

PIONEER JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION
HIGHER 1

CANDIDATE
NAME

CT
GROUP

1	6			
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INDEX
NUMBER

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CHEMISTRY

8872/02

12 September 2017

2 hours

Additional Materials: Data Booklet
Writing Paper
Graph Paper

READ THESE INSTRUCTIONS FIRST

Write your name, CT group and index number in the spaces provided.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

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

Section A

Answer **all** the questions in the spaces provided.

Section B

Answer **two** questions on separate writing papers. If there is no answer to the question, a blank sheet of paper must still be submitted.

You are advised to show all working in calculations.

You may use a calculator.

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

At the end of the examination, fasten all your work securely together.

FOR EXAMINER'S USE			
Paper 1		Paper 2 Section B	
Total	/ 30	Total	/ 40
Paper 2 Section A			
1	/ 10	4	/ 6
2	/ 10	5	/ 7
3	/ 7	Total	/ 40
Penalty	s.f. / units	GRADE	

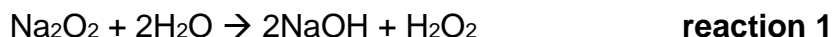
This document consists of **19** printed pages

Section A (40 marks)

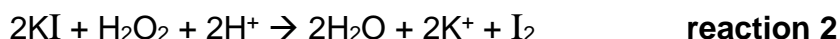
Answer **all** questions. Write your answers in the spaces provided.

- 1 (a) Burning sodium in air produces a mixture of sodium oxide, Na_2O , and sodium peroxide, Na_2O_2 . The amount of sodium oxide in the mixture can be determined by the following method.

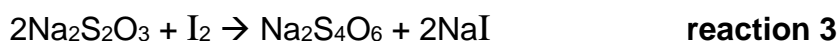
- The mixture is dissolved in water



- The solution is acidified and an excess of potassium iodide solution is added, iodine is liberated by the following reaction.



- The iodine is titrated with standard sodium thiosulfate solution



- (i) When a sample of the mixed oxides, of mass 1.00 g was treated in this way, it was found that 33.40 cm^3 of $0.200 \text{ mol dm}^{-3}$ $\text{Na}_2\text{S}_2\text{O}_3$ was required to react with all the iodine released.

Calculate the amount of Na_2O in the oxide mixture. [4]

$$\text{Amt of } \text{S}_2\text{O}_3^{2-} = (33.40/1000)(0.200) = 6.68 \times 10^{-3} \text{ mol}$$

$$\begin{aligned} \text{Amt of } \text{I}_2 \text{ liberated from reaction 2} &= \frac{1}{2} (6.68 \times 10^{-3}) = 3.34 \times 10^{-3} \text{ mol [1]} \\ &= \text{amt of } \text{H}_2\text{O}_2 \text{ formed from reaction 1} = \text{Amt of } \text{Na}_2\text{O}_2 \text{ reacted in reaction 1 [1]} \end{aligned}$$

$$\text{Mass of } \text{Na}_2\text{O}_2 = 3.34 \times 10^{-3} \times (2(23.0) + 2(16.0)) = 0.2605 \text{ g}$$

$$\text{Mass of } \text{Na}_2\text{O} = 1.00 - 0.2605 = 0.7395 \text{ g [1]}$$

$$n(\text{Na}_2\text{O}) = 0.7395 / [2(23.0) + 16.0] = 0.01192 \text{ mol [1]}$$

- (ii) In terms of oxidation state, deduce all the changes in oxidation number that occurs for **reaction 3**, stating which element is involved in each change. [2]

The oxidation state of S changes from +2 in $\text{S}_2\text{O}_3^{2-}$ to +2.5 in $\text{S}_4\text{O}_6^{2-}$ [1]

The oxidation state of I changes from 0 in I_2 to -1 in NaI [1]

- (b) Sodium oxide and aluminium oxide are white solids.

A student is tasked to add sodium oxide to water followed by a few drops of universal indicator.

- (i) Describe what will be observed when a few drops of universal indicator is added to the resultant solution prepared by adding sodium oxide to water. Write a balanced equation for this reaction.

Sodium hydroxide solution will give a blue/ violet / indigo colour with the universal indicator. [1]

Equation: $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ [1]

[2]

Another student is tasked to add aluminium oxide to hydrochloric acid and aqueous sodium hydroxide separately.

- (ii) Write balanced equations to show the reaction between aluminium oxide with hydrochloric acid and aqueous sodium hydroxide

Equation for the reaction between aluminium oxide and hydrochloric acid.

$\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$ [1]

[1]

Equation for the reaction between aluminium oxide and aqueous sodium hydroxide. [1]

$\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{Na}[\text{Al}(\text{OH})_4]$ [1]

[total:10]

[Turn Over

- 2 (a) Chromium, potassium and sodium are common elements that are found in many compounds commonly used in the school laboratory.

(i) Give the full electronic configuration of chromium atom:



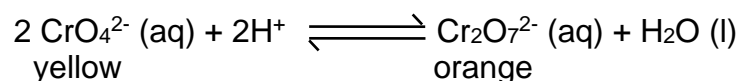
[1]

(ii) The first ionisation energy of potassium is lower than that of sodium. Explain why.

Atomic radius increases down the group due to increasing number of quantum shells [1], attraction decreases down the group. [1]

[2]

- (b) An aqueous sodium chromate (VI) contains yellow CrO_4^{2-} ions. An aqueous potassium dichromate (VI) contains orange $\text{Cr}_2\text{O}_7^{2-}$ ions. These chromate (VI) ions exist in equilibrium with dichromate (VI) ions as shown by the expression below:



(i) Write an expression for the equilibrium constant K_c , for this reaction.

$K_c = \frac{[\text{Cr}_2\text{O}_7^{2-}]}{[\text{CrO}_4^{2-}]^2 [\text{H}^+]^2}$ [1]

[1]

(ii) A 2.0 dm^3 solution is prepared in which the initial amount of CrO_4^{2-} ions, H^+ ions and $\text{Cr}_2\text{O}_7^{2-}$ ions are 2.40 mol , 3.00 mol and 0.112 mol respectively. When equilibrium is reached, the pH of the mixture is 0 at 298 K .

Show relevant workings to calculate the amount of H^+ ions at equilibrium.

$[\text{H}^+] = 10^{-\text{pH}} = 10^{-0} = 1.00 \text{ mol dm}^{-3}$. $n(\text{H}^+) 1.00 \times 2 = 2.00 \text{ mol}$

Amount of H^+ ions at equilibrium = 2.00 mol

[1]

(iii) Using your answer in (b)(ii), fill in the blanks with the correct values

	$2\text{CrO}_4^{2-} (\text{aq})$	$+2\text{H}^+ (\text{aq})$	\rightleftharpoons	$\text{Cr}_2\text{O}_7^{2-} (\text{aq})$	$+ \text{H}_2\text{O} (\text{l})$
Initial/ mol	2.40	3.00		0.112	--
Change/ mol	-1.00	-1.00		+0.50	--
Equilibrium/ mol	1.40	2.00		0.612	--

[1]

- (iv) Using your K_c expression in **b(i)**, calculate the numerical value of K_c for this equilibrium, stating its units.

$$\begin{aligned}
 K_c &= [\text{Cr}_2\text{O}_7^{2-}] / [\text{CrO}_4^{2-}]^2 [\text{H}^+]^2 \\
 &= (0.612/2) / (1.40/2)^2 (2.00/2)^2 \\
 &= 0.6244 \approx 0.624 \quad [1]
 \end{aligned}$$

Units: $\text{mol}^{-3} \text{ dm}^9$ [1]

[2]

- (v) Describe and explain the colour changes when solid P_4O_6 was added into the equilibrium mixture containing the $\text{CrO}_4^{2-}(\text{aq})$ and $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ions.

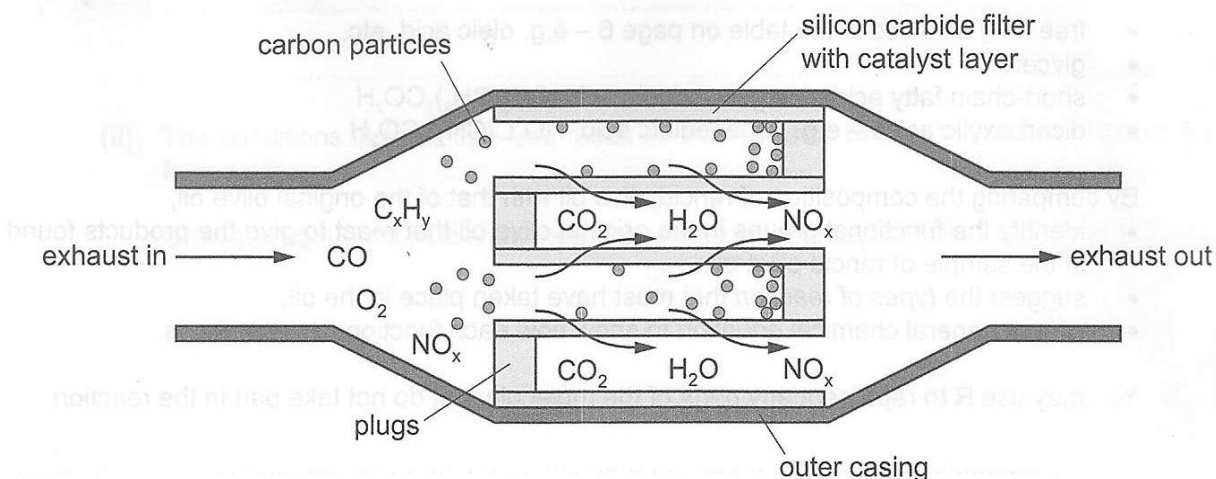
When phosphorus oxide is added, $[\text{H}^+]$ increases, position of equilibrium shift to the right to decrease H^+ , [1]
 hence higher percentage of orange $\text{Cr}_2\text{O}_7^{2-}$ and lower percentage of yellow CrO_4^{2-} is formed, giving rise to a solution that is more orange and less yellow at the next equilibrium. [1]

[2]

[Total: 10]

- 3 Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of polluting substances emitted into the atmosphere.

For diesel engines the catalytic converter may also include a particle filter to remove solid particles of carbon. The diagram shows one design of diesel particle filter.



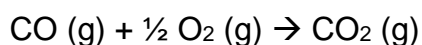
- (a) The walls of the particle filter are made from silicon carbide, SiC. This is a hard solid that will not melt at the high temperatures of the exhaust.

Suggest how the structure and bonding in silicon carbide makes it resistant to melting, even at high temperatures.

SiC has a giant molecular structure [1] with extensive network of strong covalent bonds [1] to be overcome during melting. Hence even at high temperatures, the energy provided is not sufficient to overcome the bonds .

[2]

- (b) CO pollutants react with oxygen and are removed from the exhaust. The reaction is as shown below:

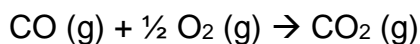


- (i) Name the enthalpy change of reaction that is represented by the above reaction.

Enthalpy change of combustion of CO. [1]

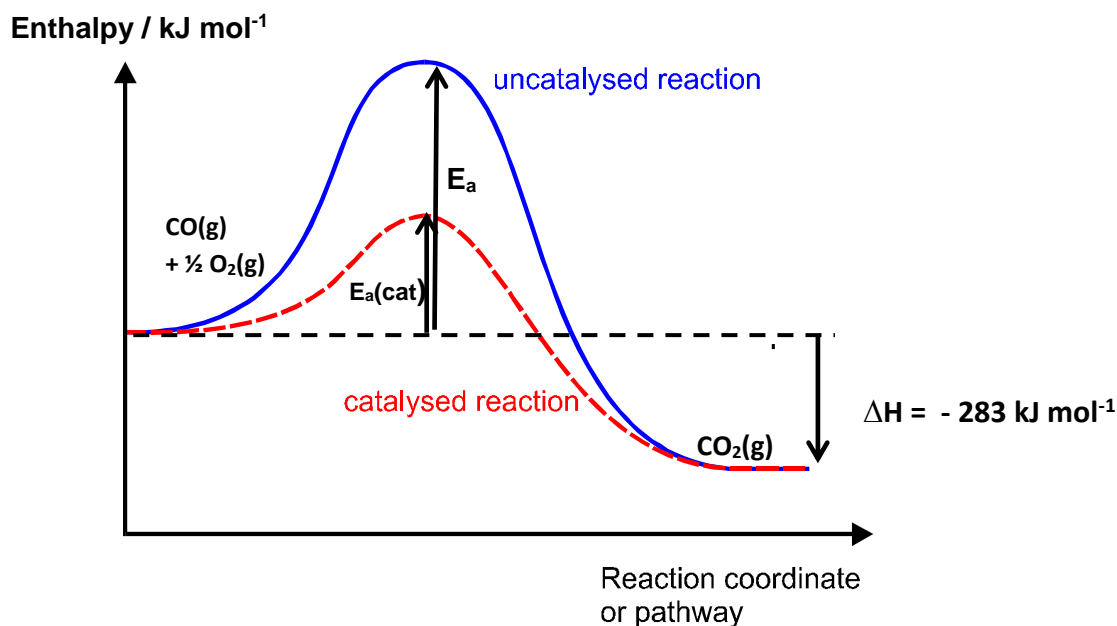
[1]

- (ii) The enthalpy change of reaction for this reaction, ΔH is **-283 kJ mol⁻¹**



The catalyst from the catalytic converter helps to remove the CO pollutants from the exhaust more quickly.

Draw a reaction pathway diagram to represent the reaction. Draw labelled arrows to show ΔH , activation energy, E_a , of the reaction and activation energy of the catalysed reaction, $E_a(\text{catalysed})$ on your diagram.



(any 1 to 2 mistake minus 1 mark, 3 mistakes and more zero mark)

[2]

- (iii) Using bond energy data from the *Data Booklet*, calculate the enthalpy change of the reaction: $\text{CO (g)} + \frac{1}{2} \text{O}_2 \text{ (g)} \rightarrow \text{CO}_2 \text{ (g)}$

[Use a value of 1070 kJ mol⁻¹ for the bond energy of CO bond in carbon monoxide and a value of 805 kJmol⁻¹ for the bond energy of each C=O bond in CO₂ respectively.]

$$\Delta H = \text{BE}(\text{bonds broken}) - \text{BE}(\text{bonds formed})$$

$$= 1070 + \frac{1}{2} (496) - 2(805)$$

$$= -292 \text{ kJ mol}^{-1} [1]$$

[1]

- (iv) The theoretical value given in **(b)(ii)** is -283 kJmol⁻¹. Comment on the difference between your calculated value in **(b)(iii)** and the theoretical value in **(b)(ii)**.

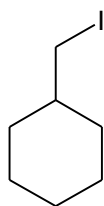
Bond energy used in (b)(iii) are average values and they differ in different chemical and electronic environment the bonds are in. [1] [1]

[total:7]

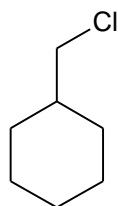
[Turn Over]

- 4 Suggest simple chemical tests to distinguish the following pairs of compounds. You are required to state the observations of each compound.

(a)



and



Compound **A**

Compound **B**

[3]

Step 1: NaOH(aq), heat

Step 2: cool

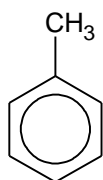
Step 3: acidify with HNO₃(aq)

Step 4: AgNO₃(aq) [1]

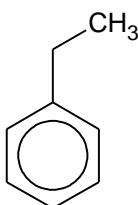
Compound **A**: yellow precipitate of AgI is formed [1]

Compound **B**: white precipitate of AgCl observed [1]

(b)



and



Compound **C**

Compound **D**

KMnO₄(aq), H₂SO₄(aq), heat [1]

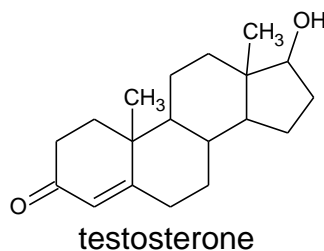
Compound **C**: purple KMnO₄ decolourises [1]

Compound **D**: purple KMnO₄ decolourises, effervescence observed. Gas forms white precipitate when pass through Ca(OH)₂(aq). Gas is CO₂. [1]

[3]

[Total: 6]

- 5 (a) Androstanes are a group of compounds with a tetracyclic hydrocarbon ring structures. An example of an androstane is testosterone.

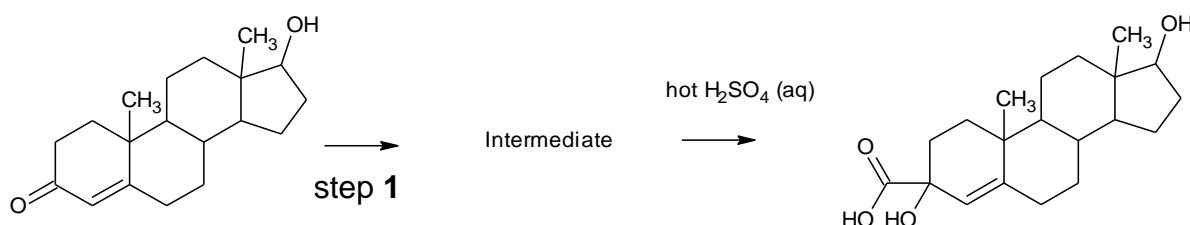


- (i) Name the functional groups present in testosterone.

Ketone, alkene, 2° alcohol [2 marks for all 3, 1 mark for 2]

[2]

Testosterone can be converted into the compound **A** as shown.



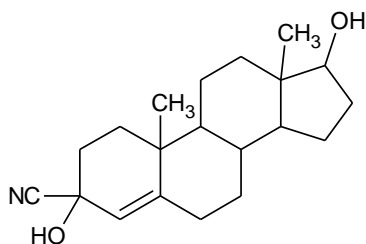
- (ii) Give the reagents and conditions for step 1.

[1]

Step I: HCN(aq), trace amount of NaCN/NaOH, 10-20 °C [1]

- (iii) Draw the structure of the intermediate formed.

[1]

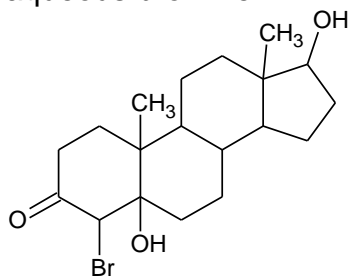


[1]

(if there is missing C atoms in the cyclic ring , BOD)

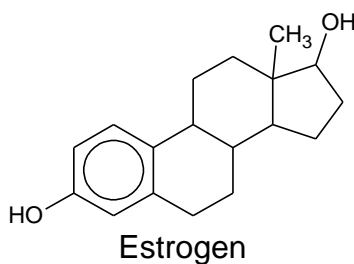
- (iv) Draw the structure when testosterone undergoes addition reaction with aqueous bromine.

[1]

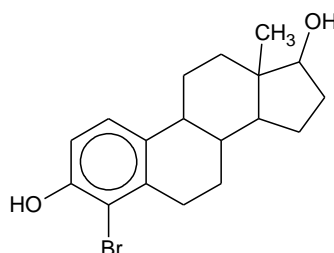


[1]

- (b) In the body, the enzyme aromatase can convert testosterone into estrogen.



The following product is obtained when estrogen undergoes substitution with bromine under suitable conditions.



Unlike Testosterone which undergoes addition reaction with aqueous bromine, explain why estrogen undergoes substitution with aqueous bromine instead of addition ?

Addition reaction will cause the destruction of the delocalised pi electron system, thus destroying the aromatic character of benzene. [1]

Hence when benzene reacts, the C-H bonds are broken and not the pi bonds so as to retain its aromaticity which stabilises benzene. [1]

[2]

[Total:7]

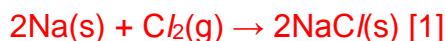
[total: 40]

Section B (40 marks)

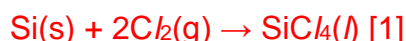
Answer **two** of the three questions in this section on separate paper.

- 1 (a) Sodium and silicon are elements in Period 3 of the Periodic Table.

Describe what will you see when both elements are burned separately in chlorine? Give an equation for each reaction. [4]



Reacts vigorously in chlorine with an orange flame to give a white solid, sodium chloride. [1 for both observations]



Reacts slowly to form a colourless liquid [1]

- (b) Ethanol can be burned in an excess of oxygen as a fuel but in the body ethanol is partially oxidised. Complete combustion of ethanol to give carbon dioxide releases 1367 kJ mol^{-1} whilst the metabolism of ethanol in the human body leads to partial oxidation to give ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$, which releases 770 kJ mol^{-1} . Complete oxidation of ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$, to give carbon dioxide releases 873 kJ mol^{-1}

- (i) Write an equation to represent the enthalpy change of combustion of ethanol. [1]



- (ii) Calculate the energy released if one mole of ethanol in the body were to be oxidised to ethanoic acid and water only. [1]

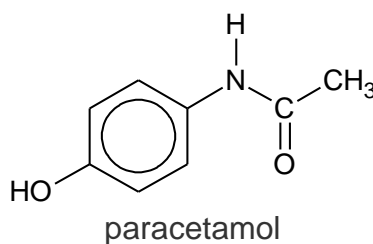
$$1367 - 873 = 494 \text{ kJ mol}^{-1} \quad [1]$$

- (iii) Assuming in the body, ethanol is oxidised to a mixture of ethanoic acid and carbon dioxide, use the data to calculate the proportion of ethanol metabolised to form CH_3COOH . [2]

Let 1 mol of $\text{C}_2\text{H}_5\text{OH}$ be partially oxidised, such that x mol is oxidised to CH_3COOH , and $1 - x$ mol is oxidised to CO_2 .

$$\begin{array}{lcl} \text{Amt of heat released} = 494x + 1367(1-x) \approx 770 & [1] \\ 873x = 597 & x = 0.683 & [1] \end{array}$$

Paracetamol is a suitable analgesic for patients who regularly drink moderate to large amounts of alcohol. It is also used widely to treat fever and pain. Paracetamol is also commonly known as panadol.



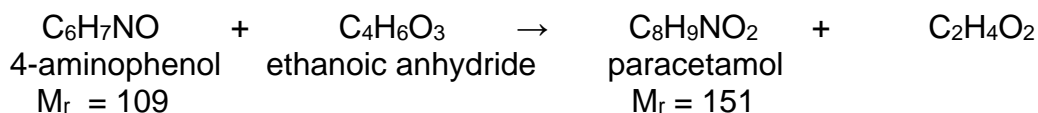
Some information on paracetamol is provided in the table below.

Molecular Formula	C ₈ H ₉ NO ₂
Density	1.263 g/cm ³
Melting Point	169 °C
Boiling Point	420 °C
Bioavailability	75% (oral) 100% (intravenous)
Biological half-life	2 hours

**Bioavailability refers to the percentage of a drug which enters the blood circulation system when introduced into the body and hence able to have an active and effective effect.*

**Biological half-life of a drug is the time taken for the drug to reduce to half its original amount in the body.*

- (c) Paracetamol can be produced from the reaction between 4-aminophenol and ethanoic anhydride as shown below.

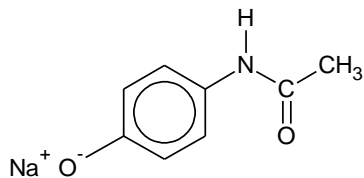


Excess ethanoic anhydride is used in this reaction and it is known that the yield of this reaction is 60%.

- (i) Calculate the minimum mass of the 4-aminophenol that are required to produce 10 g of paracetamol. [1]

$$\text{Mass of 4-aminophenol required} = \frac{10}{151} \times \frac{100}{60} \times 109 = 12.0 \text{ g [1]}$$

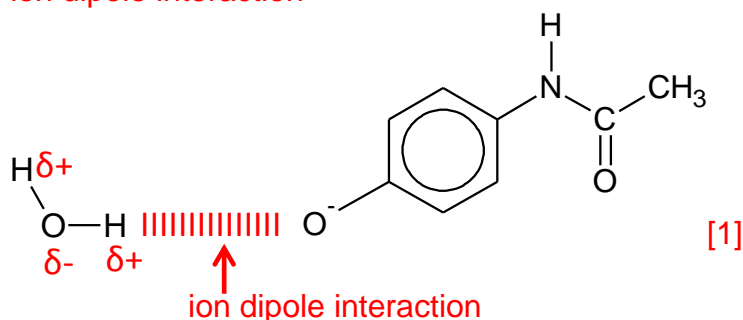
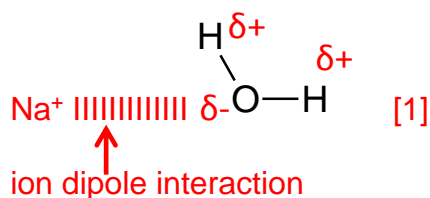
- (ii) Paracetamol is usually sold as its sodium salt:



in authorised pharmacies.

When the sodium salt has dissolved inside the patient's body, the anions and cations are each surrounded by a number of water molecules. This process is known as ion dipole interaction which will improve the solubility of drug inside the bloodstream.

Draw simple diagrams to show how a water molecule can be attached to a sodium cation, and to the anion. Label each diagram to show the type of interaction involved. [2]



show the correct interaction for cation and anion with water molecules [1] each

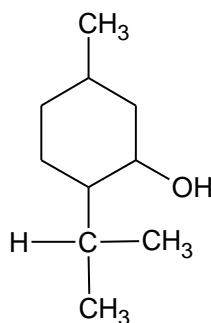
- (iii) A doctor wishes to prescribe oral medication for one of his patients suffering from acute dental pain.

The patient is advised to take four 250 mg paracetamol tablets in each dosage. Calculate the total mass of paracetamol which remains in the blood circulation system when it is introduced into the body after 4 hours. [2]

Mass of paracetamol in 4 x 250 mg tablets = 1000 mg
 Mass of paracetamol that will be useful and effective
 = 75% x 1000 = 750 mg [1]

Since biological half-life of paracetamol is 2 hours,
 2 hours 2 hours
 750 mg → 375 mg → 187.5 mg [1]

- (d) Menthol is another molecule that is used medicinally in ointments, cough drops, and nasal inhaler. Menthol has the following structure show below:



Pulegone, **A** and isopulegone, **B** are isomers with the molecular formula $C_{10}H_{16}O$.

Both isomers decolourise bromine water, and give an orange precipitate with 2,4-dinitrophenylhydrazine reagent but none reduces Fehling's solution.

On treatment with H_2 , and a platinum catalyst, both isomers are reduced to menthol.

When treated with hot concentrated $KMnO_4$, **A** gives two compounds: C_3H_6O , and **C**, $C_7H_{10}O_2$; **B** gives only a single compound **D**, $C_{10}H_{16}O_4$;

Compound **D** gives a yellow precipitate with alkaline aqueous iodine.

Suggest structures for **A**, **B**, **C** and **D**, and explain the observations described above. [7]

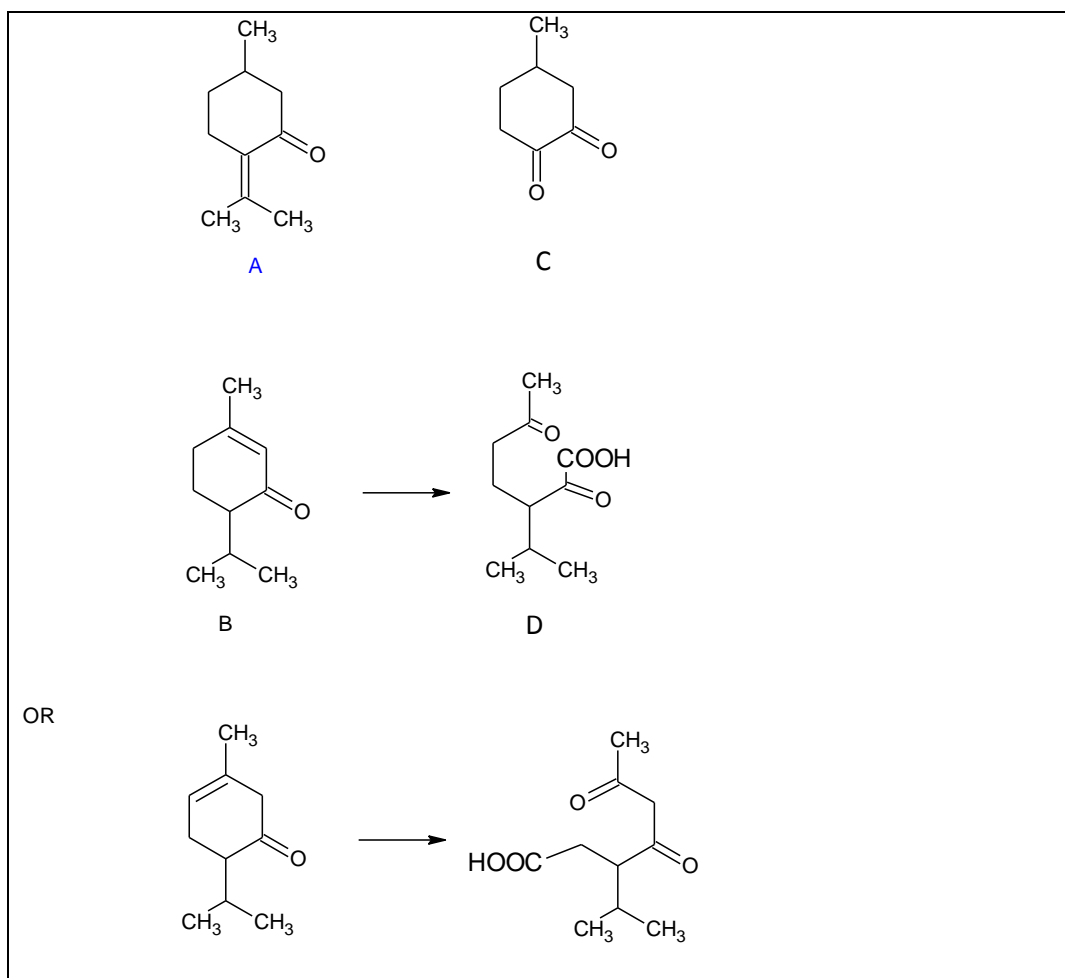
[Total: 20]

- **A**, **B** undergoes addition and have alkene functional group.
- **A**, **B** undergoes condensation with 2,4-DNPH, and does not undergo oxidation with Fehlings solution, therefore ketones are present.
- **A**, **B** undergoes oxidation with $KMnO_4$.
- **D** has CH_3CO- in its structure, it undergoes oxidation with I_2 , $NaOH(aq)$. (Yellow ppt is CHI_3)

6-7 pt – 3 marks

4-5 pt – 2 marks

2-3 pt – 1 mark



[Total: 20]

- 2 (a) A white solid is formed when magnesium is burn in air. The solid dissolves partially when water is added, forming a solution which turns red litmus paper blue. When solid phosphorus pentachloride is added, the white solid dissolves.

Explain the observation as fully as you can.

[3]

Burning Mg in air produces MgO , a white solid. [1]

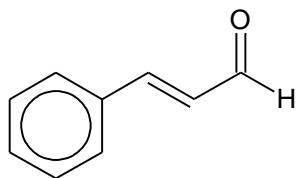
MgO is dissolves partially in water to form Mg(OH)_2 , turning the solution basic. [1]

When PCl_5 dissolves in water it forms HCl which neutralises the Mg(OH)_2 to form soluble $\text{MgCl}_2(\text{aq})$ / causing the solid to dissolve. [1]

Equations also accepted.

- (b) The benzene ring is an important functional group for many natural aromatic compounds. The earliest use of the term '*aromatic*' was by August Wilhelm Hofmann in 1855. The term was used to describe a group of compounds, many of which have aromas.

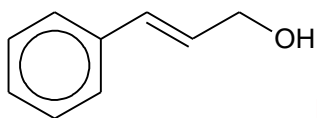
- (i) The compound that gives cinnamon its characteristic smell is cinnamaldehyde.



cinnamaldehyde

Draw the organic products when cinnamaldehyde is treated with

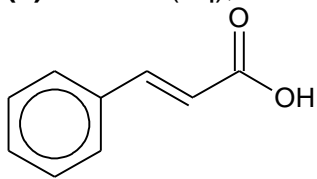
- (I) LiAlH_4 in dry ether



[1]

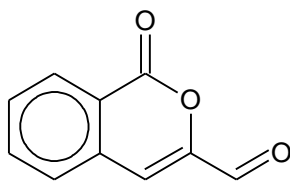
- (II) $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $\text{H}_2\text{SO}_4(\text{aq})$, heat

[2]



[1]

The functional group responsible for the smell of butter and cheese is the lactone functional group. An example of a lactone is artemidinal.

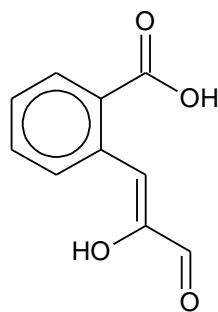


artemidinal

- (ii) State the molecular formula of artemidinal.

[1]

$\text{C}_{10}\text{H}_6\text{O}_3$ [1]



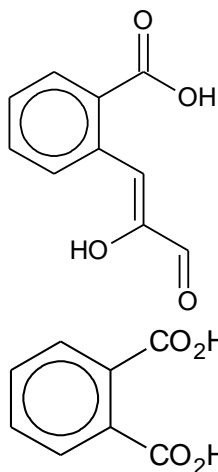
Artemidinal undergoes a reaction to form

- (iii) Name the type of reaction that occurs to effect this conversion. [1]

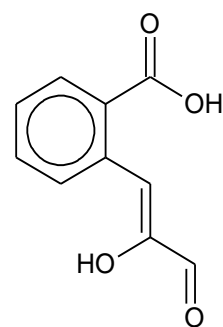
acid hydrolysis [1]

- (iv) State the reagents and conditions to effect this conversion. [1]

H_2SO_4 (aq), heat [1]

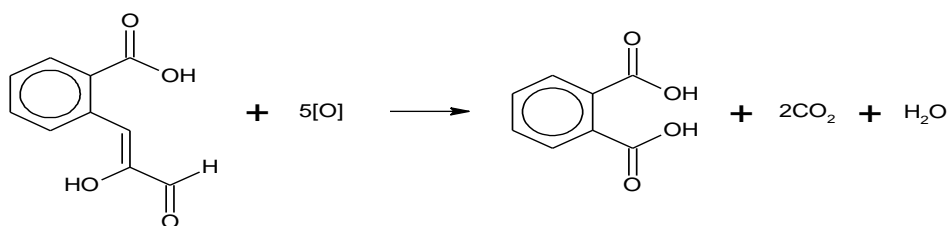


can be oxidised to benzene-1,2-dicarboxylic acid



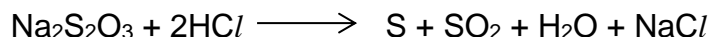
- (v) Write a balanced equation for the conversion of benzene-1,2-dicarboxylic acid.

[1]



[1]

- (c) The kinetics of the reaction between sodium thiosulfate(V) and hydrochloric acid was investigated.



An experiment was performed in which $0.200 \text{ mol dm}^{-3}$ of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, was reacted with 2.00 mol dm^{-3} of hydrochloric acid, HCl . A graph of concentration of $\text{Na}_2\text{S}_2\text{O}_3$ against time was plotted.

The following table shows $[\text{Na}_2\text{S}_2\text{O}_3]$ at various times

Time / s	$[\text{Na}_2\text{S}_2\text{O}_3] / \text{mol dm}^{-3}$
0	0.200
80	0.167
183	0.135
315	0.103
490	0.071
760	0.039

- (i) Plot these data on suitable axes and, showing all your working and drawing clearly any construction lines on your graph, deduce the order of reaction with respect to $\text{Na}_2\text{S}_2\text{O}_3$. [3]

Correct plotting to $\frac{1}{2}$ small square & Correct axes ($[\text{Na}_2\text{S}_2\text{O}_3] / \text{mol dm}^{-3}$ on vertical axis and time/s on the horizontal axis --- (1)

Construction lines to show two constant half lives $\approx 325 \text{ s}$ on graph paper (1)

Correct determination of first order for $\text{Na}_2\text{S}_2\text{O}_3$ – (1)

In order to determine the order of reaction with respect to hydrochloric acid, two more experiments are carried out as shown in the table.

Experiment	Volume of $\text{Na}_2\text{S}_2\text{O}_3 / \text{cm}^3$	Volume of HCl added / cm^3	Volume of deionised water / cm^3	Relative rate
1	20	30	10	1
2	20	20	20	1

In both **experiment 1** and **2**, deionised water was added to thiosulfate solution first and hydrochloric acid was added last before timing was started. The time taken for a fixed amount of sulfur to be produced is measured and the relative rate of the reaction is recorded.

- (ii) Explain why different volume of deionised water is used in both experiments? [1]

To maintain a constant total volume so that the volume of reagent added is proportional to the concentration in the reaction mixture. [1]

- (iii) With relevant workings, determine the order of reaction with respect to hydrochloric acid. [1]

When the volume (hence $[S_2O_3^{2-}]$) is kept constant, and the volume increases by $30/20 = 1.5$ times from experiment 2 to 1, the relative rate remains unchanged, hence it is zero order with respect to HCl [1]

OR

$$\text{Rate} = k[S_2O_3^{2-}]^a[HCl]^b \propto \frac{k(V_{S_2O_3^{2-}})^a (V_{HCl})^b}{k(V_{S_2O_3^{2-}})^a (V_{HCl})^b}$$

$$\frac{(\text{Relative rate})_{\text{experiment 1}}}{(\text{Relative rate})_{\text{experiment 2}}} = \frac{k(V_{S_2O_3^{2-}})^a (V_{HCl})^b}{k(V_{S_2O_3^{2-}})^a (V_{HCl})^b}$$

$$\frac{1}{1} = \frac{k(20)^a (30)^b}{k(20)^a (20)^b}$$

Hence $b = 0$ hence it is zero order wrt HCl [1]

- (iv) In **experiment 3**, 20 cm³ of thiosulfate solution was added to 30 cm³ of hydrochloric acid first and 10cm³ of deionised water was added last before timing was started.

He realised that the time taken to produce the same amount of sulfur is shorter than **experiment 1**.

Give a reason when the time taken for **experiment 3** is shorter than **experiment 1**? [1]

Before (timing) deionised water is added, the reaction has already started hence the time recorded for the fixed amount of sulfur to be produced will be shorter.

OR

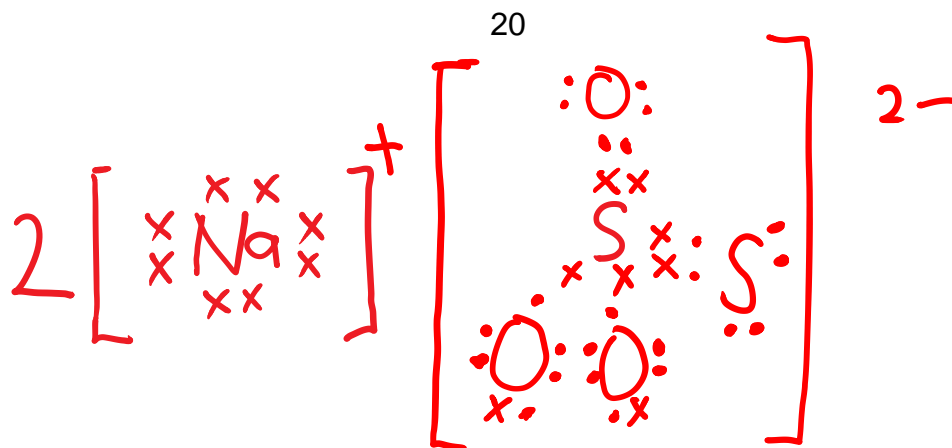
The total volume is 50 cm³ instead of 60cm³ hence the reaction started with higher concentration of $S_2O_3^{2-}$ resulting in shorter time required to produce fix amount of sulfur.

- (v) Draw the dot and cross diagram for the **ionic compound** $Na_2S_2O_3$ given that in the $S_2O_3^{2-}$ anion,

- it is tetrahedral around the central S atom
- there is no dative bond in the $S_2O_3^{2-}$ anion.
- the negative charge resides on the more electronegative atom.

[2]

[1] for "2" Na^+ with eight valence electrons [1] for correct $S_2O_3^{2-}$



- (d) The oxides of sulfur namely sulfur (IV) oxide, SO_2 and sulfur (VI) trioxide, SO_3 have different boiling points.

Oxides of sulfur	Boiling point ($^{\circ}\text{C}$)
SO_2	-10
SO_3	45

In terms of structure and bonding, account for the difference in the boiling points between the two compounds. [3]

Both have simple molecular structure. [1]

There are more electrons to be polarised in SO_3 than in SO_2 . [1]

Hence, the instantaneous dipole - induced dipole attraction between SO_3 molecules is stronger than the permanent dipole – dipole forces between SO_2 molecules, [1] accounting for the higher boiling point of SO_3 .

[total: 20]

- 3 Magnesium ions, chloride ions and other ions that are found inside a lake from the weathering of soils and rocks in the watershed, the atmosphere, and dissolved gases such as carbon dioxide is the source of “mineral water”. The table below shows the composition of ions found inside a typical lake that is a source of mineral water.

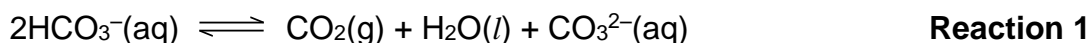
Ion	Concentration / mol dm ⁻³
Ca ²⁺	2.00 × 10 ⁻⁴ mol dm ⁻³
Mg ²⁺	2.00 × 10 ⁻⁴ mol dm ⁻³
Cl ⁻	2.00 × 10 ⁻⁴ mol dm ⁻³
HCO ₃ ⁻	6.00 × 10 ⁻⁴ mol dm ⁻³

- (a) From the data in the table shown above, suggest the relative amounts of the following four ionic compounds, CaCl₂ : MgCl₂ : Ca(HCO₃)₂ : Mg(HCO₃)₂, in the mineral water respectively. [1]

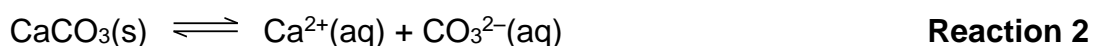
Mol ratio of CaCl₂ : MgCl₂ : Ca(HCO₃)₂ : Mg(HCO₃)₂ = 1 : 1 : 3 : 3 [1]

- (b) Various reactions take place in this ecosystem:

Reaction 1 involves the decomposition of aqueous hydrogen carbonate into the lake as shown:



Reaction 2 involves the dissolution of calcium carbonate from the rock into its aqueous ions that were released into the lake as shown



Reaction 3 involves the dissolution of calcium hydrogen carbonate from the rock into its aqueous ions that were released in the lake as shown.



By using the appropriate reactions above, answer **(b)(i)**, **(ii)** and **(iii)**.

- (i) When a sample of the mineral water was partially evaporated, a white solid was formed and the amount of gaseous carbon dioxide increased. Suggest whether the white solid is calcium hydrogen carbonate or calcium carbonate. [1]

Calcium carbonate [1]

- (ii) Hence explain how this process leads to the formation of the white solid. [3]

When mineral water was evaporated, $[\text{HCO}_3^-]$ and $[\text{CO}_3^{2-}]$ increased, [1pt] but $[\text{HCO}_3^-]$ increase to a greater extent [1pt] since there are more moles

Hence POE in reaction 1 shift to the right [1pt] and increased $[\text{CO}_3^{2-}]$ overall.[1pt]

The increase in $[\text{CO}_3^{2-}]$ caused POE in reaction 2 to shift to the left, [1pt] producing $\text{CaCO}_3(\text{s})$

4-5 pt – 3 marks 3 pt – 2 marks 2 pt – 1 mark

- (iii) When rainwater containing dissolved carbon dioxide gas had percolated through the rocks, the concentration of calcium ions in mineral water increased. Explain why. [2]

When rainwater percolates through the rock, the carbon dioxide reacts with some of the dissolved CO_3^{2-} from the partial dissolution of calcium carbonates to form HCO_3^- as present in the mineral water.

[1]

The decrease in concentration of CO_3^{2-} causes the equilibrium position of reaction 2 to shift to the right, [1] enabling more carbonate to dissolve to produce the calcium ions present in the mineral water.

- (c) A sample of rainwater collected from the lake contains carbonic acid, $\text{H}_2\text{CO}_3(\text{aq})$.

A conical flask containing 25.0 cm^3 of H_2CO_3 obtained from the lake is titrated against $\text{NaOH}(\text{aq})$ with three drops of phenolphthalein indicator. The end point is reached when 20.0 cm^3 of NaOH is added.

He proceeded with two more titrations as described in (c)(i) and (c)(ii)

- (i) In the second titration, the student rinsed a new conical flask with deionised water but forget to dry it with towel paper.

Predict how will the end point compared to that of the first titration? Explain your answer. [2]

It will be the same [1]. The amount of carbonic acid in the conical flask is the same hence it will require the same amount of sodium hydroxide.

- (ii) In the third titration, a student added twenty drops of phenolphthalein in the hope to see a more distinct end point colour change.

Predict how will the end point compared to that of the first titration?
Explain your answer. [2]

Since indicator is weak acid [1], hence higher volume of sodium hydroxide is required to reach end point [1]

- (d) Carbon dioxide exists in equilibrium with the water in our bloodstream and an equilibrium consisting of H_2CO_3 and HCO_3^- is set up.

This pair of compounds forms a natural buffer solution in our bodies.

- (i) Define what is meant by a buffer solution. [1]

A solution that resists changes in pH when a small amount of acids or alkalis is added or upon dilution. [1]

- (ii) When we exercise, lactic acid is produced in our muscles.

Write one equation to represent how the buffer system works in our body when we exercise. [1]



- (e) Halogenoalkanes are an important part in the history of humans. They are present in many forms such as antibiotics, refrigerants and polymers.

When one mole of 1-bromo-4-chlorobutane is heated with one mole of aqueous sodium hydroxide, 4-chlorobutan-1-ol is produced but not 4-bromobutan-1-ol.

Explain your answer. [2]

The C-Br bond is weaker than the C-C/ bond [1] as it is longer due to the larger atomic radius of I. Less energy is required to break the bond to form 4-chlorobutan-1-ol [1]

- (f) Substitution of alkanes with halogens can be performed to obtain halogenoalkanes in the laboratory.

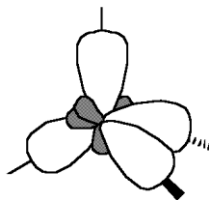
- (i) Alkanes are used in increasing quantities as refrigerant instead of chlorofluorocarbons as they do not contribute to ozone depletion.

Suggest one potential hazard of using alkanes instead of chlorofluorocarbons. [1]

Alkanes are flammable.

- (ii) Alkanes have carbon atoms which undergo sp^3 hybridisation. Draw a sp^3 hybridised carbon atom. [1]

sp^3 Hybrid Orbitals



[1]

- (iii) In terms of electron donating ability, a sp^3 hybridised carbon atom is more electron donating than a sp^2 hybridised carbon atom which is more electron donating than a sp hybridised carbon atom.

By using the above information, explain why $CH_2=CHCO_2H$ is a stronger acid than $CH_3CH_2CO_2H$ [3]

The carbon atoms in the $CH_2=CHCO_2H$ are sp^2 hybridised.
While the type of hybridisation in C atom of CH_3CH_2COOH is sp^3
 [1 mark for both correctly identified hybridisation]

Since sp^2 is less electron donating than sp^3 C [1],

hence the negative charge on oxygen of anion of $CH_2=CHCO_2^-$ is less intensified (or $CH_3CH_2CO_2^-$ is more destabilised and less stable than anion of $CH_2=CHCO_2^-$) and more stable [1] than $CH_3CH_2CO_2^-$

resulting in higher percentage of H^+ formed for $CH_2=CHCO_2H$

[total:20]

End of paper