1	(a)	When studying Hydrocarbons, we recognised the environmental consequences of	
		carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the	
		internal combustion engine.	
		Because of these environmental concerns, alongside with high oil prices and oil	
		being a limited natural resource, development of cleaner alternative fuels and	
		advanced power systems for vehicles has become a high priority for many	
		governments and vehicle manufacturers around the world.	
		An alternative fuel vehicle is a vehicle that runs on a fuel other than "traditional"	
		petroleum fuels (petrol or diesel): and also refers to any technology of powering an	
		engine that does not involve solely petroleum (e.g. electric car, hybrid electric	
		vehicles, solar powered).	
		One such source of alternative fuel is the <b>hydrogen / oxygen fuel cell</b> , which is	
		increasingly used in space crafts.	
		Describe, providing details, the hydrogen / oxygen fuel cell.	
		Include the following in your answer:	
		Draw a well-labeled diagram for the cell.	
		• Outline the reactions taking place at each electrode, assuming an alkaline	
		medium.	
		<ul> <li>State one advantage of using this fuel cell.</li> </ul>	[6]
		steam	
		(-) $(+)$ porous graphite	
		porous graphite coated with nickel and nickel oxide (+)	
		coated with nickel (–)	
		hydrogen — oxygen	
		[KOH(4())	
		(1 mark for correct electrolyte, 1 mark for labelled anode, 1 mark for labelled	,,,
		In alkaline electrolyte Reaction at anode: $H_{2(q)} + 2OH^{-}_{(aq)} \otimes 2H_2O_{(1)} + 2e$	;
		Reaction at cathode: $\frac{1}{2}O_{2(g)} + H_2O_{(l)} + 2e \ \mathbb{B} \ 2OH^{-}_{(aq)}$	;
		Overall cell reaction: $H_{2(g)} + \frac{1}{2}O_{2(g)} \otimes H_2O_{(l)}$	

	Advantage: Clean products are produced. OR Water produced in hydrogen-oxygen fuel cell used in spacecraft can be used for	;
	drinking and washing.	
(b)	Cyanogen is a highly toxic gas, composing of 46.2% carbon and 53.8% nitrogen by	
()	mass. At 25 °C and 1 atm, 1.05 g of cyanogen occupies 0.500 dm <sup>3</sup> .	
(i)	Determine the molecular formula of cyanogen.	
	C N	
	% mass 46.2 53.8	
	Mole ratio 3.85 3.84	
	Simple ratio 1 1	
		;
	Empirical formula of cyanogen is CN.	
	Using PV = nRT	
	$1.01 \times 10^5 \times 0.5 \times 10^{-3} = (1.05 / Mr) \times 8.31 \times 298$	
	$M_r = 51.5 (1 \text{ d.p})$	;
	Thus, molecular formula of Cyanogen = $\underline{C_2N_2}$	;
(ii)	Draw the dot-and-cross diagram for cyanogen. Hence, state its shape.	
	N≡C-C≡N , linear	;;
(iii)	<i>'Cyanogen is soluble in ethanol.'</i> Explain this statement with the aid of a suitable diagram.	[7]
	Cyanogen can form hydrogen bonds with ethanol as it has a lone pair of electrons	;
	on nitrogen, thus soluble in ethanol.	
	$CH_3CH_2$ $H_1$ $H_2$ $H_3$ $H_2$ $H_2$ $H_3$ $H_2$ $H_3$ $H_2$ $H_3$	;
	(lone pairs on N and O, $\delta$ +, $\delta$ - must all be clearly shown)	
(-)	Olympic and even a the two of the second for the stands and invite we differ the second	
(C)	Sketch and explain the trend observed for the atomic and ionic radii of the elements (from Na to $Cl$ ) in Period 3.	[4]
	radius / nm 0.22 0.20 0.18 0.16 0.14 0.12 0.10 0.08 0.06 0.04 0.08 0.06 0.04 0.14 0.12 0.18 0.16 0.14 0.12 0.18 0.16 0.14 0.12 0.08 0.06 0.08 0.06 0.08 0.06 0.08 0.06 0.08 0.06 0.04 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.00 0.02 0.02 0.00 0.02	;

	Atomic Radius:	
	nuclear charge ↑ as proton number ↑	
	change in the screening effect is negligible (Same no. of inner shells of ers across	;
	the period). Thus the outer es are more strongly attracted by the nucleus	
	∖ atomic radii ↓	
	Cations (Nat to Si <sup>4+</sup> )	
	cations have one shell less than neutral atoms. Thus, the outer es are more	;
	strongly attracted by the nucleus therefore having a smaller radius than its parent	
	atoms.	
	Anions (P <sup>3-</sup> to C <i>l</i> )	
	• anions have more es than protons and so, the effective attractive force on the	;
	outer es is less than that in neutral atoms.	
	P the outer e's are less strongly attracted by the nucleus, thus having a radius that is larger than its parent atoms.	
(d)	Phosphine, PH <sub>3</sub> , a gas at room temperature can be prepared by action of sodium	
	hydroxide on phosphonium iodide, $PH_4I$ . When 1.00 g of phosphonium iodide	
	reacted with solid sodium hydroxide, 0.925 g of white solid was formed, together	
	with steam and 150 cm <sup>3</sup> of PH <sub>3</sub> gas.	
	All measurements were taken at room temperature and pressure.	
	Identify the white solid and use the information given to write a balanced equation	[3]
	with state symbols for the preparation of PH <sub>2</sub>	[0]
	The white solid is Nat	
	Molar mass of $PH_{4}I = 162.0$	,
	Amount of $PH_4I = 1 / 162 = 0.00617$ mol	
	Amount of Na I = $0.925 / (23.0 + 127.0) = 0.00617$ mol	
	Amount of $PH_3 = 150 / 24000 = 0.00625 \text{ mol}$	
	Mole ratio of $PH_4 I : PH_3 : Na I \approx 1 : 1 : 1$	;
	Thus,	
	$PH_4 \operatorname{I}(s) + NaOH(s) \rightarrow Na\operatorname{I}(s) + PH_3(g) + H_2O(g)$	
	(state symbols must be correct to earn this mark)	;
	[Total: 20 marks]	

2	(a)	Halogen o	lerivatives	can be used to synthesize alcohols.	
		The overa	Il reaction	is shown below:	
			С	$H_3CH_2Br$ + NaOH $\rightarrow$ CH <sub>3</sub> CH <sub>2</sub> OH + NaBr	
		State the	type of rea	ction mechanism for the above reaction and illustrate how the	
		reaction p	roceeds via	a the mechanism you stated.	[3]
		Nucleoph	ilic Substitu	ition, S <sub>N</sub> 2	
			$\mathcal{H}$		
		О́Н <sup>Н</sup>	l − C − Br	$HO \xrightarrow{-} C \xrightarrow{-} HO $	
			H <sub>3</sub> C	$\begin{bmatrix} H & CH_3 \end{bmatrix}$ $CH_3$	
		1 mark fo	r name of n	nechanism S <sub>N</sub> 2	
		1 mark fo	r clearly sh	own arrow pushing	
		1 mark fo	r correct in	ntermediate and the final product must have the structure of an	
		'inverted u	umbrella'		
	(b)	Describe	the reaction	ons of chloride, bromide and iodide ions with the following	
		reagents:			
		Ι.	Aqueous	silver nitrate, followed by aqueous ammonia	
		II.	Concentra	ated sulfuric acid	
		You are re	equired to v	write equations where appropriate and give explanations for the	
		difference	s in their re	eactions.	[7]
		difference	s in their re	eactions.	[7]
		difference Ppt	s in their re	Reaction with NH <sub>3</sub> (aq)	[7]
		difference Ppt	s in their re	eactions. Reaction with NH <sub>3</sub> (aq) $AgCl(s) + 2NH_3 (aq) \rightarrow [Ag (NH_3)_2]^+ (aq) + Cl^- (aq)$	[7]
		difference Ppt	s in their re	Provide the section of the section section section section section section with NH <sub>3</sub> (aq) $AgCl(s) + 2NH_3 (aq) \rightarrow [Ag (NH_3)_2]^+ (aq) + Cl^- (aq)$ $diamine \ silver \ (l) \ ion$	[7]
		Ppt AqC/	s in their re Colour	eactions. Reaction with NH <sub>3</sub> (aq) $AgCl(s) + 2NH_3 (aq) \rightarrow [Ag (NH_3)_2]^+ (aq) + Cl^- (aq)$ <i>diamine silver (I) ion</i>	[7]
		Operation       Ppt       AgCl	s in their re Colour White	Provide the section is $I = I + I + I + I + I + I + I + I + I + $	[7]
		Operation       Ppt       AgCl	s in their re Colour White	Provide the section is the section	;
		Operation       Ppt       AgCl	s in their re	Provide the section of the section of the section sec	;
		Ppt AgC <i>l</i>	s in their re Colour White	Predictions. Reaction with NH <sub>3</sub> (aq) AgCl(s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +Cl <sup>-</sup> (aq) <i>diamine silver (I) ion</i> White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (I) ion. AgBr (s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq)	[7]
		Ppt       AgCl	s in their re Colour White Pale	eactions. Reaction with NH <sub>3</sub> (aq) AgCl(s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +Cl <sup>-</sup> (aq) <i>diamine silver (I) ion</i> White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (I) ion. AgBr (s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq) <i>diamine silver (I) ion</i>	[7]
		Ppt AgC <i>l</i> AgBr	s in their re Colour White Pale yellow/	eactions. $\frac{\text{Reaction with NH}_3 (aq)}{\text{AgC}l(s) + 2\text{NH}_3 (aq) \rightarrow [\text{Ag} (\text{NH}_3)_2]^+ (aq) + Cl^- (aq)}{diamine silver (l) ion}$ White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion. AgBr (s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq) $diamine silver (l) ion$	[7]
		Output       Output	s in their re Colour White Pale yellow/ Cream	Reaction with NH <sub>3</sub> (aq)         AgCl(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +Cl <sup>-</sup> (aq)         diamine silver (l) ion         White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion.         AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq)         diamine silver (l) ion         Cream precipitate ONLY dissolves in Conc. NH <sub>3</sub>	[7]
		Output       Output	s in their re Colour White Pale yellow/ Cream	AgCl(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +Cl <sup>-</sup> (aq) diamine silver (l) ion White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion. AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq) diamine silver (l) ion Cream precipitate ONLY dissolves in <b>Conc.</b> NH <sub>3</sub> solution.	[7]
		Output       Output         AgCl       AgBr	s in their re Colour White Pale yellow/ Cream	eactions. Reaction with NH <sub>3</sub> (aq)         AgCl(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +Cl <sup>-</sup> (aq)         diamine silver (l) ion         White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion.         AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq)         diamine silver (l) ion         Cream precipitate ONLY dissolves in Conc. NH <sub>3</sub> solution.         Precipitate insoluble in NH <sub>2</sub> (aq)	[7]
		Ppt         AgCl         AgBr         AgI	s in their re Colour White Pale yellow/ Cream Deep yellow/	eactions. $\frac{\text{Reaction with NH}_3 (aq)}{\text{AgC}l(s) + 2\text{NH}_3 (aq) \rightarrow [\text{Ag} (\text{NH}_3)_2]^+ (aq) + Cl^- (aq)}{diamine silver (l) ion}$ White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion. AgBr (s) + 2NH <sub>3</sub> (aq) $\rightarrow$ [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br (aq) $diamine silver (l) ion$ Cream precipitate ONLY dissolves in <b>Conc.</b> NH <sub>3</sub> solution. Precipitate insoluble in NH <sub>3</sub> (aq)	[7]
		Ppt         AgCl         AgBr         AgI	s in their re Colour White Pale yellow/ Cream Deep yellow	AgC/(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +C <i>l</i> <sup>-</sup> (aq) <i>diamine silver (l) ion</i> White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion. AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq) <i>diamine silver (l) ion</i> Cream precipitate ONLY dissolves in <b>Conc.</b> NH <sub>3</sub> solution. Precipitate insoluble in NH <sub>3</sub> (aq)	[7] ; ;
		Ppt         AgCl         AgBr         AgI	s in their re Colour White Pale yellow/ Cream Deep yellow	Reaction with NH <sub>3</sub> (aq)         AgC/(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +C <i>I</i> <sup>-</sup> (aq)         diamine silver (l) ion         White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (l) ion.         AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq)         diamine silver (l) ion         Cream precipitate ONLY dissolves in Conc. NH <sub>3</sub> solution.         Precipitate insoluble in NH <sub>3</sub> (aq)	[7] ; ;
		Ppt         AgCl         AgBr         AgI	s in their re Colour White Pale yellow/ Cream Deep yellow	Reaction with NH <sub>3</sub> (aq)         AgCI(s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) +CI <sup>-</sup> (aq)         diamine silver (I) ion         White precipitate readily dissolves in NH <sub>3</sub> (aq) to give a colourless solution, diamine silver (I) ion.         AgBr (s) + 2NH <sub>3</sub> (aq) → [Ag (NH <sub>3</sub> ) <sub>2</sub> ] <sup>+</sup> (aq) + Br <sup>-</sup> (aq)         diamine silver (I) ion         Cream precipitate ONLY dissolves in Conc. NH <sub>3</sub> solution.         Precipitate insoluble in NH <sub>3</sub> (aq)	[7]



	$\begin{array}{c} CO_2H \\ \hline \\ $	
	reflux NO <sub>2</sub>	
	$\begin{array}{c} & & & & & & \\ Sn, & & & & & \\ \hline conc. \ HCl \\ \hline heat \ under \\ reflux \\ \hline \end{array} \begin{array}{c} & & & & \\ NH_2 \\ \hline \end{array} \begin{array}{c} & & & \\ NH_2 \\ \hline \end{array} \begin{array}{c} & & & \\ NH_2 \\ \hline \end{array} \begin{array}{c} & & & \\ NaNO_2 \\ dilute \ HCl \\ \hline \\ S^{\circ}C \\ \hline \end{array} \begin{array}{c} & & \\ N_2^+ \\ \hline \end{array} \begin{array}{c} & & \\ N_2^+ \\ \hline \end{array} \begin{array}{c} & & \\ N_2^+ \\ \hline \end{array} \begin{array}{c} & & \\ Cl \\ \hline \end{array} \begin{array}{c} & & \\ CO_2H \\ \hline \\ & & \\ Cl \\ \hline \end{array} \begin{array}{c} & & \\ CO_2H \\ \hline \\ & & \\ Cl \\ \hline \end{array} \begin{array}{c} & & \\ Br \\ \hline \end{array}$	
	(1 mark for every underlined answer)	
 (d)	Arrange the following halogen containing compounds according to increasing $pK_a$	
	values. Explain your answer.	[0]
		[3]
	Increasing pKa value: CH <sub>3</sub> CCl <sub>2</sub> COOH , CH <sub>3</sub> CHC/COOH , CH <sub>3</sub> CHBrCOOH	;
	$CH_3CCl_2COOH$ has the smallest pK <sub>a</sub> (thus most acidic) as there is the presence of	
	two electron withdrawing Cl atoms. This, the negative charge on the O atom in	
	$(CH_3CCl_2COO^-)$ is more dispersed than in $(CH_3CHClCOO^-)$ . Thus the $CH_3CCl_2COO^-$	
	anion is more stable, and the acid is more willing to donate a proton, increasing the acidity of the solution.	;
	$CH_3CHBrCOOH$ has the largest pK <sub>a</sub> value (least acidic) as Br is less electronegative	
	than C <i>l</i> . Thus, the electron withdrawing ability of Br is less than C <i>l</i> . Thus the	
	CH <sub>3</sub> CHBrCOO <sup>-</sup> anion is less stable, and the acid is less willing to donate a proton,	
	decreasing the acidity of the solution.	;
	(no marks for correct arrangement without explanation)	
(e)	Explain the following physical property trends of transition metals across the Period.	
	I: relatively constant atomic radius	[0]
		[2]
	P Electrons are being added to inner 3d subshell.	
	Screening effect of 3d electrons effectively cancels almost all increase in nuclear charge across series.	
	Hence, there is a relatively small difference in the effective nuclear charge and	
	atomic radius remains relatively constant.	;
	Strong metallic bonding in transition elements due to availability of both the 4s and 3d electrons for delocalisation, thus melting point increases.	;
	[Total: 20 marks]	

3	(a)	An Ellingham diagram shows how the change in Gibbs free energy for a particular	
		reaction varies with temperature.	
		The following shows a sketch of an Ellingham diagram for three reactions:	
		I: $2C(s) + O_2(g) \rightarrow 2CO(g)$ $\Delta G = (-223 - 0.18T) \text{ kJ mol}^{-1}$	
		II: 2Fe (s) + O <sub>2</sub> (g) $\rightarrow$ 2FeO (s) $\Delta G = (-525 + 0.13T) \text{ kJ mol}^{-1}$	
		III: $\frac{4}{3}$ Al (s) + O <sub>2</sub> (g) $\rightarrow \frac{2}{3}$ Al <sub>2</sub> O <sub>3</sub> (s) $\Delta G = (-1116 + 0.21T)$ kJ mol <sup>-1</sup>	
		$\begin{array}{c} -200 \\ -400 \\ -100 \\ -1200 \\ 0 \\ -1200 \\ 0 \\ -1000 \\ -1$	
	(i)	Predict and explain what will happen to the value of $\Delta G$ when the pressure of the system	
		in reaction I is reduced.	
		When pressure in reaction I is reduced, By LCP the system will counteract by increasing	
		pressure, thus equilibrium will shift to the right where more amount of gas will be	
		produced. Thus, $\Delta S > 0$ .	;
		Since $\Delta G = \Delta H - T\Delta S$ , and $\Delta S > 0$ ,	
		$\Delta G$ then becomes more negative, as pressure is reduced.	;
	(11)		
	(ii)	Explain why the gradient for reaction I is negative (downward sloping), while the gradient	
		for reactions II and III are positive (upward sloping)?	
		The gradient of the graph represents - $\Delta S$ .	,
		in reaction 1, there is an <u>increase in the disordeniness</u> as number of moles of gaseous	
		Increased from 1 to 2 moles. Thus, $\Delta S > 0$ and the overall gradient is negative.	,
		moles of gases decreased from 1 to 0 moles. Thus, AS<0, and the overall gradient is	
			;
-			
$\vdash$	(iii)	Calculate $\Lambda G$ of the following reaction at 1000K:	
		FeO (s)+ C (s) $\rightarrow$ Fe (s) + CO (a)	

	At T = 1000 K, (I) $2C(s) + O_2(g) \rightarrow 2CO(g)$ $\Delta G = -223 - 0.18(1000) = -403 \text{ kJ mol}^{-1}$ (II) $2Fe(s) + O_2(g) \rightarrow 2FeO(s) \Delta G = -525 + 0.13(1000) = -395 \text{ kJ mol}^{-1}$	;;
	Adding:	:
	2FeO + 2C → 2Fe + 2CO △G= -403 - (-395) = -8 kJ mol <sup>-1</sup>	;
	For the reaction: $FeO(s) + C(s) \rightarrow Fe(s) + CO(g)$ $\Delta G = -4 \text{ kJ mol}^{-1}$	,
 (iv)	Hence, what is the minimum temperature at which the reduction of iron (II) oxide by	
	carbon becomes thermodynamically feasible?	
	For the minimum temperature in which the extraction can occur, this happens at	
	the intersection point.	;
	$\Delta G^{\Theta} = -223 - 0.18T = -525 + 0.31T$	
	Solving, T = <u>974 K</u>	;
(v)	Aluminium oxide and carbon have high melting points. With reference to the Ellingham	
	diagram, explain why carbon is <b>not</b> used to line vessels that are used to contain molten	
	steel saturated with oxygen.	[14]
	[The melting point of steel is 1800 K]	
	From the Ellingham diagram, at T=1800K, reaction I is still thermodynamically feasible.	;
	$\Delta G = -223 - 0.18 (1800) = -547 \text{ kJ mol}^{-1}$	;
	Thus oxygen can react with carbon to form CO since $\Delta G < 0$ and reaction is spontaneous.	
	Thus carbon is not used as a lining material at such a high temperature in the presence of	
	oxygen gas.	,
 (h)	The manipulation and rearrangement of the Cikbe free energy equation shows a relation	
(a)	The manipulation and rearrangement of the Globs free energy equation shows a relation	
 (i)	Define the term standard electrode notential of a cell	
 (1)	Standard electrode potential Effect a call in the relative potential of this call under	
	standard electrode potential, E <sup>22</sup> of a cell is the <u>relative potential of this cell under</u>	,
	standard conditions compared with the standard hydrogen electrode whose electrode	,
 (ii)	With the use of relevant data from the data booklet, state and illustrate how the relative	
(11)	stabilities of the Ee (II) / Ee (III) oxidation states are affected by the following changes:	
	L CN-ligands	
		[6]
		[0]
	Or $Fe^{3^{*}} + e^{-7^{*}} = Fe^{2^{*}} = E^{0} = +0.77 V$	
	$[Fe(CN)_6]^{3^-} + e \implies [Fe(CN)_6]^{4^-} = +0.36 V$	,
	Fe <sup>3+</sup> is stabilised with respect to Fe <sup>2+</sup> when complexed with CN <sup>-</sup> resulting in a less	:
	positive reduction potential.	

	$ \begin{bmatrix} Fe(H_2 O)_6 \end{bmatrix}^{3^+} + e & \longrightarrow \\ Fe^{3^+} + e & \longrightarrow \\ Fe(OH)_3 + e & \longrightarrow \\ Fe(OH)_2 + OH^- & E^0 = +0.77 \text{ V} \\ Fe^{(OH)_3 + e} & \longrightarrow \\ Fe^{(OH)_2 + OH^-} & E^0 = -0.56 \text{ V} \\ \end{bmatrix} $ Fe <sup>3+</sup> is stabilised with respect to Fe <sup>2+</sup> by an alkaline medium, resulting in a less positive reduction potential.	- 3 3
	[Total: 20 marks]	

(a)	) Compound K is formed when phenylhydroxylamine, $C_6H_5NHOH$ , is warmed with	n dilute	
	sulfuric acid. Compound <b>K</b> has the following properties:		
	• <b>K</b> is not very soluble in water, but dissolves in HC <i>l</i> (aq)		
	<ul> <li>K dissolves in NaOH (aq) but not in Na<sub>2</sub>CO<sub>3</sub> (aq)</li> </ul>		
	• <b>K</b> reacts with 1 mol of ethanoyl chloride to give compound $L$ , $C_8H_9O_2N$ , w	vhich is not	
	soluble in HCl (aq), but is soluble in NaOH (aq).		
	• <b>L</b> reacts with $Br_2$ (aq) to give compound <b>M</b> , $C_8H_7O_2NBr_2$ .		
	• K reacts with 2 mol of ethanoyl chloride to give compound N, $C_{10}H_{11}O_3N_2$	, which is not	
	soluble in HC <i>l</i> (aq) or NaOH (aq).		
(i)	Suggest structures for compounds K, L, M and N.		
	Present your reasoning clearly by explaining the Chemistry involved.		
(ii)	Write balanced chemical equations for each of the bullet points above to show h	low the	
	reactions proceeded.		[12]
	OH OH NHCOCH <sub>3</sub> NHCOCH <sub>3</sub>		
	Br Br		
	K: $\dot{NH}_2$ L: $\dot{NHCOCH}_3$ M: $\dot{OH}$ N: $\dot{OCOCH}_3$		
	Observations Deductions		
	ObservationsDeductionsK is not very soluble in water,K contains a hydrophobic group.		
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.		
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) butK contains an acidic group that is not	a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a	a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.	a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoylL is acidic (contains the phenol group)	a a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a 	a a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a 	a a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in HCl (aq)K contains a basic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a 	a a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a 	a a	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HC/ (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a 	a a b	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group. K contains a basic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, 	a a o	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, C <sub>8</sub> H <sub>9</sub> O <sub>2</sub> N, which is not soluble 	a a )	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HC/ (aq)K contains a hydrophobic group.K dissolves in HC/ (aq)K contains a basic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, C8H9O2N, which is not soluble 	a a b ly le r	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HC/ (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, CaHaO2N, which is not soluble in HCI (aq), but is soluble in NaOH (aq).L is acidic (contains the phenol group from K) and also contains an amide.L reacts with Br2 (aq) to give compound M, CaHrO2NBr2.Electrophilic substitution occurs readi as the benzene ring is activated by th phenol group.K reacts with 2 mol of ethanoyl chloride to give compound N, and amide functional groups.N is neutral and N contains both ester and amide functional groups.	a a ) ly ie r	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group.K dissolves in NaOH (aq) but not in Na <sub>2</sub> CO <sub>3</sub> (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, C <sub>8</sub> H <sub>9</sub> O <sub>2</sub> N, which is not soluble in HCl (aq), but is soluble in NaOH (aq).L is acidic (contains the phenol group from K) and also contains an amide.L reacts with Br <sub>2</sub> (aq) to give compound M, C <sub>8</sub> H <sub>7</sub> O <sub>2</sub> NBr <sub>2</sub> .Electrophilic substitution occurs readi as the benzene ring is activated by th phenol group.K reacts with 2 mol of ethanoyl chloride to give compound N, C <sub>10</sub> H <sub>11</sub> O <sub>3</sub> N, which is not solubleN is neutral and N contains both ester and amide functional groups.	a a b ly le r	
	ObservationsDeductionsK is not very soluble in water, but dissolves in HCl (aq)K contains a hydrophobic group. K contains a basic group.K dissolves in NaOH (aq) but not in Na2CO3 (aq)K contains an acidic group that is not carboxylic group. Hence, K contains a phenol group.K reacts with 1 mol of ethanoyl chloride to give compound L, C <sub>8</sub> H <sub>9</sub> O <sub>2</sub> N, which is not soluble in HCl (aq), but is soluble in NaOH (aq).L is acidic (contains the phenol group from K) and also contains an amide.L reacts with Br2 (aq) to give compound M, C <sub>8</sub> H <sub>7</sub> O <sub>2</sub> NBr2.Electrophilic substitution occurs readi as the benzene ring is activated by th phenol group.K reacts with 2 mol of ethanoyl chloride to give compound N, C <sub>10</sub> H <sub>11</sub> O <sub>3</sub> N, which is not soluble 	a a b ly le r	



(b)	A student was given 4 unlabelled bottles and each bottle contains one of the following	
	organic compounds with a different functional group:	
	· 2º Alcohol	
	· Aldehyde	
	· Ketone	
	· 1º Amide	
	Outline a sequence of simple chemical tests by which you could identify each of the above	
	organic substances.	
	[Note: you are not allowed to identify the substances by elimination. You must give a positive test to prove the presence of each functional group present.]	[8]
	1. Test for aldehyde	
	Add tollen's reagent to 4 test tubes each of the unknown, warm.	;
	Silver mirror will be formed in the test tube containing the aldehyde only.	;
	2. Test for ketone	
	Add brady's reagent to new samples of the remaining 3 unknowns, warm.	;
	Orange ppt observed in the test tube containing the ketone only.	;
	3. Test for 2 <sup>o</sup> alcohol.	
	Add KrCr <sub>2</sub> O <sub>7</sub> / $H_2SO_4$ to the remaining two unknowns. Heat under reflux.	;
	Orange solution of $Cr_2O_7^{2-}$ decolorize for test tube containing the 2 <sup>o</sup> alcohol only.	;
	(KMnO₄ accepted, iodoform test not accepted)	
	4. Test for 1° amide	
	Add NaOH (aq) to a new sample of the remaining test tube. Warm.	;
	Effervescence, colourless, pungent gas evolved that turned moist red litmus blue.	,
	[Total: 20 marks]	

piece of sodium (of known mass) to a large excess of ethanol and measured the total volume of gas liberated every minute. The results obtained are given below:	
volume of gas liberated every minute. The results obtained are given below:	
Time / min         0         1         2         3         4         5         6         7         ∞	
Total vol. of         0         23.0         36.5         46.0         51.0         54.5         57.0         58.5         58.5	
gas produced /	
(i) Write an equation with state symbols for the above reaction.	
Na (s) + C <sub>2</sub> H <sub>5</sub> OH ( $l$ ) $\rightarrow$ C <sub>2</sub> H <sub>5</sub> O <sup>-</sup> Na <sup>+</sup> (aq) + $\frac{1}{2}$ H <sub>2</sub> (g)	;
(ii) Give two reasons why sodium must be freshly cut?	
Na must be freshly cut because it rapidly oxidised by O <sub>2</sub> in air to form a layer of oxide (Na <sub>2</sub> O)	;
on its surface.	
Na also reacts with the water vapour present in air.	;
(iii) By plotting a suitable graph on graph paper, explain why the experimental results indicate	
that the overall kinetics is first order.	
1 mark for correct axis chosen (graph of total volume of gas produced against time)	
1 mark for collect plotting	
1 mark for indicating on graph that half-life of the reaction is first order (must state the value	
of half-life to be 1.5min)	
(half-life measured from 0 - 29.3 cm <sup>3</sup> , and from 29.3 - 43.9 cm <sup>3</sup> of $H_2$ )	
70	
(iv) Hence, suggest why the reaction appears to be zero order with respect to ethanol in this	
experiment.	
Since ethanol is present in large excess, the concentration of ethanol does not change. Thus	
rate is independent on concentration of ethanol / reaction is zero order with respect to	:
ethanol.	,
(v) The student modified the experiment by changing the concentration of ethanol.	
With the aid of a suitable equation, explain why water should not be used to dilute ethanol	
	[8]
Na (s) + H <sub>2</sub> O (l) $\rightarrow$ NaOH (aq) + ½ H <sub>2</sub> (q)	;

	(b)	A solution containing ethanoic acid and sodium ethanoate functions as a buffer.	
	(i)	Explain what is meant by the term buffer solution, and write suitable equations to show how	
		this solution functions as a buffer.	
		A buffer solution is a solution whose pH remains relatively unchanged when a small amount	;
		of acid or alkali is added to it.	
		When a small amount of base is added,	
		$CH_{3}COOH + OH^{-} \rightarrow CH_{3}COO^{-} + H_{2}O$	;
		When a small amount of acid is added,	
		$CH_3COO^- + H^+ \rightarrow CH_3COOH$	;
	(ii)	Calculate the pH of the resulting solution when 25 cm <sup>3</sup> of 0.10 mol dm <sup>-3</sup> of ethanoic acid was	
		added to 10 cm <sup>3</sup> of 0.20 mol dm <sup>-3</sup> of NaOH.	
		[K <sub>a</sub> of ethanoic acid = $1.8 \times 10^{-5}$ mol dm <sup>-3</sup> ]	[7]
		Amount of ethanoic acid = 0.00250 mol	
		Amount of NaOH = 0.00200 mol	
		The limiting reagent is NaOH.	;
		Amount of $CH_3COO^2$ formed = 0.00200 mol	
		$[CH_3COO^-]_{eqm} = 0.002 / 0.035 = 0.05714 \text{ mol}$	;
		$[CH_3COOH]_{eqm} = (0.0025 - 0.002) / 0.035 = 0.01428$	
		$pH = pK_a + lg(0.05714)/(0.01428)$	
		$= -\lg (1.8 \times 10^{-5}) + \lg (0.05714) / (0.01428)$	;
		= <u>5.35 (3s.f)</u>	;
	(c)	A solution <b>X</b> is saturated with the soluble salts, NaNO <sub>3</sub> and Mg(NO <sub>3</sub> ) <sub>2</sub> .	
	(i)	When solution <b>X</b> is heated strongly, the salts start to decompose. State which salt will begin	
		to decomposes first, and the expected observations you will see to indicate that	
		decomposition has taken place. Explain your answer.	
		Mg(NO <sub>3</sub> ) <sub>2</sub> will decompose first.	
		Mg <sup>2+</sup> has a higher charge density as compared to Na <sup>+</sup> due to its higher charge and smaller	;
		ionic radius. Thus, its polarising power increases.	;
		$Mg^{2+}$ will polarise the <u>electron cloud of <math>NO_3^{-}</math>, distorting the N-O bonds</u> , releasing O <sub>2</sub> and N <sub>2</sub> .	
		Brown fumes of $N_2$ will be observed to indicate that the reaction has occurred.	
			;
	(11)	A student conducted an experiment to dissolve magnesium carbonate in solution $\mathbf{X}$ .	
		She noted down her observations as follows: 'I he solubility product of magnesium	
		carbonate decreased in solution X. Unly a small amount of magnesium carbonate dissolved.	
		Discuss in detail the validity of this statement, making corrections to the observations where	
		necessary.	[5]

The statement recorded by the student is wrong.	
The solubility product of magnesium carbonate does not decrease in Solution X. The	
solubility product <u>remains the same</u> in solution <b>X</b> , as solubility product is only affected by	;
changes in temperature.	
However, in solution X, due to the presence of the common ion, Mg <sup>2+</sup> , the solubility of	,
magnesium carbonate decreases.	
[Total: 20 marks]	

## END OF PAPER