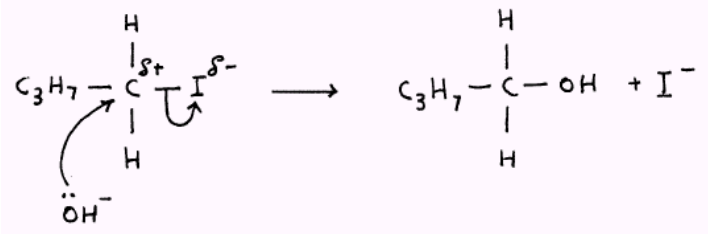
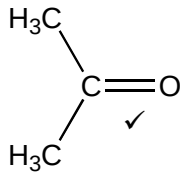
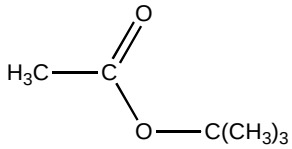
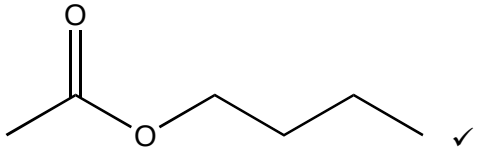
Question			Expected Answers	Marks	Additional Guidance
1	a		Answers clockwise from top left $CH_3CH_2CH_2COOH$ ✓ $CH_3CH_2CHCH_2$ ✓ $CH_3COOCH_2CH_2CH_2CH_3$ ✓ $CH_3CH_2CH_2CHO$ ✓	4	**ALLOW** skeletal formula **ALLOW** butanoic acid **ALLOW** but-1-ene **ALLOW** butyl ethanoate **ALLOW** butanal If name and structure given both must be correct If C_3H_7 used instead of $CH_3CH_2CH_2$ penalise once and then apply ECF If wrong carbon skeleton used then penalise once then apply ECF If a hydrogen is missing then penalise once

Question			Expected Answers	Marks	Additional Guidance
	b	**i**	Nucleophilic substitution ✓ Heterolytic ✓ Dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ Curly arrow from OH^- to carbon atom of C–I bond ✓ Curly arrow from C–I bond to the iodine atom ✓	5	**ANNOTATE WITH TICKS AND CROSSES** **DO NOT ALLOW** fish hooks No need to show lone pair on OH^- or I^- Curly arrow must come from the negative sign or lone pair on the oxygen of the hydroxide ion  **ALLOW S_N1 mechanism** dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ curly arrow from C–I bond to the iodine atom ✓ curly arrow from OH^- to correct carbonium ion ✓
		ii	Use reflux **OR** heat for more than 20 minutes ✓ C–C*l* stronger bond (than C–I bond) **OR** C–C*l* shorter bond (than C–I bond) **OR** C–C*l* bond is harder to break **OR** needs more energy to break C–C*l* bond **OR** ora ✓	2	**ALLOW** heat stronger **OR** heat for longer **OR** heat at a higher temperature **OR** more heat Answer must refer to the C–C*l* bond or C–I bonds
			Total	**11**	

Question			Expected Answers	Marks	Additional Guidance
2	(a)		**method 1:** fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓ $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ **method 2:** hydration of ethene OR reaction of ethene with water **OR** reaction of steam with ethene ✓ $C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓	**4**	**ALLOW** sugar from equation **ALLOW** C_2H_6O in equation **ALLOW** correct multiples **IGNORE** state symbols **ALLOW** ethene from the equation **IGNORE** mention of any catalyst **ALLOW** C_2H_6O in equation **OR** H_2O over the arrow **ALLOW** correct multiples **IGNORE** state symbols
	(b)	(i)	$(CH_3)_2CO$ **OR**  ✓ $(CH_3)_2CHOH + [O] \longrightarrow (CH_3)_2CO + H_2O$ ✓	**2**	If name and formula given both need to be correct **ALLOW** propanone **OR** acetone **IGNORE** propone **NOT** incorrect named compound **ALLOW** $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ **ALLOW** O instead of [O] **ALLOW** correct multiples **IGNORE** state symbols
		(ii)	CH_3CH_2COOH **OR** propanoic acid ✓ Any number or range of numbers between 1750–1640 (cm^{-1}) for C=O ✓ Any number or range of numbers between 2500–3300 (cm^{-1}) for O–H ✓	**3**	 **ALLOW** C=O and O—H marks independent of compound identified **i.e. stand alone marks** **ALLOW** correct bonds shown by the appropriate absorption on the IR spectrum **IGNORE** reference to C—O bond
	(c)	(i)	2-methylpropan-2-ol ✓	**1**	**ALLOW** methylpropan-2-ol **OR** tertiarybutanol

Question			Expected Answers	Marks	Additional Guidance
		(ii)	ester ✓	1	
		(iii)	$CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$ **OR**  ester group shown ✓ rest of molecule ✓	2	**ALLOW** skeletal formula **OR** displayed formula **ALLOW** ester linkage even if rest of structure is wrong
			Total	13	

Question			Answer	Mark	Guidance
3	(a)		 ✓	1	**IGNORE** any structural or displayed formula shown even if wrong (ie treat as rough working)
	(b)		(M_r of all reactants **or** M_r of all products) is 134.0 **OR** 134 **OR** (M_r of desired product) is 116.0 **OR** 116 ✓ Atom economy = $100 \times \frac{116.0}{134.0}$ ✓	2	Remember the marks are for the working out and not for the answer **IGNORE** lack of decimal place in answer **ALLOW** correct expressions to calculate the M_r or the atom economy eg Atom economy = $100 \times \frac{(6\times12)+(12\times1)+(2\times16)}{116+18}$ Award 2 marks for this expression: $100 \times \frac{116.0}{134.0}$ or similar expressions such as that above (subsumes 1st marking point)
	(c)	(i)	**acid** (catalyst) ✓ heat **OR** reflux ✓	2	**ALLOW** any acid, concentrated or dilute **ALLOW** 'high temperature' **OR** any temperature from 70 ºC to 120 ºC Warm is **not** sufficient **but ALLOW** warm to 80 ºC **IGNORE** pressure

Question			Answer	Mark	Guidance
3	(c)	(ii)	maximum mass of ester than can be made is 9.7972973 (g) ✓ % yield = $\frac{6.57}{9.80} \times 100$ ✓ **ALLOW** 2 or more sig figs up to calculated value but rounded up correctly, ie **ALLOW** $\frac{6.57}{9.797} \times 100$ **OR** $\frac{6.57}{9.8} \times 100$	2	**ALLOW** moles of butan-1-ol = 0.08445946 **AND** moles of ester = 0.05663791 **OR** moles of butan-1-ol = $\frac{6.25}{74}$ **AND** moles of ester = $\frac{6.57}{116}$ for one mark **ALLOW** % yield = $\frac{0.05664}{0.08446} \times 100$ for one mark **ALLOW** 2 or more sig figs up to calculated value but rounded up correctly, ie $\frac{0.057}{0.084} \times 100$ **OR** $\frac{0.0566}{0.0845} \times 100$ Remember the marks are for the working out
	(d)		Link between yield **AND** explanation required: (high percentage) yield shows a high % conversion (of reactants into products) ✓ Link between atom economy **AND** explanation required: (low) atom economy shows a **lot** of waste (product) **OR** (low) atom economy shows not much desired product ✓	2	**ALLOW** percentage yield takes into account the practical difficulties of the process **OR** high % yield very little experimental loss of product **OR** high % yield because the process is not reversible **OR** most of reactants react to form products **DO NOT ALLOW** 'a lot of product made' There are waste products is **NOT** sufficient Reaction forms many products is **NOT** sufficient **ALLOW** undesired product(s) as alternative for waste **IGNORE** a lot of by-products but …….. **ALLOW** a lot of **waste** by-products **ALLOW** (low) atom economy shows a **lot** of HCl **OR** a lot of SO_2 is made **ALLOW** (low) atom economy shows not much ester / butyl ethanoate made

Question			Answer	Mark	Guidance
	(e)		**NOTE**: **Comparison** essential throughout, ie **higher**, **less**, etc. **ANY TWO FROM** Less waste (products) **OR** higher atom economy ✓ Less toxic reactants **OR** less toxic (waste) products **OR** less corrosive reactants **OR** less corrosive (waste) products **OR** less harmful reactants **OR** less harmful (waste) products **OR** less hazardous reactants **OR** less hazardous (waste) products ✓ Cheaper starting materials **OR** more readily available starting materials ✓ Fewer steps **OR** one step rather than two steps ✓	2	**ALLOW** more sustainable **ALLOW** poisonous for toxic **IGNORE** 'dangerous' 'Water is produced' is **not** sufficient Cheaper is **not** sufficient on its own **IGNORE** less energy **OR** easier to carry out **OR** reversible
			Total	**11**	