RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME	**Suggested Answer**						
CLASS	2	0	J			INDEX NUMBER	

H1 CHEMISTRY 8873/02

Paper 2 Structured Questions **15 Sep 2021**

2 hours

Additional Materials: 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 an pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section **A**
Answer **all** questions in the space provided.

Section **B**
Answer **one** question in the space provided.

A Data Booklet is provided. Do NOT write anything on it.

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

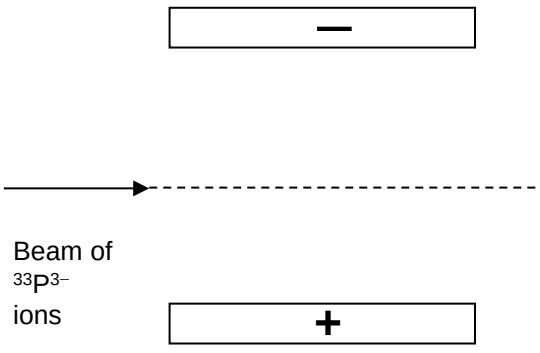
For Examiner's Use	
Paper 1	/30
Paper 2	
1	/9
2	/7
3	/6
4	/5
5	/18
6	/15
7	/20
8	/20
s.f.	
units	
Paper 2	/80
Total	/110

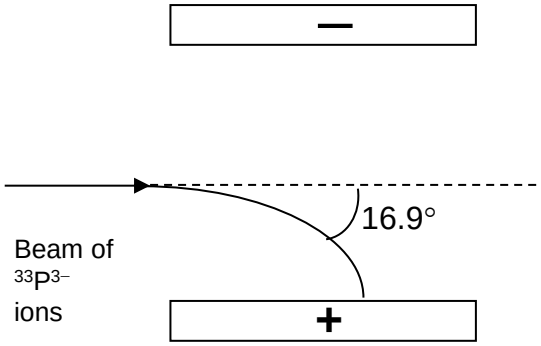
This paper consists of **20** printed pages.

Section A (60 marks)

Answer all the questions in this section.

1	**(a)**	**(i)**	Describe the reactions, if any, of the chlorides $MgCl_2$ and PCl_5 with water. Write equations for all reactions that occur, and suggest the pH of the resulting solutions. Relate the reactivity of these chlorides to their structure and bonding.	
			…… …… …… …… …… …… …… …… …… …… …… ……	**[3]**
			$MgCl_2$ has a giant ionic lattice structure and strong electrostatic attraction between Mg^{2+} and Cl^- ions. $MgCl_2$ dissolves in water readily to form an acidic solution of pH 6.5. Both hydration of ions and partial hydrolysis of $Mg^{2+}(aq)$ occurs. Hydrolysis occurs due to the polarisation of water molecules by the Mg^{2+} ion $MgCl_2(s) + 6H_2O(l) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + 2Cl^-(aq)$ $[Mg(H_2O)_6]^{2+}(aq) + H_2O(l) \ll [Mg(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$ PCl_5 has a simple covalent structure. PCl_5 dissolves and undergoes hydrolysis in water to form an acidic solution of pH 2. P atom in PCl_5 has energetically accessible vacant 3d orbitals to form dative bonds with water molecules. $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$	
		(ii)	Carbon is in the same group as silicon. Suggest and explain if CCl_4 will react with water.	

			…… ……	[1]
			CCl_4 does not react with water as carbon does not have energetically accessible empty 3d orbitals to accept the lone pair of electrons from water molecules.	
	(b)	Phosphorus exist as ^{31}P, ^{32}P and ^{33}P isotopes. ^{31}P is the most stable isotopes.		
		(i)	Define the term *isotopes*.	
			…… ……	[1]
			Isotopes are atoms of the same element with the same number of protons but different number of neutrons.	
		(ii)	^{31}P can react with chlorine to form phosphorus chloride. Phosphorus in phosphorus chloride can exhibit variable oxidation states. Based on your knowledge in periodicity, state the two common oxidation states of phosphorus in phosphorus chloride	
			……	[1]
			+5, +3	
		(iii)	Phosphorus can exist as cations or anions. The angle of deflection for a beam of $^{31}P^{+}$ ions in an electric field is 6°. Calculate the angle of deflection for a beam of $^{33}P^{3-}$ ions in the same electric field and show in the diagram below, Fig 1, how a beam of $^{33}P^{3-}$ ions will deflect in the electric field.  **Fig. 1**	[2]



$\frac{\text{charge}}{\text{mass}}$ for $^{31}P^{+} = |\frac{+1}{31}| = 0.03225$

$\frac{\text{charge}}{\text{mass}}$ for $^{33}P^{3-} = |\frac{-3}{33}| = 0.09091$

Since angle of deflection $\propto \frac{\text{charge}}{\text{mass}}$,

Angle of deflection= $\frac{0.09091}{0.03225} \times 6 = 16.9°$

(iv) ^{32}P is unstable and decays rapidly to another element. During the decay, a neutron is converted to a proton with the release of an electron, forming a charged ion.

Write an equation to show the reaction.

…… **[1]**

$^{32}P \rightarrow {}^{32}S^{+} + e^{-}$

[Total : 9]

2	**(a)**	Propanoic acid is a weak acid and can be used to make a *buffer solution*.		
		(i)	State the difference between a weak acid and a strong acid.	
			…… …… ……	**[1]**
			A strong acid is one that ionises/dissociates completely in solution to give a large amount of H^+. A weak acid is one that ionises/dissociates partially in solution to give a small amount of H^+.	
		(ii)	Explain what is meant by the term *buffer solution*.	
			…… …… ……	**[1]**
			A buffer solution is one that can resist a change in pH when a small amount of acid or base is added to it.	
		(iii)	The hydrogencarbonate ion, HCO_3^-, is part of the buffer in the blood. Write an equation showing how HCO_3^- reacts with acid in the blood.	
			……	**[1]**
			$HCO_3^- + H^+ \rightarrow H_2CO_3$	
		(iv)	After consuming food or drink containing sugar, the pH in the mouth can drop from pH 6.8 to a pH of approximately 4.8 as the sugar is broken down into lactic acid. In time, hydrogencarbonate ions in saliva restore the pH to its original value. Define pH and calculate the H^+ ion concentration in the mouth at pH 4.8.	
			…… …… …… ……	**[2]**

			…… ……	
			pH is the negative logarithm to the base ten of the concentration of $H^+(aq)$ in mol dm^{-3}. or $pH = -\lg [H^+(aq)]$ $[H^+] = 10^{-4.8} = 1.58 \times 10^{-5}$ mol dm^{-3}	
	(b)	**(i)**	Write an equation for the reaction between propanoic acid and sodium hydroxide. Label the conjugate acid and the conjugate base in your equation.	
			…… ……	**[2]**
			$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COO^-Na^+ + H_2O$ Conjugate base Conjugate acid	
				[Total: 7]

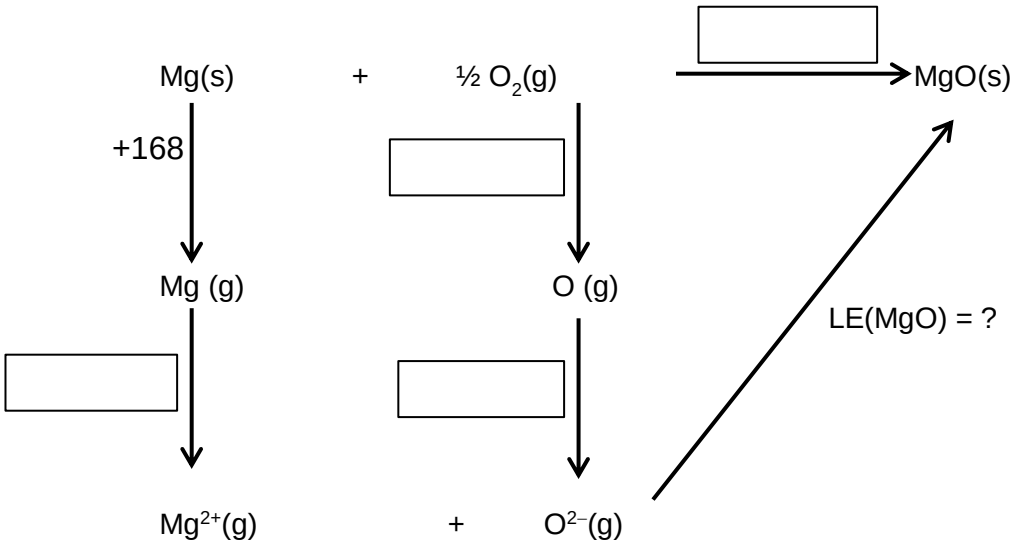
3	When 40 cm^3 of a gaseous organic compound, C_xH_yO, underwent complete combustion with an excess of oxygen, the total volume reduced by 130 cm^3. A further contraction of 200 cm^3 took place when the residual gas was passed through aqueous sodium hydroxide. All volumes were measured at 25 °C and 1 atm.			
	(a)	Write a balanced equation for the complete combustion of C_xH_yO.		
		……		**[1]**
		$C_xH_yO(g) + (x + \frac{y}{4} - \frac{1}{2})O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$		
	(b)	State the function of NaOH(aq).		
		……		**[1]**
		To react with $CO_2(g)$.		
	(c)	**(i)**	State the volume of CO_2 produced in this reaction	
			……	**[1]**
			200 cm^3	

		(ii)	Hence, determine the values of ***x*** and ***y***.	
				[3]
			x = 200 ÷ 40 = 5 volume reduction = volume of ($C_xH_yO + O_2$) combusted – volume of CO_2 produced $130 = 40 + (5 + \frac{y}{4} - \frac{1}{2}) \times 40 - 200$ $290 = (5 + \frac{y}{4} - \frac{1}{2}) \times 40$ $(5 + \frac{y}{4} - \frac{1}{2}) = 7.25$ ***y*** = 11	
				[Total: 6]

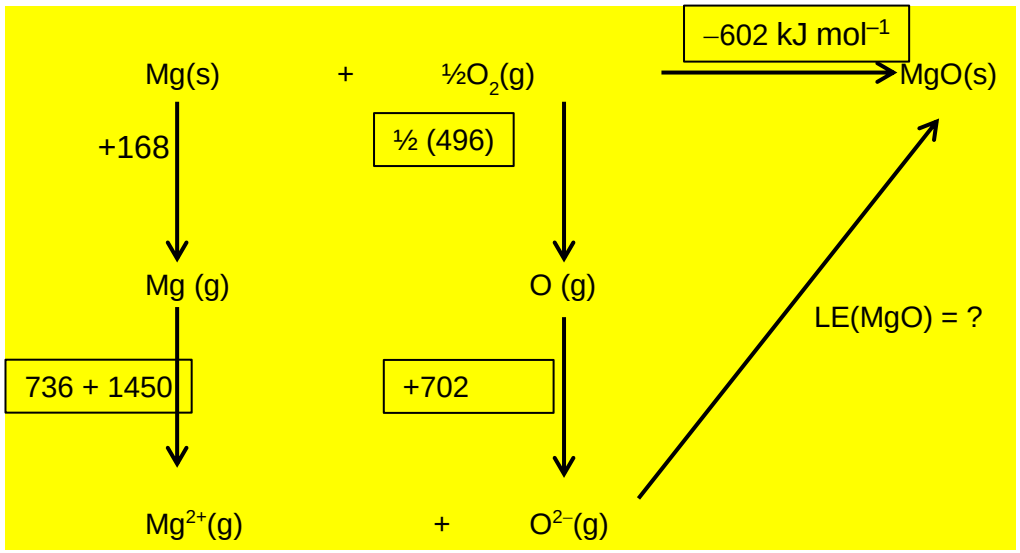
4	Magnesium oxide is available for purchase without a prescription. It is added to dietary supplements as well as over-the-counter medications used to treat constipation, indigestion, and headaches.

(a) Using the given Born-Haber cycle for the formation of MgO(s), the following data given as well as data from the *Data Booklet*, calculate the lattice energy of MgO(s).

sum of 1st and 2nd electron affinity of oxygen	+702 kJ mol^{-1}
enthalpy change of formation of magnesium oxide	–602 kJ mol^{-1}



[2]



$-602 = +168 + 736 + 1450 + (496/2) + 702 + LE(MgO)$

$= -3906$ kJ mol^{-1}

(b) Predict and explain how the lattice energy of Mg_3N_2 will differ as compared to MgO.

……

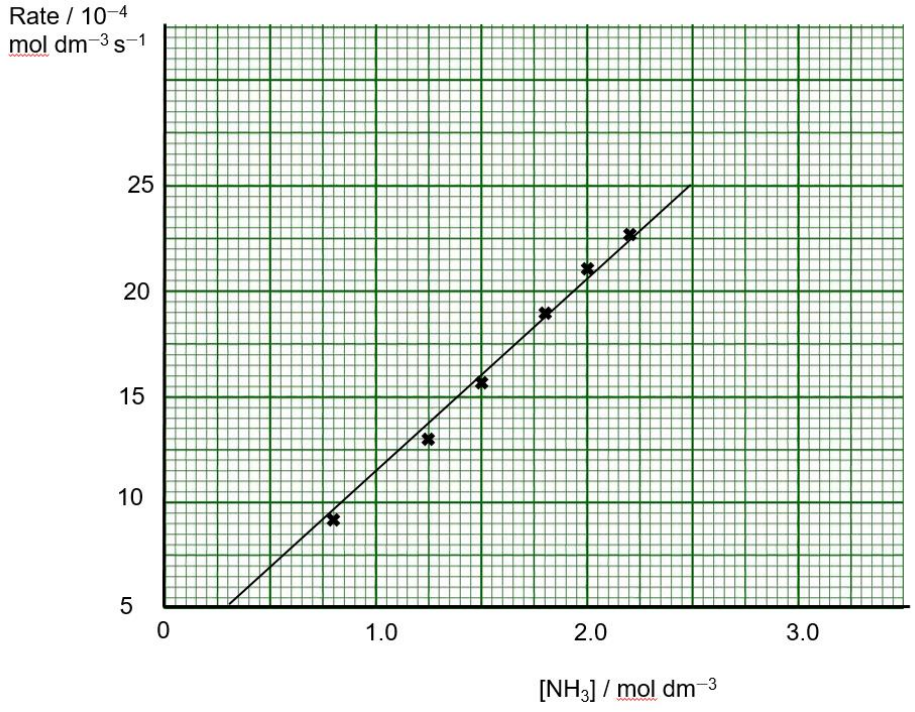
[3]

		…… …… …… …… …… ……	
		$\left\|\text{Lattice energy}\right\| \propto \left\|\frac{q^+ q^-}{r^+ + r^-}\right\|$ The charge and size is the same for cation. The charge on N^{3-} is larger than that of O^{2-} while the size of N^{3-} is larger than O^{2-}. The effect of the charge is larger than the effect of the size. Thus the magnitude of the lattice energy of Mg_3N_2 will be larger than that of MgO.	
			[Total: 5]

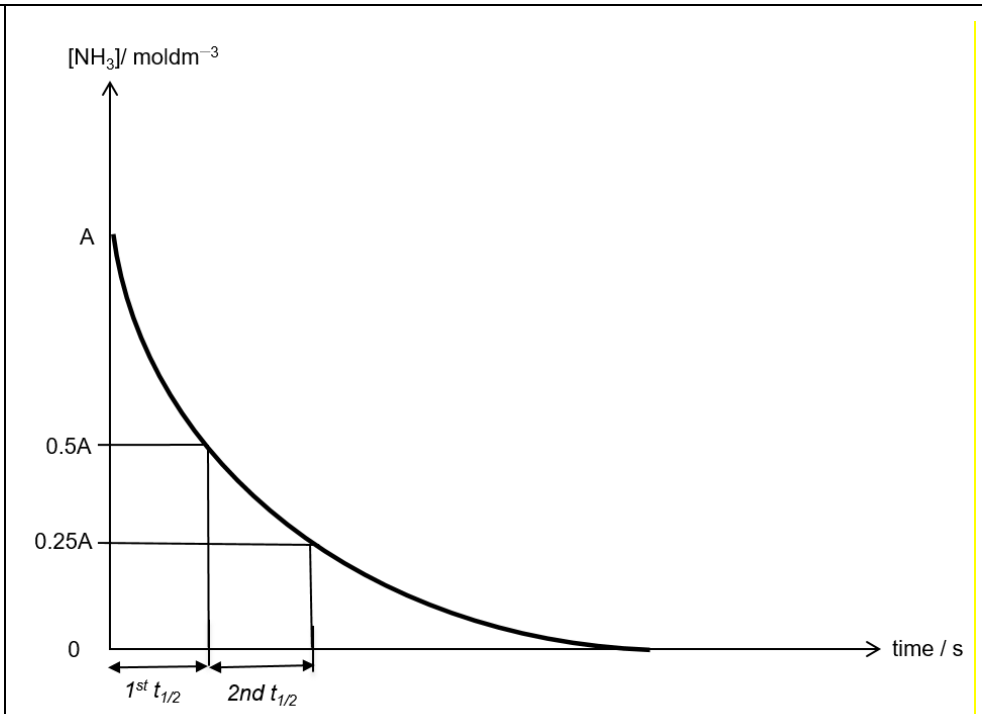
5	Chemists use ideas of collisions and rates of reaction to help them be more efficient when manufacturing chemicals on a large scale. One such process is the Haber process for the production of ammonia. The enthalpy change of the reaction is `46 kJ per mole of ammonia.			
	(a)	**(i)**	Write an equation to show the chemical reaction that happens in the Haber process.	
			……	**[1]**
			$N_2 + 3H_2 \ll 2NH_3$	
		(ii)	Define the term *heterogeneous catalyst*.	
			…… …… ……	**[1]**
			A heterogeneous catalyst is a substance which is in a different phase from the reactants. It increases the rate of a chemical reaction by providing an alternative pathway of lower activation energy without itself being changed by the reaction.	
		(iii)	Name the catalyst used in the Haber process.	
			……	**[1]**

			Iron.		
		(iv)	State the conditions used in the Haber process.		
			…….....		**[1]**
			High temperature of 450 °C and high pressure of 200 atm.		
		(v)	Describe and explain what would happen to the yield of the desired product if		
			I	the temperature is increased,	
				…….. …….. ……..	
				When temperature is increased, equilibrium position shifts to the left, favouring the backward endothermic reaction to remove some of the excess heat. The yield of ammonia decreases.	
			II	more hydrogen is added to the reaction vessel.	
				…….. …….. ……..	**[2]**
				When more hydrogen is added, the equilibrium position shifts to the right to consume of the added hydrogen, causing the yield of ammonia to increase.	
	(b)	Ammonia is oxidised by air to nitric acid in the presence of a platinum/rhodium catalyst. There are several stages to the reaction. The following equation is a summary of the overall process. $NH_3(g) + 2O_2(g) \rightarrow HNO_3(l) + H_2O(l) \quad \Delta H = -409 \text{ kJ mol}^{-1}$ The rate of reaction was measured at different times and the results are shown in the table below:			
		(i)	Plot a graph of rate against $[NH_3]$ in the space below.		

$[NH_3]$ / mol dm^{-3}	2.20	2.00	1.80	1.50	1.25	0.80
Rate / 10^{-4} mol dm^{-3} s^{-1}	22.7	21.1	18.9	15.7	13.1	8.3

				[3]
				
		(ii)	Use your graph to find the order of the reaction with respect to NH_3	
			…… ……	**[1]**

			Since the graph is a straight line, rate is directly proportional to $[NH_3]$ and order of reaction wrt NH_3 is 1.	
		(iii)	The order of reaction with respect to oxygen is zero. Write an expression for the rate equation.	
			……....	**[1]**
			Rate = $k[NH_3]$	
		(iv)	Calculate the rate constant, giving its units.	
				[2]
			Using a point on the graph, $10 \times 10^{-4} = k(0.95)$ $k = 1.05 \times 10^{-3}\ s^{-1}$	
		(v)	Sketch the shape of the graph of $[NH_3]$ against time.	
				[2]



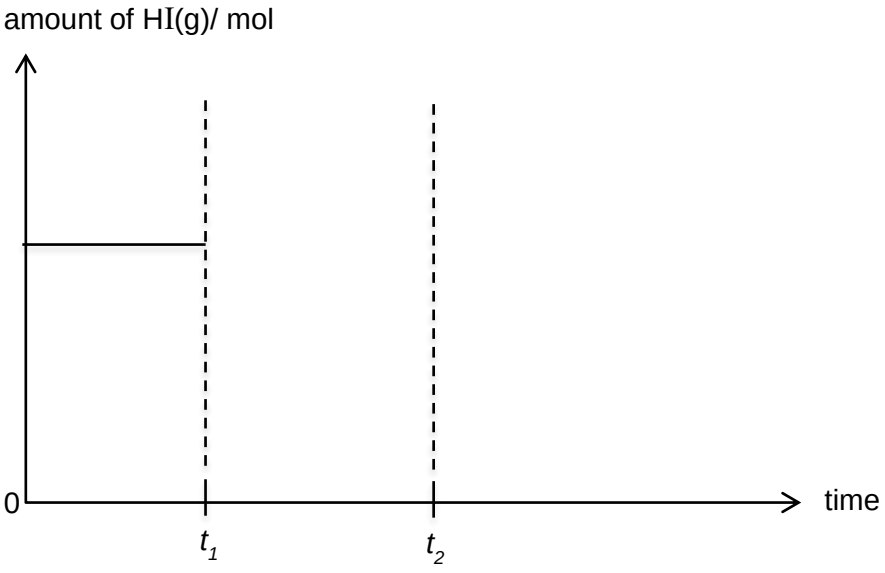
(c) Hydrogen reacts with iodine reversibly. The reaction is allowed to reach an equilibrium.

$$H_2(g) + I_2(g) \ll 2HI(g) \quad \Delta H = +26.5 \text{ kJ mol}^{-1}$$

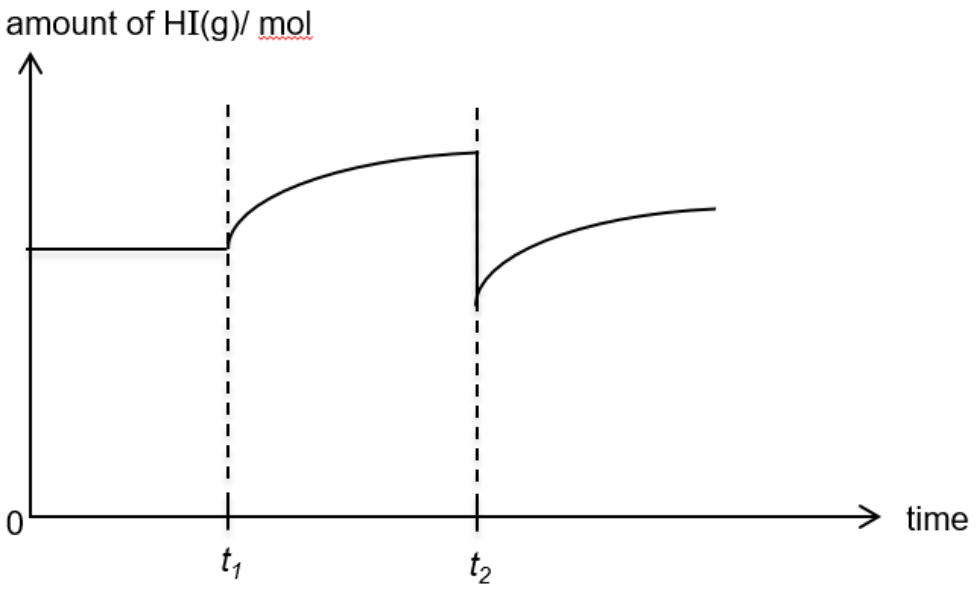
Using Le Chatelier's Principle, show on the graph the effect of:

I. increasing the temperature at time t_1,
II. removing some HI(g) at time t_2

on this equilibrium.



[3]



[Total: 18]

6 Super-absorbent polymers commonly known as hydrogel have the ability to absorb 200-300 times their own mass of water. Hydrogel is used in baby diapers and exists as small crystals of hydrogel at the core of the diaper. It absorbs the urine and swells up. Hydrogel has high water retention, enabling the baby to stay dry.

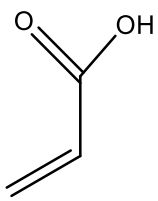
A diaper is known to be effective if the swelling capacity is greater than 6000%. The swelling capacity is calculated by the following formula.

$$\text{swelling capacity} = \frac{m_2 - m_1}{m_1} \times 100\%$$

m_1 : mass in grams, of hydrogel before swelling
m_2 : mass, in grams, of hydrogel after swelling

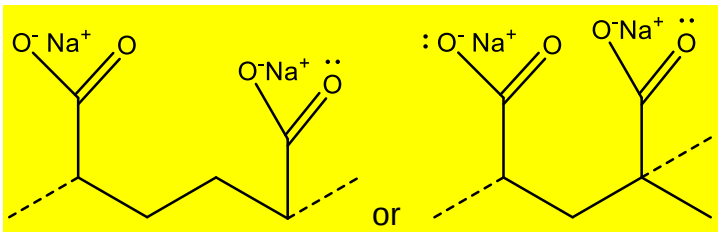
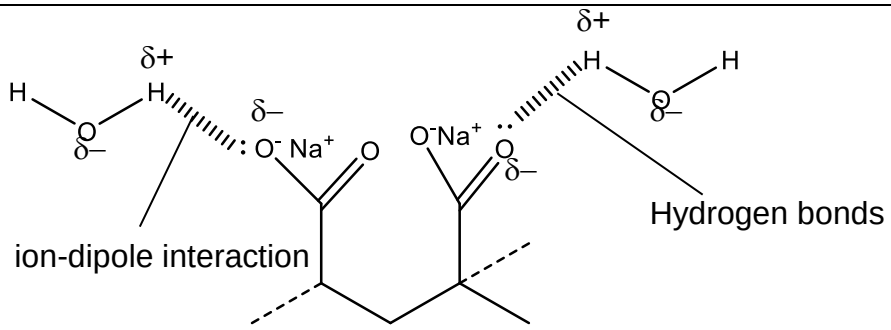
In a particular brand of diaper, Momocool, 3.97g of dried hydrogel is found in a piece of baby diaper. Typically, a baby passes 55.0 cm^3 of urine each time and a piece of diaper can hold 220.0 cm^3 of urine.

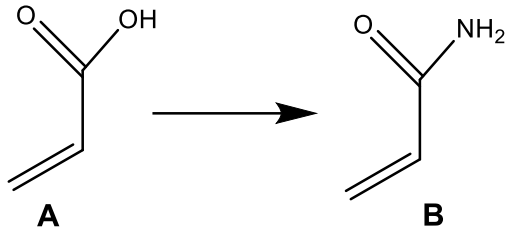
The hydrogel used in baby diapers is known as sodium polyacrylate. These polymers are commonly made by the polymerisation of monomer **A** mixed with sodium hydroxide in the presence of an initiator.



Monomer **A**

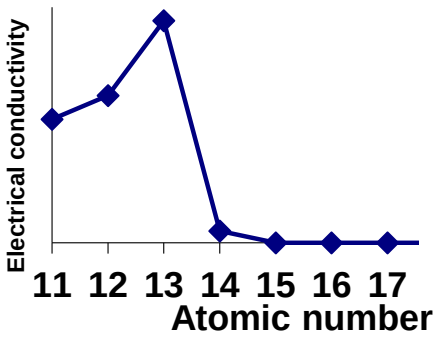
	(a)	**(i)**	Given that the density of a baby's urine is 1.003 g cm^{-3}, calculate the swelling capacity of the diaper.	
				[2]
			$1.003 = \frac{m}{220} \times 100\% = 220.66$ g swelling capacity $= \frac{220.66}{3.97} \times 100\% = 5558\%$ $\approx 5560\%$	
		(ii)	Based on the calculation in **(i)**, state if Momocool is a good brand of diapers. Explain your answer.	
			……	**[1]**
			It is not a good brand to purchase as the swelling capacity is only 5550% which is less than 6000%	
	(b)	**(i)**	Give the IUPAC name of monomer **A**.	
			……	**[1]**
			propenoic acid	
		(ii)	State the type of polymerisation involved in the formation of hydrogels.	
			……	**[1]**
			addition polymerisation	
		(iii)	Draw the structure of two repeat units of the polymer formed by the above method from monomer **A** when mixed with NaOH.	
				[1]

				
		(iv)	With the help of a diagram, explain how the hydrogel can absorb large quantities of water.	
			…… …… ……	
				**[3]**
			Hydrogel can form <u>hydrogen bonds</u> and <u>ion-dipole interaction</u> with water molecules so that large amount of water can be absorbed.	
	(c)	Monomer **A** can be converted into monomer **B**, which can be polymerised to form a super-adsorbent polymer.		

		 **A** **B**		
		(i)	Name the functional groups in monomer **A** and **B**.	
			.....	**[3]**
			alkene, carboxylic acid and amide	
		(ii)	Identify the other product that is formed when monomer **A** is converted to monomer **B**.	
			.....	**[1]**
			H_2O	
		(iii)	State the reagents and conditions necessary to reform monomer **A** from monomer **B**.	
			.....	**[1]**
			H_2SO_4, heat under reflux (for prolonged period of time)	
		(iii)	State the reagents and conditions need to convert monomer **A** to propanoic acid.	
			.....	**[1]**
			H_2, Ni catalyst, heat	
				[Total: 15]

Section B (20 marks)

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

7	**(a)**	Electrical conductivity varies greatly across period 3 from Na to C*l*. Sketch a graph to show how their electrical conductivity differs, and explain this variation in terms of structure and bonding.	
		……... ……... ……... ……... ……... ……... ……... ……... ……... ……... ……... ……... ……... ……... ……...	**[5]**
		 • Student can write the actual element	

		Na, Mg and Al have giant metallic structures. Number of delocalised valence electrons increases from Na to Al. Hence, electrical conductivities are high and increase from Na to Al. Si has a giant covalent structure. Electrical conductivity drops sharply at Si. P_4 to Cl_2 have simple covalent structures. Electrical conductivities drop to zero at P_4 to Cl_2 because there are no mobile charge carriers to conduct electricity.		
	(b)	Ferromanganese is an alloy added to steels to improve their mechanical properties. A 15g sample of ferromanganese was dissolved in 250cm^3 of dilute sulfuric acid to give an solution containing iron(II) sulfate and manganese(II) sulfate. 25.0 cm^3 of the resulting solution required 20.0 cm^3 of 0.0360 mol dm^{-3} potassium manganate(VII) for complete reaction.		
		(i)	By using the *Data Booklet*, write the oxidation and reduction half-equations for the reaction between the resulting solution and potassium manganate(VII).	
			…… …… ……	**[1]**
			Oxidation : $Fe^{2+} \rightarrow Fe^{3+} + e$ Reduction : $MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$	
		(ii)	Hence or otherwise, construct an equation for the reaction.	
			…… ……	**[1]**
			$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$	
		(iii)	Calculate the percentage by mass of iron in ferromanganese.	
				[3]
			amt of $MnO_4^- = \frac{20.0}{1000} \times 0.036 = 7.20 \times 10^{-4}$ mol amt of Fe^{2+} in 25 cm^3 = 7.20 × 10–4 × 5 = 3.60 × 10^{-3} mol	

amt of Fe^{2+} in 250 cm^3 = $3.60 \times 10^{-3} \times \frac{250}{25} = 3.60 \times 10^{-2}$ mol

mass of Fe in sample = $3.60 \times 10^{-2} \times 55.8 = 2.009$ g

% of Fe in sample = $\frac{2.009}{15} \times 100\% = 13.4\%$

(c) Propanol can be converted from propene or propanone as shown below.

$CH_3CH{=}CH_2 \xrightarrow{\text{step I}} CH_3CHBrCH_3 \xrightarrow{\text{step II}} CH_3CH(OH)CH_3 \xleftarrow{\text{step III}} CH_3COCH_3$

(i) With the aid of a diagram, describe the bonding in C^C bond in propene.

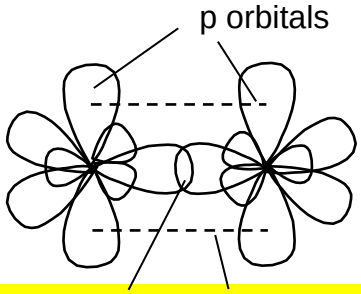
……

……

……

……

…… **[3]**



σ bond π bond

1 2p orbital of the carbon atom overlap head-on to forms a σ bond while another 2p orbital overalp side-on to form π bond.
The π electron cloud lies above and below the plane of the atoms.

		(ii)	State the types of reaction for step **I** and step **III**.	
			…… ……	**[2]**
			step I : addition step III : reduction	
		(iii)	State the reagents and conditions needed for step **III**	
			……	**[1]**
			step III : $NaBH_4$/ $LiAlH_4$ in dry ether/ H_2, heat	
		(iv)	State and explain how the rate of reaction for step **II** changes when 2-bromopropane is replaced by 2-iodopropane.	
			…… …… …… ……	**[2]**
			C–I covalent bond is weaker than C–Br. Less energy is required to break the C–I bond than C–Br bond. Hence the rate of reaction increase when 2-bromopropane is substituted with 2-iodopropane.	
		(v)	A student was given an unlabelled bottle and was told that it contains either a pure sample of propanone or a pure sample of propanol. Describe a chemical test, with appropriate observations, which would confirm the identity of the compound in the bottle.	
			……	**[2]**
			Reagent and condition : acidified $KMnO_4$/ $K_2Cr_2O_7$, heat Observation: if purple $KMnO_4$ remains purple, the bottle contains propanone. If purple $KMnO_4$ decolourise, the bottle contains propanol.	
				[Total: 20]

8 **(a)** Pure samples of ethanol and propanoic acid are mixed, and an equilibrium is established, as shown,

$$C_2H_5OH(l) + CH_3CH_2COOH(l) \ll CH_3CH_2COOC_2H_5(l) + H_2O(l)$$

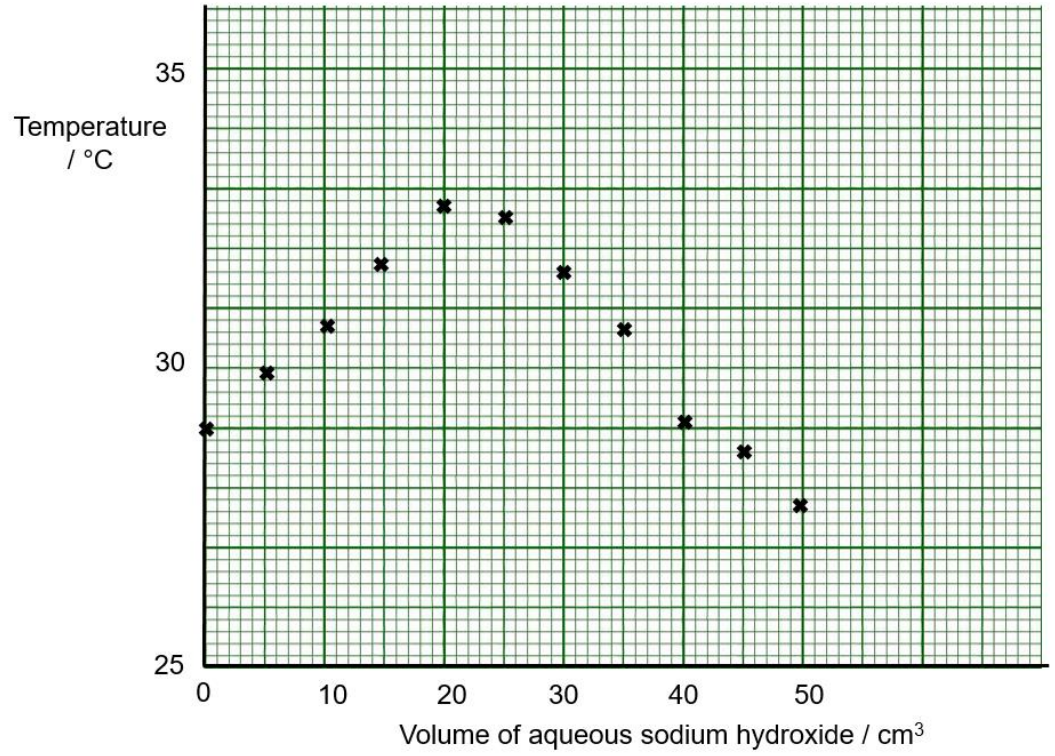
Holmes prepared a mixture containing 0.0300 mol of propanoic acid, 0.161 mol of ethanol and 0.150 mol of water. He added 0.00600 mol of concentrated sulfuric acid, H_2SO_4, to the mixture as a catalyst. The total volume of the reaction mixture was 90 cm^3.

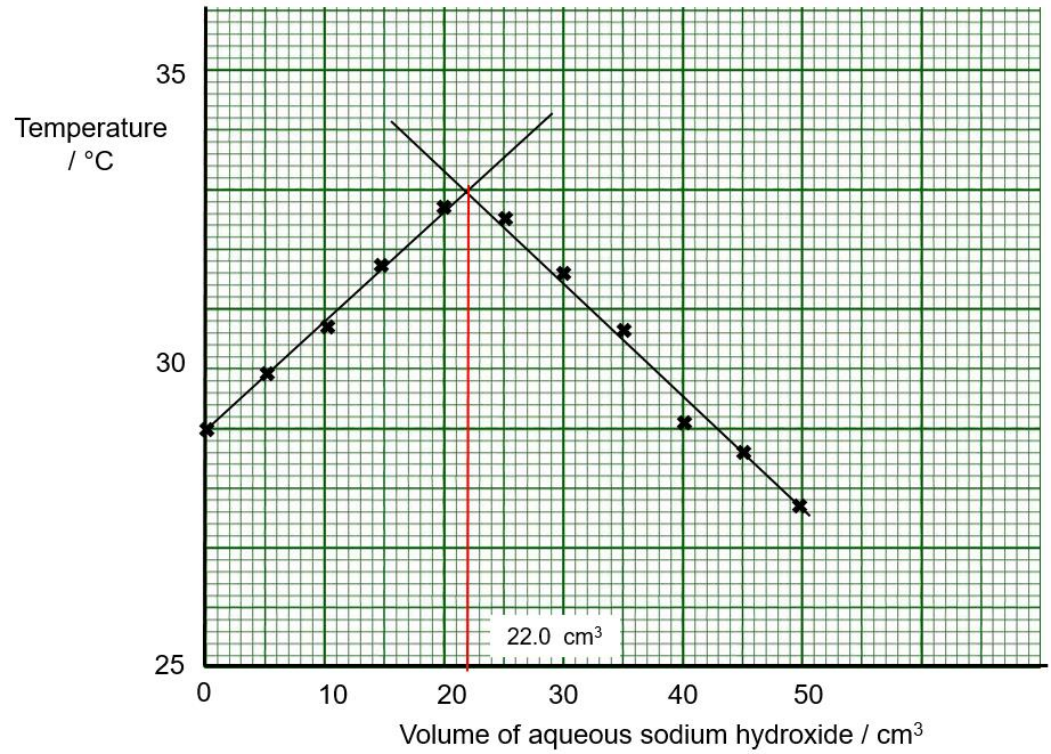
The reaction mixture was closed and sealed and left at a constant temperature of 25 °C for 5 days so that an equilibrium can be established.

The reaction mixture was transferred to a polystyrene cup and quickly titrated with 1.50 mol dm^{-3} aqueous NaOH. The initial temperature of the reaction mixture before the addition of aqueous NaOH was added is measured and recorded.

5.0 cm^3 portions of aqueous NaOH were added to the polystyrene cup. The temperature of the solution in the cup was measured after each addition. The maximum temperature occured when complete neutralisation has been achieved.

The results are shown in the graph below.





(i) By drawing two separate straight lines of best fit, determine the maximum temperature rise, ΔT_{max}, of the titration. Show your working. **[2]**

From the graph, T_{max} = 33.0 °C

ΔT_{max} = 33.0 ` 29.0 = 4.0 °C

(ii) Describe and explain the significance of:

I. the straight line of best fit before the maximum temperature
II. the straight line of best fit after the maximum temperature as more aqueous NaOH added.

……

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…… **[4]**

			I. The first straight line has a positive gradient and takes into account the increasing temperatures as sodium hydroxide is being added to neutralise the concentrated sulfuric acid in the reaction mixture. As enthalpy change of neutralisation is also exothermic, heat released by the reaction causes an increase in temperature measured. II. The second straight line has a negative gradient as the reaction is complete. As excess sodium hydroxide is being added to the reaction mixture, the heat is redistributed over an increasing volume of solution in the polystyrene cup, leading to a decrease in temperature.	
		(iii)	By showing evidence on the graph, determine the volume of sodium hydroxide, V_{NaOH}, required for neutralisation.	
			……	**[1]**
			V_{NaOH} = 22.0 cm^3	
		(iv)	Calculate the amount of NaOH required for complete neutralisation.	
				[1]
			Amount of NaOH = 0.022 × 1.50 = 0.0330 mol	
		(v)	Calculate the amount of NaOH that react with H_2SO_4.	
				[1]
			Amount of NaOH that react with H_2SO_4 = 2(0.006) = 0.0120 mol	
		(vi)	Construct a balanced equation for the reaction of propanoic acid with NaOH.	
			……	**[1]**
			$CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$	

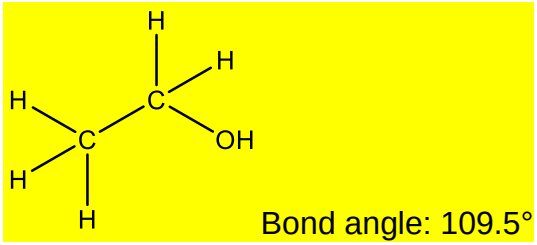
		(vi)	Assuming that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and density of the solution is 1.00 g cm^{-3}, calculate the energy, in kJ, evolved during the reaction.	
				[1]
			Heat evolved = (90 + 22.0)(1.00)(4.18)(4.0) = 1.87 kJ	
		(vii)	Calculate the enthalpy change of neutralisation, in kJ mol^{-1}.	
				[2]
			$H^+ + OH^- \rightarrow H_2O$ ΔH_{neut} = −1.87 / [(1.50)(0.022)] = −56.7 kJ mol^{-1}	
	(b)	**(i)**	Using your answers from **a(iv)** and **a(v)**, calculate the amount of propanoic acid present at equilibrium.	
				[1]
			Amount of propanoic acid at equilibrium =(1.50)(0.022) − 0.0120 = 0.0210 mol	
		(ii)	Define *dynamic equilibrium.*	
			…… ……	**[1]**

			……..……..	
			Dynamic equilibrium refers to a reversible process at equilibrium in which the rate of forward reaction is equal to the rate of backward reaction where [product] and [reactant] remain constant.	
		(iii)	Use the information given and the answer from **b(i)**, complete the table below.	**[2]**

	C_2H_5OH	CH_3CH_2COOH	$CH_3CH_2COOC_2H_5$	H_2O
Initial amount / mol				
Equilibrium amount / mol				

	C_2H_5OH	CH_3CH_2COOH	$CH_3CH_2COOC_2H_5$	H_2O
Initial amount / mol	0.161	0.0300	0	0.150
Equilibrium amount / mol	0.152	0.021	9×10^{-3}	0.159

		(iv)	Write an expression for the equilibrium constant, K_c.	
			……..…….. ……..……..	**[1]**
			$K_c = \frac{[C_2H_5OH][CH_3CH_2COOH]}{[CH_3CH_2COOC_2H_5][H_2O]}$	
		(iv)	Calculate the numerical value of K_c.	
				[1]

			$K_c = \frac{(\frac{0.009}{v})(\frac{0.159}{v})}{(\frac{0.152}{v})(\frac{0.021}{v})} = 0.448$ (no units)	
	(c)	Draw the structure of ethanol and state the bond angle about the carbon atoms.		
				[2]
		 Bond angle: 109.5°		
				[Total: 20]