



# RIVER VALLEY HIGH SCHOOL

## YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE  
NAME

MARK SCHEME

CLASS

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CENTRE  
NUMBER

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INDEX  
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### H1 CHEMISTRY

**8872/02**

Paper 2 Structured and Free Response Questions

**13 Sep 2017**

**2 hours**

Additional Materials:

Ruled paper, Graph Paper, Section B Cover Page, Data Booklet

**READ THESE INSTRUCTIONS FIRST.**

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

Write your name, class and index number in the spaces at the top of this page. Write in dark blue or black pen. You may use a soft pencil for any diagrams, graphs or rough working. Do not use staples, paper clips, highlighters, glue or correction fluid.

#### Section A

Answer **all** questions on the Question Paper.

#### Section B

Answer **all** questions on separate ruled paper. Begin each question on a fresh sheet of ruled paper. At the end of the examination, fasten all ruled paper securely, with the cover page for Section B on top.

Hand in the Question Paper and answers to Section B **separately**.

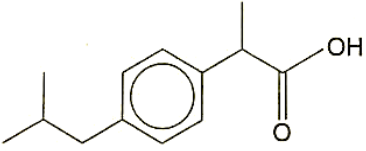
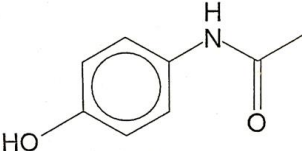
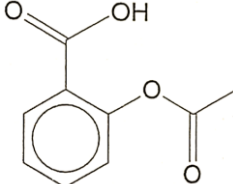
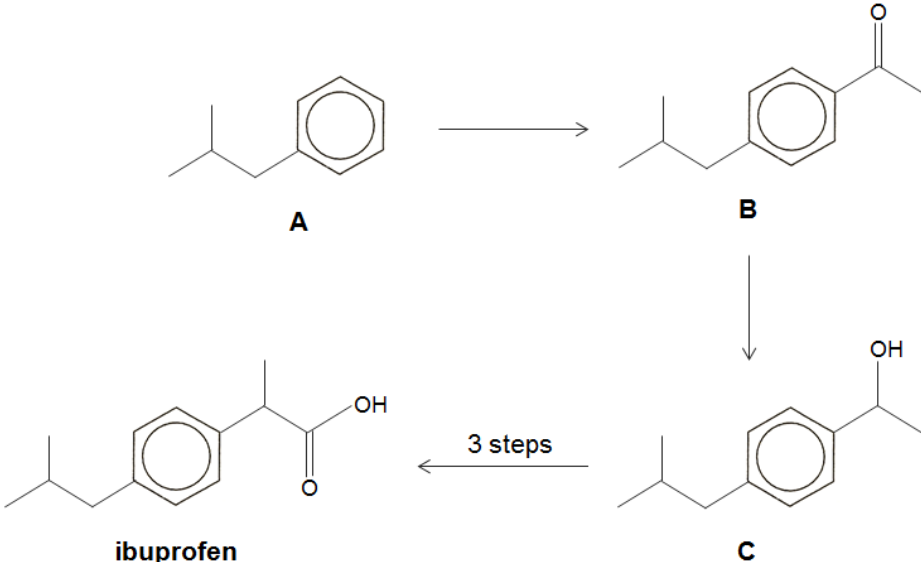
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use							
Paper 2							
	1	2	3	4		5/6/7	Total (Paper 2)
Section A	15	11	7	7	Section B	40	80
Paper 1	30				Total	110	Grade

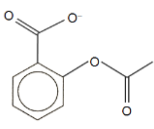
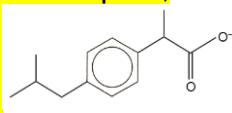
This paper consists of **17** printed pages.

**Section A (40 marks)**

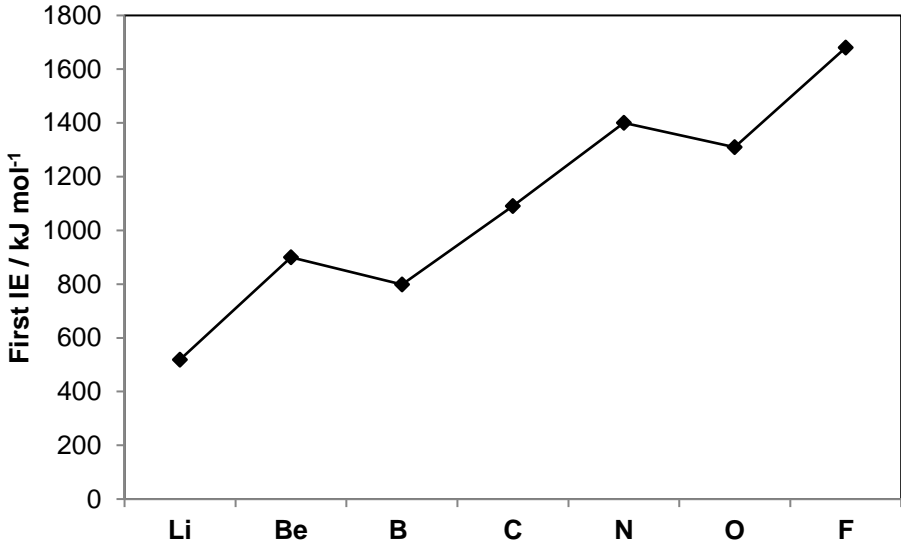
Answer **all** the questions in this section in the spaces provided.

1	<p>Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.</p> <div style="display: flex; justify-content: space-around; align-items: flex-end; text-align: center;"> <div data-bbox="300 421 667 739">  <p><b>ibuprofen</b> (<math>M_r = 206</math>)</p> </div> <div data-bbox="710 421 1013 739">  <p><b>paracetamol</b> (<math>M_r = 151</math>)</p> </div> <div data-bbox="1098 421 1332 739">  <p><b>aspirin</b> (<math>M_r = 180</math>)</p> </div> </div> <p>Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers.</p> <p>Ibuprofen can be synthesised via the following process:</p> <div style="text-align: center; margin-top: 20px;">  <p style="margin-top: 10px;"><b>A</b> → <b>B</b> → <b>C</b> → <b>ibuprofen</b> (3 steps)</p> </div>	
(a)	<p>A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption is safe for the man.</p>	
	<p>Since <math>4 \times 200 = 800 \text{ mg}</math> is lower than the maximum dosage of 1200 mg, the level of consumption is safe for the man.</p>	<b>[1]</b>
(b)	<p>State the type of reaction that converts Compound <b>A</b> to <b>B</b>.</p>	

		(Electrophilic) substitution	[1]	
(c)	<p>In the laboratory, Compound <b>C</b> can be converted to ibuprofen using a 3-step synthesis route.</p> <p>Suggest reagents and conditions for each step, and draw the structures of all intermediates.</p>			
		[5]		
(d)	<p>Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an “infant formula” emulsion.</p> <p>Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture.</p>	<p style="text-align: center;"><b>polysorbate 80</b></p> <p>Explain why this molecule is able to act as an emulsifier.</p>		
	<p>The <u>-OH polar groups</u> allow the molecule to be soluble in water, while the <u>non-polar hydrocarbon groups</u> allow the molecule to be soluble in oil / non-polar liquids.</p> <p><b>Accept hydrogen bonding and id-id interactions, in addition to identification of groups.</b></p>		[1]	
(e)	<p>A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.</p>			

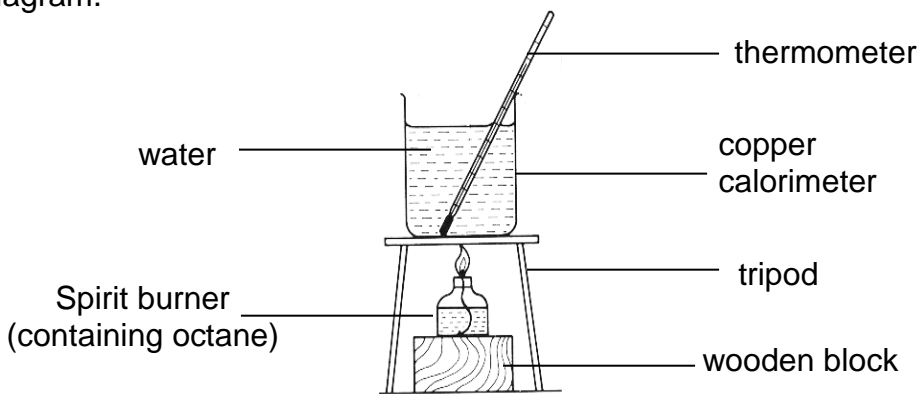
		<p>To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm<sup>3</sup> of 0.450 mol dm<sup>-3</sup> aqueous KOH. 25.0 cm<sup>3</sup> of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm<sup>3</sup> of 0.180 mol dm<sup>-3</sup> of sulfuric acid for complete neutralisation.</p> <p>Showing relevant calculations, deduce if the claim is valid.</p>	
		<p>Amount of H<sub>2</sub>SO<sub>4</sub> = <math>\frac{25.50}{1000} \times 0.180</math>  = 0.00459 mol</p> <p>Amount of unreacted KOH = 0.00459 x 2  = 0.00918 mol</p> <p>Amount of unreacted KOH (in 250 cm<sup>3</sup>) = 0.0918 mol</p> <p>Amount of KOH reacted with ibuprofen sample = <math>\frac{250}{1000} \times 0.450 - 0.0918</math>  = 0.0207 mol</p> <p>Since ibuprofen <math>\equiv</math> KOH,  Amount of ibuprofen = 0.0207 mol</p> <p>Mass of ibuprofen = 0.0207 x [13(12.0) + 18(1.0) + 2(16.0)]  = 4.26 g</p> <p>Percentage purity = <math>\frac{4.26}{5.00} \times 100\%</math>  = 85.2%</p> <p>Hence, the claim is invalid.</p>	[3]
	(f)	Compare the acidity of ibuprofen and aspirin. Explain your answer.	
		<p>Aspirin is a stronger acid than ibuprofen.</p> <div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p>The anion of aspirin,</p>  </div> <div style="flex: 2;"> <p>, is <u>more stable</u> than the anion of</p> </div> </div> <div style="display: flex; align-items: center;"> <div style="flex: 1;">  </div> <div style="flex: 2;"> <p>ibuprofen, as the <u>negative charge is delocalised over the COO<sup>-</sup> group and into the benzene ring.</u></p> </div> </div>	[2]

	(g)	Describe a simple chemical test to distinguish between ibuprofen and aspirin.	
		<p>Test: Heat with acidified <math>\text{KMnO}_4(\text{aq})</math></p> <p>Observations: Purple <math>\text{KMnO}_4</math> turns colourless for ibuprofen. <math>\text{KMnO}_4</math> remains purple for paracetamol and aspirin.</p>	[2]
			[Total: 15]

2	(a)	The first ionisation energies of the elements lithium to fluorine are shown below.		
				
	(i)	Using an equation, define the first ionisation energy of boron.		
		$\text{B(g)} \rightarrow \text{B}^{\text{+}}\text{(g)} + \text{e}^{-}$	[1]	
	(ii)	Describe and explain the general trend in first ionisation energies for the elements lithium to fluorine.		
		There is a <u>general increase</u> in the first ionisation energies for elements lithium to fluorine. Across a period, <u>nuclear charge increases</u> while <u>shielding effect remains approximately constant</u> . Effective nuclear charge increases and <u>valence electrons are increasingly attracted to the nucleus</u> . Thus, more energy is required to remove the valence electrons.	[2]	
	(iii)	Stating the electronic configurations of oxygen and nitrogen, suggest why the first ionisation energy of oxygen is lower than that of nitrogen.		
		O: $1\text{s}^2 2\text{s}^2 2\text{p}^4$ N: $1\text{s}^2 2\text{s}^2 2\text{p}^3$	[2]	

		Due to coulombic repulsion between the paired 2p electrons in oxygen, less energy is required to remove the 2p electron.	
	(b)	<p>Across Period 3, the nature of elements changes from metallic to non-metallic. The difference in electronegativity between the elements and the oxide decreases correspondingly, giving rise to different types of oxides.</p> <p>Choose and describe three oxides which are different in terms of structure and bonding. For each type of oxide, write equations for the reactions with water when applicable, and give the approximate pH of resultant solutions.</p>	
		<p><math>\text{Na}_2\text{O}/\text{MgO}/\text{Al}_2\text{O}_3</math> has giant ionic lattice structure with strong electrostatic forces of attraction between its oppositely-charged ions.</p> <p><math>\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{aq}) \quad \text{pH} = 12</math></p> <p><math>\text{MgO}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{Mg}(\text{OH})_2(\text{aq}) \quad \text{pH} = 8</math></p> <p><math>\text{Al}_2\text{O}_3</math> is insoluble in water and hence gives a resultant solution of pH 7.</p> <p><math>\text{SiO}_2</math> has giant covalent structure with strong covalent bonds between the Si and O atoms.</p> <p><math>\text{SiO}_2</math> is insoluble in water and hence gives a resultant solution of pH 7.</p> <p><math>\text{P}_4\text{O}_6/\text{P}_4\text{O}_{10}/\text{SO}_2/\text{SO}_3</math> has simple covalent structure with weak van der Waals forces between molecules.</p> <p><math>\text{P}_4\text{O}_6(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_3(\text{aq}) \quad \text{pH} = 2</math></p> <p><math>\text{P}_4\text{O}_{10}(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_4(\text{aq}) \quad \text{pH} = 2</math></p> <p><math>\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_3(\text{aq}) \quad \text{pH} = 2</math></p> <p><math>\text{SO}_3(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{aq}) \quad \text{pH} = 2</math></p>	[6]
	[Total: 11]		

3	(a)	Some important uses of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.	
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		<p>(i) James carried out an experiment to determine the enthalpy change of combustion of octane, <math>C_8H_{18}</math>, using the apparatus shown in the diagram.</p>  <p>These are the results that James obtained:</p> <p>Volume of water = <math>1000\text{ cm}^3</math></p> <p>Initial temperature of water = <math>29.6\text{ }^\circ\text{C}</math></p> <p>Highest temperature of water = <math>50.0\text{ }^\circ\text{C}</math></p> <p>Initial mass of burner and octane = <math>59.35\text{ g}</math></p> <p>Final mass of burner and octane = <math>53.77\text{ g}</math></p> <p>Specific heat capacity of water = <math>4.18\text{ J g}^{-1}\text{ K}^{-1}</math></p> <p>Heat capacity of calorimeter = <math>385\text{ J K}^{-1}</math></p> <p>Use these results to determine the experimental enthalpy change of combustion of octane.</p>	
		<p>Heat evolved = <math>1000 \times 4.18 \times 20.4 + 385 \times 20.4</math></p> <p style="text-align: center;"><math>= 93100\text{ J}</math></p> <p>Amount of octane reacted = <math>\frac{59.35 - 53.77}{8 \times 12.0 + 18 \times 1.0}</math></p> <p style="text-align: center;"><math>= 4.89 \times 10^{-2}\text{ mol}</math></p> <p>Enthalpy change of combustion of octane = <math>-\frac{93100}{4.89 \times 10^{-2}}</math></p> <p style="text-align: center;"><math>= -1900\text{ kJ mol}^{-1}</math></p>	<b>[3]</b>
		<p>(ii) Define the standard enthalpy change of combustion.</p>	
		<p>Standard enthalpy change of combustion is the <u>energy evolved when one mole of the substance is burnt in excess oxygen under standard conditions.</u></p>	<b>[1]</b>



	(b)	<p>Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.</p> $  \begin{array}{ccc}  \text{N}_2\text{H}_4(\text{l}) + \text{O}_2(\text{g}) & \longrightarrow & \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \\  \downarrow & & \downarrow \\  \text{N}_2\text{H}_4(\text{g}) + \text{O}_2(\text{g}) & \longrightarrow & 2\text{N}(\text{g}) + 4\text{H}(\text{g}) + 2\text{O}(\text{g})  \end{array}  $	
	(i)	Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ mol <sup>-1</sup> , use appropriate bond energies from the <i>Data Booklet</i> to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.	
		$  \begin{aligned}  \Delta H_{\text{r}} &= \Delta H_{\text{vap}}(\text{N}_2\text{H}_4) + [\text{BE}(\text{N}-\text{N}) + 4\text{BE}(\text{N}-\text{H}) + \text{BE}(\text{O}=\text{O})] \\  &\quad - [\text{BE}(\text{N}\equiv\text{N}) + 4\text{BE}(\text{O}-\text{H})] \\  &= +58 + [(+160) + 4(+390) + (+496)] - [(+944) + 4(+460)] \\  &= -510 \text{ kJ mol}^{-1}  \end{aligned}  $	[2]
	(ii)	Suggest a reason to account for the discrepancy between the theoretical enthalpy change of reaction between liquid hydrazine and oxygen and your answer in (b)(i).	
		The bond energy values obtained from the <i>Data Booklet</i> are <u>average values</u> and would not be representative of the specified reaction.	[1]
[Total: 7]			

4	Under suitable conditions, $\text{SCl}_2$ reacts with water to produce a yellow precipitate of sulfur and an acidic solution <b>G</b> . Solution <b>G</b> contains a mixture of $\text{SO}_2(\text{aq})$ and another compound.	
(a)	State the oxidation number of S in $\text{SCl}_2$ .	
	+2	[1]
(b)	Construct an equation for the reaction between $\text{SCl}_2$ and water.	

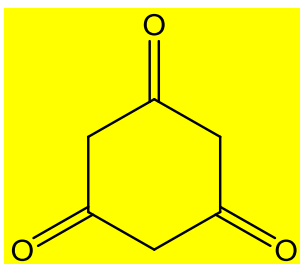
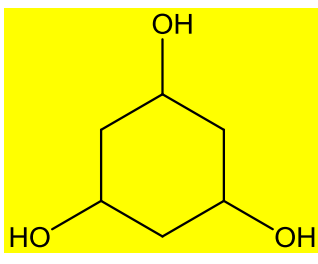
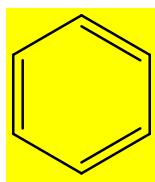
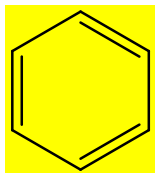
		$2\text{SCl}_2 + 2\text{H}_2\text{O} \rightarrow \text{S} + \text{SO}_2 + 4\text{HCl}$						[1]	
(c)	In the Contact Process, one important step is the conversion of $\text{SO}_2$ to $\text{SO}_3$ as shown below. $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ 2.00 L flask was filled with 0.0400 mol $\text{SO}_2$ and 0.0200 mol $\text{O}_2$ . At equilibrium, at 900 K, the flask contained 0.0296 mol of $\text{SO}_3$ . Determine the value of $K_c$ .								
			$2\text{SO}_2$	+	$\text{O}_2$	$\rightleftharpoons$	$2\text{SO}_3$		
		I / mol	0.0400		0.0200		0		
		C / mol	-0.0296		-0.0148		+0.0296		
		E / mol	0.0104		0.00520		0.0296		
		$K_c$ (where $V = 2$ ) $= \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$ $= \frac{[0.0296/V]^2}{[0.0104/V]^2 [0.0052/V]}$ $= 3116$ $= 3120 \text{ mol}^{-1} \text{ dm}^3$						[3]	
(d)	State and explain how the position of equilibrium and equilibrium constant, $K_c$ , will change when the volume of the flask is doubled.								
	<u>When the volume of flask is doubled, concentration of all gases will be halved. Since there are more concentration terms on the left hand side of the equation, equilibrium position will shift left.</u> <u>There will be no change to <math>K_c</math> as temperature remains unchanged.</u>								[2]
									[Total: 7]

**Section B (40 marks)**

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

5	(a)	Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with CO <sub>2</sub> , are given in Table 5.1.																						
		<b>Table 5.1</b>																						
		<table><tr><th>Compound</th><th>Structure</th><th>Dipole moment</th><th>Boiling point / °C</th></tr><tr><td>CO<sub>2</sub></td><td>O=C=O</td><td>0</td><td>sublimes</td></tr><tr><td>CS<sub>2</sub></td><td>S=C=S</td><td>0</td><td>46</td></tr><tr><td>COS</td><td>S=C=O</td><td>0.71</td><td>−50</td></tr><tr><td>COSe</td><td>Se=C=O</td><td>0.73</td><td>−22</td></tr></table>	Compound	Structure	Dipole moment	Boiling point / °C	CO <sub>2</sub>	O=C=O	0	sublimes	CS <sub>2</sub>	S=C=S	0	46	COS	S=C=O	0.71	−50	COSe	Se=C=O	0.73	−22		
Compound	Structure	Dipole moment	Boiling point / °C																					
CO <sub>2</sub>	O=C=O	0	sublimes																					
CS <sub>2</sub>	S=C=S	0	46																					
COS	S=C=O	0.71	−50																					
COSe	Se=C=O	0.73	−22																					
		(i)	Explain, in terms of structure and bonding, the difference in the boiling point of CS <sub>2</sub> and COS.	[2]																				
			Both CS <sub>2</sub> and COS have <u>simple covalent structures</u> . CS <sub>2</sub> has a <u>larger number of electrons</u> (or larger electron cloud) than COS. More energy is required to overcome the <u>stronger instantaneous dipole-induced dipole interactions between CS<sub>2</sub> molecules</u> than the weaker <u>permanent dipole-induced dipole interactions between COS molecules</u> . Hence, CS <sub>2</sub> has a higher boiling point.																					
		(ii)	Explain why <ul style="list-style-type: none"><li>• CO<sub>2</sub> has no overall dipole moment.</li><li>• COSe has a greater dipole moment than COS.</li></ul>	[2]																				
			CO <sub>2</sub> is <u>linear</u> and hence the <u>dipoles cancel out</u> .  <u>C=S bond is more polar than C=O</u> . There is smaller difference between the dipole moment of C=O and C=S than that between C=O and C=Se.																					
	(b)	Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, C <sub>3</sub> O, a reactive molecule found in space.																						
		(i)	Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present.	[1]																				



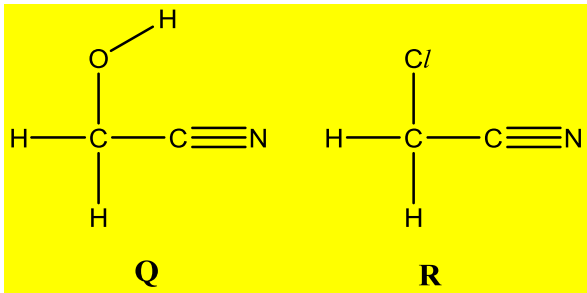
		<b>Structures:</b>										
				 or 								
		<b>X</b>	<b>Y</b>	<b>Z</b>								
	<b>(d)</b>	<b>(i)</b>	Define the term <i>Bronsted acid</i> .		<b>[1]</b>							
			A Bronsted acid is a <u>proton donor</u> .									
		<b>(ii)</b>	The concentration of a monobasic acid, HY is 0.01 mol dm <sup>-3</sup> , while the pH of the solution is 3.5.  Calculate the concentration of H <sup>+</sup> in this solution. State, with reasoning, if HY is a strong or weak acid.		<b>[2]</b>							
			pH = 3.5 [H <sup>+</sup> ] = 10 <sup>-3.5</sup> = 3.16 x 10 <sup>-4</sup> mol dm <sup>-3</sup>  Given that the concentration of HY is 0.01 mol dm <sup>-3</sup> which is much larger than the concentration of H <sup>+</sup> , it is a <u>weak acid as it ionises partially</u> .									
	<b>(e)</b>	Values for the ionic product of water, <i>K<sub>w</sub></i> , at two different temperatures are given in Table 5.2.  <b>Table 5.2</b> <table border="1" data-bbox="402 1395 1366 1610"><thead><tr><th>Temperature / °C</th><th><i>K<sub>w</sub></i> / mol<sup>2</sup> dm<sup>-6</sup></th></tr></thead><tbody><tr><td>25</td><td>1.00 × 10<sup>-14</sup></td></tr><tr><td>50</td><td>5.48 × 10<sup>-14</sup></td></tr></tbody></table> Using Le Chatelier's Principle, explain whether the ionisation of water is an endothermic or exothermic process.				Temperature / °C	<i>K<sub>w</sub></i> / mol <sup>2</sup> dm <sup>-6</sup>	25	1.00 × 10 <sup>-14</sup>	50	5.48 × 10 <sup>-14</sup>	<b>[2]</b>
Temperature / °C	<i>K<sub>w</sub></i> / mol <sup>2</sup> dm <sup>-6</sup>											
25	1.00 × 10 <sup>-14</sup>											
50	5.48 × 10 <sup>-14</sup>											
		When temperature increases, the value of <i>K<sub>w</sub></i> increases. This implies that <u>equilibrium position of H<sub>2</sub>O(l) ⇌ H<sup>+</sup>(aq) + OH<sup>-</sup>(aq) lies more to the right to remove some of the added heat</u> . Hence, the ionisation of water is an <u>endothermic process</u> .										

6	<p>In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon (<math>^{14}\text{C}</math>), a radioactive isotope of carbon. The principle of carbon dating is as such:</p> <p>During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of <math>^{14}\text{C}</math> as the atmosphere. Once it dies, it ceases to acquire <math>^{14}\text{C}</math>, but the <math>^{14}\text{C}</math> within its biological material at that time will continue to decay, and so the ratio of <math>^{14}\text{C}</math> to <math>^{12}\text{C}</math> in its remains will gradually decrease.</p> <p>Because <math>^{14}\text{C}</math> decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less <math>^{14}\text{C}</math> will be left.</p>	
	<p><b>(a)</b> A sample of carbon dioxide gas (that contained both <math>^{12}\text{CO}_2</math> and <math>^{14}\text{CO}_2</math>) was analysed to determine the proportion of <math>^{14}\text{CO}_2</math> found within. Analysis results showed that there is one <math>^{14}\text{CO}_2</math> molecule for every <math>10^{12}</math> <math>\text{CO}_2</math> molecules.</p>	
	<p><b>(i)</b> Calculate the number of <math>^{14}\text{CO}_2</math> molecules in a <math>10.0 \text{ dm}^3</math> carbon dioxide gas sample, measured under s.t.p.</p>	[2]
	<p>Number of moles of <math>\text{CO}_2 = \frac{10}{22.7}</math></p> <p><math>= 0.441 \text{ mol}</math></p> <p>Number of <math>^{14}\text{CO}_2</math> molecules <math>= 0.441 \times \frac{6.02 \times 10^{23}}{10^{12}}</math></p> <p><math>= 2.65 \times 10^{11} \text{ molecules}</math></p>	
	<p><b>(ii)</b> Calculate the mass of <math>^{14}\text{CO}_2</math> in the <math>10.0 \text{ dm}^3</math> sample.</p>	[1]
	<p>Mass of <math>^{14}\text{CO}_2 = \frac{2.65 \times 10^{11}}{6.02 \times 10^{23}} \times (14.0 + 16.0 \times 2)</math></p> <p><math>= 2.03 \times 10^{-11} \text{ g}</math></p>	
	<p><b>(iii)</b> Hence, explain why it would be difficult to determine the proportion of <math>^{14}\text{CO}_2</math> by means of mass measurement.</p>	[1]
	<p>The amount/mass of <math>^{14}\text{CO}_2</math> is too small to be accurately measured.</p>	
	<p><b>(b)</b> To more accurately determine the proportion of <math>^{14}\text{C}</math> in a sample of graphite, the graphite is vaporised and ionised to <math>\text{C}^+(\text{g})</math> ions. These ions were then passed through two electric plates.</p> <p>Given that <math>\text{H}^+</math> is deflected with an angle of <math>8.4^\circ</math>, what is the angle of deflection for <math>^{14}\text{C}^+</math> ions under the same experimental set-up?</p>	[1]

		<p>Angle of deflection of <math>^{14}\text{C}^+ = \left(\frac{1}{14}\right) (8.4)</math></p> <p><math>= 0.60^\circ</math></p>																					
	(c)	<p>The half-life of <math>^{14}\text{C}</math> is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original <math>^{14}\text{C}</math>.</p>	[2]																				
		<p>Let the number of half-life be <math>n</math>.</p> $\frac{30.0}{100} = \left(\frac{1}{2}\right)^n$ $n = \frac{\lg\left(\frac{30.0}{100}\right)}{\lg\left(\frac{1}{2}\right)}$ <p><math>n = 1.74</math></p> <p>Time taken = <math>5730 \times 1.74 = 9970</math> years</p>																					
	(d)	<p>Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst.</p> <p>A series of experiments were carried out at a specific temperature to study the kinetics of this reaction, and the results are shown in Table 6.1.</p> <p style="text-align: center;"><b>Table 6.1</b></p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Experiment</th><th>[nitrobenzene] / <math>\text{mol dm}^{-3}</math></th><th><math>[\text{H}_2]</math> / <math>\text{mol dm}^{-3}</math></th><th>Initial rate / <math>\text{mol dm}^{-3} \text{s}^{-1}</math></th></tr> </thead> <tbody> <tr> <td>1</td><td>0.010</td><td>0.010</td><td><math>4.50 \times 10^{-5}</math></td></tr> <tr> <td>2</td><td>0.015</td><td>0.010</td><td><math>6.74 \times 10^{-5}</math></td></tr> <tr> <td>3</td><td>0.020</td><td>0.020</td><td><math>1.80 \times 10^{-4}</math></td></tr> <tr> <td>4</td><td>0.030</td><td><math>x</math></td><td><math>4.05 \times 10^{-4}</math></td></tr> </tbody> </table>	Experiment	[nitrobenzene] / $\text{mol dm}^{-3}$	$[\text{H}_2]$ / $\text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$	1	0.010	0.010	$4.50 \times 10^{-5}$	2	0.015	0.010	$6.74 \times 10^{-5}$	3	0.020	0.020	$1.80 \times 10^{-4}$	4	0.030	$x$	$4.05 \times 10^{-4}$	
Experiment	[nitrobenzene] / $\text{mol dm}^{-3}$	$[\text{H}_2]$ / $\text{mol dm}^{-3}$	Initial rate / $\text{mol dm}^{-3} \text{s}^{-1}$																				
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4	0.030	$x$	$4.05 \times 10^{-4}$																				
	(i)	Define the term <i>catalyst</i> .	[1]																				
		A catalyst is a substance that <u>increases the rate of reaction</u> by providing an <u>alternative reaction pathway of lowered activation energy</u> , and is <u>regenerated at the end of the reaction</u> .																					
	(ii)	Determine the order of reaction with respect to nitrobenzene and hydrogen.	[2]																				

		<p>Comparing Experiment 1 and 2, when [nitrobenzene] is increased to 1.5 times, rate is increased to 1.5 times. Hence, the reaction is first order with respect to nitrobenzene.</p> <p>Let the rate equation be <math>\text{Rate} = k[\text{nitrobenzene}][\text{H}_2]^a</math></p> <p>Comparing Experiment 2 and 3:</p> $\frac{6.74 \times 10^{-5}}{1.80 \times 10^{-4}} = \frac{k(0.015)(0.01)^a}{k(0.02)(0.02)^a}$ $\left(\frac{6.74 \times 10^{-5}}{1.80 \times 10^{-4}}\right) \left(\frac{0.02}{0.015}\right) = \left(\frac{0.01}{0.02}\right)^a$ $a = 1$	
	(iii)	Calculate the rate constant, stating its units.	[2]
		<p>Using Experiment 1,</p> $4.50 \times 10^{-5} = k(0.01)(0.01)$ $k = 0.450 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$	
	(iv)	Hence, determine the value of $x$ .	[1]
		$4.05 \times 10^{-4} = (0.45)(0.03)^x$ $x = 0.0300 \text{ (mol dm}^{-3}\text{)}$	
(e)	<p>Ethylenediamine tetraacetate, <math>[\text{EDTA}]^{4-}</math>, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions.</p> <p>A possible reaction scheme used to synthesise <math>[\text{EDTA}]^{4-}</math> from methanal is given below.</p> <div style="text-align: center;"> <p style="text-align: center;"> <math>\text{HCHO} \xrightarrow{\text{I}} \text{Q} \xrightarrow{\text{II}} \text{R} \xrightarrow{\text{III}} \text{H-C(Cl)(H)-COOH (S)} \xrightarrow{\text{NaOH}} \text{H-C(Cl)(H)-COO- (T)} \xrightarrow[\text{heat}]{\text{limited 1,2-diaminoethane}} [\text{EDTA}]^{4-}</math> </p> </div>		

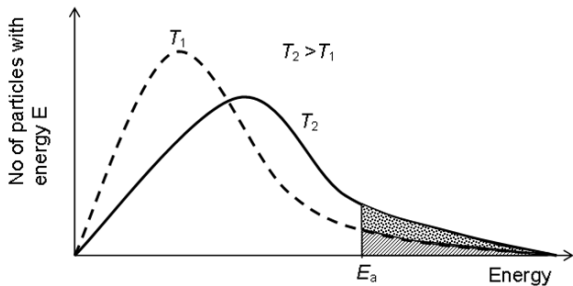


		(i)	Suggest the reagents and conditions in steps I, II and III.	[3]
			Step I: HCN with small amount of NaCN Step II: $\text{PCl}_5/\text{PCl}_3/\text{SOCl}_2$ Step III: $\text{H}_2\text{SO}_4(\text{aq})$ , heat under reflux	
		(ii)	Draw the displayed formulae of intermediates <b>Q</b> and <b>R</b> .	[2]
			 <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <math>\text{CH}_3\text{-CH(OH)-CN}</math>  <b>Q</b> </div> <div style="text-align: center;"> <math>\text{CH}_3\text{-CH(Cl)-CN}</math>  <b>R</b> </div> </div>	
		(iii)	State the type of reaction when <b>T</b> is converted to $[\text{EDTA}]^{4-}$ . Give a reason why a limited amount of 1,2-diaminoethane is used.	[2]
			(Nucleophilic) substitution To enable multiple substitution on the amine group.	
		<b>[Total: 20]</b>		

<b>7</b>	<b>(a)</b>	2-chlorobutane undergoes a substitution reaction with hot aqueous sodium hydroxide. Two separate experiments with different concentrations of 2-chlorobutane were carried out to investigate the kinetics of the reaction.  The obtained results are presented in Table 7.1.	
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Table 7.1

Table 7.1				
		Experiment 1 [2-chlorobutane] = 0.05 mol dm <sup>-3</sup>	Experiment 2 [2-chlorobutane] = 0.10 mol dm <sup>-3</sup>	
	Time / min	[NaOH] / mol dm <sup>-3</sup>	[NaOH] / mol dm <sup>-3</sup>	
	0	0.0050	0.0050	
	15	0.0045	0.0040	
	30	0.0040	0.0032	
	45	0.0036	0.0026	
	60	0.0032	0.0021	
	75	0.0029	0.0017	
	90	0.0026	0.0014	
		(i)	On the same axes, plot graphs of [2-chlorobutane] against time for both Experiments 1 and 2. Label each curve clearly.	[2]
			See graph	
		(ii)	Use your graphs to determine the order of reaction with respect to 2-chlorobutane and NaOH. Justify your answer in each case.	[4]
			Using graph of Experiment 2, $t_{1/2}$ is constant at 48 min. Hence, order of reaction with respect to NaOH is 1. For Experiment 1, initial rate = -gradient $= 3.64 \times 10^{-5} \text{ mol dm}^{-3} \text{ min}^{-1}$ For Experiment 2, initial rate = -gradient $= 6.67 \times 10^{-5} \text{ mol dm}^{-3} \text{ min}^{-1}$ When [2-chlorobutane] is doubled, rate is doubled. Hence, order of reaction with respect to 2-chlorobutane is 1.	
		(iii)	Hence, write a rate equation for the reaction.	[1]
			Rate = $k[2\text{-chlorobutane}][\text{NaOH}]$	
		(iv)	With the aid of a Maxwell-Boltzmann distribution curve, explain how an increase in temperature affects the rate of reaction in Experiment 2.	[3]

		 <p>When temperature increases, the <u>average kinetic energy of the reactant particles increases</u>. <u>More reactant particles possess energy greater than or equal to the activation energy</u>. As a result, the <u>frequency of effective collisions increases</u> and the <u>rate of reaction increases</u>.</p>	
	(b)	<p>Fumaric acid is a dibasic acid. When fumaric acid and its potassium salt are added to foods, they act as an acidity regulator and flavouring agent.</p> $  \begin{array}{c}  \text{HOOC} \quad \text{H} \\  \diagdown \quad \diagup \\  \text{C} = \text{C} \\  \diagup \quad \diagdown \\  \text{H} \quad \text{COOH}  \end{array}  $ <p style="text-align: center;"><b>fumaric acid</b></p>	
	(i)	Identify the type of isomerism fumaric acid exhibits, and explain how it arises.	[2]
		<u>Geometrical isomerism</u> , because the presence of $\pi$ bond in $\text{C}=\text{C}$ prevents free rotation about the double bond.	
	(ii)	<p>When <math>25 \text{ cm}^3</math> of fumaric acid was titrated against <math>0.15 \text{ mol dm}^{-3}</math> potassium hydroxide, the volume of potassium hydroxide required for complete neutralisation was <math>27 \text{ cm}^3</math>. The pH at this end point was approximately 8.2.</p> <p>Calculate the concentration of fumaric acid used in the titration.</p>	[2]
		<p>Amount of <math>\text{KOH} = \frac{27}{1000} \times 0.15</math></p> <p style="text-align: center;"><math>= 0.00405 \text{ mol}</math></p> <p>Amount of fumaric acid <math>= \frac{0.00405}{2}</math></p> <p style="text-align: center;"><math>= 0.00203 \text{ mol}</math></p> <p>Concentration of fumaric acid <math>= \frac{0.00203}{0.025}</math></p> <p style="text-align: center;"><math>= 0.0812 \text{ mol dm}^{-3}</math></p>	

		(iii)	Suggest an indicator that is suitable for the titration of fumaric acid with potassium hydroxide.	[2]
			Phenolphthalein, because its working pH range (8-10) lies within the sharp pH change near the equivalence point of the titration.	
	(c)		<p>The buffer system of lactic acid, <math>\text{CH}_3\text{CH}(\text{OH})\text{COOH}</math>, and sodium lactate, <math>\text{CH}_3\text{CH}(\text{OH})\text{COO}^-\text{Na}^+</math>, can also be used as acidity regulators in food.</p> <p>The following equilibrium is established in the buffer system:</p> $\text{CH}_3\text{CH}(\text{OH})\text{COOH}(\text{aq}) \rightleftharpoons \text{CH}_3\text{CH}(\text{OH})\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$ <p>The numerical value of the equilibrium constant, <math>K_a</math>, is <math>1.38 \times 10^{-4}</math>.</p>	
		(i)	Write the $K_a$ expression for the equilibrium shown above.	[1]
			$K_a = \frac{[\text{CH}_3\text{CH}(\text{OH})\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}(\text{OH})\text{COOH}]}$	
		(ii)	<p>The pH of a buffer solution is deduced using the formula:</p> $\text{pH} = -\lg K_a + \lg \frac{[\text{salt}]}{[\text{acid}]}$ <p>Given that the equilibrium concentrations of lactic acid and sodium lactate are <math>0.35 \text{ mol dm}^{-3}</math> and <math>0.20 \text{ mol dm}^{-3}</math> respectively, calculate the pH of this buffer solution.</p>	[1]
			$\text{pH} = -\lg(1.38 \times 10^{-4}) + \lg \left( \frac{0.20}{0.35} \right)$ $= 3.62$	
		(iii)	Write two equations to show how this buffer solution controls pH when a small amount of acid or base is added.	[2]
			$\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}$ $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}$	
		[Total: 20]		

END OF PAPER