Catholic Junior College

JC2 Preliminary Examinations

Higher 1

CANDIDATE NAME

CLASS 2T

CHEMISTRY

8873/02

Paper 2 Structured Questions

26 August 2024

2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class 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.

Section A
Answer **all** the questions**.**

Section B
Answer **one** question.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.
A Data Booklet is provided.

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

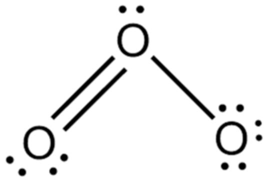
Section A	**Q1**	**10**
	Q2	**9**
	Q3	**10**
	Q4	**21**
	Q5	**10**
Section B	**Q6**	**20**
	Q7	**20**
Paper 2 (67%)		**80**
Paper 1 (33%)		**30**
Percentage		
Grade		

1 Dioxygen, O_2 and ozone, O_3 are two allotropes of oxygen found in the atmosphere. The thermochemical equation for the reversible conversion between ozone and dioxygen is shown below.

$$2O_3(g) \rightleftharpoons 3O_2(g) \qquad \Delta H = -286.0\ \text{kJ mol}^{-1}$$

(a) Draw the structure and suggest the shape of ozone, O_3.

Structure of O_3



Shape of ozone: **Bent**

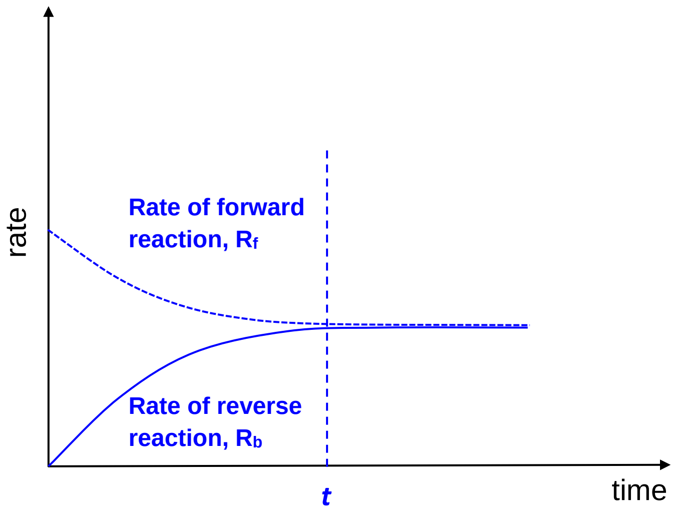
[2]

(b) Using *Le Chatelier's Principle*, explain why an increase in temperature causes the ozone concentration to increase.

By Le Chatelier's Principle, an increase in temperature favours the endothermic reaction which is the backward reaction. in this instance. Hence, position of equilibrium shifts to the left resulting in an increase in the concentration of

[2]

(c) Sketch, on the same axis below, two graphs that show how the rate of forward and reverse reactions vary over time. Label your graphs clearly and indicate *t*, the time when equilibrium was established.



[1]

(d) The diagram below shows that the concentration of ozone in the atmosphere varies with altitude above sea level.

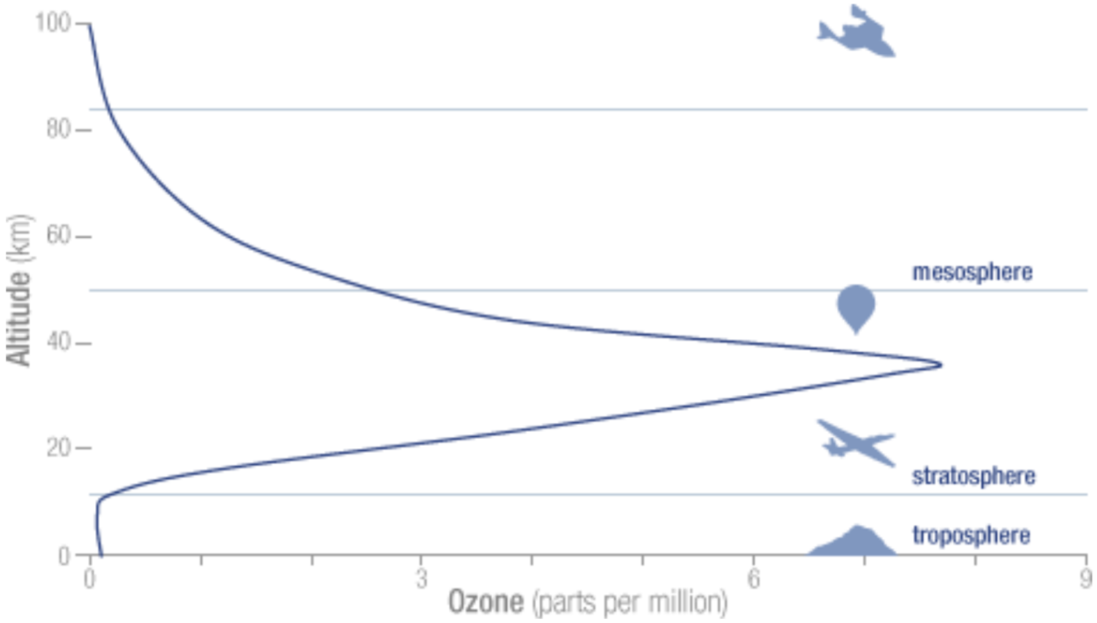


Diagram taken from https://ozonewatch.gsfc.nasa.gov/facts/SH.html

Between about 20 to 50 km above sea level, at the stratosphere, the ozone layer consists of a mixture of dioxygen and ozone molecules. Different types of Ultraviolet (UV) radiation from the Sun is absorbed by the ozone layer during the dioxygen-ozone reversible reaction.

The table below shows information on the different types of ultraviolet radiation.

Type of ultraviolet rays	Relative activation energy	Absorption by ozone layer
UV-A	Low	No
UV-B	Moderate	Yes
UV-C	High	Yes

Table 1.1

(i) Give a reason why the reversible conversion between dioxygen and ozone in the atmosphere is unlikely to reach a state of dynamic equilibrium.

Ozone concentration is regulated by the UV-rays from the Sun, hence the ozone concentration is constantly changing at differing times of the day.

As a result the position of equilibrium will be shifting regularly to offset the constant decrease in the concentration of ozone in the atmosphere .... [1]

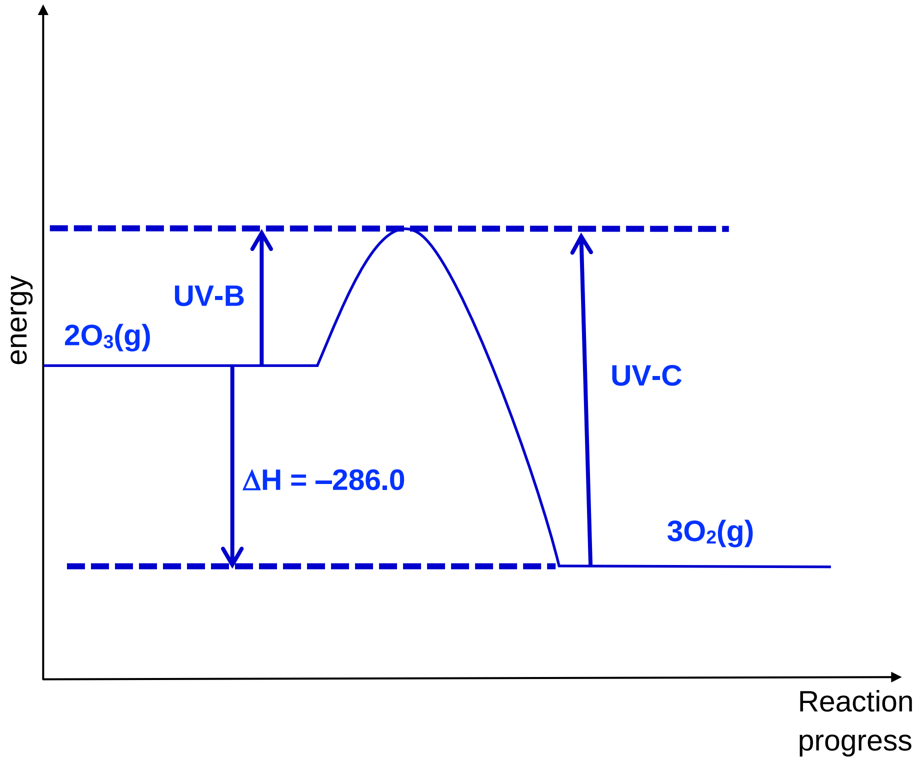
OR it is not a closed system

OR Intensity of ultraviolet radiation is not constant, rate of forward and backward reaction is unequal

(d) **(ii)** Complete the energy profile diagram of the dioxygen-ozone reversible reaction using the axes below.

The sketch should include labels for

- The formula, stoichiometric coefficient, and state symbols of both reactants and products;
- The enthalpy change of reaction, ΔH;
- Based on Table 1.1, indicate the type of ultraviolet rays, UV–A, UV–B or UV–C, absorbed to the relative activation energies of both the forward and backward reactions respectively. Each type of UV rays should be used only once or not at all.



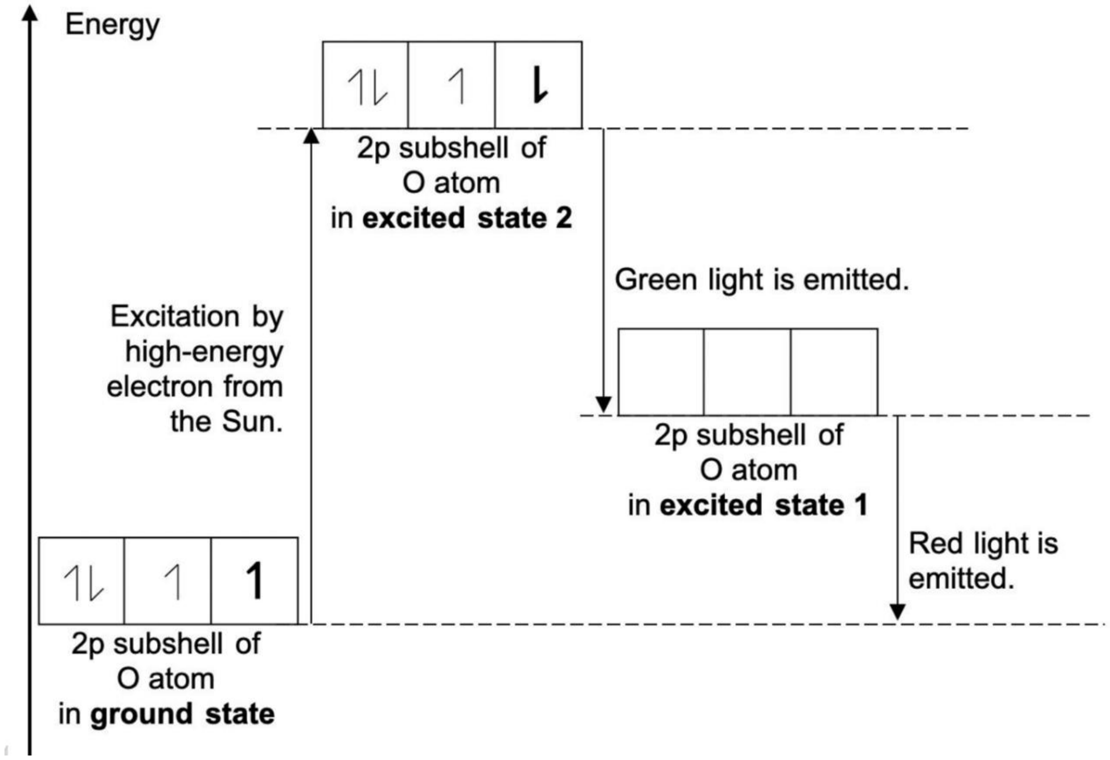
[3]

(e) The Northern Lights or *Aurora Borealis* occurs near the North Pole about 100 to 300 km above sea level. Absorption of UV rays by an oxygen molecule causes the O=O bond to break and two oxygen atoms are formed as shown in the equation below.

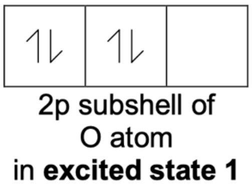
$$O_2(g) \rightarrow 2O(g)$$

When an oxygen atom in its **ground state** collides with a high energy electron from the Sun, one of its valence electrons (**bolded** in the energy level diagram below) is excited to a higher energy arrangement as seen in **excited state 2**. As energy is released, green light is emitted with an electron arrangement in **excited state 1** that violates Hund's rule.

When the electron transits to a lower energy level, coloured light is emitted as shown in the energy level diagram below.



In the diagram above, draw the electron arrangement in the 2p subshell of an oxygen atom in excited state 1 by changing the arrangement of the **bold electron only**. [1]



[Total: 10]

2 25.0 cm^3 of H_2O_2 solution reacted with 23.40 cm^3 of 0.0250 mol dm^{-3} $KMnO_4$ in a titration in the presence of excess dilute sulfuric acid according to the following equation:

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5O_2(g)$$

(a) Explain in terms of change in oxidation number why the above reaction is considered a redox reaction. Identify all the relevant species in your explanation.

Manganese in MnO_4^- is reduced from an oxidation state of +7 in to +2 in Mn^{2+}

Oxygen in H_2O_2 is oxidised from an oxidation state of -1 to 0 in O_2

[2]

(b) Calculate the concentration, in mol dm^{-3}, of the H_2O_2 solution.

Amount of MnO_4^- = $\frac{23.40}{1000} \times 0.0250 = 5.85 \times 10^{-4}$ mol
Since 2 $MnO_4^- \equiv 5\ H_2O_2$,
Amount of H_2O_2 in 25.0 cm^3 = $\frac{5}{2} \times 5.85 \times 10^{-4} = 1.46 \times 10^{-3}$ mol

Conc. of H_2O_2 = $1.46 \times 10^{-3} \div (\frac{25.0}{1000})$
= 0.0585 mol dm^{-3}

[2]

(c) With reference to structure and bonding, explain why the melting point of H_2O_2 is higher than O_2.

Both compounds have simple molecular structure held together by stronger intermediate intermolecular hydrogen bonding for H_2O_2 and weaker intermolecular instantaneous dipole – induced dipole attractions for O_2.
As a result, more energy is required to overcome the stronger hydrogen bonding accounting for a higher melting point.

[2]

(d) The Winkler Test is used to determine the amount of dissolved oxygen in a water sample. In the test, oxygen reacts with excess Mn^{2+} under alkaline conditions to produce a precipitate of $MnO(OH)_2$.

equation 1 $2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$

The precipitate, $MnO(OH)_2$ is then dissolved in acid and reacted with iodide ions, I^-, forming iodine, I_2, and Mn^{2+}.

equation 2 $MnO(OH)_2(s) + 2I^-(aq) + 4H^+(aq) \rightarrow I_2(aq) + Mn^{2+}(aq) + 3H_2O(l)$

Finally, the amount of iodine, I_2, produced is determined by titration with thiosulfate, $S_2O_3^{2-}$.

equation 3 $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

When a sample was analysed using the Winkler Test, 25.0 cm^3 of 0.10 mol dm^{-3} of thiosulfate was used in the reaction.

(i) From the three equations given above, deduce the stoichiometric relationship between thiosulfate ions and oxygen gas.

$$2\,S_2O_3^{2-} \equiv I_2 \equiv MnO(OH)_2 \equiv \tfrac{1}{2}\,O_2$$

$$\Rightarrow S_2O_3^{2-} \equiv \frac{1}{4}\,O_2 \quad \text{OR} \quad 4S_2O_3^{2-} \equiv O_2$$

[1]

(ii) Hence, calculate the volume of oxygen gas present in the original sample at r.t.p.

Amount of $S_2O_3^{2-}$ used in 25 cm^3 $= \frac{25.0}{1000} \times 0.10$

$= 2.50 \times 10^{-3}$ **mol**

Amount of O_2 present $= \frac{1}{4} \times 2.50 \times 10^{-3} = 6.25 \times 10^{-4}$ **mol**

Vol. of O_2 present $= 6.25 \times 10^{-4} \times 24\,000 = \underline{15.0\ cm^3}$

[2]

[Total: 9]

3 Period 3 solid oxides, **X** and **Y** react with water as follows:

- **X** reacts with water to form a triprotic acid.
- **Y** reacts with water to form a strongly alkaline solution.

(a) **(i)** State the identities of **X** and **Y**.

X is Phosphorus, Y is Sodium [1]

(ii) Write the equations for the reactions of the oxides of **X** and **Y** with water, and state the pH of the resulting solution.

$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ pH = 3

$Na_2O + H_2O \rightarrow 2NaOH$ pH = 13 [2]

(b) 1.00 g of a supplement tablet containing MgO was dissolved in 100 cm^3 of 1.00 mol dm^{-3} of dilute sulfuric acid which was in excess to form solution **A**.

25.0 cm^3 of solution **A** containing excess H_2SO_4 required 22.00 cm^3 of 2.00 mol dm^{-3} aqueous NaOH for complete reaction.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

(i) Write an equation between MgO and dilute sulfuric acid.

$MgO + H_2SO_4 \rightarrow MgSO_4 + H_2O$ [1]

(ii) Calculate the percentage of MgO in the supplement tablet.

Amount of NaOH used = $\frac{22.00}{1000} \times 2.00$
= 0.0440 mol
Amount of H_2SO_4 in in 25.0 cm^3 solution A = $\frac{0.0440}{2}$
= 0.0220 mol
Amount of unreacted H_2SO_4 in in 100.0 cm^3 = $\frac{100.0}{25.0} \times 0.0220$
= 0.0880 mol

Amount of H_2SO_4 that reacted with MgO = 0.100 – 0.0880 = 0.0120 mol
Mass of MgO in supplement tablet = 0.0120× 40.3 = 0.484 g

Percentage of MgO in supplement table = $\frac{0.484}{1.00} \times 100$

= 48.4 %

[4]

(iii) With the knowledge of the acid-base behaviour of Period 3 oxides, suggest how SiO_2 can be obtained from a mixture of MgO and SiO_2 via filtration. Identify the species present in the residue and filtrate.

Add excess dilute acid to the mixture and filter

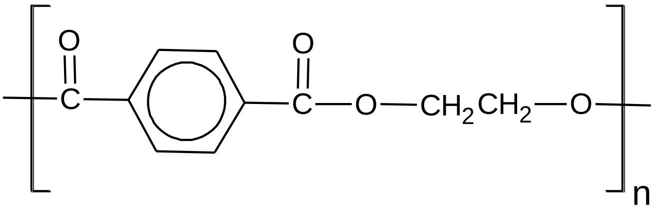
Residue: SiO_2

Filtrate: MgO

.... [2]

[Total: 9]

4 Polyethylene terephthalate, PET, is a thermoplastic polymer.



PET

(a) **(i)** Define the term *polymer*.

Polymers are macromolecules built up from monomers, with <u>average molar mass of at least 1000</u> or <u>at least 100 repeat units</u>.

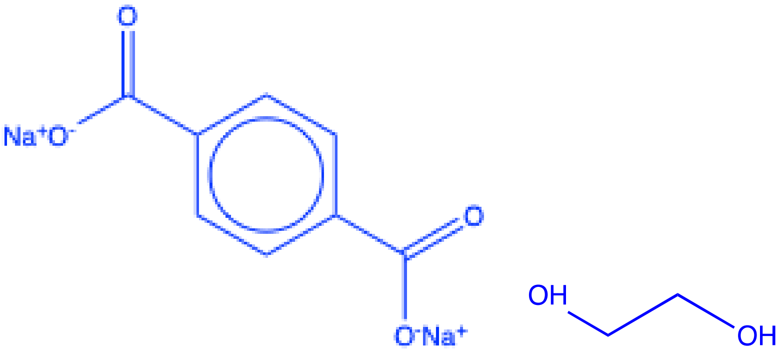
.... [1]

(ii) Name the type of reaction PET undergoes as it is heated with sodium hydroxide.

(Basic) hydrolysis

.... [1]

(iii) Draw the structure of the products formed from the reaction in **(a)(ii)**.



[2]

(b) Another type of PET degradation results in the formation of compound **Y** with an infra-red absorption frequency of 1670−1740 cm^{-1}.
Some reactions of compound **Y** are given below.

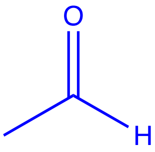
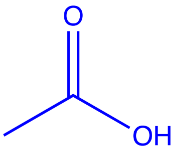
$$\underset{(C_2H_6O)}{\mathbf{X}} \longleftarrow \underset{(C_2H_4O)}{\mathbf{Y}} \xrightarrow[\text{heat}]{Cr_2O_7^{2-}\ /\ H^+} \underset{(C_2H_4O_2)}{\mathbf{Z}}$$

Compound **Z** gives an effervescence when reacted with sodium carbonate solution.

(i) Name the functional groups present in compounds **Y** and **Z**.

Y: aldehyde **Z: carboxylic acid** [2]

(ii) Suggest the structures of compounds **X**, **Y** and **Z**.

Compound X	**Compound Y**	**Compound Z**
		

[3]

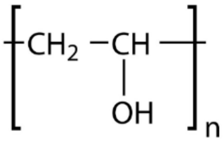
(iii) State the reagent and conditions needed to convert compound **Y** to **X**.

H_2 /Pt catalyst [1]

(iv) Name the type of reaction observed in the conversion of compound **Y** to **Z**.

Oxidation [1]

(c) In contrast to PET, poly vinyl alcohol (PVA) is water soluble.



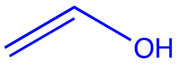
$$\left[\!-CH_2-\underset{\displaystyle OH}{\underset{|}{CH}}-\!\right]_n$$

poly vinyl alcohol (PVA)

(i) State the type of polymerisation that occurs during the production of PVA.

Addition [1]

(c) **(ii)** Draw the skeletal formula of the monomer used in PVA.



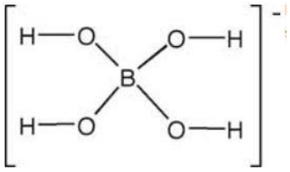
[1]

(iii) With reference to structure and bonding, explain why PVA is soluble in water.

PVA has a giant molecular structure held together by strong covalent bonds. PVA contains numerous –OH groups that can form hydrogen bonds with water that releases sufficient energy to break the hydrogen bonds in water and the hydrogen bonds between PVA.

.... [2]

(iv) Upon the addition of borate ion, PVA can be cross-linked forming a thermoset polymer. The reaction produces water as a by-product.

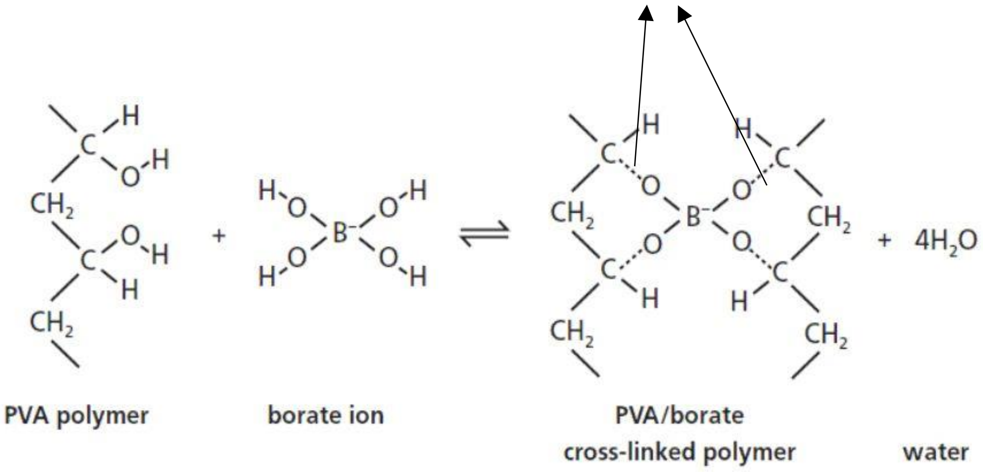


Borate ion

With the aid of a diagram, illustrate how PVA is cross-linked with a borate ion, showing clearly how the covalent bonds are formed.

1. show covalent bonds (borate ether bonds) formed
2. cross links between borate and 2 polymer chains

Covalent bonds formed between
polymer chains that act as cross links



[2]

(d) Poly(tetrafluoroethene) is used as non-stick coating for pans and textile finishes that repels water and oil stains. It is also used in containers for reactive and corrosive chemicals due to its non-reactive properties.

(i) With reference to the structure and bonding in PTFE, suggest a reason to explain the property of PTFE in its uses as non-reactive containers.

It possesses strong carbon-fluorine and carbon-carbon covalent bonds which are difficult to break.

[1]

(ii) Geckos may not be able to stick on non-stick pans, but geckos can climb walls.
Explain why geckos have the ability to climb walls.

On coming in contact with any surface, each spatula deforms to enabling maximum contact with the wall(substrate) surface, forming instantaneous dipole induced dipole interactions.

As spatulae are nanostructure which possessing high surface to volume ratio and there are billions of spatulae per gecko, thus creating a huge collective surface area of contact.

The culmulative spatula-wall instantaneous dipole induced dipole interactions generated is therefore translated to enormous attractive/adhesive forces capable of supporting many times the gecko's body weight.

[3]

[Total: 21]

5 Oleic acid is one of three fatty acids formed from the degradation of olive oil with a melting point of 13.0 °C and a condensed structural formula of $CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$. It can exist as a pair of isomers.

(a) **(i)** State the type of isomerism exhibited in oleic acid.

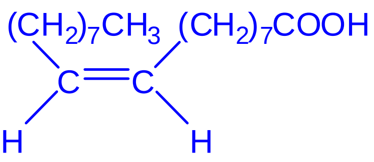
Cis-trans **isomerism.** [1]

(ii) Explain how the type of isomerism in **(a)(i)** occurs.

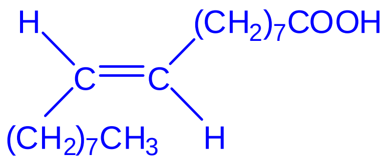
Cis-trans isomerism arises due to restricted rotation about the C=C and each carbon of the C=C has different substituents attached to it.

[2]

(iii) Draw and label the structural formulae of the pair of isomers in oleic acid.



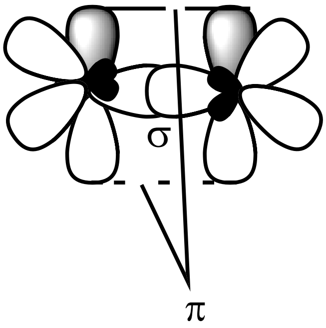
cis isomer



trans isomer

[2]

(iv) With the use of a labelled diagram, describe the bonding in C=C in terms of orbital overlap.



The C–C σ bond is formed by the <u>head-on overlap between one orbital of the carbon atom and one orbital of adjacent carbon atom</u>.

The C–C π bond is formed by the <u>sideway overlap</u> <u>between the 2*p* orbital of the carbon atom and 2*p* orbital of adjacent carbon atom</u>. [3]

(v) Describe a simple chemical test to distinguish between oleic acid and ethane, stating clearly the observations for both compounds.

Add <u>Br_2 in CCl_4</u> to each compound in the dark at r.t.p.

Oleic acid: Orange-red bromine solution is decolourised to form colourless solution

Ethane: Orange-red bromine solution is NOT decolourised. [2]

[Total: 10]

Section B

Answer **one** question from this section in the spaces provided.

6 **(a)** Carbonic acid, H_2CO_3, is a *weak Bronsted acid*.

(i) Explain the term *weak Bronsted acid*.

Proton donor that partially dissociates in water [1]

(ii) The equation for the reaction between carbonic acid and water is as shown:

$$H_2CO_3(aq) + H_2O \ \square\ HCO_3^-(aq) + H_3O^+(aq)$$

Write an expression for the acid dissociation constant, K_a, for the above, stating its units clearly.

$$K_a = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]} \quad \text{mol dm}^{-3}$$

[2]

Carbonic acid can be mixed with sodium hydrogen carbonate to make a buffer solution.

(iii) Explain what is meant by the term buffer solution.

A buffer solution is a solution which is capable of maintaining a fairly constant pH even when small amounts of acids or base are added to it. [1]

(iv) Explain, by reference to the equilibrium in **(a)(ii)**, how this mixture behaves as a buffer. Write relevant equations in your answers.

When small amount of acid is added,

$HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3$

When small amount of base is added,

$H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-$

[2]

A number of equilibria exist when carbon dioxide is dissolved in water.

Equilibrium 1 $CO_2(g) \rightleftharpoons CO_2(aq)$
Equilibrium 2 $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$ $K_c = 1.20 \times 10^{-3}$ at 25 °C
Equilibrium 3 $H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

(b) A bottle of Coca-Cola drink contains carbon dioxide dissolved in water. The equilibrium concentration of aqueous carbon dioxide in an unopened bottle of Coca-Cola is 0.082 mol dm^{-3}.

(i) Write the equilibrium constant, K_c, of equilibrium 2, showing its units clearly.

$K_c = \frac{[H_2CO_3]}{[CO_2]}$ (no unit)

[1]

(ii) Calculate the equilibrium concentration of carbonic acid, H_2CO_3 in an unopened bottle of Coca-Cola drink at 25 °C.

$K_c = \frac{[H_2CO_3]}{[CO_2]}$

$1.20 \times 10^{-3} = \frac{[H_2CO_3]}{0.082}$

$[H_2CO_3] = 9.84 \times 10^{-5}$ moldm^{-3}

[1]

(iii) Suggest the effect on the pH of the drink when the Coca-Cola bottle is opened. Explain your reasoning in terms of the effect on the equilibrium concentrations and relative positions based on the reactions above.

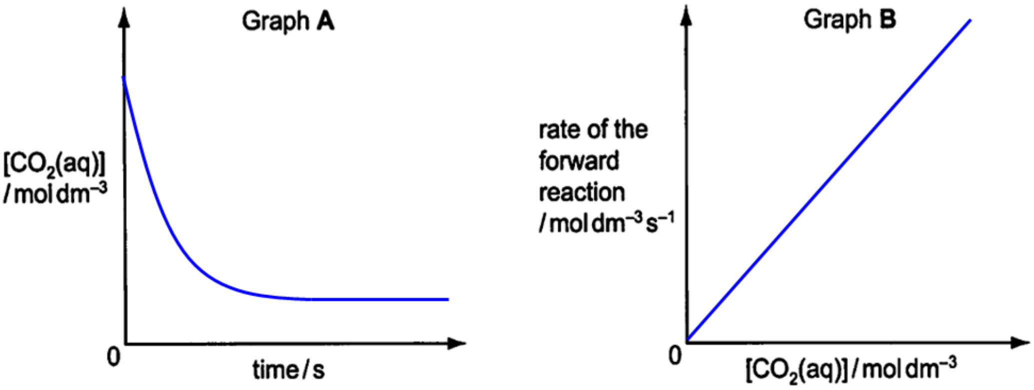
When the bottle is opened, pressure decreases so $CO_2(g)$ escapes, causing $[CO_2(g)]$ to decrease. This results in the position of equilibrium for equilibrium 1 to shift to the left to increase $[CO_2(g)]$. As a result, $[CO_2(aq)]$ decreases.

The position of equilibrium for equilibrium 2 shifts to the left to increase $[CO_2(aq)]$, resulting in the decrease of $[H_2CO_3]$. Hence, position of equilibrium for equilibrium 3 shifts to the left to increase $[H_2CO_3]$, causing a decrease in $[H^+]$. As a result of lower $[H^+]$, pH increases. [3]

(c) The reaction of carbon dioxide with water to reach equilibrium with carbonic acid, H_2CO_3, was found to exhibit first order kinetics with a half life of 0.028s.

(i) Sketch the graphs of

- $[CO_2(aq)]$ in mol dm^{-3} against time in seconds.
- Rate of forward reaction in mol dm^{-3} s^{-1} against $[CO_2(aq)]$ in mol dm^{-3}



[2]

(ii) Determine the rate constant for this reaction, stating its units clearly.

For a first order reaction, $t_{1/2} = \frac{\ln 2}{k}$

$k = \frac{\ln 2}{0.028} = 24.8\ s^{-1}$

[1]

(iii) Using, $\frac{c_t}{c_0} = (\frac{1}{2})^n$, calculate the time taken for carbonic acid to reach 98% of its equilibrium concentration.

$\frac{c_t}{c_0} = (\frac{1}{2})^n$

When carbonic acid is 98% of its equilibrium concentration,

$[CO_2(aq)] = 2\%$

$0.02 = (\frac{1}{2})^n$ where n= no. of half lives

$n = 5.65$

$t = 5.65 \times 0.028 = 0.158s$

[2]

(d) The enzyme, carbonic anhydrase, speeds up the reaction of carbon dioxide in water in living cells.

Fig. 6.1 shows how the rate of reaction is affected by the presence of the small amount of carbonic anhydrase

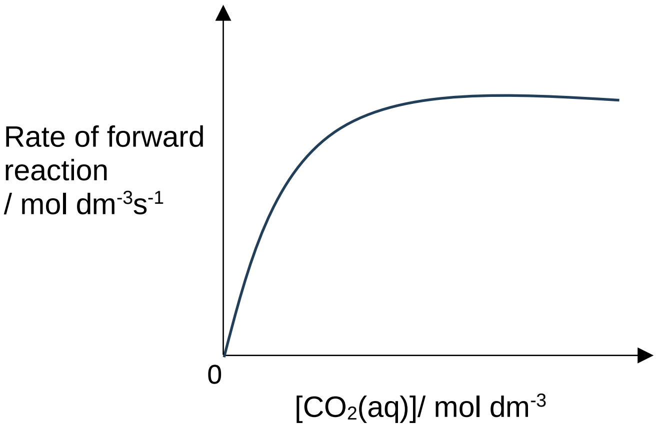


Fig. 6.1

Explain fully the shape of the graph.

When [CO_2(aq)] is low, ...**the active sites of the enzymes are not fully filled and the rate of enzyme catalysed reaction increases linearly with [CO_2(aq)], therefore the reaction is first order with respect to [CO_2(aq)].**

When [CO_2(aq)] is high, ...**all the active sites of the enzymes are filled up, and the enzyme is saturated. Increasing [CO_2(aq)] has no effect on the rate of reaction and reaction becomes zero order with respect to [CO_2(aq)].** [2]

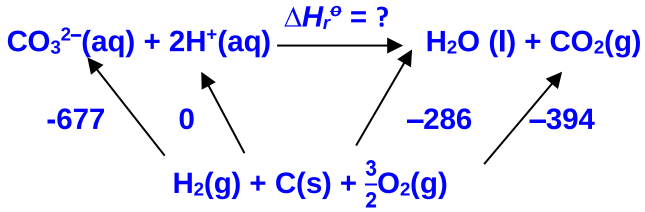
(e) Solutions of carbonates react with acids according to the following equation.

$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g)$ ---- reaction 4

The table below shows the enthalpy change of formations for the following species.

Species	$\Delta H_f^\ominus$ / kJ mol^{-1}
$H_2O(l)$	–286
$CO_2(g)$	–394
$CO_3^{2-}(aq)$	–677
$H^+(aq)$	0.0

Calculate the enthalpy change of reaction of carbonate with acid, ΔH_r, in reaction 4.



By Hess' Law,

$\Delta H_r = \Sigma\Delta H_f^\ominus$ **of products –** $\Sigma\Delta H_f^\ominus$ **of reactants**

$\Delta H_r = [-286 + (-394)] - (-677 + 0)$

$\therefore \Delta H_r = -3.00$ **kJ mol^{-1}**

[2]

[Total: 20]

7 This question is about oxides of nitrogen.

(a) Dinitrogen tetroxide, N_2O_4, decomposes into NO_2 as shown in the equation below.

$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

An experiment was conducted at 25 °C by varying initial concentrations of N_2O_4 and NO_2 contained in a closed reaction vessel. The initial and equilibrium concentrations of the two gases are shown in Table 7.1.

Expt	Initial concentration /mol dm^{-3}		Equilibrium concentration /mol dm^{-3}	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
1	0.000	0.200	0.0898	0.0204
2	0.600	0.040	0.594	0.0523
3	0.500	0.030	0.491	0.0475

Table 7.1

(i) State *Le Chatelier's Principle*.

Le Chatelier's Principle states that if a system in dynamic equilibrium is subjected to a change which disturbs the equilibrium, the system responds in such a way to counteract/oppose the effect of the change and a new equilibrium is established. [1]

(ii) State and explain what will be observed when the pressure in the reaction vessel is decreased.

When pressure in the reaction vessel is decreased, the system will respond by shifting the position of equilibrium to the right, increasing the number of gaseous particles to increase pressure. The colour of the gas darkens or turns a darker brown due to more NO_2 gas formed.

[2]

(iii) Using experiment 2, calculate the equilibrium constant, K_c, of the reaction, stating its units.

$$K_c = \frac{[NO_2]^2}{[N_2O_4]}$$

$$= \frac{(0.0523)^2}{(0.594)} = 4.60 \times 10^{-3} \text{ mol dm}^{-3}$$

[1]

(b) Catalytic converters are fitted in cars to remove oxides of nitrogen, which has significant environmental consequences if emitted into the atmosphere.
Platinum can be used as a catalyst in the catalytic converter.

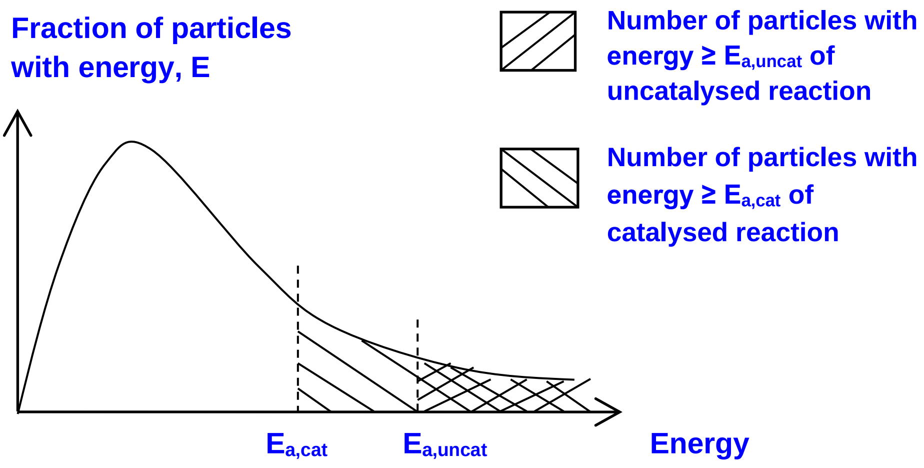
(i) State the type of catalysis and outline the sequence and mode of action of the catalyst in the catalytic converter.

Heterogeneous catalysis

Catalysis takes place at the surface of the catalyst, where reactants are adsorbed and bonds within the reactants are weaken / broken to form products with lower E_a. After new bonds are formed, the products are desorbed from the surface.

[4]

(ii) Draw a Boltzmann distribution curve for the catalysed reaction and explain the effect on how the addition of catalyst would have on the rate of reaction



The catalyst lowers the activation energy of the reaction and increases the rate of reaction by providing an alternative reaction pathway with lower activation energy. With a lowered activation energy, there will be a higher fraction of the reactants with sufficient energy greater or equal to the new activation energy, E_a, of the catalysed reaction. Thus, there will be a higher frequency of effective collisions and the rate of reaction of oxidation of CO also increases.

[3]

]

(c) Nitric acid, HNO_3, is formed by the reaction of NO_2 with water. This is an example of an inorganic *strong acid*. Ethanoic acid, CH_3COOH, on the other hand, is an example of an organic acid, and is considered a *weak acid*.

(i) Explain what is meant by the terms in italics and illustrate your answers with the use of relevant equations.

A strong acid dissociates completely into its ions when dissolved in water whereas a weak acid dissociates partially when dissolved in water.

$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$

$HNO_3 \rightarrow NO_2^- + H^+$

.... [2]

(ii) In an experiment, 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is added to 30 cm^3 of 1.00 mol dm^{-3} aqueous nitric acid. The temperature of the mixture increases by 5.6 °C
Calculate the enthalpy change of the neutralisation between sodium hydroxide and nitric acid.
The specific heat capacity of water is 4.18 J cm^{-3} K^{-1}.

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

no. of moles of HNO_3 = 0.030 mol

no. of moles of NaOH = 0.020 mol

since NaOH : HNO_3 = 1 : 1, NaOH is the limiting reagent.

no. of moles of H_2O = 0.020 mol

$Q = mc\Delta T$

$Q = (50)(4.18)(5.6) = 1170.4$ J

$\Delta H = -1170.4/0.02 = -58520$ $Jmol^{-1}$ = -58.5 kJ mol^{-1}

[3]

(iii) A student repeated the experiment using 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide and 30 cm^3 of 1.00 mol dm^{-3} aqueous ethanoic acid. All other conditions were kept constant.
Suggest whether the temperature increase will be more or less than 5.6 °C and give an explanation for your answer.

Temperature rise will be below 5.6°C.

Ethanoic acid is a weak acid that partially ionises in water. Additional amount of energy is required to completely ionise the acid into its ions and thus overall enthalpy change of neutralisation between ethanoic acid and sodium hydroxide will be less exothermic .

.... [2]

(iv) Suggest a suitable indicator for the titration of ethanoic acid with aqueous sodium hydroxide. Explain your choice.

Indicators	Working range
Screened methyl orange	2.2 to 4.4
Congo red	3.0 to 5.0
Phenolphthalein	8.0 to 9.6

Phenolphthalein

The range of rapid pH change over the equivalence point coincides with the working range of the indicator.

[2]

[Total: 20]