MATIGO EXAMINATIONS BOARD

P525/2
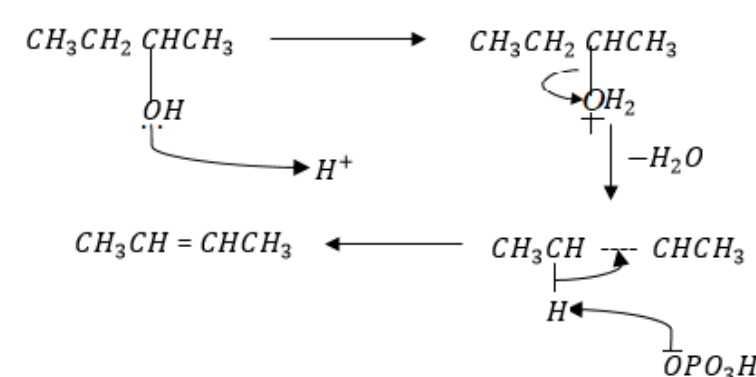**CHEMISTRY**
MARKING GUIDE 2023
PAPER 2

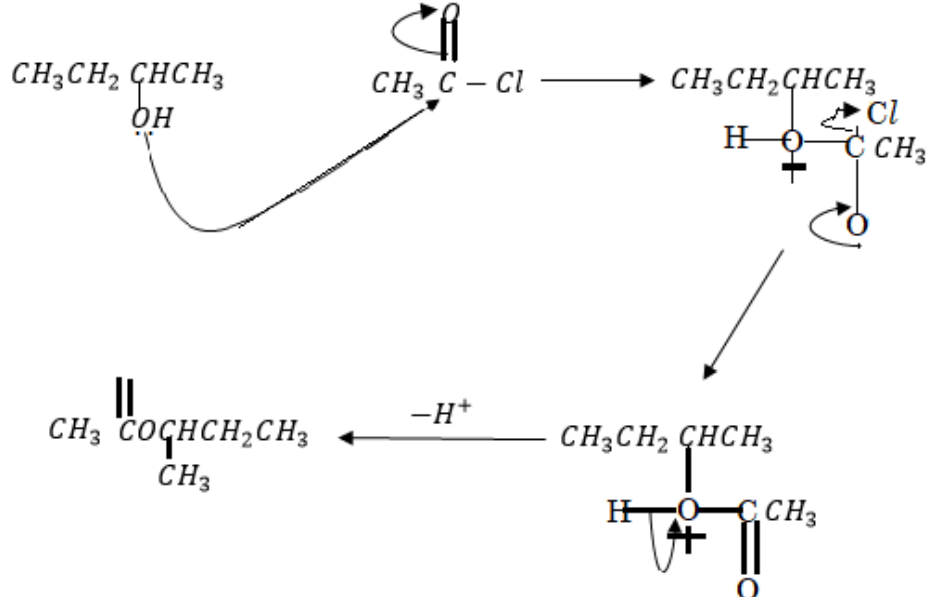| Qn	Answers	marks
1(a)	Kohlrausch's law states that the molar conductivity at infinite dilution of an electrolyte is equal to the sum of the molar conductivities at infinite dilution of the ions produced by the electrolyte. ✔	01
(b)(i)	$$Ca_3(PO_4)_{2(s)} + aq \rightleftharpoons 3Ca^{2+}_{(aq)} + 2PO^{3-}_{4(aq)}$$ ✔✔	$1\frac{1}{2}$
(ii)	$$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$$ ✔	01
(c)(i)	$$3CaCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + 6NaCl_{(aq)}$$ ✔ $$\Lambda_0(Ca_3(PO_4)_2) = 3\Lambda_0(Ca^{2+}) + 2\Lambda_0(PO_4^{3-})$$ $$\Lambda_0(Ca_3(PO_4)_2) = 3\Lambda_0(CaCl_2) + 2\Lambda_0(Na_3PO_4) - 6\Lambda_0(NaCl)$$ ✔✔ $$\Lambda_0(Ca_3(PO_4)_2) = [\,3(271.8) + 2(390.3) - 6(126.5)]\Omega^{-1}cm^2mol^{-1}$$ ✔ $$\Lambda_0(Ca_3(PO_4)_2) = 837\Omega^{-1}cm^2mol^{-1}$$ ✔	04
(ii)	$$\Lambda_0(Ca_3(PO_4)_2) = \Lambda_c(Ca_3(PO_4)_2)$$ ✔ $$K_{Ca_3(PO_4)_2} = 1.31 \times 10^{-2}\Omega^{-1}cm^{-1}$$ $$\Lambda_c(Ca_3(PO_4)_2) = \frac{1000K_{Ca_3(PO_4)_2}}{C}$$ ✔ $$C = \frac{1000K_{Ca_3(PO_4)_2}}{\Lambda_c(Ca_3(PO_4)_2)}$$ ✔ $$C = \frac{1000 \times 1.31 \times 10^{-2}}{837}$$ ✔ $$C = 0.01565 moldm^{-3}$$ ✔	

	$$[Ca^{2+}] = 3[Ca_3(PO_4)_2] = 3 \times 0.01565$$ $$= 0.04695M$$ $$[PO_4^{3-}] = 2[Ca_3(PO_4)_2] = 2 \times 0.01565$$ $$= 0.0313M$$ $$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2$$ $$K_{sp} = (0.04695)^3(0.0313)^2(moldm^{-3})^5$$ $$K_{sp} = 1.04 \times 10^{-7} mol^5 dm^{-15}$$		04
(d)(i)	As concentration increases, the molar conductivity of the acid decreases. Bromoethanoic acid is a very weak acid that that partially ionizes. Increase in concentration of electrolyte decreases the degree of ionization of electrolyte leads to fewer conducting particles in the electrolyte hence reduction in ionic mobility leading to increased dragging effect.		$02\frac{1}{2}$
(ii)	$$\text{Dilution} = \frac{1}{c}$$ $$c = \frac{1}{50}$$ $$c = 0.02 moldm^{-3}$$ $$At\ 0.02,\ \Lambda_c = 18$$ $$\alpha = \frac{\Lambda_0}{\Lambda_c} = \frac{18}{411} = 0.0438$$		03
(iii)	$$[H^+] = c\alpha$$ $$= 0.02 \times 0.0438$$ $$= 8.76 \times 10^{-4}M$$ $$P^H = -log_{10}^{[H^+]}$$ $$= -log_{10}^{[8.76 \times 10^{-4}]}$$ $$P^H = 3$$		03

2(a)(i)	$CH_3CH_2CH_2CH_2OH$	$Butan - 1 - 01$	
	$CH_3CH_2\underset{\underset{OH}{\vert}}{C}HCH_3$	$Butan - 2 - 01$	
	$CH_3\underset{\underset{CH_3}{\vert}}{C}H\ CH_2OH$	$2 - Methylpropan - 1 - 01$	
	$CH_3\ \underset{\underset{CH_3}{\vert}}{\overset{\overset{CH_3}{\vert}}{C}}\!\!-\!\!OH$	$2 - Methylpropan - 2 - 01$	04
(ii)	Reagent: Anhydrous Zinc Chloride and concentrated hydrochloric acid Observations: With $CH_3CH_2CH_2CH_2OH$: NO Observable change at room temperature With $CH_3\underset{\underset{CH_3}{\vert}}{C}HCH_2OH$: NO Observable change at room temperature With $CH_3CH_2\underset{\underset{OH}{\vert}}{C}HCH_3$: Cloudy solution formed after 5 - 10 minutes With $(CH_3)_3C - OH$: Cloudy solution formed immediately		04

(b)(i)	W is $CH_3CH_2\underset{\underset{OH}{\vert}}{C}HCH_3$ R is $CH_3CH_2COCH_3$ Yellow solid is CHI_3	03
(ii)	Reagent: 2,4 – Dinitrophenylhydrazine solution in methanol and concetrated sulphuric acid Accept: Brady's reagent. Observation: Yellow precipitate is formed	02
(c)(ii)	$CH_3CH_2\underset{\underset{OH}{\vert}}{C}HCH_3 \xrightarrow[360°C]{Conc\ H_3PO_4} CH_3CH=CHCH_3$ Mechanism: $H_3PO_{4(aq)} \rightleftharpoons H^+_{(aq)} + \bar{O}PO_3H_{2(aq)}$ 	04
(ii)	$CH_3CH_2\underset{\underset{OH}{\vert}}{C}HCH_3 + CH_3COCl \longrightarrow CH_3COO\underset{\underset{CH_3}{\vert}}{C}HCH_2CH_3$	

The reaction mechanism shows:

$CH_3CH_2\underset{\underset{\ddot{O}H}{|}}{C}HCH_3$ reacting with $CH_3\overset{\overset{O}{||}}{C}-Cl$ $\longrightarrow$ $CH_3CH_2\underset{\underset{H-O-\overset{\overset{Cl}{}}{\underset{}{C}}CH_3}{|}}{C}HCH_3$

$CH_3\overset{\overset{O}{||}}{C}\underset{\underset{CH_3}{|}}{O}CHCH_2CH_3$ $\xleftarrow{-H^+}$ $CH_3CH_2\underset{\underset{H-O-C-CH_3}{|}}{C}HCH_3$

		03

| 3(a) | Name: Bauxite   Formula: $Al_2O_3 2H_2O$ | 02 |
| (b)(i) | The Ore is heated in presence of oxygen to remove water of crystallization and also convert Iron (II) ions to Iron (III) oxide. $$Al_2O_3 2H_2O_{(s)} \rightarrow Al_2O_{3(s)} + 2H_2O_{(l)}$$ The roasted product is crushed into fine power and heated with excess concentrated sodium hydroxide solution. The amphoteric aluminium oxide and acidic silicon dioxide dissolve in the alkali. $$Al_2O_{3(s)} + 2\bar{O}H_{(aq)} + 3H_2O_{(l)} \rightarrow 2Al(OH)^-_{4(aq)}$$ $$SiO_{2(s)} + 2\bar{O}H_{(aq)} \rightarrow H_2O_{(l)} + SiO^{2-}_{3(aq)}$$ The basic iron (III) oxide and titanium (iv) oxide don't dissolve hence filtered off as residue while the aluminium and the silicate form the filtrate.

 The filtrate is cooled, diluted with water and seeded with pure aluminium hydroxide to precipitate aluminium hydroxide. $$Al(OH)^-_{4(aq)} + Al(OH)_{3(s)} \rightarrow Al(OH)_{3(s)} + \bar{O}H_{(aq)}$$ | 05 |

	The aluminium hydroxide is then filtered off, washed, dried and then heated strongly to form pure anhydrous aluminium oxide. $$2Al(OH)_{3(s)} \rightarrow Al_2O_{3(s)} + 3H_2O_{(l)}$$	
(ii)	Aluminium is dissolved in molten cryolite to lower its melting point and then electrolyzed between graphite electrodes at 850℃ and at a low voltage and high current density. Aluminium oxide is decomposed by electric current as below: $$Al_2O_{3(l)} \rightarrow Al^{3+}_{(l)} + 3O^{2-}_{(aq)}$$ Aluminium is discharged at the cathode. $$Al^{3+}_{(l)} \, 3\bar{e} \rightarrow Al_{(l)}$$	03
(c)(i)	Conditions: strongly heated aluminium and excess air. $$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$$ $$2Al_{(s)} + N_{2(g)} \rightarrow 2AlN_{(S)}$$	$02\frac{1}{2}$
(ii)	Condition: Hot concentration sodium hydroxide solution. $$2Al_{(s)} + 2\bar{O}H_{(aq)} + 6H_2O_{(l)} \rightarrow 2Al(OH)^-_{4(aq)} + 3H_{2(g)}$$	$02\frac{1}{2}$
(iii)	Condition: Hot concentrated hydrochloric acid. $$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$	$02\frac{1}{2}$
(d)	Soap is a salt of weak organic acid and strongly basic sodium hydroxide. Soap undergoes hydrolysis in solution forming hydroxide ions. $$RCO\bar{O}_{(aq)} + H_2O_{(l)} \rightarrow ROCOOH_{(aq)} + \bar{O}H_{(aq)}$$ The hydroxide ions react with aluminium to form aluminate ions and hydrogen gas. $$2Al_{(s)} + 2\bar{O}H_{(aq)} + 6H_2O_{(l)} \rightarrow 2Al(OH)^-_{4(aq)} + 3H_{2(g)}$$ This causes wearing off of the aluminium utensils.	$02\frac{1}{2}$
4(a)(i)	It is the energy change when one mole of crystalline compound is formed from it's constitute ions in gas phase. $e.g; Na^+_{(g)} \, Cl^-_{(g)} \rightarrow NaCl_{(s)} \qquad \Delta H = -Ve$	02

(ii)		03

$K^+_{(g)} \quad + \quad Cl^-_{(g)}$ ————————|

$\uparrow \Delta H_{Ions} \qquad \uparrow \Delta H_{E.A}$

$\qquad\qquad\qquad\qquad\qquad \Delta H_{latt}$

$K_{(g)} \qquad\qquad Cl_{(g)}$

$\uparrow \Delta H_{Sub} \qquad \uparrow \Delta H_{atoms}$

$K_{(s)} \quad + \quad \frac{1}{2}Cl_{2(g)} \xrightarrow{\Delta H_{Form}} KCl_{(s)}$

OR

$\Delta H_{Sub} \rightarrow$ Enthalpy of sublimation
$\Delta H_{atoms} \rightarrow$ Ethalpy of atomisation
$\Delta H_{ion} \rightarrow$ Ethalpy of Ionisation
$\Delta H_{E.A} \rightarrow$ Eletron Affinity
$\Delta H_{Latt} \rightarrow$ Lattice energy
$\Delta H_{Form} \rightarrow$ Enthalpy of formation
$\Delta H_{Latt} = \Delta H_{Form} - (\Delta H_{Sub} + \Delta H_{atoms} + \Delta H_{E.A})$

03

(ii)		04

$M^+_{(g)} \quad + \quad X^-_{(g)} \qquad -788KJmol^{-1}$

$\uparrow +495KJmol^{-1} \qquad \uparrow -348KJmol^{-1}$

$M_{(g)} \qquad\qquad X_{(g)}$

$\uparrow +130KJmol^{-1} \qquad \uparrow +121KJmol^{-1}$

$M(s) \quad + \quad \frac{1}{2}X_{(g)} \xrightarrow{\Delta H^\theta_f} MX_{(s)}$

$\Delta H^\theta_f = (+130 + 495 + 121 + -348 + -788) KJmol^{-1}$
$\qquad = -390 \, KJmol^{-1}$
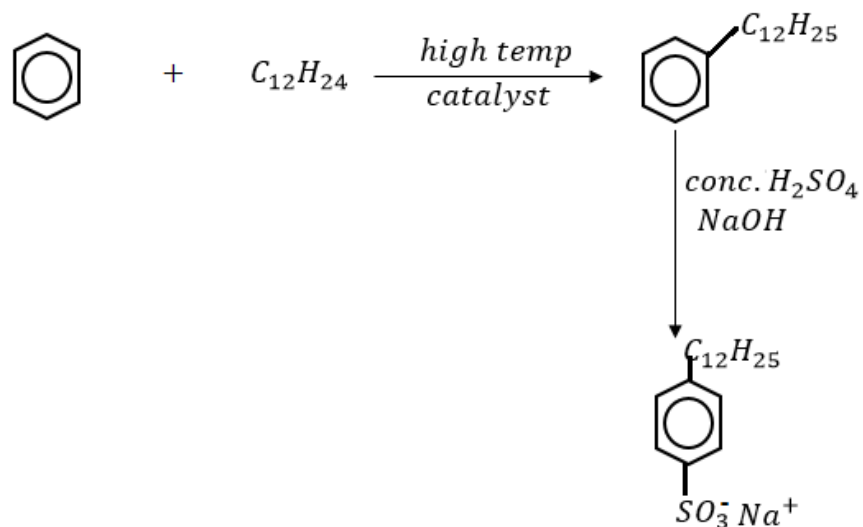
(b)(i)	Hydration Energy	01
(ii)	Ionic radius; the higher the ionic radius, the lower the hydration energy; because the charge density of the ion is low; and water molecules are less strongly attracted. Change of the ion; the higher the charge the higher the hydration energy, because the polar water molecules are more strongly attracted by the increased charge density.	04
(iii)	$$\Delta H_{solution} = \Delta H_{lattice} + \Delta H_{hydration}$$ $$= +788 + {}^-784$$ $$= 4 KJmol^{-1} \; (Deny \; \tfrac{1}{2} \; for \; missing \; units)$$	02
(c)	Benzene has three double bonds and its expected enthalpy of hydrogenation would be three times that of cyclohexene with only one double bond. The double bond pi electrons of benzene participate in resonance that stabilizes the benzene ring, thus they are partial double bonds; the resonance energy reduces the enthalpy of hydrogenation of benzene, since its stability is destroyed.	03
5(a)	$$nS^2 nP^5$$	01
(b)(i)	Flourine reacts with water to form hydrogen flouride (hydrofluoric acid) and oxygen gas. $$2F_{2(g)} \; 2H_2O_{(l)} \rightarrow 4HF_{(aq)} + O_{2(g)}$$ The rest of the elements react with water to form hypo and hydrohalic acid. $$X_2 + H_2O_{(l)} \rightarrow HOX_{(aq)} + HX_{(aq)}$$ $$(X_2 \rightarrow Cl_2, Br_2, I)$$ The reactivity with water decrease down the group.	04
(ii)	Flourine reacts with cold dilute sodium hydroxide to for, sodium Flouride oxygen difluoride and water. $$2F_{2(g)} + 2NaOH_{(aq)} \rightarrow 2NaF_{(aq)} + OF_{2(g)} + H_2O_{(l)}$$ The rest of the halogens react with cold dilute sodium hydroxide to for hypohalite, sodium halide and water. $$X_2 + 2NaOH_{(aq)} \rightarrow NaOX_{(aq)} + NaX_{(aq)} + H_2O_{(l)}$$ $$(X \rightarrow Cl, Br, I)$$	$05\frac{1}{2}$

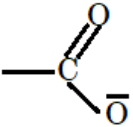|		
	Flourine reacts with hot concentrated sodium hydroxide solution to form sodium flouride, oxygen gas and water. $$2F_{2(g)} + 4NaOH_{(aq)} \rightarrow 4NaF_{(aq)} + O_{2(g)} + 2H_2O_{(l)}$$ The rest of the halogens react with hot concentrated sodium hydroxide to form halite (v), sodium halide and water. $$3X_2 + 6NaOH_{(aq)} \rightarrow NaXO_{3(aq)} + 5NaX_{(aq)} + 3H_2O_{(l)}$$ $$(X_2 \rightarrow Cl_2, Br_2, I_2)$$	
(iii)	Sulphurous acid react with all the halogens in aqueous solution to form hydrogen halide (hydrohalic acid) and sulphuric acid. $$X_2 + H_2SO_{3(aq)} + H_2O_{(l)} \rightarrow 2HX_{(aq)} + H_2SO_{4(aq)}$$	$02\frac{1}{2}$
(c)(i)	Pale green solution turn to pale brown. $$Cl_{2(g)} + 2FeCl_{2(aq)} \rightarrow 2FeCl_{3(aq)}$$ $$\textbf{Or} \quad Cl_{2(g)} + 2Fe^{2+}_{(aq)} \rightarrow 2Fe^{3+}_{(aq)} + 2Cl^-_{(aq)}$$	02
(ii)	Colourless solution forms yellow precipitate. $$Na_2S_2O_{3(aq)} + H_2O_{(l)} + Cl_{2(g)} \rightarrow Na_2SO_{4(aq)} + S_{(s)} + 2HCl_{(aq)}$$	$02\frac{1}{2}$
(iii)	Green solution turn purple. $$2K_2MnO_{4(aq)} + Cl_{2(g)} \rightarrow 2KMnO_{4(aq)} + 2KCl_{(aq)}$$	$02\frac{1}{2}$
6(a)	Ammonia is a weak base that partially ionses in water to form ammonium ion and hydroxyl ions $$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH^+_{4(aq)} + \bar{O}H_{(aq)}$$ 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. $$Mg^{2+}_{(aq)} + 2\bar{O}H_{(aq)} \rightarrow Mg(OH)_{2(s)}$$ Ammonium chloride is a strong electrolyte that completely ionises to form ammonium ions $$NH_4Cl_{(aq)} \rightarrow NH^+_{4(aq)} + Cl^-_{(aq)}$$ 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.	05
(b)	Carbon dioxide is non- polar. It has discrete molecules with a simple molecular structure held by weak Van der Waals's 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 atom to form a tetrahedral structure which is continuous to form a giant molecule structure with very many	04

	strong covalent bond's that require a high amount of energy to be broken at room temperature, keeping its molecules very close to each other	
(c)	For anhydrous copper (ii) sulphate, the hydration energy out weights lattice dissociation energy making the enthalpy of the 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 out weights the enthalpy of hydration associated with any further hydration making the enthalpy of solution positive.	04
(d)	The strength of an acid depends on the ease of release of protons in the solution. In phenol, the lone pairs of electrons on the oxygen atom interacts with benzene and forms part of the delocalized pi-electrons of the benzene ring. This increases the effective electron density resulting into formation of partial double bond which shorten and strengthens the $C - O$ bond. This weakens the $O - H$ bond hence can easily break when phenol is dissolved in water to release hydrogen ions. In cyclohexanol, the cyclohexyl group has a positive inductive effect hence pushes electron towards the oxygen atom, making $O - H$ bond stronger hence doesn't easily break to release hydrogen ions when dissolved in water.	03
(e)	The aluminium ion in aluminium chlorine has a high charge and a small ionic radius. It has high charge density and high polarising power, it 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. $$AL(H_2O)_{6(aq)}^{3+} + 3H_2O_{(l)} \rightarrow Al(H_2O)_3(OH)_{3(s)} + 3H_3O_{(aq)}^+$$ The hydrogen ions reacts with carbonate ions forming carbon dioxide gas $$2H_3O_{(aq)}^+ + CO_{3(aq)}^{2-} \rightarrow CO_{2(g)} + 3H_2O_{(l)}$$	04
7(a)	$$P^H = -log_{10}^{[H^+]} [H^+] \rightarrow Molar\ Concentration\ of\ hydrogen\ Ion$$	01

(b)	A graph of P^H against volume of $NaOH$ added	04
(c)(i)	P^H at end point $= \dfrac{5.4 + 12.0}{2}$ $= 8.7 \pm 0.2$	01
(ii)	Volume of $NaOH$ at endpoint $= 25.0 \ cm^3$ $1000 cm^3$ of $NaOH$ contains 0.1 moles $25.0 cm^3$ of $NaOH$ contains $\left(\dfrac{0.1 \times 25.0}{1000}\right)$ moles $NaOH_{(aq)} + HA_{(aq)} \rightarrow H_2O_{(l)} + NaA_{(aq)}$ Mole ratio of $NaOH : HA = 1 : 1$ $Number$ of moles of Acid $= \left(\dfrac{0.1 \times 1000}{25.0}\right)$ moles $25 cm^3$ of Acid of Acid contains $= \left(\dfrac{0.1 \times 1000}{25.0}\right)$ moles $1000 cm^3$ of Acid contain $\left(\dfrac{0.1 \times 1000 \times 25}{25 \times 1000}\right)$ $= 0.1M$	05
(d)	The acid is weak and Ionises to give fewer hydrogen Ions $$HA_{(aq)} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$$ As more $NaOH_{(aq)}$ is added, the P^H increases gradually because the acid is being neutralized Unreacted acid together with salt formed give a buffer mixture which resist change in P^H. At the end point, a small amount of $NaOH_{(aq)}$ added produces a sharp rise in P^H because $NaOH_{(aq)}$ in a strong base which Ionises completely to produce high concentration to hydroxyl ions. The P^H at the end point is above 7 because the salt formed undergoes hydrolysis to produce hydroxide ions which make the solution alkaline. After the end point, there is a gradual increase in P^H due to excess sodium hydroxide solution.	05
(e)	$$P^H = 2.5$$ $$P^H = -log_{10}[H^+];$$ $$[H^+] = 10^{-2.5} = 3.162 \times 10^{-3} moldm^{-3}$$ $$K_a = \dfrac{[A^-][H^+]}{[HA]}$$	04

	$$K_a = \frac{(3.162 \times 10^{-3})^2}{0.1}$$ $$K_a = 1 \times 10^{-4} mol\, dm^{-3}$$ $$pK_a = -log_{10}^{K_a}$$ $$= -log_{10}^{(1 \times 10^{-4})}$$ $$pK_a = 4$$	
8(a)(i)	Oil(fat) and alkali	02
(ii)	$Oil + Alkali \rightarrow Soap + glycerol$	02
(iii)	Common salt is added to the reaction mixture. The soap is precipitated (separates as a scum on top of the reaction mixture) it is then removed and washed with boiling water several times to remove the sodium chloride and then dried.	02
(b)(i)	React a long chain hydrocarbon containing a hydroxyl group with concentrated sulphuric acid and sodium hydroxide to give a sulphonic group. $$CH_3(CH_2)_{12}CH_2OH \xrightarrow[NaOH, heat]{Conc\ CH_2SO_4} CH_3(CH_2)_{12}CH_2S\bar{O}_3Na^+$$ $$Detergent$$	
OR		02

Accept descriptive writing

(ii)	Soap has a carboxylic group $\overset{\displaystyle O}{\underset{\displaystyle \overline{O}}{-C}}$ Detergent has a sulphonic group $-SO_3^-$ as functional group	02
(iii)	A detergent is effective in both soft and hard water. Soap in only effective in soft and precipitated in hard water.	02
(c)(i)	Remove dirt They react calcium and magnesium ions present in hard water	02
(ii)	The phosphates encourage growth of algae in water bodies. The algae deprive water bodies of air and suffocate aquatic life.	01
(iii)	It help whitening by removing stains.	01
(iv)	Sodium sulphate. It promotes god physical characteristics of detergent. It improves the hydrophilic character of the detergent molecule, it also increases bulkiness of the detergent or silicates. It is ant rust.	02

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