ANDERSON JUNIOR COLLEGE

2017 JC 2 H1 PRELIMINARY EXAMINATIONS

NAME:_____ **PDG:**____ /16

CHEMISTRY **8872/02**

Paper 2 **13 September 2017**

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Data Booklet
Writing paper

READ THESE INSTRUCTIONS FIRST

Write your name, PDG and register number on all the work you hand in.
Write in dark blue or black pen.
You may use a 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.

Section B
Answer **two** questions on separate writing paper.
Start each question on a fresh sheet of paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use							
Paper 1 (33%)	Paper 2 (67%)						
	Section A				Section B		Total
	Q1	Q2	Q3	Q4			
/30							/ 80
			Final marks		/100		
			Grade				

This document consists of **19** printed pages.

Section A

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

1 (a) *Use of the Data Booklet will be relevant to this question.*

Iron ore from different mines will contain different percentages by mass of iron. The percentage of iron in a sample of ore can be estimated by converting all of the iron present into $Fe^{2+}(aq)$ ions and then using a redox titration.

The sample of ore is crushed, weighed and then dissolved in aqueous acid. The $Fe^{3+}(aq)$ ions are then reduced to $Fe^{2+}(aq)$ ions by reaction with an excess of aqueous tin(II) chloride, $SnCl_2$.

(i) Construct an ionic equation for the reduction of $Fe^{3+}(aq)$ ions by $Sn^{2+}(aq)$ ions.

……...[1]

A sample of iron ore weighing 11.05 g was converted to $Fe^{2+}(aq)$ ions using the method described above. The resultant solution was then made up to a volume of 250 cm^3 in a volumetric flask.

25.0 cm^3 portions of this solution were then titrated with 0.100 mol dm^{-3} of aqueous potassium dichromate(VI) using a suitable indicator. The results are shown below.

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	19.95	39.95	22.15
titre / cm^3	19.95		

(ii) Complete the table above and use the results to determine the number of moles of potassium dichromate(VI) required to react with the Fe^{2+} ions in 25.0 cm^3 of the solution.

[2]

(iii) Write an ionic equation for the reaction of Fe^{2+} ions with acidified $Cr_2O_7^{2-}$ ions.

……...[1]

(iv) Calculate the total number of moles of Fe^{2+} in the original solution made up from the iron ore, and hence calculate the percentage by mass of iron in the sample of iron ore.

[2]

[Total: 6]

2 The Pollutant Standards Index (PSI) is an air quality indicator. It is based on five pollutants: particulate matter (PM10), sulfur dioxide, carbon monoxide, ozone and nitrogen dioxide.

To calculate the overall PSI, the PSI value is first determined, using the following table, for **each** of the five pollutants.

i	PSI value, P_i	Concentration, C_i				
		PM10 ($\mu g\ m^{-3}$)	SO_2 ($\mu g\ m^{-3}$)	CO ($mg\ m^{-3}$)	Ozone ($\mu g\ m^{-3}$)	NO_2 ($\mu g\ m^{-3}$)
1	50	50	80	5.0	118	–
2	100	150	365	10.0	157	–
3	200	350	800	17.0	235	1130
4	300	420	1600	34.0	785	2260
5	400	500	2100	46.0	980	3000
6	500	600	2620	57.5	1180	3750

[1 $\mu g = 10^{-6}$ g; 1 mg = 10^{-3} g]

Given the concentration of a pollutant (with units as stated in the table above), where C_{i+1} > concentration of pollutant > C_i ,

$$\text{PSI of pollutant} = \left[\left(\frac{P_{i+1} - P_i}{C_{i+1} - C_i}\right)(\text{concentration of pollutant} - C_i)\right] + P_i$$

The overall PSI is then based on the maximum value out of the five calculated PSI pollutant values.

In Singapore, the 24–hr PSI is used by the National Environment Agency (NEA) to provide health advisory.

24−hr PSI	Healthy Persons	Elderly, Pregnant women, Children	Persons with chronic lung disease, heart disease, stroke
< 100	Normal activities		
101–200	Minimise prolonged or strenuous outdoor physical exertion.	Minimise prolonged outdoor activity.	Avoid all outdoor activities. If outdoor activity is unavoidable, wear N95 mask.
201–300	Avoid prolonged or strenuous outdoor physical exertion. If outdoor activity is unavoidable, wear N95 mask.	Avoid all outdoor activities. If outdoor activity is unavoidable, wear N95 mask (for adults).	
>300	Minimise all outdoor exposure. If outdoor activity is unavoidable, wear N95 mask.		

(a) **(i)** In a 1 m^3 sample of air, the mass of PM10 and carbon monoxide were found to be 320 μg and 20 mg respectively. Calculate the PSI values for each of the above pollutants, leaving your answers to **3 significant figures**.

[2]

(ii) Given that the PSI value of sulfur dioxide, ozone and nitrogen dioxide are 150, 112 and 133 respectively for the same sample of gas, use these values and your answers to **(a)(i)** to determine the overall PSI.

[1]

(iii) Assuming that the current overall PSI level is your answer in **(a)(ii)**, what advice would you give to a Physical Education (PE) teacher in Anderson Junior College who will be conducting a PE lesson soon?

……

……...[1]

(b) The amount of sulfur dioxide in a sample of air can be determined by first reacting it with sodium iodate, $NaIO_3$. Iodine is one of the products in this reaction.

(i) Write an ionic equation for the reaction between sulfur dioxide and sodium iodate.

……...[1]

(ii) When a 1 m^3 sample of air was bubbled through a solution of sodium iodate, the resulting solution was neutralised by 10.0 cm^3 of 0.005 mol dm^{-3} sodium hydroxide solution.

Calculate the concentration of sulfur dioxide, in $\mu g\ m^{-3}$, in the sample of air.

[2]

(c) Some countries have set limits for particulates in the air. For example, the European Union has a daily average (24–hour) limit of 180 μg m^{-3} for PM10. Cities that violate this daily limit face a hefty financial penalty that is calculated with consideration of many factors such as the severity the violation has on the ecosystem, duration of the non–compliance and country's GDP etc.

(i) A collected sample of air from the German city of Leipzig contains 2×10^{-5} % by mass of PM10. Given that the density of air is 1 kg m^{-3}, calculate the concentration of PM10 in the sample collected.

[1]

(ii) Hence, deduce whether the German city of Leipzig will be faced with any financial penalty.

……

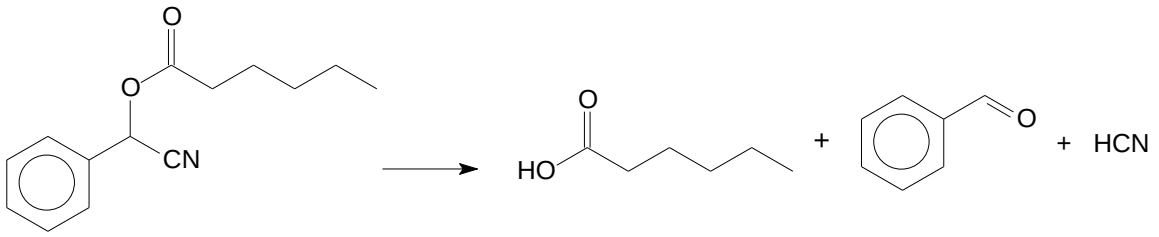
……[1]

[Total: 9]

3 The *Oribatula tibialis* mite uses hydrogen cyanide, HCN, a highly volatile and toxic substance, to poison its predators.

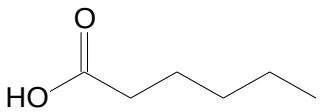
The HCN is stored in the form of mandelonitrile hexanoate, $C_{14}H_{17}NO_2$, in the mite's oil glands, to avoid poisoning itself. When attacked by predators, the mite secretes mandelonitrile hexanoate, which then release HCN, when in contact with the moisture, for example, from the predators' saliva.

(a) One of the possible reaction pathways of how mandelonitrile hexanoate secreted by *Oribatula tibialis* mite can release HCN is shown below.



mandelonitrile hexanoate $C_6H_{12}O_2$ C_7H_6O

(i) Name the functional group present, in addition to the hydrocarbon groups, in each of these compounds.



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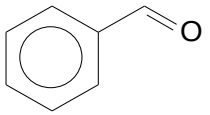


…..……

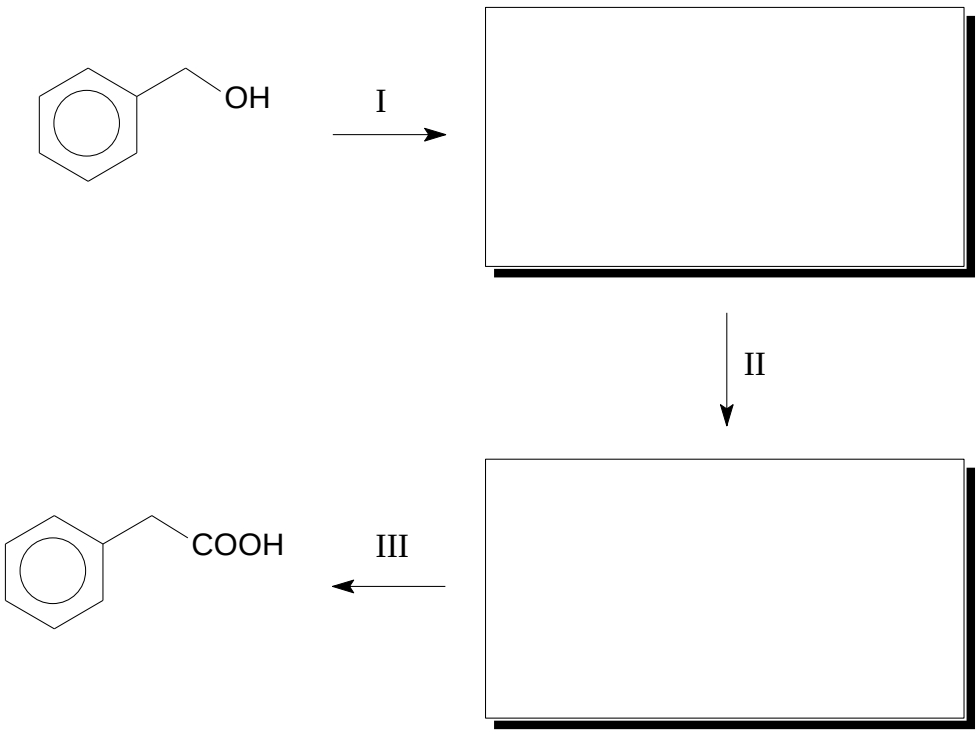
[1]

(ii) Describe a chemical test that would allow you to distinguish between the two organic products of the reaction. State what you would observe for each compound.

……

……[2]

(b) A sequence of reactions, starting from benzyl alcohol, is shown below.



(i) In the appropriate boxes, draw the structure of the two intermediates. [2]

(ii) State the reagents and conditions required for

stage I ……...

stage II ……...

stage III ……...

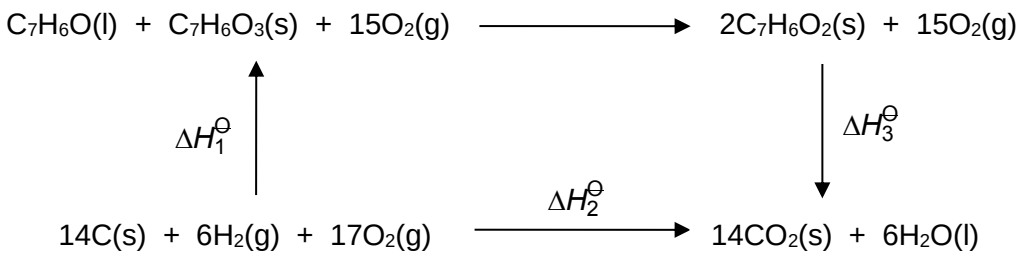
[3]

(c) Benzoic acid, $C_7H_6O_2$, can be produced by the following reaction.

Reaction 1: $C_7H_6O(l) + C_7H_6O_3(s) \longrightarrow 2C_7H_6O_2(s)$

(i) Write an equation which represent the enthalpy change of combustion of benzoic acid.

……[1]



(ii) Use the above energy cycle and the following data to calculate the value for $\Delta H_1^{\ominus}$, $\Delta H_2^{\ominus}$ and $\Delta H_3^{\ominus}$.

$\Delta H_c^{\ominus}$ carbon	=	–393.5 kJ mol^{-1}
$\Delta H_c^{\ominus}$ hydrogen	=	–285.8 kJ mol^{-1}
$\Delta H_f^{\ominus}$ $C_7H_6O(l)$	=	–87.0 kJ mol^{-1}
$\Delta H_f^{\ominus}$ $C_7H_6O_3(s)$	=	–367.0 kJ mol^{-1}
$\Delta H_c^{\ominus}$ $C_7H_6O_2(s)$	=	–3228 kJ mol^{-1}

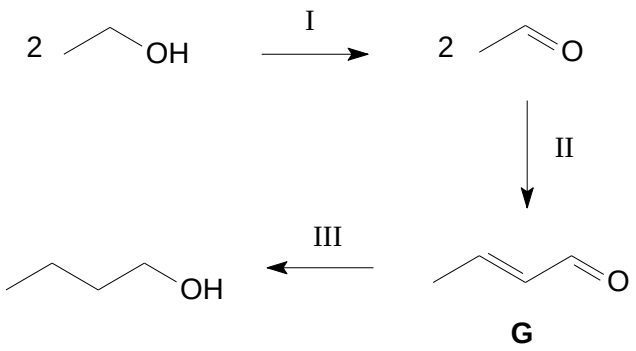
[3]

(iii) Hence, calculate the standard enthalpy change of reaction for reaction 1.

[1]

[Total: 13]

4 Scientists in the United States of America have come up with a simple 3–stage process to convert ethanol into butan–1–ol, in what could be an important step forward for renewable energy.



G

(a) **(i)** State the reagents and conditions required for stages I and III.

stage I ……

stage III ……
[2]

(ii) By considering the change in molecular formula shown in stage II, suggest the type of reaction occurred.

……[1]

(iii) Describe the type(s) of stereoisomerism shown by compound **G**.
Draw the displayed formula of the stereoisomers of **G**.

Type of isomerism ……..

[2]

(iv) **G** reacts with a suitable reducing agent to give a compound **H**.

H effervesces with sodium metal and also decolourises aqueous bromine.

Suggest the structure of **H** and explain these observations.

……

……

……[2]

(b) Butan–1–ol has a number of structural isomers.

(i) Explain what is meant by *structural isomers.*

……

……[1]

(ii) Draw the structural formula of the other three alcohols with the same molecular formula as butan–1–ol. Label your structures **J**, **K** and **L**. Classify these alcohols as primary, secondary or tertiary.

[2]

(iii) Identify which alcohol reacts with alkaline aqueous iodine and write a balanced equation for the reaction, showing the structural formula of the products.

……[2]

[Total: 12]

Section B

Answer **two** questions from this section on separate writing paper.

5 **(a)** The melting points of four chlorides are given below.

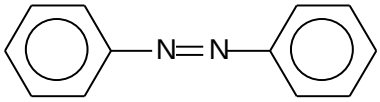
compound	*formula*	*m.p.* / °C
sodium chloride	NaC*l*	801
aluminium chloride	A*l*C*l*$_3$	178
carbon tetrachloride	CC*l*$_4$	–23
silicon tetrachloride	SiC*l*$_4$	–70

(i) Briefly relate these melting points to the structure of, and bonding in, each of these chlorides. [2]

(ii) Describe the reaction, if any, of each of these four chlorides with water, stating the approximate pH of any solution formed, and writing a balanced equation for any reaction that takes place. Offer an explanation for any differences that occur in their reactivities. [6]

(b) Scientists in Germany have developed a liquid crystal elastomers (LCE)–based adhesive that uses UV light to switch and control its level of stickiness within seconds.

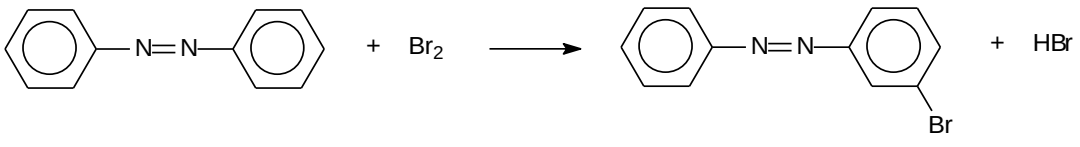
To control adhesion, the team used azobenzene, $C_{12}H_{10}N_2$ in the LCE as the light responsive molecule, which isomerises quickly from one state to another and changes size under UV light. This effect flexes the material enough to cause the microstructures to peel away from a surface and unstick, akin to how a gecko loses adhesion by moving its feet. When the light is removed, the material quickly recovers to its flat, sticky state.



azobenzene

(i) Outline the principles of Valence Shell Electron Pair Repulsion (VSEPR) theory and use it to suggest the bond angle around the nitrogen atom. [3]

(ii) Azobenzene can react with bromine under certain conditions as shown in the equation below.



Name the type of reaction and state the conditions necessary for the reaction to occur. [2]

(iii) Suggest the type of attraction that exists between the microstructures and the surface during adhesion. [1]

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

Compound **W** contains a primary amine functional group and has a molecular formula of $C_4H_7NO_3$. **W** gives an orange precipitate when treated with 2,4–dinitrophenylhydrazine but it has no reaction with Tollens' reagent. **W** gives a yellow precipitate when warmed with alkaline aqueous iodine.

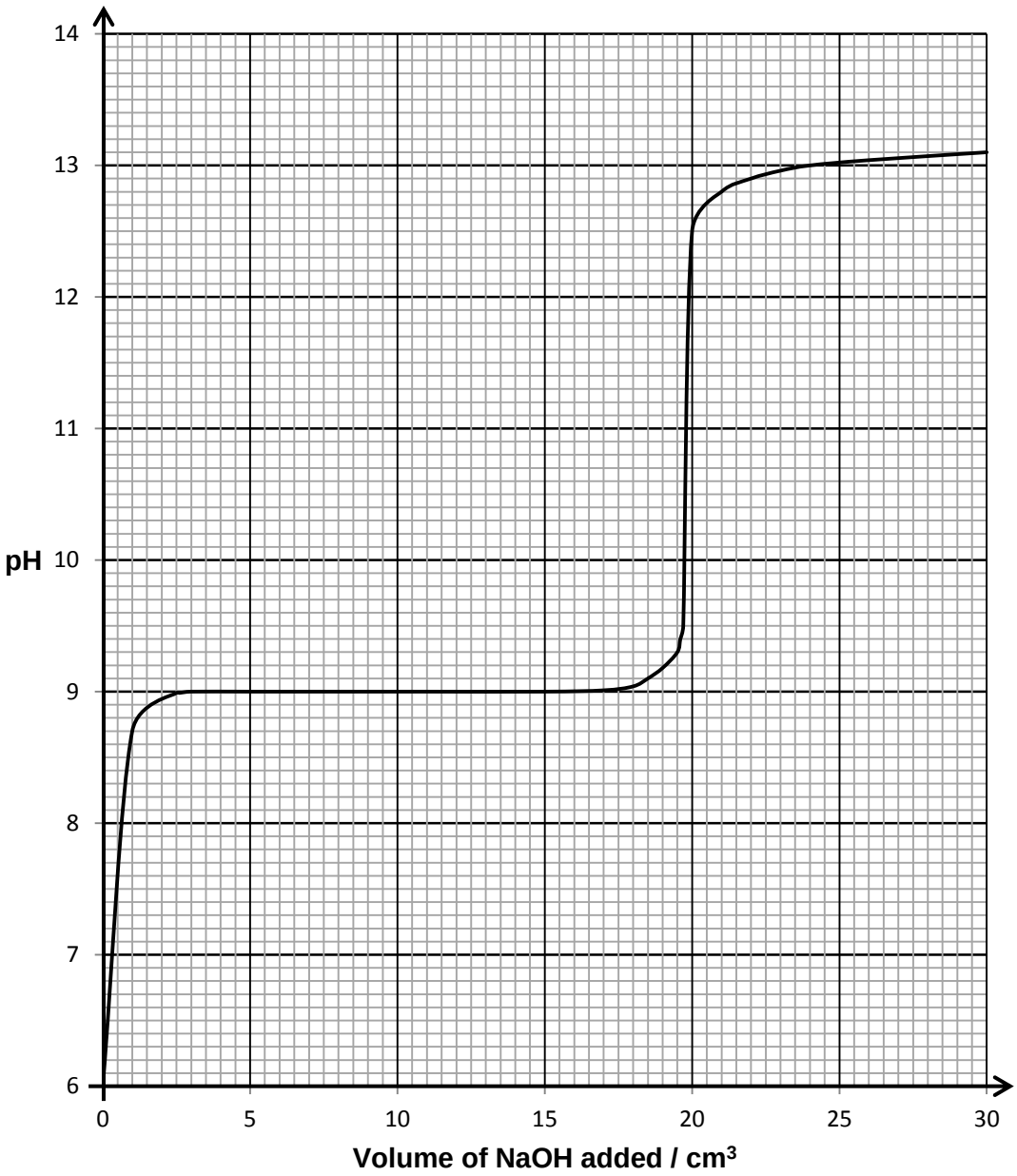
W has a proton chemical shift value (δ) of 13.0 ppm.

When **W** is heated with excess CH_3COCl, it gives an organic compound $C_7H_{14}NO_3Cl$, as the major product.

Suggest the structure for **W** and show how you deduced the structure, write equations for all of the reactions described above and suggest the types of reactions that are occurring. [6]

[Total: 20]

6 **(a)** In an experiment, 50.0 cm^3 of aqueous magnesium chloride were titrated with 1.00 mol dm^{-3} sodium hydroxide. The pH of the solution changed as in the diagram.



In this experiment, the hydrated magnesium ion, $Mg(H_2O)_6^{2+}$, acts as a weak acid.

(i) Write equation(s) to account for the initial pH of aqueous magnesium chloride. [1]

(ii) Hence, write an expression for the acid dissociation constant, K_a of $Mg(H_2O)_6^{2+}$ ion. [1]

(iii) Use the graph to determine the concentration of hydrogen ions, in mol dm^{-3}, present initially in the sample of aqueous magnesium chloride. [1]

(iv) The following table lists the information about two indicators.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
alizarin yellow	yellow	orange	10.1 – 13.0
phenolphthalein	colourless	pink	8.2 – 10.0

Both indicators are added to aqueous magnesium chloride before the start of the titration.

State the colour of the solution at the following points of the titration.

(I) Before NaOH(aq) has been added.

(II) After 10 cm^3 of NaOH(aq) has been added.

(III) After 20 cm^3 of NaOH(aq) has been added.

[1]

(b) When hydrogen is reacted with iodine, the equilibrium is established.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

The reaction below has an activation energy of +173.2 kJ mol^{-1}.

(i) Calculate the activation energy of the reverse reaction. [1]

(ii) Suggest the effect **each** of the following conditions has on the position of equilibrium and the rate of the reaction.

pressure 10 atm

temperature 2000 K

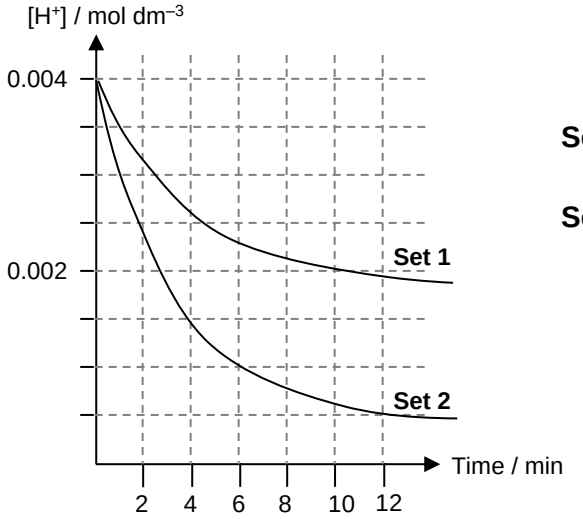
catalyst platinum

[6]

(c) The Harcourt and Esson reaction is that between hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$$

To determine the order of reaction of each reactant, two sets of reaction mixtures containing varying concentrations of I^- and H^+ were prepared. The concentration of hydrogen peroxide used for both experiments is 0.200 mol dm^{-3}. The results are as follows.



Set 1: $[I^-] = 0.175$ mol dm^{-3}

Set 2: $[I^-] = 0.350$ mol dm^{-3}

(i) Calculate the initial rate of reaction for **Set 1** and **2**. Show your working clearly. [1]

(ii) Use the information given above to determine the order of reaction with respect to I^- and H^+. Show your reasoning clearly. [2]

(iii) Using the information about **Set 1** and **2**, and your answers to **(c)(i)**, sketch a graph to show how the rate of reaction changes with concentration of iodine. Label your graph clearly. [2]

(iv) A student performed another experiment to determine the order of reaction with respect to H_2O_2, using the following concentrations.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 3	0.3	0.10	0.004	

He made a random guess that the order of reaction with respect to hydrogen peroxide is two. Deduce an estimated value of the initial rate of reaction for **Set 3** if his guess is correct. [2]

(v) The actual order of reaction with respect to H_2O_2 is one.

The rate of the reaction was measured as 4.4 x 10^{-5} mol dm^{-3}s^{-1} when $[H_2O_2] = 0.002$ mol dm^{-3}, $[H^+] = 0.2$ mol dm^{-3} and $[I^-] = 0.2$ mol dm^{-3}

Determine the rate constant for this reaction and state its units.

[2]

[Total: 20]

7 The oxygen family, also called the chalcogens, consists of the elements found in Group 16 of the Periodic Table and is considered among the main group elements. It consists of the elements oxygen, sulfur, selenium, tellurium and polonium.

(a) **(i)** State and explain the trend in the first ionisation energy of the Group 16 elements down the group. [2]

(ii) How would you expect the first ionisation energy of $_{34}Se$ to compare with that of $_{35}Br$? Give your reasoning. [2]

(b) **(i)** Describe the structure of a ^{128}Te atom, in terms of number and type of sub–atomic particles and give the electronic configuration for a tellurium(II) ion, Te^{2+}. [3]

(ii) State the formula of the oxide of tellurium in its highest oxidation state. [1]

(iii) State one physical property that you would expect this oxide of tellurium to possess. Explain, in terms of the structure and bonding present, why it possesses this property. [2]

(iv) Write an equation to illustrate the behavior of this oxide of tellurium in water. [1]

(c) When SO_3 is distilled into ICl_3 at 10 ^oC, a single ionic product is formed.

$$ICl_3 + SO_3 \longrightarrow (ICl_2^+)(SO_3Cl^-)$$

(i) Draw dot–and–cross diagrams to illustrate the bonding in **each** of the ions and predict their shapes. [4]

(ii) SO_3 dissolves in water to form sulfuric acid while the other oxide of sulfur, SO_2, gives H_2SO_3. The structures of the two acids are as shown below.

Explain why H_2SO_4 is a stronger acid than H_2SO_3. [2]

(d) $CH_3CH(OH)CH_2COCH_2CO_2H$ forms a cyclic 6–membered ring when heated with concentrated sulfuric acid.

(i) Suggest the role of concentrated sulfuric acid in this reaction. [1]

(ii) Write a balanced equation for the reaction and draw the organic compound formed. [2]

[Total: 20]