Mark Scheme

Question	Answer	Marks	Guidance
1	C	**1**	

Mark Scheme

Question			Answer	Marks	Guidance
2	(a)		$[H^+] = 10^{-pH} = 10^{-2.19} = 6.46 \times 10^{-3}$ (mol dm^{-3}) ✓ $[CH_3CH(OH)COOH] = \frac{[H^+]^2}{K_a} = \frac{(6.46 \times 10^{-3})^2}{1.38 \times 10^{-4}}$ ✓ $= 0.0302$ (mol dm^{-3}) ✓ $n(CH_3CH(OH)COOH) = \frac{0.302 \times 250}{1000} = 0.0755$ mol ✓ Mass of $CH_3CH(OH)COOH = 0.0755 \times 90 = 6.80$ g ✓ Dissolve 6.80 g of the solid in distilled water (less than 250 cm^3) in a beaker ✓ (then) transfer the solution to a 250 cm^3 volumetric flask **AND** ensure that all solution is washed out of beaker (washings transferred to volumetric flask) ✓ (then) make solution up to 250 cm^3 with distilled water **AND** ensure thorough mixing by inverting the flask several times ✓	**8**	**ALLOW** 5 marks for 6.80 g through any calculation. **ALLOW ECF** for incorrect calculation of mass. Mass used must be linked to calculation.
	(b)		$CH_3CH(OH)COO^- + CH_3CH_2CH_2COOH_2^+$ ✓ $CH_3CH(OH)COOH$ **AND** $CH_3CH(OH)COO^-$ $CH_3CH_2CH_2COOH$ **AND** $CH_3CH_2CH_2COOH_2^+$ **Both** pairs identified ✓	**2**	State symbols **NOT** required **ALLOW** labels ‘acid 1’, ‘base 1’ etc. **ALLOW ECF** for second mark

Mark Scheme

Question			Answer	Marks	Guidance
	(c)	**(i)**	$[H^+] = \frac{1 \times 10^{-14}}{0.185} = 5.405 \times 10^{-14}$ (Use of K_w) ✓ pH = –log(5.405×10^{-14}) = 13.27 ✓	**2**	**ALLOW** 5.405405405 × 10^{-14} and correct rounding to 5.4 × 10^{-14} **ALLOW** alternative approach using pOH: pOH = –log(0.185) = 0.73 pH = 14 – 0.73 = 13.27 Correct answer scores **BOTH** marks **ALLOW** 13.267
		(ii)	$n(A^-) = 9.25 \times 10^{-3}$ (mol) ✓ n(HA) = 0.0165 – 9.25×10^{-3} = 7.25×10^{-3} (mol) ✓ $[H^+] = K_a \times \frac{[HA]}{[A^-]}$ ✓ pH = –log($1.5 \times 10^{-5} \times \frac{0.058}{0.074}$) = 4.93 **OR** pH = –log($1.5 \times 10^{-5} \times \frac{1000 \times \frac{7.25 \times 10^{-3}}{125}}{1000 \times \frac{9.25 \times 10^{-3}}{125}}$) = 4.93 ✓ **Final mark** also via Henderson–Hasselbalch equation: $pH = pK_a - \log\frac{[HA]}{[A^-]}$ = 4.82 – (–0.11) = 4.93 **OR** $pH = pK_a + \log\frac{[A^-]}{[HA]}$ = 4.82 + 0.11 = 4.93 ✓	**4**	**ALLOW** HA/acid and A^-/salt throughout for butanoate and butanoic acid **ALLOW** pK_a = –log K_a **OR** –log 1.5×10^{-3} **OR** 4.82 **ALLOW ECF** from incorrect values of $n(A^-)$ or n(HA) **ALLOW** $pH = -\log(1.5 \times 10^{-5} \times \frac{7.25 \times 10^{-3}}{9.25 \times 10^{-3}})$ = 4.93
			Total	**16**	

Mark Scheme

Question			Answer	Marks	Guidance
3	(a)*		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** **Develops a plan that allows identification of all six ions** **AND** **includes essential detail and equations for all test procedures and observations, with three anion tests in the correct sequence, CO_3^{2-}, SO_4^{2-} then Cl^-** **AND** **includes cation test with essential detail and all equations** *There is a well-developed, detailed plan which is clear and logically structured. The plan is substantiated with relevant information, e.g. justification of the sequence of anion tests. There is a clear explanation of how the observations allow the ions to be identified.* **Level 2 (3–4 marks)** **Develops a plan that allows identification of at least three ions** **AND** **includes detail of at least three test procedures and observations, and three equations** *There is an appropriate plan presented with some structure. Parts of the fine detail, correct sequence, or reference to use of both samples may be missing. There is some attempt to explain how the observations allow the ions to be identified.*	**6**	**Indicative scientific points may include:** Use one sample for cation test, other sample for anion tests **Details of tests** *Cation test* add Aqueous sodium hydroxide Positive observations • for Mn^{2+} : pink/buff precipitate • for Fe^{2+} : green precipitate • for NH_4^+ : litmus paper held over the opening of the tube turns blue Fine detail: • (gentle) heating for NH_4^+ test Equations: $Mn^{2+} + 2OH^- \rightarrow Mn(OH)_2$ $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$ *Anion tests* CO_3^{2-}: • add nitric acid; positive observation: effervescence SO_4^{2-}: • add aqueous barium nitrate; positive observation: white precipitate Cl^-: • add silver nitrate solution; positive observation: white precipitate Fine detail for Cl^-:

Mark Scheme

Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) **Develops a plan that allows identification of at least two ions** **AND** **includes detail of at least two test procedures and observations, and one equation** *The plan is basic and communicated in an unstructured way. The response lacks fine detail and no reference to correct sequence of anion tests. There is little or no attempt to explain how the observations allow the ions to be identified.* **0 marks** No response or no response worthy of credit.		• subsequent addition of dilute ammonia solution positive observation: precipitate dissolves. Fine detail: correct sequence of all three anion tests • carbonate test followed by sulfate test followed by halide test • justification of sequence • **ALLOW** splitting of solution over three boiling tubes/test tubes and performing each test on a different sample. Equations: $CO_3^{2-} + H^+ \rightarrow CO_2 + H_2O$ $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ $Ag^+ + Cl^- \rightarrow AgCl$
	(b)		K_w value from graph from 2.2 to 2.4 × 10^{-14} ($mol^2\ dm^{-6}$) ✓ Using 2.4 × 10^{-14}, $[H^+] = \sqrt{2.4 \times 10^{-14}}$ **OR** 1.55 × 10^{-7} ✓ pH = –log (1.55 × 10^{-7}) = 6.81 (using K_w = 2.4 × 10^{-14}) ✓	**3**	Actual K_w = 2.38 × 10^{-14} $mol^2\ dm^{-6}$ **ALLOW ECF** only if candidate uses a value between 2.0 and 2.6 × 10^{-14} ($mol^2\ dm^{-6}$), i.e. from the approximately correct region of the graph **ALLOW** 6.8 (1DP) up to calculator value **ALLOW ECF** only if candidate has generated a value of $[H^+]$ by attempting to take a square root of a value between 2.0 and 3.0 × 10^{-14}
	(c)	**(i)**	$Co : N : H : Cl = \frac{21.98}{58.9} : \frac{31.35}{14.0} : \frac{6.72}{1.0} : \frac{39.75}{35.5}$	**2**	

Mark Scheme

Question			Answer	Marks	Guidance
			= 0.373 : 2.24 : 6.72 : 1.12 ✓ = 1 : 6 : 18 : 3 Formula = $CoN_6H_{18}Cl_3$ ✓		
		(ii)	$[Co(NH_3)_6]^{3+}$ ✓	**1**	
			Total	**12**	

Mark Scheme

Question			Answer	Marks	Guidance
4	(a)	(i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓	1	
		(ii)	4	1	
	(b)		$[Fe(CN)_6]^{3-}$ shown as product in equation ✓ Remaining species and balancing correct balanced equation: $[Fe(H_2O)_6]^{3+} + 6CN^- \rightarrow [Fe(CN)_6]^{3-} + 6H_2O$ ✓	2	Notice different charges on complex ions: LHS 3+, RHS 3– **ALLOW** equations with KCN, i.e.: $[Fe(H_2O)_6]^{3+} + 6KCN \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ $[Fe(H_2O)_6]^{3+} + 6K^+ + 6CN^- \rightarrow [Fe(CN)_6]^{3-} + 6K^+ + 6H_2O$ state symbols **not** required
	(c)	(i)	$K_a = \frac{[[Fe(H_2O)_5OH]^{2+}(aq)][H^+(aq)]}{[[Fe(H_2O)_6]^{3+}(aq)]}$ ✓	1	state symbols **not** required
		(ii)	$[H^+] = \sqrt{6.00 \times 10^{-3} \times 0.100}$ **OR** 0.0245 (mol dm^{-3}) ✓ pH = –log 0.0245 = 1.61 ✓	2	**ALLOW ECF** from calculated $[H^+]$ provided that **BOTH** 6.0×10^{-3} **AND** 0.100 only have been used **ALLOW** calculation via quadratic equation → pH 1.66
	(d)		..ClO^- + ..H_2O + **2**..e^- → ..Cl^- + **2**..OH^- ✓ Fe_2O_3 + **10**..OH^- → **2**..FeO_4^{2-} + **5**..H_2O + **6**..e^- ✓	3	**ALLOW** multiples throughout

Mark Scheme

Question			Answer	Marks	Guidance
			Fe_2O_3 + **3**..$C\ell O^-$ + **4**..OH^- → **2**..FeO_4^{2-} + **3**..$C\ell^-$ + **2**..H_2O ✓		
			Total	**10**	

Mark Scheme

Question	Answer	Marks	Guidance
5	C	1	**ALLOW** 4.1 in the box

Mark Scheme

Question			Answer	Marks	Guidance
6	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = **0.753**, award **3 marks** --- $[H^+] = 10^{-pH} = 10^{-2.440} = 3.63 \times 10^{-3}$ (mol dm^{-3}) ✓ $[CH_3COOH] = \frac{[H^+]^2}{K_a}$ **OR** $\frac{(3.63 \times 10^{-3})^2}{1.75 \times 10^{-5}}$ ✓ = 0.753 (mol dm^{-3}) ✓	3	**ALLOW** use of **HA** and **A$^-$** **ALLOW 3 SF** up to calculator value of $3.630780548 \times 10^{-3}$ correctly rounded **NOTE:** Answer is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value **ALLOW** 0.749 if $[H^+]$ has been subtracted from $[CH_3COOH]$ for greater accuracy at end
	(b)		$CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COOH_2^+ + FCH_2COO^-$ ✓ **B2 A1 A2 B1** **OR** **B1 A2 A1 B2** ✓ *i.e. labels other way round*	2	Watch for opposite order on RHS, i.e.: $FCH_2COO^- + CH_3COOH_2^+$ Take **great care** matching labels **ALLOW ECF** for incorrect proton transfer as below. This is the **ONLY ECF** $CH_3COOH + FCH_2COOH \rightleftharpoons CH_3COO^- + FCH_2COOH_2^+$ × **A1 B2 B1 A2** **OR** **A2 B1 B2 A1** ✓**ECF** *i.e. labels other way round*

Mark Scheme

Question	Answer	Marks	Guidance
(c) (i)	**$[CH_3COO^-]$** $n(CH_3COONa) = \frac{9.08}{82.0}$ **OR** 0.111 ✓ (Calc: 0.1107317073) $[CH_3COO^-] = \frac{9.08}{82.0} \times \frac{1000}{250} = 0.443$ (mol dm^{-3}) **OR** $n(CH_3COOH) = 0.800 \times \frac{250}{1000} = 0.200$ (mol) ✓ **$[H^+]$** $[H^+] = K_a \times \frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $K_a \times \frac{n(CH_3COOH)}{n(CH_3COO^-)}$ = $1.75 \times 10^{-5} \times \frac{0.800}{0.443}$ **OR** $1.75 \times 10^{-5} \times \frac{0.200}{0.111}$ ✓ $= 3.16 \times 10^{-5}$ (mol dm^{-3}) ✓ **pH (must come from *calculated* $[H^+]$)** pH = –log (3.16×10^{-5}) = 4.50 ✓ --- **LAST 3 marks** are **NOT** available using • K_a square root approach (weak acid pH) • $K_w / 10^{-14}$ approach (strong base pH) --- **Henderson–Hasselbalch (HH) alternative** pK_a = –log 1.75×10^{-5} = 4.757 (or 4.756961951..) $pH = pK_a + \log \frac{[CH_3COO^-]}{[CH_3COOH]}$ **OR** $= pK_a - \log \frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $pK_a + \log \frac{0.443}{0.800}$ **OR** $= pK_a - \log \frac{0.800}{0.443}$ ✓ $= pK_a - 0.257$ ✓ $= 4.757 - 0.257 = 4.50$ ✓	**5**	**ALLOW** 2 sig fig **ALLOW** use of **HA** and **A^-** Mark by **ECF** --- **Alternative method** (If both methods are attempted, mark the method which produces the higher mark) **$[H^+]$** $[H^+] = 10^{-pH} = 10^{-4.50}$ $= 3.16 \times 10^{-5}$ (mol dm^{-3}) ✓ **$[CH_3COO^-]$** $[CH_3COO^-] = K_a \times \frac{[CH_3COOH]}{[H^+]}$ **OR** $1.75 \times 10^{-5} \times \frac{0.800}{3.16 \times 10^{-5}}$ ✓ = 0.443 (mol dm^{-3}) ✓ **mass of CH_3COONa** mass $CH_3COONa = 0.443 \times \frac{250}{1000}$ **OR** 0.111 ✓ 0.111×82.0 = **9.08** (g) ✓ --- **Common errors** **4.64** Use of $M(CH_3COONa) = 60$ 4 marks **2.40** Use of K_a of FCH_2COOH 4 marks

Mark Scheme

Question			Answer	Marks	Guidance
		(ii)	pH is the same/constant ✓ ratio/proportion $[HA]/[A^-]$ is the same ✓	2	M2 is dependent upon M1 **ALLOW** Change in [HA] and $[A^-]$ is proportional
			Total	12	

Mark Scheme

Question	Answer	Marks	AO element	Guidance
7	C	1	AO2.6	

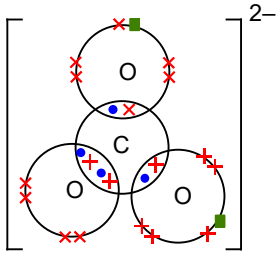
Mark Scheme

Question			Answer	Marks	Guidance
8	(a)	(i)	$K_a = \frac{[H^+]\,[CH_3COO^-]}{[CH_3COOH]}$ ✓	1	**IGNORE** state symbols Must be square brackets **IGNORE** expressions with HA or with $[H^+]^2$
		(ii)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = 4.76 award 3 marks** --- **$[H^+] = 10^{-pH}$** $= 10^{-2.41} = 3.89 \times 10^{-3}$ (mol dm^{-3}) ✓ ***K*$_a$** $= \frac{[H^+]^2}{[CH_3COOH]} = \frac{(3.89 \times 10^{-3})^2}{0.870}$ $= 1.74 \times 10^{-5}$ (mol dm^{-3}) ✓ **p*K*$_a$** $= -\log K_a = -\log 1.74 \times 10^{-5} = 4.76$ ✓	3	**ALLOW** use of **HA** and **A$^-$** **ALLOW 3 SF** up to calculator value of: $3.89045145 \times 10^{-3}$ correctly rounded ***K*$_a$** $1.739725573 \times 10^{-3}$ **NOTE:** 1.74×10^{-5} is same from unrounded $[H^+]$ calculator value and 3 SF $[H^+]$ value **2 DP required**
		(iii)	% dissociation $= \frac{[H^+]}{[CH_3COOH]} \times 100$ $= \frac{3.89 \times 10^{-3}}{0.870} \times 100 = 0.447(\%)$ ✓	1	**3 SF required**

Mark Scheme

Question	Answer	Marks	Guidance
(b)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = 95.9(%) award 4 marks** --- **$[H^+] = 10^{-pH}$** $= 10^{-13.48} = 3.31 \times 10^{-14}$ (mol dm^{-3}) ✓ **$[OH^-]$ from K_w** $= \frac{1.00 \times 10^{-14}}{3.31 \times 10^{-14}} = 0.302$ (mol dm^{-3}) ✓ ***Mass of* (NaOH)** $= 0.302 \times \frac{100}{1000} \times 40.0 = 1.21$ (g) ✓ **% of NaOH to 3 SF** $= \frac{1.21}{1.26} \times 100 = 95.9$ (%) ✓	**4**	**ALLOW ECF** throughout **IGNORE** rounding errors beyond 3rd SF throughout **ALLOW** 3.3×10^{-14} (mol dm^{-3}) **ALLOW** 0.30 **ALLOW** 0.303 if 3.3×10^{-14} used in the first marking point **ALLOW** pOH method:, pOH = 14 – 13.48 = 0.52 $[OH^-] = 10^{-0.52} = 0.302$ (mol dm^{-3}) **ALLOW** $[OH^-] \times 0.1 \times 40$ Rounding $[OH^-]$ to 0.3(0) gives 1.2/1.26 = 95.2% Award 4 marks Rounding $[OH^-]$ to 0.303 gives 1.212/1.26 = 96.2% Award 4 marks

Mark Scheme

Question	Answer	Marks	Guidance
(c)	 **Global rules** • C and O electrons must be shown differently, e.g. • for C and × for O • Na electrons shown with different symbol **MARKING** ***Bonding around central C atom*** ✓ • 4 electrons for C shown as • **OR** × • 4 electrons for O, different from C as • **OR** × • C=O bond with 2 C electrons **AND** 2 O electrons • Two C–O bonds with 1 C electron **AND** 1 O electron ***Non-bonded (nb) electrons around 3 O atoms*** ✓ • C=O oxygen has 4 nb 'O' electrons • Each C–O oxygen has 5 nb 'O' electrons **AND** 1 'extra' electron with different symbol	**2**	**NOT REQUIRED** • Charge ('2–') **IGNORE** incorrect charges • Brackets • Circles **IGNORE** inner shells **ALLOW** rotated diagram **ALLOW** diagram with missing C or O symbols. In **C=O bond**, **ALLOW** sequence × × • • In **C–O bond**, **ALLOW** 'extra' electron with different symbol for O electron **ALLOW** non-bonding electrons unpaired **ALLOW** 'extra' electron as • **OR** × if it has been **labelled** 'extra electron' or similar
	Total	**11**	

Mark Schemes

Question	Answer	Marks	AO element	Guidance
9	**D**	**1**	AO1.2	

Mark Schemes

Question			Answer	Marks	AO element	Guidance
10	(a)		***Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*** **Level 3 (5–6 mark)** Detailed explanation of equilibrium, the action of the buffer and correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Detailed explanation of equilibrium **and** the action of the buffer. **OR** Detailed explanation of equilibrium **and** correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. **OR** Detailed explanation of the action of the buffer **and** correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. **OR** Partial explanations of equilibrium, **and** the action of the buffer **and** attempt calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Detailed explanation of equilibrium. **OR** Correct calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. **OR** Detailed explanation of the action of the buffer. **OR** Partial explanations of equilibrium **and** the action of the buffer.'	**6**	**1.1 ×2** **1.2 ×2** **3.1 ×1** **3.2 ×1**	**Indicative scientific points may include:** *(State symbols not required in equations)* **Equilibrium and equilibrium shifts** • $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ • Addition of H^+ causes ⇌ to shift to left • Addition of OH^- causes ⇌ to shift to right **Action of buffer** • Increase in H^+ / addition of acid leads to: $H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$ **OR** HCO_3^- reacts with added acid • Increase in OH^- / addition of alkali leads to: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ **OR** $H_2CO_3(aq) + OH^-(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$ **OR** H_2CO_3 reacts with added alkali **Calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio** • $K_a = 10^{-6.38}$ **OR** 4.17×10^{-7} (mol dm^{-3}) • $[H^+] = 10^{-7.40}$ **OR** 3.98×10^{-8} (mol dm^{-3}) • $\frac{[HCO_3^-]}{[H_2CO_3]}$ **OR** $\frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}}$ • ratio **=** 10.47(:1) OR 10.48(:1) **ALLOW** 10.5 OR 10(:1) (after working shown) **ALLOW** $\frac{4.2 \times 10^{-7}}{4.0 \times 10^{-8}}$ **And** ratio = 10.5 **OR** 11 (after working shown)

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			OR Partial explanation of equilibrium **and** attempt at calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio.' **OR** Partial explanation of the action of the buffer and attempt at calculation of $[HCO_3^-]$: $[H_2CO_3]$ ratio. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant*. **0 marks** *No response or no response worthy of credit.*			**ALLOW** $\frac{[H_2CO_3]}{[HCO_3^-]}$ **OR** $\frac{3.98 \times 10^{-}}{4.17 \times 10^{-7}}$ **And** ratio = 1 : 0.095 ..
	(b)		*Coordinate bond mark* O_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron ✓ Ligand substitution mark (When required) O_2 is replaced by H_2O **OR** CO_2 **OR** O_2 is replaced by CO **OR** H_2O **OR** CO_2 is replaced by O_2 ✓ *Ligand strength mark* CO forms strong(er) bonds (than O_2) ✓	**3**	**1.1 ×2** **2.1 ×1**	**ALLOW** names or symbols of ligands **ALLOW** H_2O/CO/CO_2 (coordinately or datively) bonds with Fe^{2+}/Fe(II)/Fe/Iron **ALLOW** oxygen donates electron pair to **OR** binds with Fe^{2+}/Fe(II)/Fe/Iron **DO NOT ALLOW** Fe^{3+} **ALLOW** other words for replaced **ALLOW** K_{stab} for CO (much) higher (than for O_2) **ALLOW** CO bonds irreversibly **OR** CO is a strong(er) ligand **IGNORE** affinity
			Total	**9**		

Mark Schemes

Question			Answer	Marks	AO element	Guidance
11	(a)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.98 award 2 marks** --- $[H^+] = \sqrt{(Ka \times [C_2H_5COOH])} = 1.039 \times 10^{-3}$ (mol dm^{-3}) ✓ pH = –log 1.039×10^{-3} = 2.98 (**Must be to 2 DP**) ✓	**2**	**2.2 ×2**	**ALLOW ECF** throughout **ONLY ALLOW** pH mark by **ECF** if K_a **AND** 0.080 used and **AND** pH <7 **Common errors (Must be to 2 DP)** One mark for pH = 5.97 (*No square root):* One mark for pH = 0.92 **OR** pH = 5.15 (*Using incorrect K_a values*)
	(b)	**(i)**	$n(C_2H_5COOH) = (0.0800 \times \frac{25.0}{1000}) =) 0.002$ (mol) **AND** $V(NaOH) = \frac{0.002}{0.100} \times 1000 =$ (= 20(.0) cm^3) ✓	**1**	**2.5**	**ALLOW** 0.02 dm^3 if unit given Mark is for **WORKING** which could all be shown as 1 step **ALLOW** method showing 20cm^3 NaOH contains the same moles as acid $n(C_2H_5COOH)$ = 0.08(00) x 0.025(0) = 0.002 (mol) and n(NaOH) = 0.02(00) x 0.1 = 0.002(00) (mol)
	b	**(ii)**	**FIRST CHECK THE ANSWER ON ANSWER LINE**	**4**		**ALLOW ECF** throughout

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			If answer = 12.55 award 4 marks **----------** ***Excess mol of NaOH:*** $n(OH^-)_{excess} = n(OH^-) - n(C_2H_5COOH)$ $= (0.100 \times \frac{45.0}{1000}) - (0.0800 \times \frac{25.0}{1000})$ $= 0.0045 - 0.002 = 0.0025$ (mol) ✓ ***Concentration of OH^-:*** $[OH^-] = (\frac{0.0025}{70.0 \times 10^{-3}}) = 0.0357$ (mol dm^{-3}) ✓ ***Concentration of H^+:*** $[H^+] = (\frac{1.00 \times 10^{-14}}{0.0357}) = 2.8 \times 10^{-13}$ (mol dm^{-3}) ✓ ***Conversion to pH:*** pH = ($-\log 2.8 \times 10^{-13}$) = 12.55 ✓		**1.2 ×1** **2.6 ×3**	For first mark **ALLOW** *(*Excess volume of NaOH **=** 25(.0) cm^3) $n(OH^-)_{excess} = 0.100 \times \frac{25.0}{1000} = 0.0025$ (mol) Common errors If initial *V(*NaOH) = 45 cm^3 $[OH^-] = 0.0643$ (mol) $[H^+] = 1.56 \times 10^{-13}$ (mol dm^{-3}) pH = 12.81 award three marks (no 1st mark) If $n(OH^-)_{excess}$ is used in $[H^+]$ calculation $n(OH^-)_{excess} = 0.0025$ (mol) $[H^+] = \frac{1.00 \times 10^{-14}}{0.0025} = 4.(00) \times 10^{-12}$ (mol dm^{-3}) pH = 11.40 award three marks (no 2nd mark) **ALLOW** pOH method for last two marks pOH = $-\log[OH^-] = 1.447$ pH = 14 – 1.447 = 12.55 **ALLOW** ECF for conversion from $[H^+]$ to pH provided value calculated is above 7 and from derived $[H^+]$
	b	**(iii)**	**Shape**	**3**	**2.3 ×1**	If pH curves wrong way round (i.e. adding acid to

Mark Schemes

Question			Answer	Marks	AO element	Guidance
			Slight rise/flat, **AND** (near) vertical, **AND** then slight rise/flat ✓ **pH** Vertical section within the extremes of pH 5 to 12 and a minimum range of three pH units **AND** middle of vertical section (equivalence point) needs to be above pH 7 ✓ **End point** Vertical section at ~ 20 cm^3 NaOH ✓		**2.4 ×2**	alkali), **ONLY award mark for End point** (~ 20 cm^3)
		(iv)	cresol purple **AND** pH range matches vertical section/rapid pH change **OR** end point/colour change matches vertical section/rapid pH change ✓	**1**	**3.3**	**ALLOW** pH range (of the indicator) matches equivalence point **ALLOW** end point/colour change matches equivalence point **IGNORE** colour change matches end point *Colour change is the same as end point*
		(v)	**similarity**: end point / volume (20 cm^3) of NaOH needed to neutralise **OR** **final** pH / shape of curve after end point ✓ **difference**: HCN higher **starting** pH **OR** HCN shorter vertical section ✓	**2**	**3.2 ×2**	End point must not refer to same pH **ALLOW** different equivalence point **IGNORE** different starting pH

Mark Schemes

Question			Answer	Marks	AO element	Guidance
	(c)		HIO_3 dissociation is not negligible / dissociates to a significant extent **OR** Large K_a **and** HIO_3 is 'stronger' (weak) acid **OR** $[HIO_3]_{eqm}$ is significantly lower than $[HIO_3]_{initial/undissociated}$ ✓	**1**	**3.3**	**ALLOW** use of HA **Ignore** $[HIO_3]_{equilibrium} < [HIO_3]_{initial/undissociated}$ **ALLOW** $[HIO_3]_{equilibrium} \sim [HIO_3]_{undissociated}$ is no longer a valid assumption **ALLOW** $[HIO_3]$ has a larger K_a so the assumption that $[HIO_3]$ at equilibrium = $[HIO_3]$ initially so assumption is not valid
			Total	**15**		

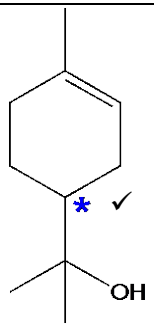
Mark Scheme

Question			Answer	Marks	AO element	Guidance
12	(a)	(i)	4-chloro-3,5-dimethylphenol ✓ **CARE**: Look for **di**methyl	1	AO1.2	**ALLOW** 3,5-dimethyl-4-chlorophenol **ALLOW** absence of hyphens or extra hyphen or space, e.g. 4 chloro 3,5 dimethylphenol **ALLOW** full stops or spaces between numbers e.g. 4-chloro-3.5-dimethylphenol **ALLOW** name based on benzene, if unambiguous e.g.1-chloro-4-hydroxy-2,6-dimethylbenzene **DO NOT ALLOW** meth **OR** methy
		(ii)	5 ✓	1	AO2.5	
		(iii)	**Functional group** Phenol ✓ **Test** Indicator/pH paper turns red / orange **OR** pH < 7 **OR** pH meter < 7 **AND** No reaction with Na_2CO_3/CO_3^{2-}/carbonate ✓	2	AO1.2 AO2.3	**DO NOT ALLOW** alcohol **OR** hydroxide **IGNORE** hydroxyl **OR** hydroxy **IGNORE** OH (*name asked for*) **ALLOW** Add bromine **AND** white precipitate **ALLOW** $FeCl_3$ **AND** violet/blue colour

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 1.71×10^{-10}, award **FOUR calculation marks** **CARE Separate mark for equation** --- **Equation (1 mark)** $C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$ ✓ *Molecular formulae required (atoms in any order)* **[C_8H_9ClO] calculation (2 marks)** Molar mass C_8H_9ClO = 156.5 (g mol^{-1}) ✓ **ONLY** correct answer $[C_8H_9ClO] = \frac{4.8 \times 10}{156.5}$ **OR** 0.3067….. (mol dm^{-3}) ✓ *Subsumes mark for molar mass = 156.5* **K_a calculation (2 marks)** $[H^+] = 10^{-5.14} = 7.244….. \times 10^{-6}$ (mol dm^{-3}) ✓ $K_a = \frac{(7.244…. \times 10^{-6})^2}{0.3067…..} = 1.71 \times 10^{-10}$ (mol dm^{-3}) ✓	**5**	AO1.2 ×1 AO2.8 ×4	**ALLOW** → for ⇌ **DO NOT ALLOW** C_8H_8ClOH in equation i.e. $C_8H_8ClOH \rightleftharpoons H^+ + C_8H_8ClO^-$ If equation is omitted, **ALLOW** equation mark for a correct K_a expression with molecular formula i.e. $\frac{[H^+]\,[C_8H_8ClO^-]}{[C_8H_9ClO]}$ **NO ECF** from an incorrect formula in equation **ALLOW ECF** from incorrect molar mass **ALLOW** 0.307 up to calculator value: 0.306709265 correctly rounded **ALLOW** 7.24×10^{-6} up to calculator value: $7.244359601 \times 10^{-6}$ correctly rounded **ALLOW 2 SF** ($1.7…. \times 10^{-10}$) up to calculator value, correctly rounded (but take care from acceptable intermediate rounding) **COMMON ERRORS** $2.36….. \times 10^{-5}$ 3/4 calculation marks *No squaring of 7.24 $\times 10^{-6}$*

Mark Scheme

Question			Answer	Marks	AO element	Guidance
	(b)	(i)	 ✓	1	AO2.5	**DO NOT ALLOW** more than one * **ALLOW** a circle for *
		(ii)	**MAXIMUM OF 4 MARKS FROM 5 MARKING POINTS** **Requirement for *E*/*Z* isomerism** ***2 marks*** C=C/double bond ✓ Each C (in C=C) is attached to (two) different groups/atoms ✓ **Identification as *E*- or *Z*- isomer** ***2 marks*** *E/Z* isomerism linked to (high) **priority groups** ✓ ***Z*- isomer AND** groups are on **same side** **OR** the ring carbons ✓ **Reason why other *E*/*Z* isomer does not exist** ***1 mark*** **ring** would be strained **OR ring** would break/deform **OR** Cannot form **ring** if high priority groups are on opposite sides **OR** ring locks groups on one side of C=C bond ✓	4	AO1.2 ×2 AO2.5 ×2	**IGNORE** no H attached to C=C **IGNORE** functional', i.e. **ALLOW** different functional groups **ALLOW** in context of groups with largest atomic number ***ORA*** ***Award BOTH identification marks for:*** ***Z*-** isomer **AND** (high) **priority groups** on **same side** Mark independently of previous part Response **MUST** be linked to the **ring**/cyclic structure **IGNORE** just '*E* isomer is impossible' **IGNORE** C=C bond cannot rotate **IGNORE** Groups can't swap sides

Mark Scheme

Question			Answer	Marks	AO element	Guidance
		(iii)	**First group**: **Reagent** **AND** **Functional group**: Alkene **OR** cycloalkene ✓ ***Examples of reagents*** Br_2 or other halogen, HBr, H_2 **AND** Ni (catalyst), H_2O(**g**)/steam **AND** H^+ (catalyst) **Organic product** for reagent with **C=C** in α-terpineol ✓ ***ALLOW*** *product from H_2 or H_2O if H^+ catalyst has been omitted from reagent.* --- **Second group** **Reagent** **AND** **Functional group**: (Tertiary) alcohol ✓ ***Examples of reagents*** NaBr/KBr/Br^- **AND** acid/H^+ (substitution), **OR** HBr Acid/H^+ (catalyst) (elimination), CH_3COOH **AND** acid/H^+ (catalyst) (esterification) $CH_3COOCOCH_3$ (esterification) CH_3COCl (esterification) **Organic product** for reagent with **OH** in α-terpineol ✓ ***ALLOW*** *product if catalyst omitted from reagent*	**4**	AO3.2 ×4	**CONTACT TEAM LEADER FOR OTHER REACTIONS** --- **ALLOW GROUPS EITHER WAY ROUND IN BOXES** Functional group **MUST** be **named** **DO NOT ALLOW** UV with halogens **ALLOW** H_2SO_4/H_3PO_4/acid for H^+ **ALLOW** addition of HBr/ H_2O either way across C=C **ALLOW ANY HALIDE**, i.e. Cl^-, Br^-, I^- **ALLOW** H_2SO_4/H_3PO_4/acid for H^+ **ALLOW** HBr for H^+ and Br^- **ALLOW** name or formula of any carboxylic acid or acyl chloride for esterification **ALLOW** Na → product with –ONa **OR** $–O^-$ **DO NOT ALLOW** $Cr_2O_7^{2-}/H^+$ (tertiary alcohol)
			Total	**18**		

Mark Scheme

Question	Answer	Marks	AO element	Guidance
13	D	1	2.2	

Mark Scheme

Question			Answer	Marks	AO element	Guidance
14	(a)		**Equation**: $Mg + 2CH_3COOH \rightarrow (CH_3COO)_2Mg + H_2$ ✓	3	2.6	**ALLOW** $Mg(CH_3COO)_2$ **ALLOW** multiples **IGNORE** Oxidation numbers in formulae **IGNORE** state symbols
			Oxidation: Mg from 0 to +2 ✓		1.2	Mark independently from equation
			Reduction: H from +1 to 0 ✓		1.2	**ALLOW** 1 mark for correct oxidation numbers but incorrectly linked to redox.
	(b)		$HCOOH + CH_3COOH \rightleftharpoons HCOO^- + CH_3COOH_2^+$ ✓ **A1 B2 B1 A2** **OR** **A2 B1 B2 A1** ✓ **CARE:** Both + and – charges required for products in equilibrium **DO NOT AWARD** the 2nd mark from an equilibrium expression that omits either charge	2	1.2×2	**IGNORE** state symbols (even if wrong) **IF** proton transfer is wrong way around **ALLOW** 2nd mark for idea of acid–base pairs, ***i.e.*** $HCOOH + CH_3COOH \rightleftharpoons HCOOH_2^+ + CH_3COO^-$ **B2 A1 A2 B1** **NOTE** For the 2nd marking point (acid–base pairs), this is the **ONLY** acceptable **ECF** ***i.e. NO ECF*** *from impossible chemistry*
	(c)	(i)	$[H^+] = 10^{-2.72}$ **OR** 1.905×10^{-3} (mol dm^{-3}) ✓ $[CH_3COOH] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}}$ ✓ (= 0.204 mol dm^{-3})	2	2.4×2	**ALLOW** 2SF up to calculator value of $1.905460718 \times 10^{-3}$ **ALLOW** use of [HA] Mark is for working.

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 2.4×10^{-2} (mol dm^{-3}) **award 4 marks** --- **Calculation of H^+ in buffer** $[H^+]_{buffer} = 10^{-4.00}$ **OR** 1×10^{-4} (mol dm^{-3}) ✓ **Calculation of CH_3COOH in buffer** $n(CH_3COOH)$ **OR** $[CH_3COOH]_{buffer}$ $= \frac{0.204}{1000} \times 400$ **OR** 8.16×10^{-2} ✓ **Calculation of $[CH_3COO^-]$ in buffer (in 1 dm^3)** $[CH_3COO^-]_{buffer} = 1.78 \times 10^{-5} \times \frac{8.16 \times 10^{-2}}{1 \times 10^{-4}}$ **OR** 1.5×10^{-2} (mol dm^{-3}) ✓ **Calculation of original $[CH_3COO^-]$ (in 600 cm^3)** $[CH_3COO^-]_{initial} = (\frac{1.45248 \times 10^{-2} \times 1000}{600})$ $= 2.4 \times 10^{-2}$ (mol dm^{-3}) ✓ ---	**4**	3.3×3 3.4×1	**ALLOW ECF** **ALLOW** [HA] and [A^-] in working **ALLOW** 1.5×10^{-2} up to calculator value 1.45248 $\times 10^{-2}$ (mol dm^{-3}) **ALLOW** 2.4×10^{-2} up to calculator value 2.4208×10^{-2} (mol dm^{-3}) **COMMON ERRORS BUT CHECK WORKING** $[CH_3COO^-]_{initial} = 8.7 \times 10^{-3}$ 3 marks *600 and 1000 inverted* $[CH_3COO^-]_{initial} = 3.6 \times 10^{-6}$ 3 marks *$[CH_3COOH] : [H^+]$ inverted* $[CH_3COO^-]_{initial} = 1.3 \times 10^{-6}$ 2 marks *$[CH_3COOH] : [H^+]$ inverted AND 600 and 1000 inverted* No volumes used = 3.6×10^{-2} 2 marks

Mark Scheme

Question	Answer	Marks	AO element	Guidance
	ALLOW alternative approach based on Henderson–Hasselbalch equation (**ALLOW** $-\log K_a$ for pK_a) e.g. $pH = pK_a + \log\frac{[CH_3COOH]}{[CH_3COO^-]}$ **OR** $pK_a - \log\frac{[CH_3COO^-]}{[CH_3COOH]}$ **OR** $4 = 4.75 + \log\frac{8.16 \times 10^{-2}}{[CH_3COO^-]}$ **OR** $4.75 - \log\frac{[CH_3COO^-]}{8.16 \times 10^{-2}}$ ✓ $\log[CH_3COO^-] = 4 - 4.75 - 1.09 = -1.84$ ✓ $[CH_3COO^-]_{buffer} = 1.5 \times 10^{-2}$ ✓ $[CH_3COO^-]_{initial} = 2.4 \times 10^{-2}$ ✓			**ALLOW** $-\log K_a$ for pK_a ----------
	Total	**12**		

Mark Scheme

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>15</td><td>(a)</td><td></td><td>
<table>
<tr><th>Bond angle</th><th>Name of shape</th></tr>
<tr><td>120(°)</td><td>Trigonal planar</td></tr>
<tr><td>104–105(°)</td><td>Non-linear</td></tr>
</table>
Mark by row OR by column to give higher mark

i.e. 2 bond angles correct ✓
2 shapes correct ✓
OR
i.e. bond angle AND shape correct in 1st row ✓
bond angle AND shape correct in 2nd row ✓
</td><td>2</td><td>1.2×2</td><td>For non-linear,
ALLOW bent, v-shaped, angular
IGNORE planar, ‘not straight’</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
$CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$ ✓

A1 B2 B1 A2 ✓

For an equilibrium shown using CH_3COOH instead of H_2O, mark acid–base pairs by ECF, i.e.
$CH_3SO_2OH + CH_3COOH \rightleftharpoons CH_3SO_2O^- + CH_3COOH_2^+$ ☒
A1 B2 B1 A2 ECF ✓

CH_3SO_2OH dissociates more (than CH_3COOH)
OR CH_3SO_2OH is a stronger acid ✓

ORA in terms of CH_3COOH being a weaker acid

Student is correct
AND
(sulfonic acid has) lower pK_a/higher K_a OR greater $[H^+]$
ORA ✓
</td><td>4</td><td>2.1×2

3.1

3.2</td><td>ALLOW → for ⇌

ALLOW acid–base pairs labelled other way round.
i.e. $CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$
A2 B1 B2 A1
ALLOW ~~small slip~~

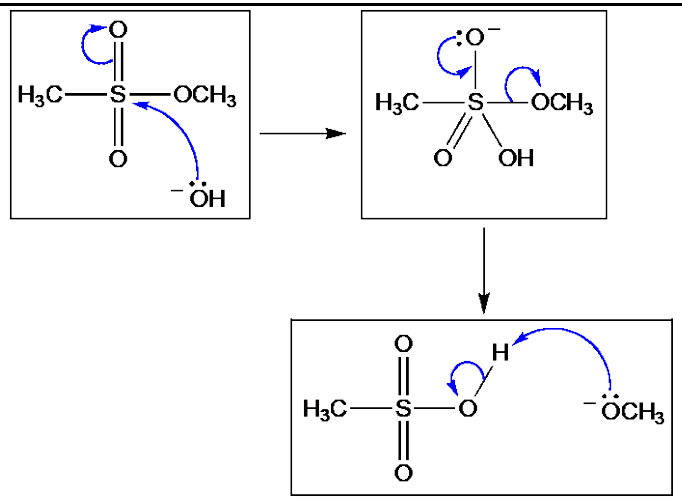
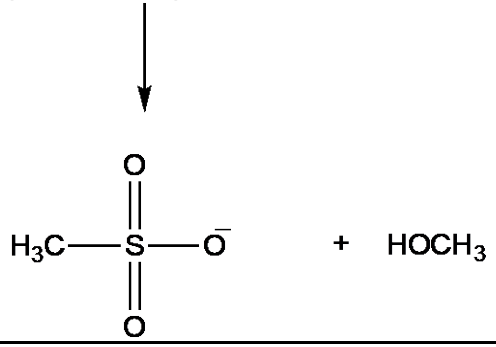
If ONE charge is missing from equilibrium.
ALLOW ECF for acid–base pairs mark

IGNORE ‘more acidic’
Response needs strength/dissociation

ALLOW maths explanation for final 2 marks, e.g.
$K_a(CH_3COOH) = 10^{-(4.76)} = 1.74 \times 10^{-5}$
$[H^+] = \sqrt{(1.74 \times 10^{-5}) \times 1)} = 4.17 \times 10^{-3}$
$pH = -\log 4.17 \times 10^{-3} = 2.38$ ✓

$K_a(CH_3SO_2OH) = 10^{-(-1.90)} = 79.4$
$[H^+] = \sqrt{(79.4) \times 1)} = 8.91$
$pH = -\log 8.91 = -0.95$ ✓
BOTH pH calcs subsumes ‘Student is correct’</td></tr>
</table>

Mark Scheme

Question	Answer	Marks	AO element	Guidance
(c)	 6 curly arrows correct ✓✓✓✓ 5 curly arrows correct ✓✓✓ 4 curly arrows correct ✓✓ 3 curly arrows correct ✓	4	3.1×4	**IGNORE** any added charges **OR** dipoles. *Marks solely for curly arrows* **IGNORE** any curly arrows on bottom structures (not in boxes): 
	Total	**10**		