

CHEMISTRY IS NOT A MYSTERY

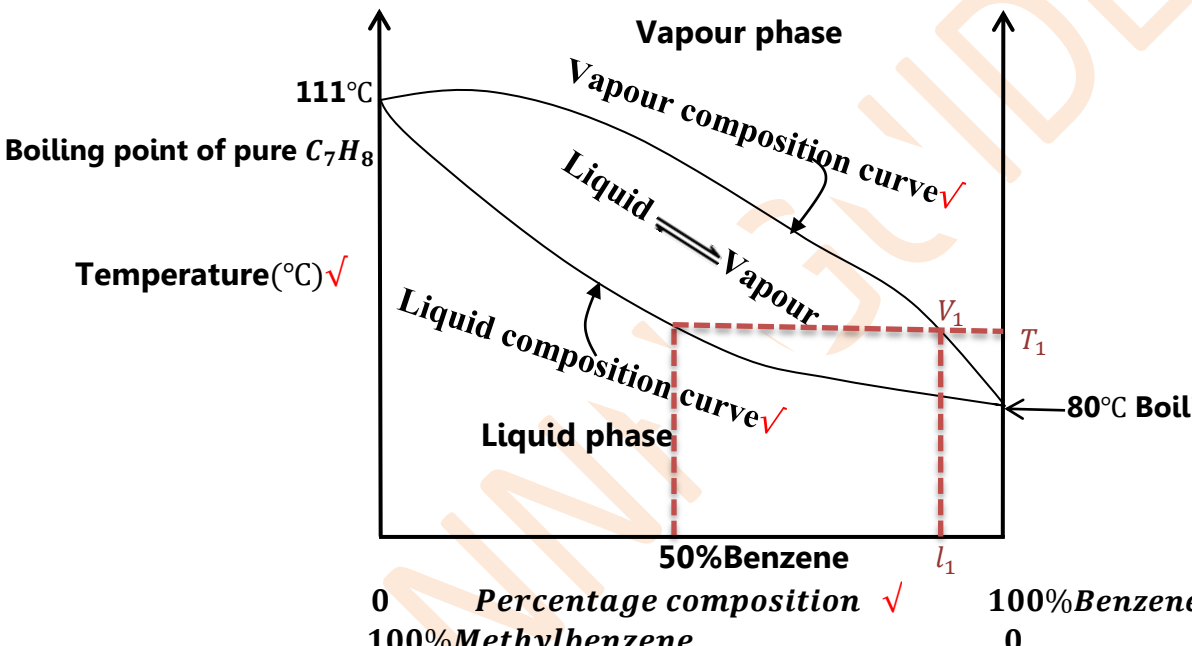
ZOOM A LEVEL SEMINAR FOUR

(Guide to discussed Qns)

	SUGGESTED ANSWER	Points to note
QUESTION ONE;		
1(a)	<p>Raoult's law states that the partial vapour pressure of a volatile component in a solution at a given temperature is equal to the vapour pressure of that pure component at the same temperature, multiplied by its mole fraction in the solution.✓</p> <p style="text-align: center;">Conditions under which Raoult's law holds</p> <ul style="list-style-type: none"> No heat change occurs on mixing the components of the solution.✓ The total volume of the solution is equal to the sum of the volumes of the pure components mixed to make the solution.✓ 	All key words must be shown.
(b) (i)	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Molar mass of $C_6H_6 = (6 \times 12) + (6 \times 1) = 78g.$✓</p> <p>Molar mass of $C_7H_8 = (7 \times 12) + (8 \times 1) = 92g.$✓</p> <p>$n_{C_6H_6} = \frac{23.4}{78} = 0.3 \text{ moles}$✓</p> <p>$n_{C_7H_8} = \frac{46}{92} = 0.5 \text{ moles}$✓</p> <p>$n_{total} = 0.3 + 0.5 = 0.8 \text{ moles}$</p> <p>$P_{C_6H_6} = x_{C_6H_6} P_{C_6H_6}^0$✓</p> <p>$= \left(\frac{0.3}{0.8}\right) \times 203 = 76.125 \text{ Nm}^{-2}.$✓</p> </div> <div style="width: 45%;"> <p>$P_{C_7H_8} = x_{C_7H_8} P_{C_7H_8}^0$</p> <p>$= \left(\frac{0.5}{0.8}\right) \times 76 = 47.5 \text{ Nm}^{-2}.$✓</p> <p>$P_{total} = P_{C_6H_6} + P_{C_7H_8}$</p> <p>$P_{total} = 76.125 + 47.5$</p> <p>$= 123.625 \text{ Nm}^{-2}.$✓</p> </div> </div>	Recall ESCA
(ii)	<p>Composition of C_6H_6 in the vapour $= \frac{P_{C_6H_6}}{P_{total}}$✓</p> <p>$= \frac{76.125}{123.625} = 0.616$✓</p> <p>Composition of C_7H_8 in the vapour $= \frac{P_{C_7H_8}}{P_{total}}$✓</p> <p>$= \frac{47.5}{123.625} = 0.384$✓</p>	Accept vapour composition expressed as a percentage other than mole fraction

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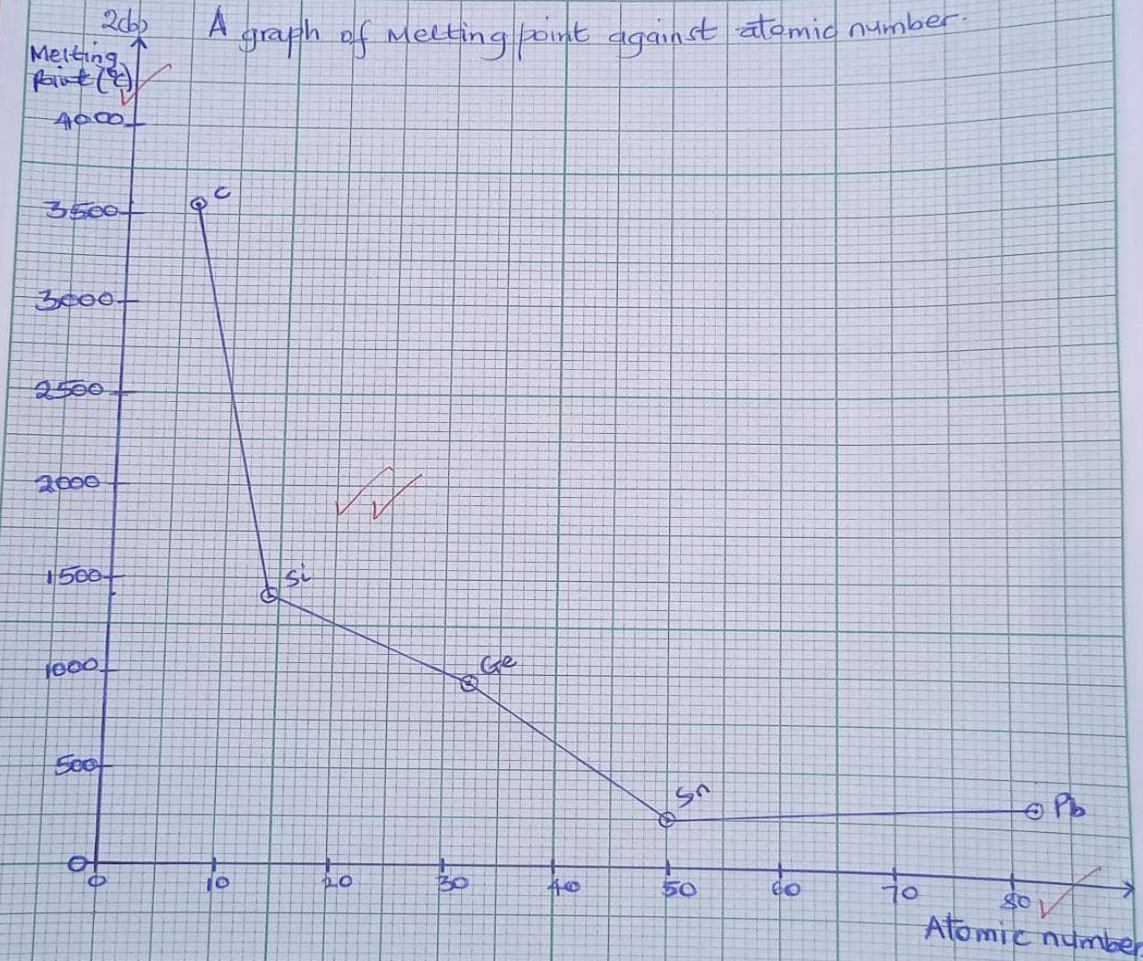
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(c)	Benzene and methylbenzene form an ideal solution because the forces of attraction between individual molecules of benzene are similar to the forces of attraction between individual molecules of methylbenzene ✓ and also similar to the forces of attraction between molecules of benzene and molecules of methylbenzene.✓ Also there is no heat change on mixing any proportions of the two liquids ✓ and the total volume of the solution is equal to the sum of the volumes of the two liquids mixed to make the solution. ✓	The whole concept is to bring out what makes a solution ideal
(d) (i)	 <p>Boiling point of pure C_7H_8 111°C</p> <p>Temperature(°C)✓</p> <p>Vapour phase</p> <p>Vapour composition curve✓</p> <p>Liquid ⇌ Vapour</p> <p>Liquid composition curve✓</p> <p>Liquid phase</p> <p>50%Benzene</p> <p>0 100% Methylbenzene Percentage composition ✓ 100%Benzene 0</p> <p>80°C Boiling point of pure C_6H_6</p> <p>T_1</p> <p>V_1</p> <p>l_1</p>	<p>Diagram should be well labeled</p> <p>Liquid and vapour curves should be smooth</p> <p>Deny marks if axes not labelled</p>
(ii)	<p>When a liquid of containing 50% of each component is heated, it boils at a temperature T_1°C✓ to form a vapour of composition, V_1,✓ containing a higher proportion of benzene✓ which is the more volatile component.</p> <p>When the vapour is condensed, it forms a liquid, l_1 of the same composition as the vapour.✓</p> <p>Repeated vapourisation and condensation,✓ will yield pure benzene as distillate and pure methylbenzene as residue.✓</p>	Evidence for use of a correctly sketched boiling point-composition diagram should shown.
(e)	Both components of an azeotropic mixture and the elements that make up a compound cannot be separated by fractional distillation.✓	

QUESTION TWO;		
2(a) (i)	+2 and +4✓	Reject subscripted or superscripted charges or just 2 and 4
(ii)	<p>Carbon does not react with chlorine. ✓</p> <p>Heated silicon reacts with dry chlorine to form silicon tetrachloride. ✓</p> $Si(s) + 2Cl_2(g) \longrightarrow SiCl_4(l)✓$ <p>Heated germanium reacts with dry chlorine to form germanium(IV) chloride. ✓</p> $Ge(s) + 2Cl_2(g) \longrightarrow GeCl_4(l)✓$ <p>Heated tin reacts with dry chlorine to form tin(IV) chloride. ✓</p> $Sn(s) + 2Cl_2(g) \longrightarrow SnCl_4(l)✓$ <p>Heated lead reacts with dry chlorine to form lead(II) chloride. ✓</p> $Pb(s) + Cl_2(g) \longrightarrow PbCl_2(s)✓$	Emphasize conditions, products and physical states for equations
(iii)	<p>Lead(II) oxide reacts with hot dilute hydrochloric acid to form lead(II) chloride and water. The lead(II) chloride precipitates out on cooling ✓ the mixture.</p> $PbO(s) + 2HCl(aq) \longrightarrow PbCl_2(aq) + H_2O(l)✓$ <p>However, with excess concentrated hydrochloric acid, lead(II) oxide reacts to form a complex of tetrachloroplumbate(II) ions, ✓ which is a soluble compound ✓ hence forming a colourless solution.</p> $PbO(s) + 2H^+(aq) + 4Cl^-(aq) \longrightarrow PbCl_4^{2-}(aq) + H_2O(l)✓$	Emphasize solubility, name of complex and equations.
(b) (i)	Melting point of a solid is the constant temperature at which the solid and liquid phases are in equilibrium at a given external pressure .	Accept correct alternative

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(ii)	<p>2(b) A graph of melting point against atomic number.</p> 	<p>Axes should be labeled and units present</p> <p>Scales should be consistent</p> <p>Points should be joined by straight lines</p>
(iii)	<p>Melting point decreases from carbon to tin ✓ and then increases slightly from tin to lead.</p> <p>Carbon has the highest melting point ✓ because it forms very many short and strong covalent bonds ✓ which require high amount of energy to break before it melts.</p> <p>From carbon to germanium, atomic radius increases, ✓ bond length increases, bond strength decreases, ✓ and a decreasing amount of energy is required to break the covalent bonds. ✓</p> <p>The further decrease in melting point from germanium to tin is because of longer and weaker metallic bonds in tin ✓ since tin has a larger atomic radius than germanium. ✓</p> <p>Melting point increases slightly from tin to lead ✓ due to increase in metallic bond strength as a result of inert pair effect. ✓</p>	<p>Variation in melting points are explained in terms of bonding and structure, forces of attraction holding the atoms/ molecules and factors affecting them</p>

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QUESTION THREE;

3(a)	This is the elevation of boiling point caused when one mole of a non-volatile solute is dissolved in 1000g of a solvent.✓	Emphasize key words.
(b)	<div data-bbox="240 373 1338 953" data-label="Image"> </div> <p>A known mass of pure carbon disulphide, g ✓ is placed in a wide boiling tube fitted with a side arm leading to a reflux condenser. The boiling tube is closed by a stopper through which is passed a second inner tube, open at the lower end and fitted with a Beckmann thermometer. ✓ In the carbon disulphide is immersed a Cottrell pump, C to prevent super heating The carbon disulphide is then heated until the Beckmann thermometer shows a constant temperature.✓ and the boiling point, T_b^0 °C.✓ is recorded. A known mass of phosphorus, y g is then added.✓ through the side arm to the carbon disulphide. The resulting solution is also heated until the Beckmann thermometer shows a constant temperature.✓ and the boiling point of the solution T_b °C.✓ is also recorded.</p> <p style="text-align: center;">Treatment of results</p> <p>Let the boiling point elevation constant of carbon disulphide be K_b °Cmol⁻¹kg⁻¹. ✓</p> <p style="text-align: center;"><i>Elevation of boiling point, $\Delta T = (T_b - T_b^0)$ °C. ✓</i></p> <p style="text-align: center;"><i>x g of carbon disulphide dissolve y g of phosphorus</i></p> <p style="text-align: center;"><i>1000 g of carbon disulphide will dissolve $\left(\frac{1000 \times y}{x}\right)$ g of phosphorus. ✓</i></p>	<p>Well labeled and working diagram</p> <p>(2 mks)</p> <p>Units of temperature shd be specified</p> <p>Experiment shd have a logical flow</p> <p>K_b shd have units and they must be correct</p> <p>Reject if RFM has units</p>

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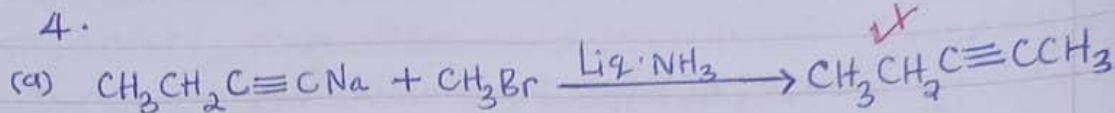
	ΔT is elevation of boiling point caused by $\left(\frac{1000 \times y}{x}\right)$ g of phosphorus. ✓ K_b will be elevation in boiling point caused by $\left(\frac{1000 \times y \times K_b}{x \times \Delta T}\right)$ g The relative molecular mass of phosphorus in carbon disulphide is $\left(\frac{1000 \times y \times K_b}{x \times \Delta T}\right)$. ✓		
(c)	Phosphorus(V) chloride reacts with water to form phosphoric acid and white fumes of hydrogen chloride gas . ✓ $PCl_5(s) + 4H_2O(l) \longrightarrow H_3PO_4(aq) + 5HCl(g)$ ✓		Reject dimerization or ionisation
(i)	Polystyrene is a polymer hence has a high relative molecular mass ✓ and in dilute solutions, the gives very few dissolved particles . ✓ The few dissolved particles cause a very small elevation in boiling point ✓ that cannot be measured by ordinary thermometers . ✓ The ebullioscopic method is not suitable because polystyrene tends to fragment and decompose at high temperatures . ✓		Already discussed in previous online seminars
(d)	100g of CS_2 dissolve 4.65 g of sulphur 1000g of CS_2 dissolve $\left(\frac{1000 \times 4.65}{100}\right)$ g of sulphur ✓ = 46.5 g of sulphur ✓ Elevation in boiling point, $\Delta T = 0.42^\circ C$ Molar mass of sulphur = 256g 46.5g of sulphur elevate boiling point by $0.42^\circ C$ ✓ 256 g of sulphur elevate boiling point by $\left(\frac{256 \times 0.42}{46.5}\right)$ ✓ = $2.312^\circ C mol^{-1} kg^{-1}$ The boiling point constant of carbon disulphide is $2.312^\circ C mol^{-1} kg^{-1}$ ✓		Reject substitution into a given formula Only accept first principles The final answer must have correct units
(i)	37.4g of CS_2 dissolve 2.00g of Phosphorus 1000g of CS_2 dissolve $\left(\frac{1000 \times 2}{37.4}\right)$ g ✓ of Phosphorus = 53.4759g of Phosphorus ✓ $1.003^\circ C$ is elevation in boiling point caused by 53.4759g ✓ $2.312^\circ C$ is elevation in boiling point caused by $\left(\frac{2.312 \times 53.4759}{1.003}\right)$ ✓ = 123.2665g Molar mass of Phosphorus in Carbon disulphide $\approx 123.27g$ ✓		“ ” Molar mass should have units
(ii)	37.4g of CS_2 dissolve 2.00g of Phosphorus 1000g of CS_2 dissolve $\left(\frac{1000 \times 2}{37.4}\right)$ g ✓ of Phosphorus = 53.4759g of Phosphorus ✓ $1.003^\circ C$ is elevation in boiling point caused by 53.4759g ✓ $2.312^\circ C$ is elevation in boiling point caused by $\left(\frac{2.312 \times 53.4759}{1.003}\right)$ ✓ = 123.2665g Molar mass of Phosphorus in Carbon disulphide $\approx 123.27g$ ✓		
(e)	$P_n = 123.27$ $31n = 123.27$ ✓ $n = 3.976$ $n \approx 4$ ✓	Molecular formula of Phosphorus in carbon disulphide is P_4 ✓	

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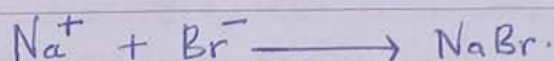
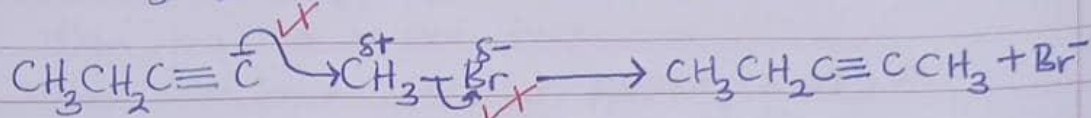
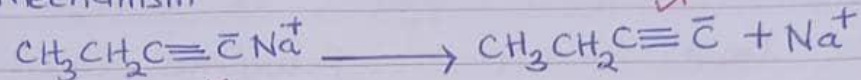
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QUESTION FOUR

4
(a)

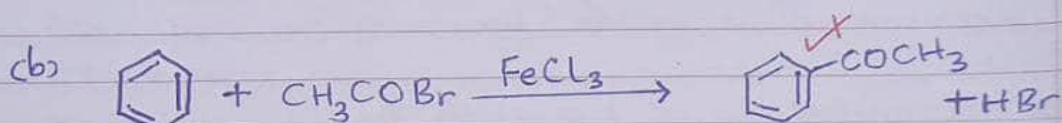


Mechanism:

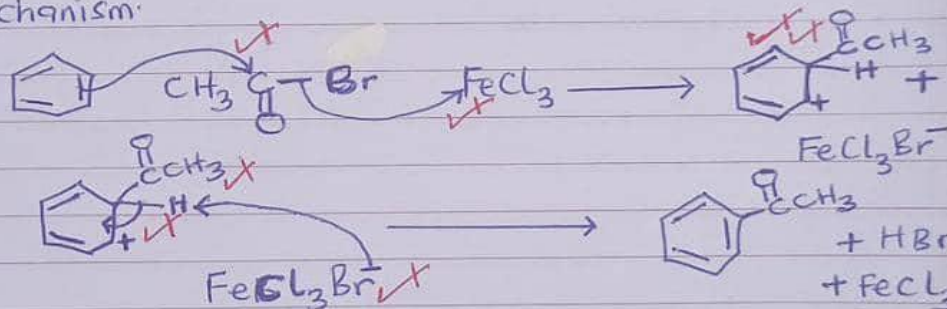


Reject hanging
arrows
Consider bond
proximity

(b)



Mechanism:

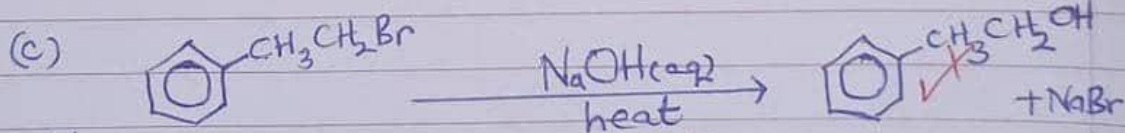


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Accept other
correct
alternative

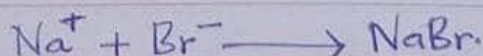
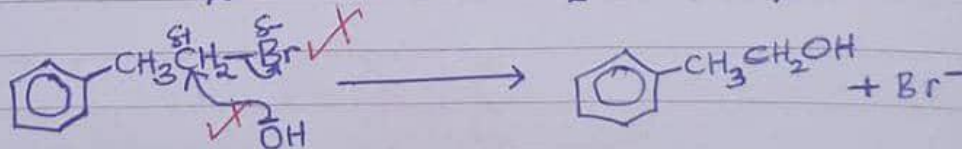
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(c)



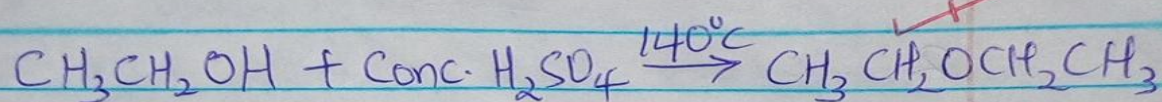
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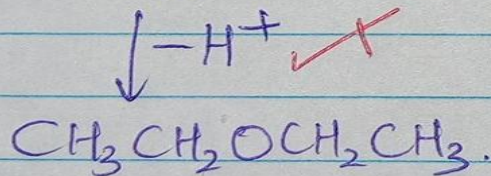
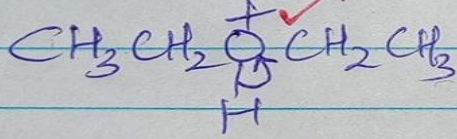
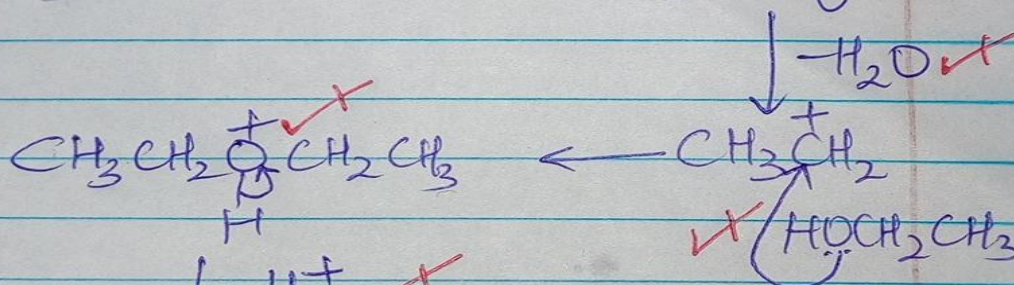
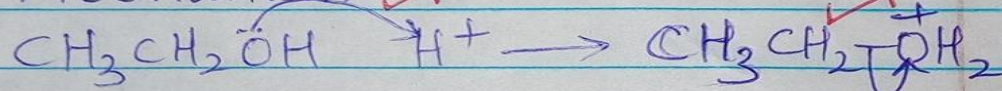
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Reject SN_1
mechanism

(d)



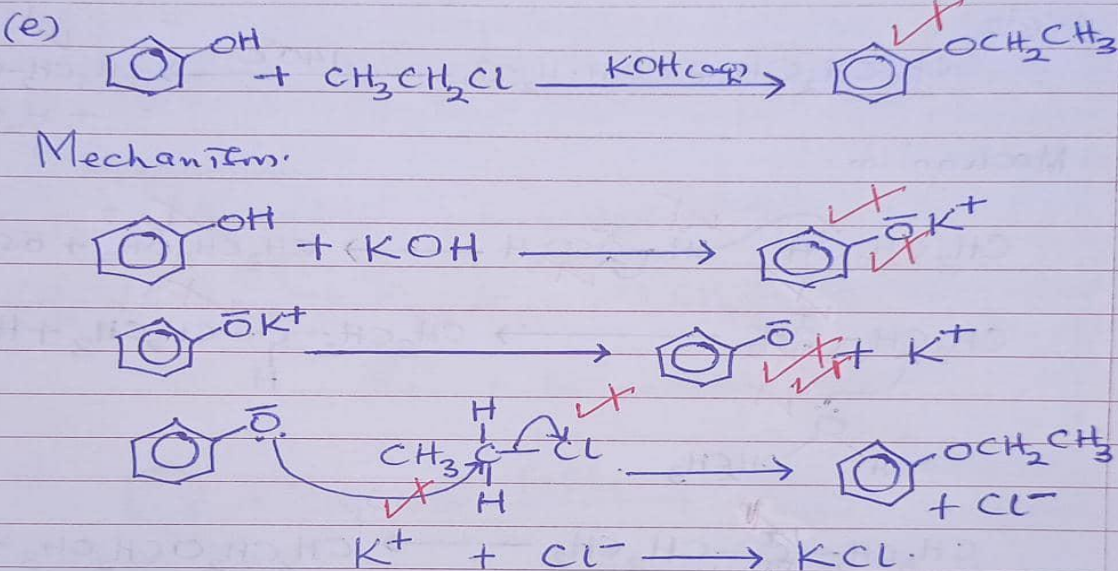
Mechanism:



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(e)	<p>(e) </p>	----do----
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QUESTION FIVE

(a)	A weak acid is an acid which only partly ionises in its aqueous solution and does not easily release protons. ✓	
(ii)	$\text{CH}_3\text{COOH}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}_3\text{O}^+(aq) \checkmark$ $K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]} \checkmark$ <p>At equilibrium; $[\text{CH}_3\text{COO}^-] = [\text{H}_3\text{O}^+] \checkmark$ $[\text{CH}_3\text{COOH}] = 0.25M$ $K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{CH}_3\text{COOH}]}$</p> <p>But from $pK_a = -\log_{10} K_a = 4.76$ $K_a = 10^{-4.76} = 1.738 \times 10^{-5} \text{ mol dm}^{-3} \checkmark$ $[\text{H}_3\text{O}^+]^2 = K_a \times [\text{CH}_3\text{COOH}]$ $[\text{H}_3\text{O}^+] = \sqrt{1.738 \times 10^{-5} \times 0.25} \checkmark$ $= 0.00208M \checkmark$ $pH = -\log_{10} [\text{H}_3\text{O}^+] \checkmark$ $pH = -\log_{10} (0.00208) = 2.68 \checkmark$</p>	Units shd be present for K_a and $[\text{H}^+]$
(b)	<p>Moles of $\text{CH}_3\text{COONa} = \left(\frac{25 \times 0.1}{1000} \right) = 0.0025 \text{ moles} \checkmark$ Moles of $\text{CH}_3\text{COOH} = \left(\frac{75 \times 0.25}{1000} \right) = 0.01875 \text{ moles} \checkmark$ Total volume of solution = $(25 + 75) = 100 \text{ cm}^3$ 100 cm^3 of solution contain 0.0025 moles of CH_3COONa 1000 cm^3 of solution contain $\left(\frac{1000 \times 0.0025}{100} \right)$ moles of $\text{CH}_3\text{COONa} \checkmark$</p>	Accept use of $[\text{H}^+] = K_a \frac{[\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COONa}]}$

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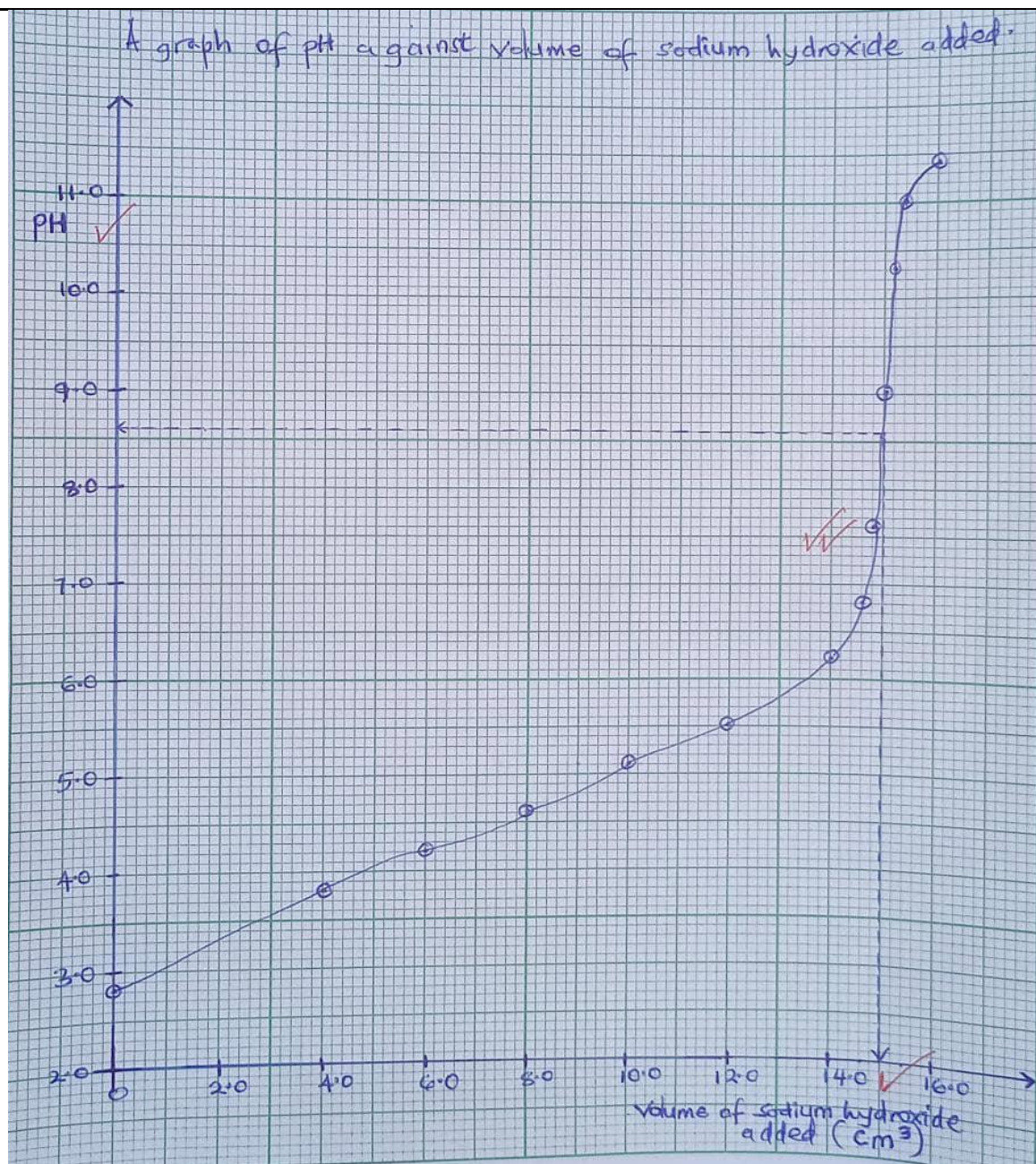
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	$[CH_3COONa] = 0.025 M \checkmark$ $100 \text{ cm}^3 \text{ of solution contain } 0.01875 \text{ moles of } CH_3COOH$ $1000 \text{ cm}^3 \text{ of solution contain } \left(\frac{1000 \times 0.01875}{100} \right) \text{ moles of } CH_3COOH \checkmark$ $[CH_3COOH] = 0.1875 M \checkmark$ $pH = pK_a + \log \frac{[CH_3COONa]}{[CH_3COOH]} \checkmark$ $pH = 4.67 + \log \left(\frac{0.025}{0.1875} \right) \checkmark$	
		$pH = 4.76 - 0.875$ $pH = 3.885 \checkmark$

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(c)
(i)



Axes should be labeled and units present

Scales should be consistent

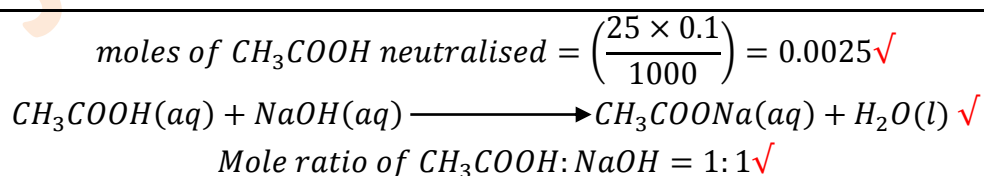
Points should be joined by a smooth curve

(ii)

Volume of sodium hydroxide needed to neutralize the acid is 15 cm³ ✓

+/-0.2

(iii)



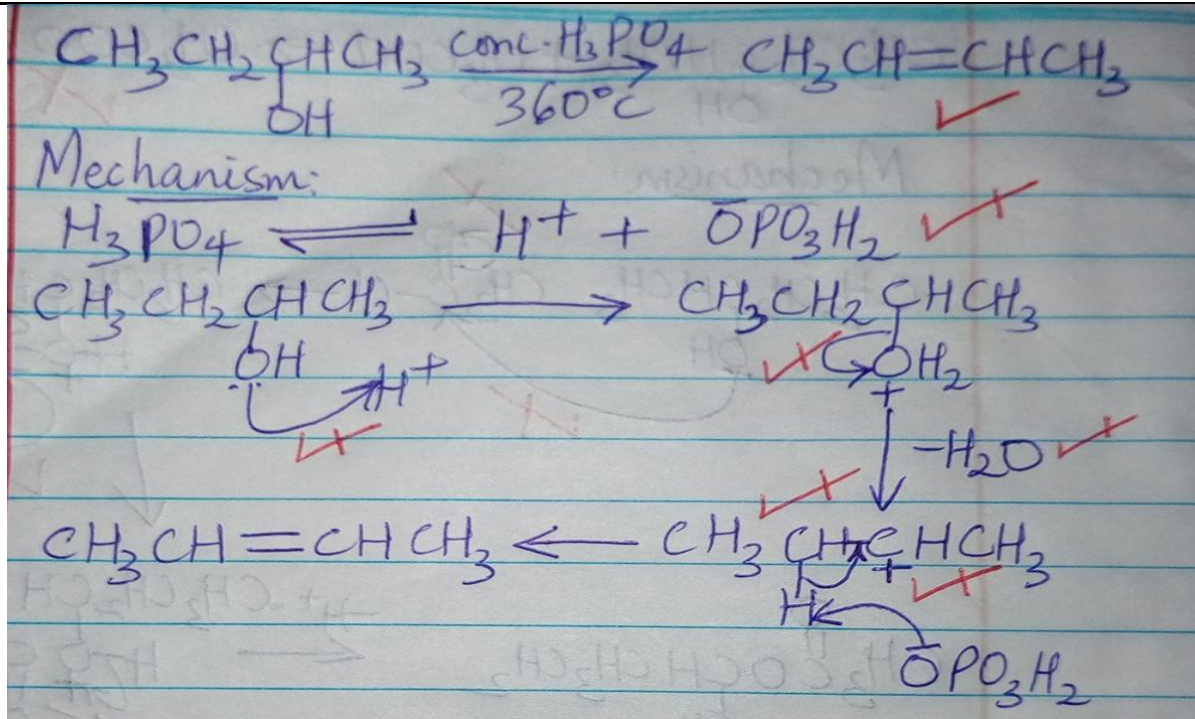
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	<p>Moles of NaOH that reacted = 0.0025✓</p> <p>15cm³ of solution contain 0.0025 moles of NaOH</p> <p>1000cm³ will contain $\left(\frac{1000 \times 0.0025}{15}\right)$ moles of NaOH✓</p> <p>Molar concentration of sodium hydroxide = 0.1667 moldm⁻³✓</p>	
(iv)	<p>pH when 5cm³ of sodium hydroxide solution had just been added to the 25cm³ of the 0.1M ethanoic acid is 4.1. This pH is due to the excess unneutralised ethanoic acid still present and some sodium ethanoate formed which constitute an acidic buffer.</p>	<p>Treatment of an acidic buffer solution by calculation</p>
	<div>$pH = pK_a + \log \frac{[CH_3COONa]}{[CH_3COOH]}$$4.1 = -\log(1.8 \times 10^{-5}) + \log \left(\frac{[CH_3COONa]}{[CH_3COOH]} \right)$$4.1 = 4.745 + \log \left(\frac{[CH_3COONa]}{[CH_3COOH]} \right)$$\log \left(\frac{[CH_3COONa]}{[CH_3COOH]} \right) = -0.645$$\frac{[CH_3COONa]}{[CH_3COOH]} = 10^{-0.645} = 0.226$$[CH_3COO^-]:[CH_3COOH] = 0.226$</div> <div><p>OR;</p>$pH = -\log_{10}[H^+] = 4.1$$[H^+] = 10^{-4.1} = 0.0000794$$[H^+] = K_a \frac{[CH_3COOH]}{[CH_3COONa]}$$\frac{[H^+]}{K_a} = \frac{[CH_3COOH]}{[CH_3COONa]}$$\frac{[CH_3COOH]}{[CH_3COONa]} = \frac{0.0000794}{1.8 \times 10^{-5}}$$\frac{[CH_3COONa]}{[CH_3COOH]} = \frac{1.8 \times 10^{-5}}{0.0000794}$$= 0.226$</div>	
<p>QUESTION SIX</p>		
(a)	<p>Hint Q was an ester of the structural formula; $CH_3CH_2COO\overset{\overset{CH_3}{ }}{CH}CH_2CH_3$</p> <p>Acid catalysed hydrolysis of esters under reflux or on heating yields a carboxylic acid and an alcohol. In this particular case, the equation for the reaction is;</p> $CH_3CH_2COO\overset{\overset{CH_3}{ }}{CH}CH_2CH_3 + H_2O \longrightarrow CH_3CH_2COOH + CH_3CH_2\overset{\overset{OH}{ }}{CH}CH_3$	<p>Try to do practice by using all the possible isomeric esters of Q and all the possible carboxylic acids and alcohols formed on hydrolysis of each</p>

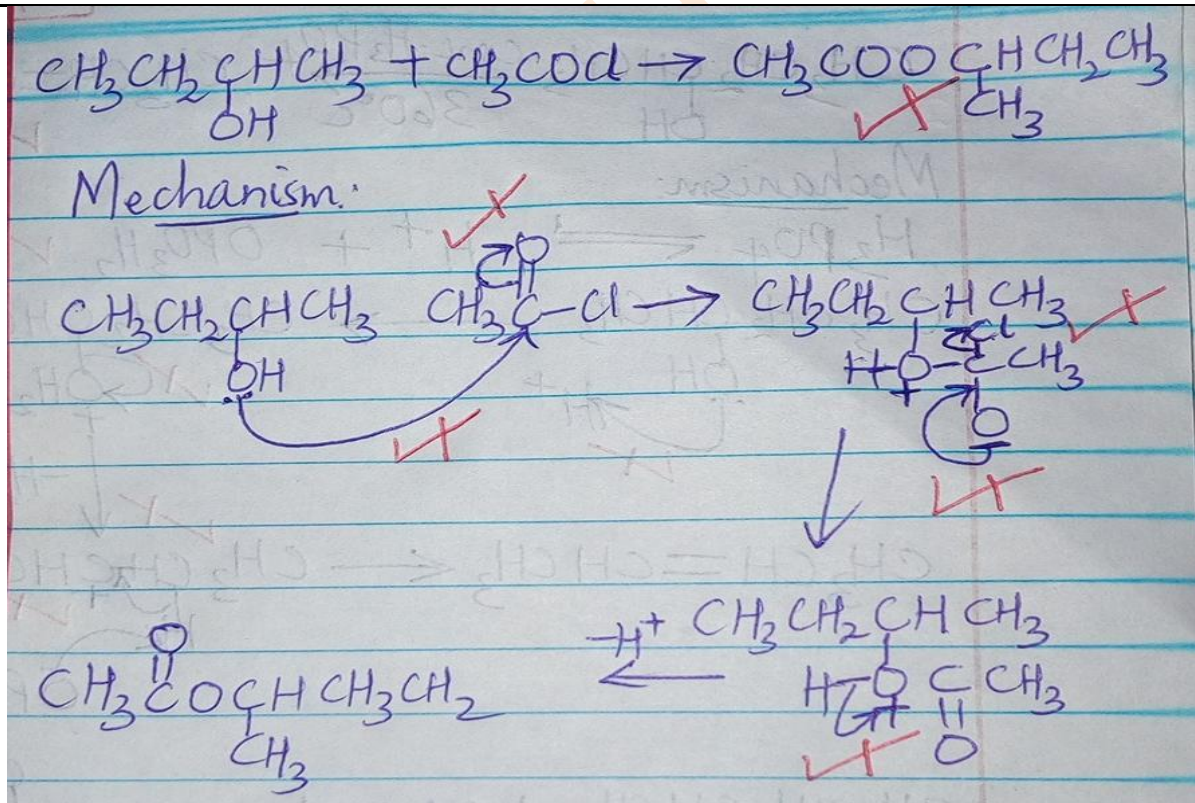
(i)	Name Butan-1-ol ✓ Butan-2-ol ✓ 2-Methylpropan-1-ol ✓ 2-Methylpropan-2-ol ✓	Structural formula $CH_3CH_2CH_2CH_2OH$ ✓ $CH_3CH_2\underset{\substack{ \\ OH}}{CH}CH_3$ ✓ $CH_3\underset{\substack{ \\ CH_3}}{CH}CH_2OH$ ✓ $CH_3\underset{\substack{ \\ CH_3}}{\overset{\substack{ \\ CH_3}}{C}}-OH$ ✓	Only accept IUPAC names Reject isomeric ethers
(ii)	Reagent; Anhydrous zinc chloride and concentrated hydrochloric acid ✓ Observations; With $CH_3CH_2CH_2CH_2OH$: No observable change at room temperature ✓ With $CH_3CH_2\underset{\substack{ \\ OH}}{CH}CH_3$; Cloudy solution formed after 5-10 minutes ✓ With $CH_3\underset{\substack{ \\ CH_3}}{CH}CH_2OH$; No observable change at room temperature ✓ With $(CH_3)_3COH$: Cloudy solution formed immediately ✓	Accept Lucas reagent Reject an hydrous Deny all marks if there is a word solution in nam of the reagent	
(b) (i)	W is $CH_3CH_2\underset{\substack{ \\ OH}}{CH}CH_3$ ✓ R is $CH_3CH_2COCH_3$ ✓ The yellow solid is CHI_3 ✓	Accept correct IUPAC names of the compounds	
(ii)	Reagent; 2,4-Dinitrophenylhydrazine solution in methanol and concentrated sulphuric acid ✓ Observation; Yellow precipitate is formed ✓	Accept Brady's reagent Reject wrong spelling of reagent. Reject ppt	

(c)
(i)



Reject hanging
arrows
Consider bond
proximity

(ii)



---do---

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QUESTION SEVEN

(a)	<p>Ammonia is a weak base that partially ionises in water to form ammonium ions and hydroxyl ions. ✓</p> $\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \checkmark$ <p>The concentration of the hydroxyl ions formed from the ammonia solution is enough to react with magnesium ions for the ionic product of magnesium hydroxide to exceed its solubility product. ✓ Therefore, insoluble magnesium hydroxide is precipitated. ✓</p> $\text{Mg}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \longrightarrow \text{Mg}(\text{OH})_2(\text{s}) \checkmark$ <p>Ammonium chloride is a strong electrolyte that completely ionises to form ammonium ions. ✓</p> $\text{NH}_4\text{Cl}(\text{aq}) \longrightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq}) \checkmark$ <p>The ammonium ions from the salt suppress the ionisation of ammonia solution ✓ due to common ion effect. This reduces the concentration of hydroxide ions ✓ in solution hence the ionic product of magnesium hydroxide does not exceed its solubility product. ✓</p>	<p style="color: red; text-align: center;">Compare with question 8(b) seminar 3</p>
(b)	<p>Carbon dioxide is non-polar. It has discrete molecules with a simple molecular structure ✓ held by weak van der Waals forces of attraction ✓ which are easily overcome ✓ at room temperature keeping the molecules far apart from each other. ✓ However, in silicon(IV) oxide, each silicon atom is covalently bonded to four oxygen atoms to form a tetrahedral structure which is continuous to form a giant molecular structure ✓ with very many strong covalent bonds ✓ that require a high amount of energy to be broken ✓ at room temperature, keeping its molecules very close to each other ✓</p>	
(c)	<p>For anhydrous copper(II) sulphate the hydration energy outweighs lattice dissociation energy ✓ making the enthalpy of solution negative. ✓ For hydrated copper(II) sulphate, the copper(II) ion and sulphate ion are already partly hydrated. ✓ When the hydrated salt is dissolved in water, its lattice dissociation energy outweighs the enthalpy of hydration associated with any further hydration ✓ making the enthalpy of solution positive. ✓</p>	<p style="color: red; text-align: center;">Student should relate hydration enthalpy, lattice enthalpy and enthalpy solution for both salts</p>
(d)	<p>The strength of an acid depends on how easily it releases protons in solution. ✓ In phenol, the lone pair of electrons on the oxygen atom interacts with, and forms part of the delocalised pi-electrons of the benzene ring, ✓ increasing the effective electron density about it. This results into formation of a</p>	

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	<p>partial double bond which shortens and strengthens the carbon-oxygen bond✓ but weakens the oxygen-hydrogen bond✓ which is easily broken when phenol is dissolved in water to release hydrogen ions.✓ In cyclohexanol, the cyclohexyl group has a positive inductive effect✓ hence pushes electrons towards the oxygen atom, making the oxygen-hydrogen bond stronger✓ hence does not easily break to release to release hydrogen ions when dissolved in water. ✓</p>	
(e)	<p>The aluminium ion in aluminium chloride has a high charge and a small ionic radius.✓ It has a high charge density and high polarising power✓ and exists as hexaaquaaluminium(III) ion in solution. The ion therefore undergoes cationic hydrolysis✓ forming insoluble hydrated aluminium hydroxide✓ and hydrogen ions✓ making the resultant solution acidic.</p> $Al(H_2O)_6^{3+}(aq) + 3H_2O(l) \longrightarrow Al(H_2O)_3(OH)_3(s) + 3H_3O^+(aq)✓$ <p>The hydrogen ions react with carbonate ions forming carbon dioxide gas. ✓</p> $2H_3O^+(aq) + CO_3^{2-}(aq) \longrightarrow CO_2(g) + 3H_2O(l)✓$	<p>Accept alternative correct ionic or molecular equations or general equations</p>
QUESTION EIGHT		
(a)	<p>Chlorine is manufactured by electrolysis✓ of concentrated sodium chloride solution (brine)✓. The electrolysis is carried out in a diaphragm cell✓ with a titanium anode✓ and steel cathode. ✓</p> <p>Sodium ions are discharged at the cathode to form sodium which reacts with water to form sodium hydroxide and hydrogen gas.</p> <p>Chloride ions are discharged at the anode, ✓ in preference to hydroxyl ions, to form chlorine gas. ✓</p> $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-✓$ <p>Alternatively;</p> <p>In the manufacture of chlorine, concentrated sodium chloride solution✓ is electrolyzed✓ in a mercury cell✓ using a graphite (carbon) anode ✓ and a mercury cathode. ✓ The mercury enables sodium ions to be discharged in preference to hydrogen ions.</p> <p>Sodium ions are discharged by electron gain, then sodium deposited at the cathode.</p> <p>Chloride ions are are discharged✓ by electron loss, chlorine is liberated at the anode. ✓</p> $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-✓$	<p>The same process leads to manufacture of sodium hydroxide</p>

(b)	Fluorine reacts vigorously with water to form oxygen and hydrofluoric acid. ✓ $2F_2(g) + 2H_2O(l) \longrightarrow O_2(g) + 4HF(aq) \checkmark$	Reject hydrogen fluoride
(i)	Chlorine disproportionates in water to form chloric(I) acid and hydrochloric acid. ✓ $Cl_2(g) + H_2O(l) \rightleftharpoons HOCl(aq) + HCl(aq) \checkmark$	
(ii)	<p>With cold dilute sodium hydroxide</p> <p>Fluorine reacts with cold dilute sodium hydroxide solution to form oxygen difluoride, fluoride ions and water. ✓ $2F_2(g) + 2OH^-(aq) \longrightarrow OF_2(g) + 2F^-(aq) + H_2O(l) \checkmark$</p> <p>OR $2F_2(g) + 2NaOH(aq) \longrightarrow OF_2(g) + 2NaF(aq) + H_2O(l)$</p> <p>Chlorine disproportionates in cold dilute sodium hydroxide to form chloride ions, chlorate(I) ions and water. ✓ $Cl_2(g) + 2OH^-(aq) \longrightarrow Cl^-(aq) + ClO^-(aq) + H_2O(l) \checkmark$</p> <p>OR $Cl_2(g) + 2NaOH(aq) \longrightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$</p> <p>With hot concentrated sodium hydroxide</p> <p>Fluorine reacts with hot concentrated sodium hydroxide to form oxygen, fluoride ions and water. ✓ $2F_2(g) + 4OH^-(aq) \longrightarrow O_2(g) + 4F^-(aq) + 2H_2O(l) \checkmark$</p> <p>OR $2F_2(g) + 4NaOH(aq) \longrightarrow O_2(g) + 4NaF(aq) + 2H_2O(l)$</p> <p>Chlorine disproportionates in hot concentrated sodium hydroxide to form chloride ions, chlorate(V) ions and water. ✓ $Cl_2(g) + 6OH^-(aq) \longrightarrow 5Cl^-(aq) + ClO_3^-(aq) + 3H_2O(l) \checkmark$</p> <p>OR $Cl_2(g) + 6NaOH(aq) \longrightarrow 5NaCl(aq) + NaClO_3(aq) + 3H_2O(l)$</p>	All conditions under which the elements react with sodium hydroxide should be considered
(c)	The fluorine atom is more electronegative than the chlorine atom and the fluoride ion has a smaller ionic radius ✓ than the chloride ion. Therefore the fluoride ion has a lower polarisability ✓ than the chloride ion. The small aluminium ion thus more strongly polarizes the electron cloud of the chloride ion than that of the fluoride ion. ✓ This makes aluminium fluoride more ionic than covalent ✓ whereas aluminium chloride becomes more covalent than ionic. ✓ Ionic bonds require a higher amount of energy to break than covalent bonds. ✓	
(i)		
(ii)	<p>The strength of an acid depends on how easily it releases hydrogen ions in solution. ✓ The fluorine atom is more electronegative ✓ than the chlorine atom and fluorine has a smaller atomic radius ✓ than chlorine. This makes the hydrogen-fluorine bond shorter, more polar and stronger ✓ than the hydrogen-chlorine bond and thus the hydrogen-fluorine bond does not easily break, ✓ releasing fewer hydrogen ions in solution ✓ than hydrogen-chlorine bond which easily breaks.</p>	Reject hydrogen-fluoride/ hydrogen-chloride bond

THE END

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