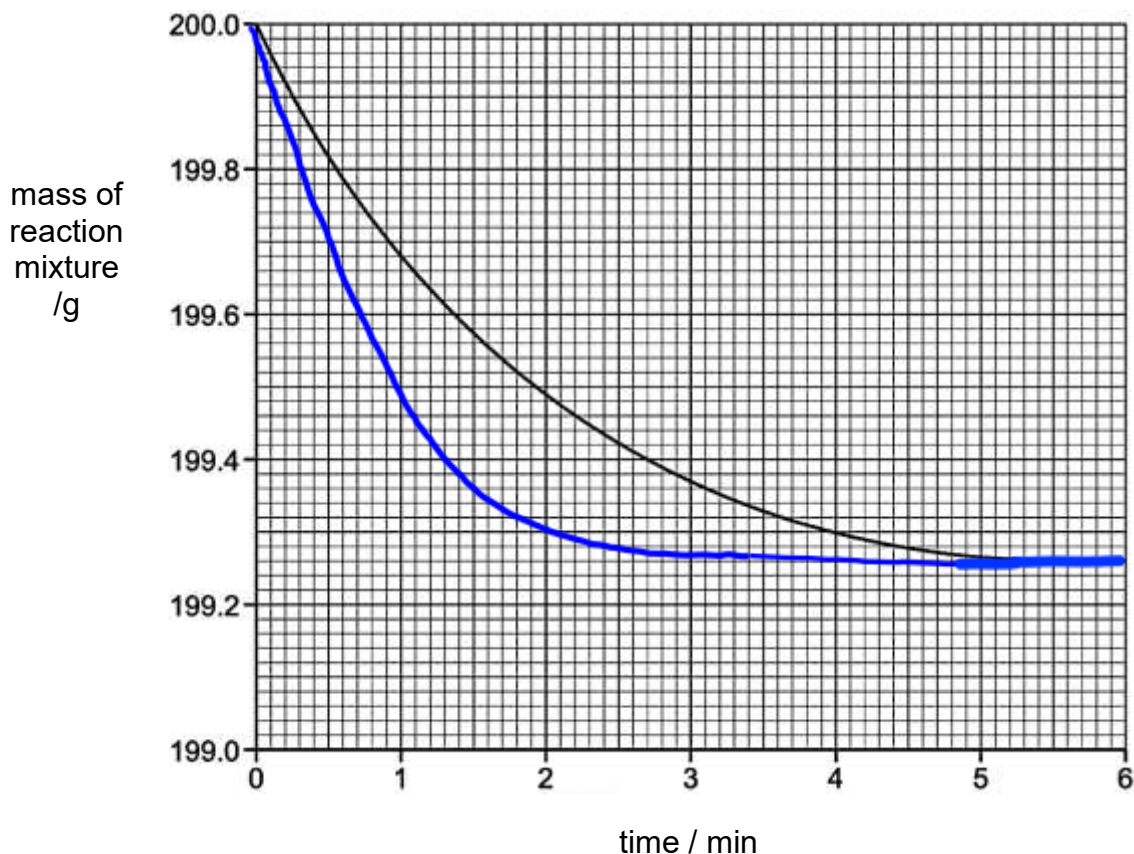


Fig. 3.1

- (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.

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 HCl is in excess. The HCl 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

- (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 cm³ 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 be 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 HCl gas.

max [3]

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

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



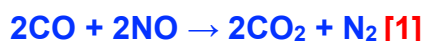
(ii) Suggest a reason why the fuel in an internal combustion engine is unlikely to undergo complete combustion.

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.



(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)

- (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 CO₂ is removed and missed out how CO₂ is produced.

[Total: 6]

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

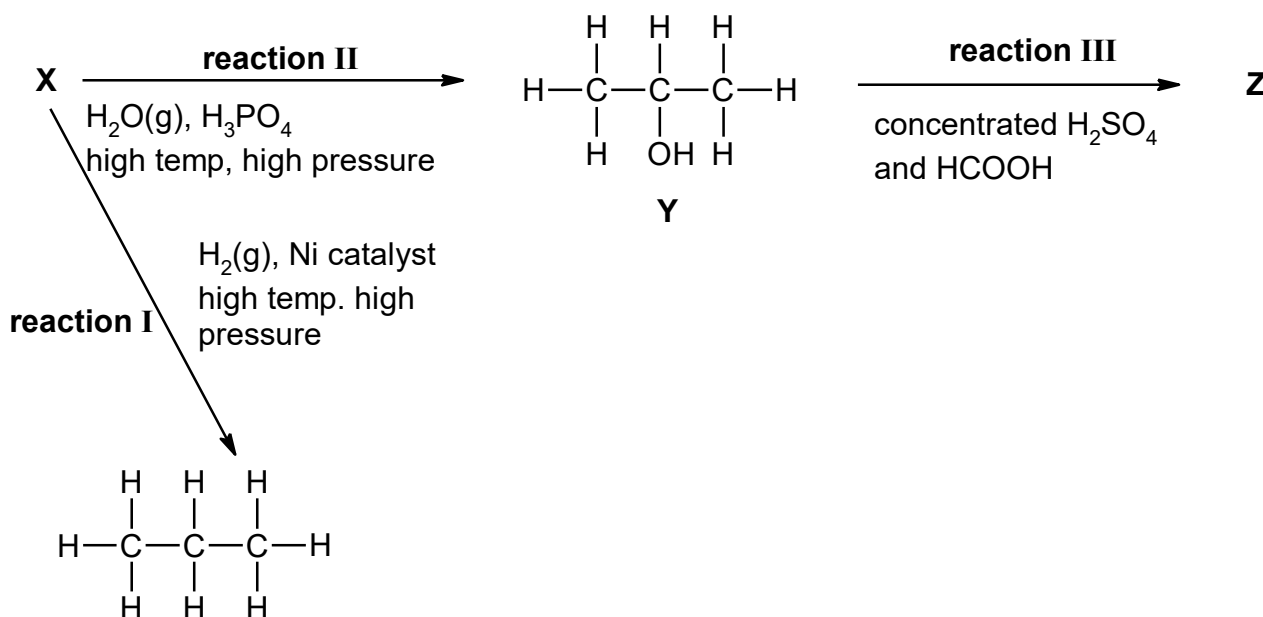
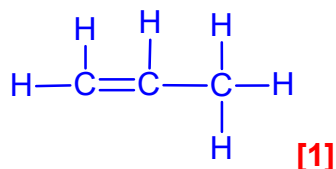


Fig. 5.1

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

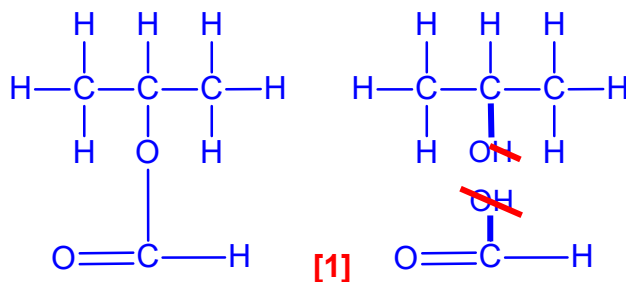
[2]

X:



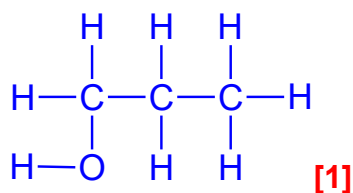
Most common mistake is drawing more than 4 bonds for carbon atoms especially the double-bonded ones.

Z:



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

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



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 KMnO₄ (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 KMnO₄ 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 KMnO₄ solution, candidates should specify that it is KMnO₄ solution that has changed colour.

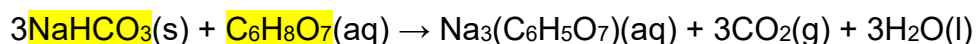
(d) 1.00 g of a powder contains

0.30 g of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$

0.45 g of citric acid, $\text{C}_6\text{H}_8\text{O}_7$

0.25 g of sodium hydrogencarbonate, NaHCO_3

In the presence of water, the powder effervesces as citric acid reacts with the sodium hydrogencarbonate to form sodium citrate, $\text{Na}_3(\text{C}_6\text{H}_5\text{O}_7)$.



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

$$\text{no. of moles of NaHCO}_3 \text{ available} = \frac{0.25}{23+1+12+(3 \times 16)} = 0.002976 \text{ mol}$$

$$\text{no. of moles of C}_6\text{H}_8\text{O}_7 \text{ available} = \frac{0.45}{(6 \times 12) + 8 + (7 \times 16)} = 0.002344 \text{ mol}$$

$$\begin{aligned} & \text{*no. of moles of NaHCO}_3 \text{ required to react with 0.002344 moles of C}_6\text{H}_8\text{O}_7 \\ & = 3 \times 0.002344 = 0.007031 \end{aligned}$$

***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]

- (ii) In an experiment, 0.043 dm³ of CO₂ is produced in the above reaction from using 1.00 g of the powder.

Calculate the percentage yield obtained in this experiment.

$$\text{no. of moles of NaHCO}_3 = \frac{0.25}{23+1+12+3(16)}$$

$$= 0.002976 \text{ mol}$$

$$\text{no. of moles of CO}_2 = 0.002976 \text{ mol}$$

$$\text{expected volume of CO}_2 = 0.002976 \times 24$$

$$= 0.071429 \text{ dm}^3$$

[1]

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

$$= 60.2\% \text{ [1]}$$

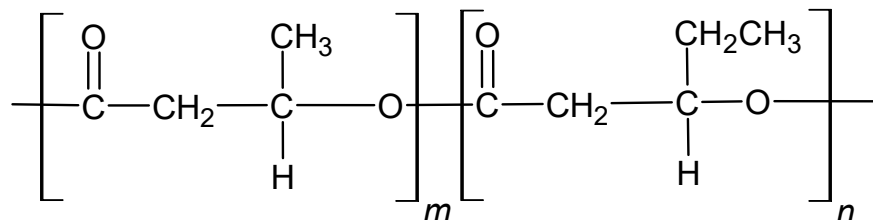
Student must use the named limiting reagent in (i) to calculate expected number of moles of CO₂. e.g. if student concludes that citric acid is the limiting reagent in (i), she needs to calculate the expected number of moles of CO₂ based on the number of moles of citric acid not sodium hydrogen carbonate. ECF will apply. Hence, it would be conceptually wrong when the student uses number of moles of NaHCO₃ if it was not named as the limiting reagent in the earlier part.

[2]

[Total: 11]

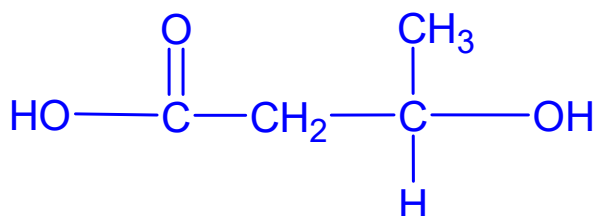
- 6 (a) Synthetic polymers are macromolecules which have many uses. They are made from monomers which combine in polymerisation reactions.

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

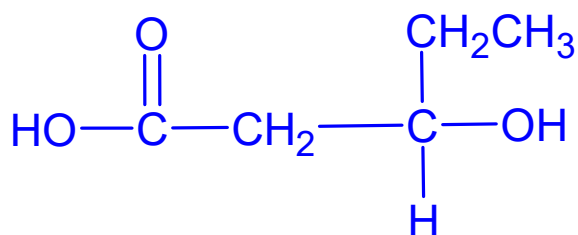


PHBV

- (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

- (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 = $15\,000 \div 28$

= 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”

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.

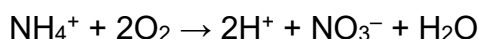
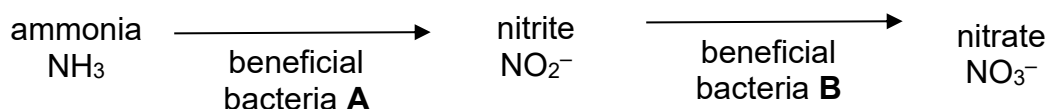


Fig. 7.1

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.

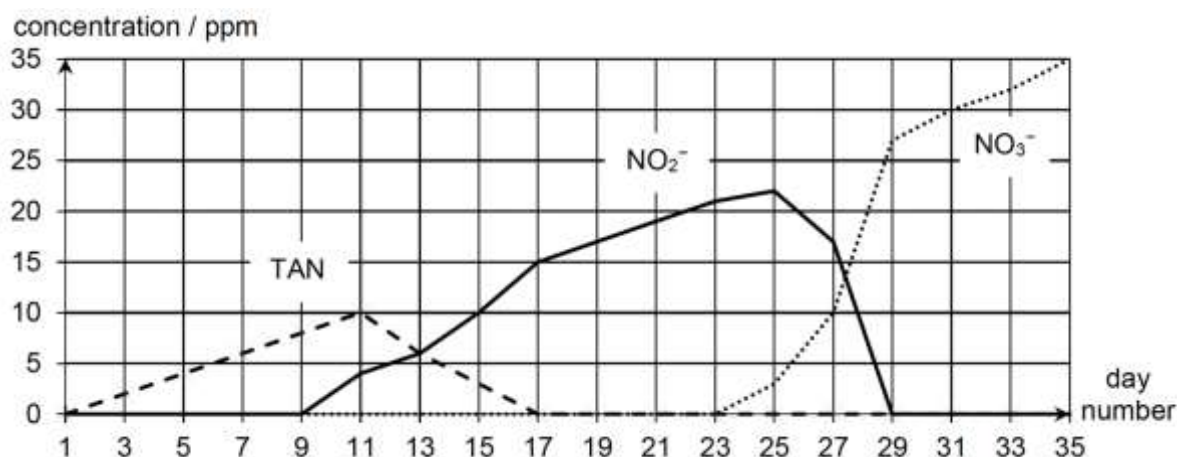


Fig. 7.2

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.

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/dm³.

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

The $\text{Mn}(\text{OH})_3$ then reacts to produce iodine, I_2 . The I_2 is then titrated with thiosulfate ions, $\text{S}_2\text{O}_3^{2-}$, solution.

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

- (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 = $(100\% - 25\%) \times 35$

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

$$= \underline{26.3 \text{ ppm}} [1]$$

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]

(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

$$\text{TAN} = [\text{NH}_3] + [\text{NH}_4^+] = 10 \text{ ppm}$$

$$\begin{aligned} [\text{NH}_3] &= \frac{6.3}{100} \times 10 \\ &= \underline{0.63} \text{ ppm} \text{ [1]} \end{aligned}$$

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.

$$\begin{aligned} \text{no. of moles of } \text{S}_2\text{O}_3^{2-} &= \frac{13.40}{1000} \times 0.0100 \\ &= 0.000134 \text{ mol [1]} \end{aligned}$$

1 mole of dissolved oxygen produces 4 moles of thiosulfate ions

$$\begin{aligned} \text{no. of moles of } \text{O}_2 &= \frac{1}{4} \times 0.000134 \text{ [1]} \\ &= 0.0000335 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{concentration of } \text{O}_2 &= 0.0000335 \div \frac{100}{1000} \\ &= \underline{0.000335} \text{ mol/dm}^3 \text{ (within recommended range) [1]} \end{aligned}$$

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]

- (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]

- 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.



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

- (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.

- (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]

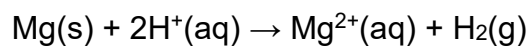
Many candidates gave the correct direction of electron flow from cadmium to nickel. Some candidates reversed the flow or stated “from negative to positive” without naming the metals, which was insufficient.

- (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).

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



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]

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.



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.

HCl 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^+ .

- (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.



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’.

- (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:

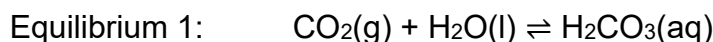


Table 9.1 shows the concentration of hydrogen ions and carbonate ions in seawater as the amount of dissolved carbon dioxide increases.

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]

- 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.



- (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

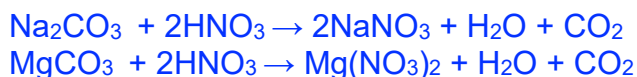
After excess acid: High concentration of H⁺ ions [1] lowers the pH to 3

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

- (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 ($M_r = 106$) compared to MgCO_3 ($M_r = 84$), lesser moles / lesser number of moles [1] are present in equal mass compared to MgCO_3 .



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.



- (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]

- (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]

The Periodic Table of Elements

Group																	
1	2											13	14	15	16	17	18
Key proton (atomic) number atomic symbol name relative atomic mass							1 H hydrogen 1										2 He helium 4
												5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
												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
11 Na sodium 23	12 Mg magnesium 24	3	4	5	6	7	8	9	10	11	12	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
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	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
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	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium —	85 At astatine —	86 Rn radon —
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						
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 —		

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 dm³ at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

