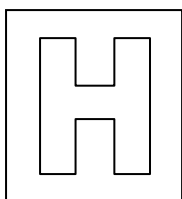


Candidate Name: \_\_\_\_\_

Class    Adm No

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## 2015 Promotional Examination II Pre-university 2

### H1 CHEMISTRY

**8872 / 02**

Paper 2 Structured Questions

**16 Sept 2015**

**2 hours**

Candidates answer Section A on the Question Paper

Additional Materials: Cover page  
Data Booklet  
Writing paper

### READ THESE INSTRUCTIONS FIRST

Write your name, index number and class on all the work you hand in.  
Write in dark blue or black pen on both sides of the writing paper.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluids.  
The use of an approved scientific calculator is expected, where appropriate.

### Section A

Answer **all** the questions.

### Section B

Answer **two** questions on the separate writing papers. Start each new question on a fresh sheet of writing 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.

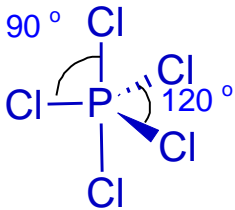
### FOR EXAMINER'S USE

	Section A				Section B			Total
Question No	1 (12m)	2 (11m)	3 (7m)	4 (10m)	5 (20m)	6 (20m)	7 (20m)	80
Marks Obtained								

## Section A (40 marks)

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

1	Phosphorus is an essential part of life for both human beings and plants. Phosphorus compounds can be found in the minerals in bones and teeth. Phosphorus is also a vital element for plants which is present in the form of phosphates in the fertiliser to maximise the growth of the plant.	For Examiner's Use										
(a)	<p>Phosphoric acid reacts with potassium hydroxide as shown in the following reaction.</p> $\text{H}_3\text{PO}_4(\text{aq}) + 3\text{KOH}(\text{aq}) \rightarrow \text{K}_3\text{PO}_4(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ <p>Some thermochemical data are shown below.</p> <table><tr><td></td><td><math>\Delta H^\ominus / \text{kJ mol}^{-1}</math></td></tr><tr><td>Standard enthalpy change of formation of <math>\text{H}_3\text{PO}_4(\text{aq})</math></td><td>-1277</td></tr><tr><td>Standard enthalpy change of formation of <math>\text{KOH}(\text{aq})</math></td><td>-482</td></tr><tr><td>Standard enthalpy change of formation of <math>\text{K}_3\text{PO}_4(\text{aq})</math></td><td>-1950</td></tr><tr><td>Standard enthalpy change of formation of <math>\text{H}_2\text{O}(\text{l})</math></td><td>-286</td></tr></table>		$\Delta H^\ominus / \text{kJ mol}^{-1}$	Standard enthalpy change of formation of $\text{H}_3\text{PO}_4(\text{aq})$	-1277	Standard enthalpy change of formation of $\text{KOH}(\text{aq})$	-482	Standard enthalpy change of formation of $\text{K}_3\text{PO}_4(\text{aq})$	-1950	Standard enthalpy change of formation of $\text{H}_2\text{O}(\text{l})$	-286	
	$\Delta H^\ominus / \text{kJ mol}^{-1}$											
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Standard enthalpy change of formation of $\text{K}_3\text{PO}_4(\text{aq})$	-1950											
Standard enthalpy change of formation of $\text{H}_2\text{O}(\text{l})$	-286											
(i)	Define <i>standard enthalpy change of formation of <math>\text{H}_3\text{PO}_4(\text{aq})</math></i> . [1]											
	The standard enthalpy change of formation of aqueous $\text{H}_3\text{PO}_4$ is the <b>enthalpy change</b> when <b>one mole of aqueous <math>\text{H}_3\text{PO}_4</math></b> is <b>formed from its constituent elements in their standard states (<math>\text{H}_2</math>, <math>\text{P}_4</math> and <math>\text{O}_2</math>)</b> under <b>standard conditions</b> .											
(ii)	Calculate the standard enthalpy change for the reaction between phosphoric acid and potassium hydroxide based on the information provided. [2]											
	$\Delta H^\ominus_{\text{rxn}} = -1950 + (-286 \times 3) - [(-1277) + (-482 \times 3)] ;$ $= -85.0 \text{ kJ mol}^{-1} ;$											
(b)	Phosphorus can react with chlorine to form phosphorus pentachloride and phosphorus trichloride.											
(i)	<p>The boiling points of phosphorus and chlorine are <math>280^\circ\text{C}</math> and <math>-34^\circ\text{C}</math> respectively.</p> <p>Explain, in terms of structure and bonding, the difference in boiling points observed in phosphorus and chlorine. [2]</p>											
	Both phosphorus and chlorine have <b>simple molecular structures</b> and are held											

			<p>by <u>temporary dipole-induced dipole forces of attraction between molecules.</u>;</p> <p><u>More</u> energy is required to overcome the <u>stronger temporary dipole-induced dipole forces of attraction between <math>P_4</math> molecules</u> due to the <u>larger electron cloud size of <math>P_4</math> compared to <math>Cl_2</math>.</u>;</p>	For Examiner's Use
		(ii)	<p>Draw a molecule of phosphorus pentachloride, <math>PCl_5</math>, showing clearly its shape. Indicate the bond angles on the molecule.</p> <p>[1]</p>	
				

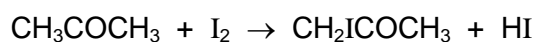
		<p>(iii) <math>\text{PCl}_3</math> and <math>\text{PCl}_5</math>, both important in the production of other phosphorous compounds, coexist in equilibrium through:</p> $\text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{PCl}_5(\text{g})$ <p>At 250 °C, 0.289 g of <math>\text{PCl}_3</math> and 2.16 g of <math>\text{Cl}_2</math> were mixed in a 2.50 dm<sup>3</sup> flask. The equilibrium mixture was found to contain 0.105 g <math>\text{PCl}_5</math>. Determine the value of <math>K_c</math>. [3]</p>	
		<p>Initial amount of <math>\text{PCl}_3 = \frac{0.289}{31.0+35.5 \times 3} = 0.002102 \text{ mol}</math></p> <p>Initial concentration of <math>\text{PCl}_3 = \frac{0.002102}{2.5} = 0.000841 \text{ mol dm}^{-3}</math></p> <p>Initial amount of <math>\text{Cl}_2 = \frac{2.16}{35.5 \times 2} = 0.03042 \text{ mol}</math></p> <p>Initial concentration of <math>\text{Cl}_2 = \frac{0.03042}{2.5} = 0.01217 \text{ mol dm}^{-3}</math> ;</p> <p>Amount of <math>\text{PCl}_5</math> at equilibrium = <math>\frac{0.105}{31.0+35.5 \times 5} = 0.0005036 \text{ mol}</math></p> <p>Equilibrium concentration of <math>\text{PCl}_5 = \frac{0.0005036}{2.5} = 0.0002014 \text{ mol dm}^{-3}</math></p> <p>Equilibrium concentration of <math>\text{Cl}_2 = 0.01217 - 0.0002014 = 0.0119 \text{ mol dm}^{-3}</math></p> <p>Equilibrium concentration of <math>\text{PCl}_3 = 0.000841 - 0.0002014</math></p> <p style="text-align: center;"><math>= 0.000640 \text{ mol dm}^{-3}</math> ;</p> <p><math>K_c = \frac{[\text{PCl}_5]}{[\text{Cl}_2][\text{PCl}_3]}</math></p> <p><math>= \frac{0.0002014}{0.0119 \times 0.000640} = 26.4 \text{ mol}^{-1} \text{ dm}^3</math> ; (final answer with units)</p>	

	(c)	Radioactivity, or radioactive decay, follows first-order kinetics and it involves the emission of a particle or a photon that results from the spontaneous decomposition of the unstable nucleus of an atom. An example of radioactive isotope of phosphorus is $^{32}\text{P}$ which is used as biochemical tracer in the identification of malignant tumours. $^{32}\text{P}$ has a half-life of 14 days.	For Examiner's Use
	(i)	Define the term <i>half-life</i> of a reaction. [1]	
		Half-life is the time taken for the concentration of reactant to fall to half of its initial concentration.	
	(ii)	If the initial mass of $^{32}\text{P}$ present was 0.0168g, calculate the mass of $^{32}\text{P}$ at the end of 42 days. [2]	
		No of half-lives= $42/14 = 3$ ;  Mass of $^{32}\text{P}$ at the end of 42 days = $0.0168 / (2^3) = \underline{0.00210\text{g}}$ ;	
		[Total:12]	

2	(a)	<p>Bauxite is an aluminium ore containing aluminium oxide and other impurities such as silica, iron oxides and titanium dioxide. The Bayer process is an important industrial process to obtain pure aluminium oxide from bauxite.</p> <p>In the Bayer process, bauxite is first reacted with hot sodium hydroxide. This converts the aluminium oxide in bauxite into a soluble salt, <b>S</b>, and water. The solid impurities are then filtered off.</p> <p>The second step in the process involves bubbling carbon dioxide gas into the products of the earlier step, producing aluminium hydroxide precipitate and sodium carbonate.</p> <p>In the third step, the precipitate obtained is heated to its decomposition temperature, producing pure aluminium oxide and water vapour.</p>																	
	(i)	<p>The soluble salt, <b>S</b>, has the following composition by mass: Na, 28.0%; Al, 33.0%; O, 39.0%.</p> <p>Determine the molecular formula of <b>S</b> given that it has a molecular mass of 82.0. [3]</p>																	
		<table border="1" data-bbox="339 1155 1307 1330"> <tr> <td></td><td>Na</td><td>Al</td><td>O</td></tr> <tr> <td>%</td><td>28.0</td><td>33.0</td><td>39.0</td></tr> <tr> <td>amount</td><td><math>28.0/23.0 = 1.217</math></td><td><math>33.0/27.0 = 1.222</math></td><td><math>39.0/16.0 = 2.438</math></td></tr> <tr> <td>ratio</td><td>1</td><td>1</td><td>2</td></tr> </table> <p> <math>(\text{NaAlO}_2)_n = (23.0 + 27.0 + 32.0)n = 82.0</math>  <math>n = 1</math> ;  molecular formula = <math>\text{NaAlO}_2</math> ;  <i>working in table ;</i> </p>		Na	Al	O	%	28.0	33.0	39.0	amount	$28.0/23.0 = 1.217$	$33.0/27.0 = 1.222$	$39.0/16.0 = 2.438$	ratio	1	1	2	<p>For Examiner's Use</p>
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ratio	1	1	2																

		(ii)	Hence using your answer in (a)(i), write balanced equations for the first two steps of the process. [2]	
			$\text{Al}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaAlO}_2 + \text{H}_2\text{O} ;$ $2\text{NaAlO}_2 + \text{CO}_2 + 3\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + \text{Na}_2\text{CO}_3 ;$	
		(iii)	<p>During an industrial production of aluminium oxide via the Bayer process, a 1 tonne sample of bauxite was used. The aluminium oxide produced reacted completely with 4060 dm<sup>3</sup> solution of 5 mol dm<sup>-3</sup> of hydrochloric acid.</p> $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$ <p>Calculate the percentage by mass of aluminium oxide in the sample. [1 tonne = 1000 kg] [2]</p>	
			<p>amount of <math>\text{Al}_2\text{O}_3 = (5 \times 4060)/6 = 3383.3 \text{ mol} ;</math></p> <p>mass of <math>\text{Al}_2\text{O}_3 = 3383.3 \times [(27.0)(2) + (16.0)(3)] = 345100 \text{ g}</math></p> <p>percentage by mass = <math>\frac{345100}{1000000} \times 100\% = 34.51\% \approx 34.5\% ;</math></p>	

- (b)** Like aluminium oxide, mineral acids are used as catalysts in many reactions. In one such reaction, sulfuric acid was used to catalyse the reaction of propanone with iodine.



The kinetics of the reaction can be investigated experimentally by varying the concentrations of propanone, iodine and sulfuric acid and determining the time for the colour of the iodine to disappear. In this method, the rate of reaction is measured in terms of the rate at which the iodine concentration changes,

$$\text{i.e. rate of reaction} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for colour of iodine to disappear}}$$

The following results were obtained.

Experiment no.	Volume of propanone /cm <sup>3</sup>	Volume of iodine /cm <sup>3</sup>	volume of sulfuric acid /cm <sup>3</sup>	volume of water /cm <sup>3</sup>	relative time for colour of iodine to disappear
1	16	8	16	0	1
2	8	8	16	8	2
3	16	8	8	8	2
4	16	4	16	4	<i>t</i>

- (i)** Deduce the order with respect to propanone and hydrogen ions. [2]

*For  
Examiner's  
Use*

Comparing experiment 1 & 2, the time doubles when (rate is halved) when the volume of propanone used is halved.

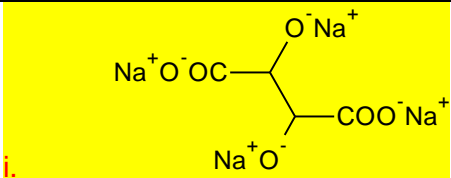
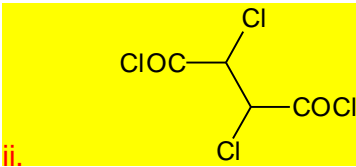
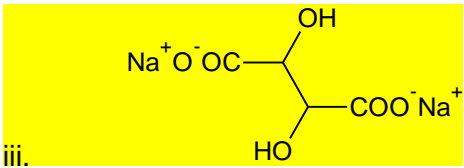
First order w.r.t. propanone;


Comparing experiment 1 & 3, the time doubles when (rate is halved) when the volume of sulfuric acid used is halved.

First order w.r.t. hydrogen ions;

		(ii)	Given that the order of reaction with respect to iodine is zero, determine the relative time, $t$ , for colour of iodine to disappear for <b>experiment 4</b> . [2]	
			$\text{rate} = k [\text{propanone}][\text{H}^+][\text{I}_2]^0$ Comparing expts 1 & 4, since [propanone] and $[\text{H}^+]$ are constant, rate is constant. Relative rate for experiment 4 = relative rate for expt 1 = $8/1 = 8$ ; $t = 4/8 = 0.5$ ;	
		[Total: 11]		

3	Tartaric acid can be made from ethene via the synthetic route shown below. <div style="text-align: center; margin: 20px;"> <math display="block">  \begin{array}{c}  \text{CH}_2=\text{CH}_2 \xrightarrow{\text{I}} \text{CH}_2(\text{OH})\text{CH}_2\text{OH} \xrightarrow{\text{II}} \begin{array}{c} \text{O}=\text{C}-\text{C}=\text{O} \\   \quad   \\ \text{H} \quad \text{H} \end{array} \\  \downarrow \text{III} \\  \begin{array}{c} \text{CO}_2\text{H} \quad \text{CO}_2\text{H} \\   \quad   \\ \text{HO}-\text{C}-\text{C}-\text{OH} \\   \quad   \\ \text{H} \quad \text{H} \end{array} \xleftarrow{\text{IV}} \begin{array}{c} \text{CN} \quad \text{CN} \\   \quad   \\ \text{HO}-\text{C}-\text{C}-\text{OH} \\   \quad   \\ \text{H} \quad \text{H} \end{array} \\  \text{tartaric acid}  \end{array}  </math> </div>			
	(a)	State the reagents and conditions for each of the following conversions, steps I to IV. [4]		
		Step I: cold, dilute, $\text{KMnO}_4 / \text{NaOH}$ (aq) ; Step II: $\text{K}_2\text{Cr}_2\text{O}_7$ , dilute $\text{H}_2\text{SO}_4$ , heat and distill ; Step III: $\text{HCN}$ , trace amount of $\text{NaOH}$ , followed by $\text{H}_2\text{SO}_4$ , $10-20^\circ\text{C}$ ; Step IV: dilute $\text{HCl}$ , heat ;		

		<b>(b)</b> Draw the structures of the organic product formed when tartaric acid reacts with each of the following reagents. <ul style="list-style-type: none"> <li>i. Na(s)</li> <li>ii. <math>\text{PCl}_5</math></li> <li>iii. NaOH(aq)</li> </ul> <div style="text-align: right;">[3]</div>	For Examiner's Use
		<div style="margin-bottom: 20px;">           i.  </div> <div style="margin-bottom: 20px;">           ii.  </div> <div>           iii.  </div>	
		[Total:7]	

4	3-fluoropropenoic acid, $\text{CHF}=\text{CHCO}_2\text{H}$ , is used as building blocks of polymers and it exhibits geometric isomerism.		
	(a)	Draw and label clearly, the geometric isomers of 3-fluoropropenoic acid. [2]	
		 <p style="text-align: center;">Cis                      trans</p>	
	(b)	Suggest how the acidity of $\text{CHF}=\text{CHCO}_2\text{H}$ might compare to that of $\text{CHCl}=\text{CHCO}_2\text{H}$ . [2]	
		<p><math>\text{CHF}=\text{CHCO}_2\text{H}</math> is more acidic than <math>\text{CHCl}=\text{CHCO}_2\text{H}</math>.</p> <p>F is more electronegative than Cl, thus there is a greater inductive effect where F <u>disperses the negative charge on the carboxylate anion to a greater extent</u>, ; in turn reducing the intensity of the negative charge on the O atom. <u>The carboxylate anion is more stable</u> and donates a proton more readily. Thus acid strength increases. ;</p>	
	(c)	Explain why $\text{CHF}=\text{CHCO}_2\text{H}$ is soluble in $\text{NaOH(aq)}$ . [2]	For Examiner's Use
		<p><math>\text{CHF}=\text{CHCO}_2\text{H}</math> reacts with <math>\text{NaOH}</math> to form <math>\text{CHF}=\text{CHCO}_2^-</math> ;</p> <p>The <u>ion-dipole interaction</u> between the <math>\text{CHF}=\text{CHCO}_2^-</math> and water <u>releases sufficient energy</u> to overcome the hydrogen bonding between water molecules. ;</p>	

	(d)	0.422 g of an organic compound, $C_3H_xI_y$ ( $M_r = 422$ ) is subjected to alkaline hydrolysis. After cooling the products, excess dilute $HNO_3$ (aq) is added followed by the addition of $AgNO_3$ (aq). The mass of the precipitate, $AgI$ formed is 0.705 g. Determine the values of $x$ and $y$ . [4]	
		<p>Amount of organic compound = <math>\frac{0.422}{422} = 1.00 \times 10^{-3}</math> mol ;</p> <p>Amount of <math>AgI = \frac{0.705}{235} = 3.00 \times 10^{-3}</math> mol ;</p> <p>Mole ratio of organic compound : <math>AgI</math> (and hence <math>I</math>) = 1 : 3, thus <u><math>y = 3</math></u> ;</p> <p><u><math>x = 422 - (3 \times 12) - (3 \times 127) = 5</math></u> ;</p>	
			[Total:10]

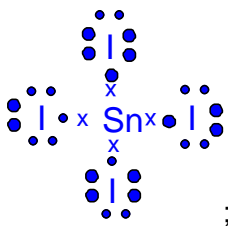
## Section B

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

5	(a)	<p>Liquid propane is commonly found in canisters used for portable gas stoves during camping trips. The enthalpy change of combustion of propane is <math>-2202 \text{ kJ mol}^{-1}</math>. A camper found a left-over canister of propane and estimates that there was about 60 g of liquid propane. Calculate the mass of water, at an initial temperature of <math>25^\circ\text{C}</math>, that he can boil before the canister becomes empty. [2]</p>
		<p>Amount of propane = <math>\frac{60}{12.0 \times 3 + 1.0 \times 8} = 1.364 \text{ mol}</math></p> <p>Energy evolved during combustion = <math>1.364 \times 2202 = 3003 \text{ kJ}</math> ;</p> <p><math>Q = mc\Delta T</math></p> <p><math>3003 \times 10^3 = m \times 4.18 \times (100 - 25)</math></p> <p><math>m = 9578 \text{ g} = 9.58 \text{ kg}</math> ;</p>
	(b)	<p>Under conditions of insufficient oxygen, propane burns to give carbon monoxide, which is a poisonous colourless and odourless gas.</p>
	(i)	<p>Construct a balanced equation for this reaction.</p> <p><math>\text{C}_3\text{H}_8 + 7/2\text{O}_2 \rightarrow 3\text{CO} + 4\text{H}_2\text{O}</math> [1]</p>
	(ii)	<p>Define <i>bond energy</i>.</p> <p>Bond energy is the energy absorbed to break one mole of covalent bond between two atoms in the gaseous state. [1]</p>
	(iii)	<p>Given that the bond energy of <math>\text{C}\equiv\text{O}</math> is <math>+740 \text{ kJ mol}^{-1}</math> and using the bond energy values from the <i>Data Booklet</i>, calculate the enthalpy change for the reaction in (b)(i). [2]</p> <p><math>\Delta H_{\text{rxn}} = 2(350) + 8(410) + 7/2(496) - 3(740) - 8(460)</math> ;</p> <p><math>= -184 \text{ kJ mol}^{-1}</math> ;</p>
	(c)	<p>Explain the following observations, writing balanced equations where appropriate.</p>
	(i)	<p>Carbon dioxide gas is produced on adding sodium carbonate to aluminium chloride solution, but not on adding sodium carbonate to sodium chloride solution. [3]</p>

		<p>NaCl dissolves in water to give <b>neutral solution</b>.</p> <p><math>\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-</math> ;</p> <p><math>\text{AlCl}_3</math> dissolves in water to give <b>acidic solution</b> due to the <b>highly charged <math>\text{Al}^{3+}</math></b> which polarizes <math>\text{H}_2\text{O}</math> molecules to liberate <math>\text{H}^+</math> ions. ;</p> <p><math>\text{AlCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{Cl}^-</math></p> <p><math>[\text{Al}(\text{H}_2\text{O})_6]^{3+} \rightarrow [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}^+</math></p> <p><math>\text{CO}_2</math> gas produced when <math>\text{Na}_2\text{CO}_3</math> added to acidic <math>\text{AlCl}_3</math> solution. ;</p> <p><math>\text{Na}_2\text{CO}_3 + 2\text{H}^+ \rightarrow 2\text{Na}^+ + \text{H}_2\text{O} + \text{CO}_2</math></p>
	(ii)	<p>On dissolving silicon tetrachloride in water, the resulting solution turned moist blue litmus paper red. [2]</p>
		<p><math>\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}</math> ;</p> <p><math>\text{SiCl}_4</math> undergoes hydrolysis in water to give acidic solution.</p> <p>Availability of vacant d orbitals for formation of dative covalent bonding with <math>\text{H}_2\text{O}</math>, weakening the O–H bond in <math>\text{H}_2\text{O}</math>, resulting in the dissociation of <math>\text{H}_2\text{O}</math> to give <math>\text{H}^+</math>. ;</p>
	(iii)	<p>In solid state, copper conducts electricity but copper(II) chloride does not. [2]</p>
		<p>Copper has a giant metallic structure where it is held by strong electrostatic forces of attraction between cations and a 'sea' of delocalised electrons. The electrons acts as <b><u>mobile charge carriers</u></b> ; to conduct electricity in the solid state. In solid state, the oppositely charged ions in copper(II) chloride are <b><u>held in fixed position</u></b> in the giant ionic lattice structure. There is <b><u>no mobile charge carriers</u></b> to conduct electricity.;</p>
	(iv)	<p>Reddish brown <math>\text{NO}_2</math> gas dimerises to give <math>\text{N}_2\text{O}_4</math>, a colourless gas. The dimerisation process is reversible. A flask containing both gases at equilibrium appeared reddish brown at high temperatures, while the same flask appeared pale brown when the temperature was lowered. [3]</p>
		<p><math>2\text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4</math></p> <p>The dimerisation process is exothermic. ;</p> <p>When temperature is high, <u>by Le Chatelier's Principle</u>, the <u>equilibrium will shift to the left</u> to lower the temperature, <u>favouring the endothermic reaction</u>. ;</p> <p>Thus, more <math>\text{NO}_2</math> is produced, therefore the flask appears reddish brown. ;</p>

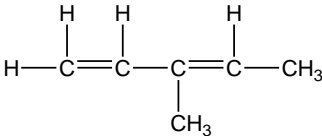
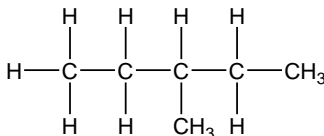
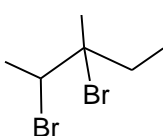
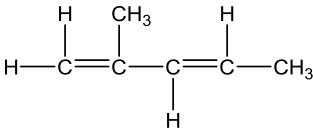
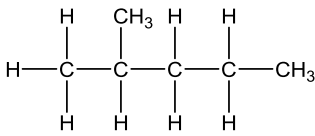
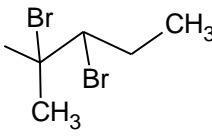
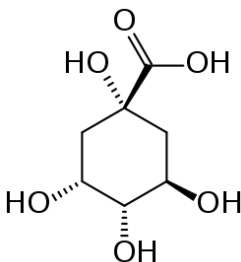
	<b>(d)</b>	Organic acids are weak acids whereas inorganic acids are generally strong acids.
	<b>(i)</b>	Define a weak acid.  A weak acid is one that dissociates partially in water to donate $H^+$ ions. [1]
	<b>(ii)</b>	Calculate the pH of a solution where the hydrogen ion concentration is $0.04 \text{ mol dm}^{-3}$ .  $pH = -\log(0.04) = 1.40$ [1]
	<b>(iii)</b>	Calculate the pH of a solution of potassium hydroxide of concentration $0.05 \text{ mol dm}^{-3}$ .  $pOH = -\log(0.05) = 1.301$ ; $pH = 14 - 1.301 = 12.7$ ; [2]
		[Total: 20]

6	(a)	Tin (Sn) exists in two forms. One known as 'white tin', which is a metal and a second form, known as 'grey tin', which has a structure similar to diamond and is more covalent in character.	
	(i)	State the noble gas configuration of tin.  <i>[Kr]4d<sup>10</sup>5s<sup>2</sup>5p<sup>2</sup></i>	[1]
	(ii)	State two physical properties of white tin which shows it to be a metal.	[2]
		<ul style="list-style-type: none"> <li>• Conducts electricity in solid state (due to presence of mobile electrons).</li> <li>• High melting/boiling points</li> <li>• Malleable and ductile</li> </ul> <i>Any two correct properties ; ;</i>	
	(iii)	<p>Grey tin was boiled under reflux with iodine (I<sub>2</sub>) dissolved in tetrachloromethane. Orange crystals of the product, SnI<sub>4</sub>, were obtained by filtering the hot reaction mixture followed by cooling the filtrate.</p> <p>Draw the 'dot-and-cross' diagram of SnI<sub>4</sub>, stating clearly its shape and bond angle.</p> <p><i>Tetrahedral, 109.5° ;</i></p> 	[2]

		(iv)	<p>The following table shows the first ionisation energy of Sn and I.</p> <table><tr><th>Element</th><th>1<sup>st</sup> Ionisation Energy/ kJ mol<sup>-1</sup></th></tr><tr><td>Sn</td><td>707</td></tr><tr><td>I</td><td>1010</td></tr></table> <p>Explain why the first ionisation energy of I is higher than that of Sn.</p> <p>I and Sn are in the same period. There is an <b>increase in effective nuclear charge</b> ; from Sn to I due to the increase in nuclear charge and negligible increase in screening effect across the period. The <b>attraction between the valence electron and nucleus is stronger</b> for I than that of Sn and <b>the distance between the valence electron and nucleus is shorter</b> for I than that of Sn. Hence <b>more energy</b> is required to remove the valence electron from I than Sn.;</p> <p>[2]</p>	Element	1 <sup>st</sup> Ionisation Energy/ kJ mol <sup>-1</sup>	Sn	707	I	1010
Element	1 <sup>st</sup> Ionisation Energy/ kJ mol <sup>-1</sup>								
Sn	707								
I	1010								
	(b)	<p>Propose a <b>2-step</b> synthesis route to show how <u>each</u> of the following conversions can occur. State all reagents and conditions used in each step of the synthesis and draw the intermediates clearly.</p> <p>i. <math>\text{CH}_3\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_3</math></p> <p>ii. <math>\text{CH}_3\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{COCH}_3</math></p> <p>[6]</p>							
		<p><math>\text{CH}_3\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{CH}(\text{Br})\text{CH}_3</math> ; <math>\rightarrow \text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_3</math> Step I: HBr (g), r.t ; Step II: excess concentrated ethanolic NH<sub>3</sub>, heated in a sealed tube. ;</p> <p><math>\text{CH}_3\text{CH}=\text{CH}_2 \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3</math> ; <math>\rightarrow \text{CH}_3\text{COCH}_3</math> Step I: H<sub>2</sub>O (g), conc H<sub>3</sub>PO<sub>4</sub>, 300 °C, 60atm ; Step II: conc KMnO<sub>4</sub> , H<sub>2</sub>SO<sub>4</sub> (aq), heat ;</p>							

(c)	<p>Alcohol <b>R</b>, <math>C_4H_{10}O</math>, reacts with concentrated sulfuric acid to give three compounds <b>S</b>, <b>T</b> and <b>U</b>. When compounds <b>S</b>, <b>T</b> and <b>U</b> were separately reacted with hot acidified potassium manganate (VII), the following was observed.</p> <ul style="list-style-type: none"> <li>Compounds <b>T</b> and <b>U</b> formed the same products.</li> <li>Effervescence was observed only for the reaction involving compound <b>S</b>.</li> <li>All 3 compounds <b>S</b>, <b>T</b> and <b>U</b> formed products that reacted with sodium carbonate.</li> </ul> <p>Deduce the structures of <b>R</b>, <b>S</b>, <b>T</b> and <b>U</b>. Explain clearly the chemistry involved in the reactions. [7]</p>												
	<table border="1"> <thead> <tr> <th data-bbox="248 658 858 741"><u>Observations</u></th><th data-bbox="866 658 1466 741"><u>Deductions</u></th></tr> </thead> <tbody> <tr> <td data-bbox="248 741 858 909">Alcohol <b>R</b>, <math>C_4H_{10}O</math>, reacts with concentrated sulfuric acid to give three compounds.</td><td data-bbox="866 741 1466 909">Elimination / dehydration. <b>R</b> is a secondary alcohol in order to give 3 products after elimination. <b>R</b> is butan-2-ol.</td></tr> <tr> <td data-bbox="248 909 858 1043"><b>S</b>, <b>T</b> and <b>U</b> were separately reacted with hot acidified potassium manganate.</td><td data-bbox="866 909 1466 1043"><b>S</b>, <b>T</b> and <b>U</b> are alkenes. Vigorous oxidation occurred.</td></tr> <tr> <td data-bbox="248 1043 858 1111"><b>T</b> and <b>U</b> formed the same products.</td><td data-bbox="866 1043 1466 1111"><b>T</b> and <b>U</b> are geometrical isomers.</td></tr> <tr> <td data-bbox="248 1111 858 1178">Effervescence was observed only for the reaction involving compound <b>S</b>.</td><td data-bbox="866 1111 1466 1178"><math>CO_2</math> evolved. <b>S</b> is a terminal alkene.</td></tr> <tr> <td data-bbox="248 1178 858 1279"><b>S</b>, <b>T</b> and <b>U</b> formed products that reacted with sodium carbonate.</td><td data-bbox="866 1178 1466 1279"><b>S</b>, <b>T</b> and <b>U</b> undergo vigorous oxidation to form carboxylic acids.</td></tr> </tbody> </table> <p><i>All correct deductions: 3marks</i></p> <p><i>3-4 deductions: 2marks</i></p> <p><i>&lt;3 deductions: 1 mark</i></p> <p><b>R</b>: Butan-2-ol ;</p> <p><b>S</b>: But-1-ene ;</p> <p><b>T</b>: Cis but-2-ene ;</p> <p><b>U</b>: Trans but-2-ene ;</p>	<u>Observations</u>	<u>Deductions</u>	Alcohol <b>R</b> , $C_4H_{10}O$ , reacts with concentrated sulfuric acid to give three compounds.	Elimination / dehydration. <b>R</b> is a secondary alcohol in order to give 3 products after elimination. <b>R</b> is butan-2-ol.	<b>S</b> , <b>T</b> and <b>U</b> were separately reacted with hot acidified potassium manganate.	<b>S</b> , <b>T</b> and <b>U</b> are alkenes. Vigorous oxidation occurred.	<b>T</b> and <b>U</b> formed the same products.	<b>T</b> and <b>U</b> are geometrical isomers.	Effervescence was observed only for the reaction involving compound <b>S</b> .	$CO_2$ evolved. <b>S</b> is a terminal alkene.	<b>S</b> , <b>T</b> and <b>U</b> formed products that reacted with sodium carbonate.	<b>S</b> , <b>T</b> and <b>U</b> undergo vigorous oxidation to form carboxylic acids.
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	[Total:20]												

7	Fuels made from oil mixtures containing large hydrocarbon molecules are not efficient. They do not flow easily and are difficult to ignite. Crude oil often contains too many large hydrocarbon molecules and insufficient small hydrocarbon molecules to meet demand. This is where cracking comes in. Cracking is a process that allows large hydrocarbon molecules to be broken down into smaller, more useful hydrocarbon molecules. One possible cracking reaction involves the hydrocarbon, $C_{15}H_{32}$ .		
	(a)	$C_{15}H_{32}$ undergoes cracking to produce ethene, propene and octane ( $C_8H_{18}$ ) <b>only</b> .	
		(i)	Write a balanced equation to illustrate the cracking reaction of $C_{15}H_{32}$ . [1]
			$C_{15}H_{32} \rightarrow 2C_2H_4 + C_3H_6 + C_8H_{18}$
		(ii)	Propene can be converted to propane. State the reagents and conditions, and the type of reaction for this reaction. [2]
			$H_2(g)$ , Ni catalyst, $150^\circ C$ Type of reaction: addition
		(iii)	Suggest a simple chemical test to distinguish between propene and octane. Your answer should include reagents and conditions and expected observations. [2]
			Aqueous $Br_2$ , room temperature. ; For propene, orange $Br_2(aq)$ decolourise whereas for octane, orange $Br_2(aq)$ remains orange. ;
		(iv)	Draw one structural isomer of octane, $C_8H_{18}$ . [1]
			Accept any chain-branched isomer.
	(b)	An alkane <b>B</b> is a component of fuel. When treated with bromine under uv light, it produces a mixture of brominated compounds, including <b>C</b> , $C_6H_{12}Br_2$ . Dehydrobromination of <b>C</b> produces <b>D</b> , $C_6H_{10}$ . When <b>D</b> is oxidised by hot concentrated $KMnO_4$ , three compounds, $CO_2$ , $CH_3CO_2H$ and $CH_3COCO_2H$ , are formed in equimolar amounts.  Deduce the structures of <b>B</b> , <b>C</b> and <b>D</b> , explaining clearly the chemistry involved in the reactions. [5]	
		<u>Observations</u>	<u>Deductions</u>
		When <b>B</b> is treated with bromine under uv light, it produces a mixture of brominated compounds.	Free radical substitution occurred.

	<p>Dehydrobromination of <b>C</b> produces <b>D</b>, C<sub>6</sub>H<sub>10</sub></p> <p>When <b>D</b> is oxidized by hot concentrated KMnO<sub>4</sub>, three compounds, CO<sub>2</sub>, CH<sub>3</sub>CO<sub>2</sub>H and CH<sub>3</sub>COCO<sub>2</sub>H</p>	<p>Elimination of 2 moles of HBr.</p> <p><b>D</b> is an alkene.</p> <p><b>D</b> contains two C=C bonds.</p>
	<p>1 mark for each correctly drawn structure.</p> <p>2 marks for all 3 deductions</p> <p>1 mark for at least 1 deduction.</p>	
	<div style="display: flex; justify-content: space-around; align-items: flex-end;"> <div style="text-align: center;">  <p><b>D</b></p> </div> <div style="text-align: center;">  <p><b>B</b></p> </div> <div style="text-align: center;">  <p><b>C</b></p> </div> </div> <p>OR</p> <div style="display: flex; justify-content: space-around; align-items: flex-end;"> <div style="text-align: center;">  <p><b>D</b></p> </div> <div style="text-align: center;">  <p><b>B</b></p> </div> <div style="text-align: center;">  <p><b>C</b></p> </div> </div>	
(c)	<p>Quinic acid is a crystalline acid obtained from coffee beans and other plant products. It is responsible for the perceived acidity of coffee. The structure of quinic acid is shown below.</p> <div style="text-align: center; margin: 10px 0;">  <p>quinic acid</p> </div>	
(i)	State 2 functional groups present in quinic acid.	[2]
	<p>Carboxylic acid, 2° alcohol, 3° alcohol</p> <p>1 mark each for any 2 correct functional groups</p>	
(ii)	<p>Suggest two simple chemical tests to <b>confirm</b> the presence of the two functional groups identified in (c)(i). Your answer should include reagents and conditions and expected</p>	

		observations.	[4]
		<u>Characteristic Test for Acids</u> $\text{Na}_2\text{CO}_3(\text{s})$ , warm. ; Effervescence observed. Colourless, odourless gas evolved gave a white ppt in $\text{Ca}(\text{OH})_2$ . For the alcohol, no effervescence observed. ;  <u>Characteristic test for alcohols</u> $\text{K}_2\text{Cr}_2\text{O}_7$ , dilute $\text{H}_2\text{SO}_4$ , heat ; Orange solution turns green. ;	
	(d)	Arrange the following compounds according to <b>decreasing</b> $K_a$ values. Explain your answer. $\text{CH}_3\text{COOH}$ , $\text{CH}_2\text{ClCOOH}$ , $\text{CH}_3\text{CH}_2\text{COOH}$	[3]
		$\text{CH}_2\text{ClCOOH} > \text{CH}_3\text{COOH} > \text{CH}_3\text{CH}_2\text{COOH}$ ; The larger the $K_a$ value, the stronger the acid.  Cl has an electron-withdrawing effect $\Rightarrow$ enabling the negative charge on the O atom to be dispersed through the anion, stabilising it. $\Rightarrow$ Reduction of the negative charge on the oxygen makes $\text{CH}_2\text{ClCOO}^-$ a more stable anion than $\text{CH}_3\text{COO}^-$ . ; $\therefore \text{CH}_2\text{ClCOOH}$ is a stronger acid than $\text{CH}_3\text{COOH}$ .  $\text{CH}_3\text{CH}_2\text{COOH}$ has a larger alkyl group compared to $\text{CH}_3\text{COOH}$ . This led to a greater electron donating effect. The negative charge on the O atom in $\text{CH}_3\text{CH}_2\text{COO}^-$ was intensified, destabilising the anion. Therefore, the acidity of $\text{CH}_3\text{CH}_2\text{COOH}$ is reduced. ;	
			[Total:20]

END OF PAPER 2

[Turn over