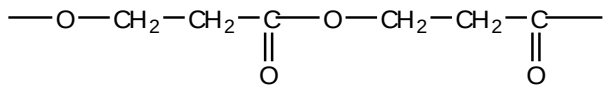
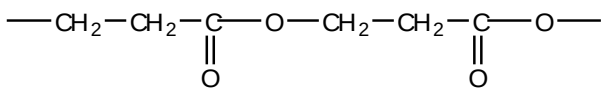
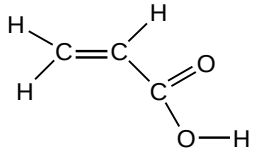
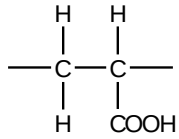
Question 1: N/A
Question 2: N/A

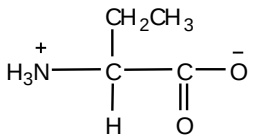
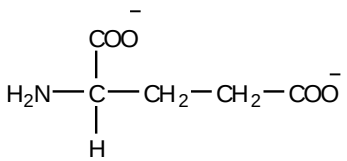
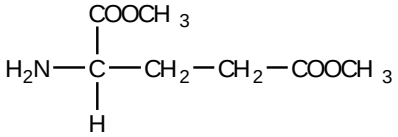
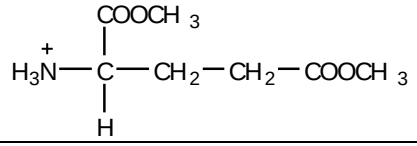
Question	Marking Guidance	Mark	Comments
3(a)	mol CH_3OH = 0.07(0) mol H_2 = 0.24(0)	1 1	
3(b)(i)	$\frac{[CH_3OH]}{[CO][H_2]^2}$ or $\frac{(0.082/1.5)}{(0.210/1.5)(0.275/1.5)^2}$	1	allow ( ) but expression using formulae must have brackets alternative expression using numbers must include volumes
3(b)(ii)	**M1** divides by vol **M2** $\frac{(0.082/1.5)}{(0.210/1.5)(0.275/1.5)^2}$ (= $\frac{(0.05467)}{(0.14)(0.1833)^2}$) **M3** 11.6 or 11.7 **M4** $mol^{-2}\,dm^6$	1 1 1 1	Mark independently from (b)(i) any AE is –1 if volume missed, can score only M3 and M4 mark is for correct insertion of correct numbers in correct Kc expression in b(ii) If Kc expression wrong, can only score M1 & M4 If numbers rounded, allow M2 but check range for M3 mark for answer above 11.7 up to 12.2 scores 2 for M1 and M2 if vol missed, can score M3 for 5.16 (allow range 4.88 to 5.21) Units conseq to their Kc in (b)(ii)
3(b)(iii)	no effect or no change or none	1	

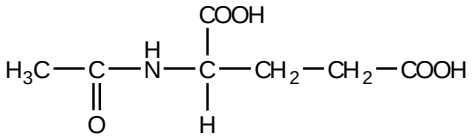
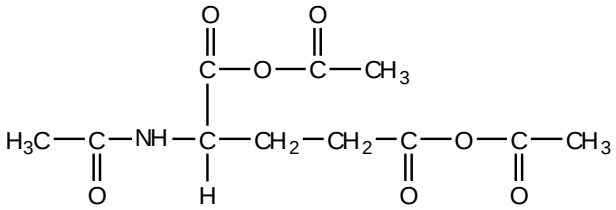
3(c)	**M1** T_1			1	if wrong - no further marks
	M2	(forward) reaction is exothermic **OR** gives out heat	<u>backward</u> reaction is endothermic	1	only award M3 if M2 is correct
	M3	shifts to RHS <u>to replace lost heat</u> **OR** <u>to increase the temperature</u> **OR** <u>to oppose fall in temp</u>	<u>backward reaction</u> takes in heat **OR** to lower the temperature	1	not just to oppose the change

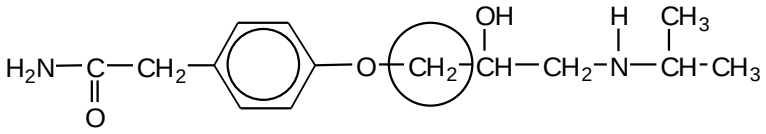
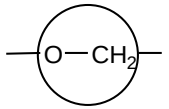
3(d)	fossil fuels used **OR** CO_2 H_2O produced/given off/formed which are <u>greenhouse gases</u> **OR** SO_2 produced/given off/formed which causes acid rain **OR** Carbon produced/given off/formed causes global dimming	1	not allow electricity is expensive ignore just global warming ignore energy or hazard discussion

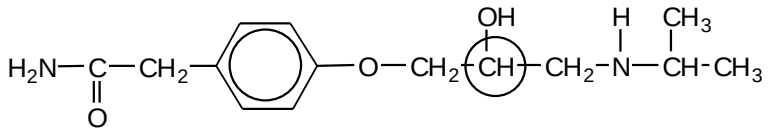
3(e)	$C_{17}H_{35}COOCH_3$ or $C_{17}H_{31}COOCH_3$ or $C_{17}H_{29}COOCH_3$ **OR** $CH_3OOCC_{17}H_{35}$ or $CH_3OOCC_{17}H_{31}$ or $CH_3OOCC_{17}H_{29}$	1	

Question	Marking Guidance	Mark	Comments
4(a)	3-hydroxypropanoic acid	1	allow 3-hydroxypropionic acid must be correct spelling
4(b)(i)	must show trailing bonds  or can start at any point in the sequence, e.g. 	1	not allow dimer allow –O–$CH_2CH_2COOCH_2CH_2CO$- or –$CH_2CH_2COOCH_2CH_2COO$- ignore ( ) or *n* NB answer has a total of 6 carbons and 4 oxygens
4(b)(ii)	condensation (polymerisation)	1	Allow close spelling
4(c)(i)	C=C or carbon-carbon <u>double</u> bond	1	
4(c)(ii)		1	must show **ALL** bonds including O–H
4(c)(iii)	must show trailing bonds 	1	allow polyalkene conseq on their c(ii) ignore *n*

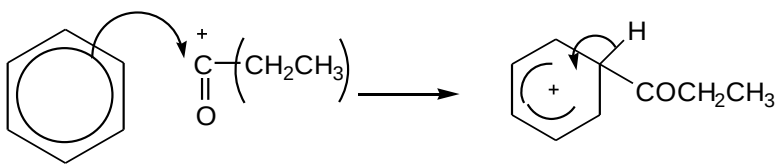
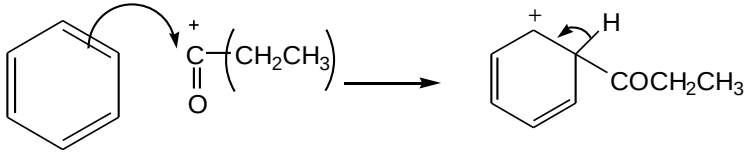
4(d)		1	allow NH_3^+— allow COO^-
4(e)(i)		1	In 4(e), do not penalise a slip in the number of carbons in the $-CH_2CH_2-$ chain, but all must be bonded correctly NB two carboxylate groups Allow COONa or COO^-Na^+ but not covalent bond to Na allow NH_2–
4(e)(ii)	 **OR** 	1	In 4(e), do not penalise a slip in the number of carbons in the $-CH_2CH_2-$ chain, but all must be bonded correctly NB two ester groups allow NH_2– or $^+NH_3$–

4(e)(iii)		1	In 4(e), do not penalise a slip in the number of carbons in the $-CH_2CH_2-$ chain, but all must be bonded correctly allow anhydride formation on either or both COOH groups (see below) with or without amide group formation 
4(f)	**M1** phase or eluent or solvent (or named solvent) is <u>moving or mobile</u> **M2** stationary phase or solid or alumina/silica/resin **M3** separation depends on balance between solubility or affinity (of compounds) in each phase **OR** different adsorption or retention **OR** (amino acids have) different R_f values **OR** (amino acids) travel at different speeds or take different times	1 1 1	

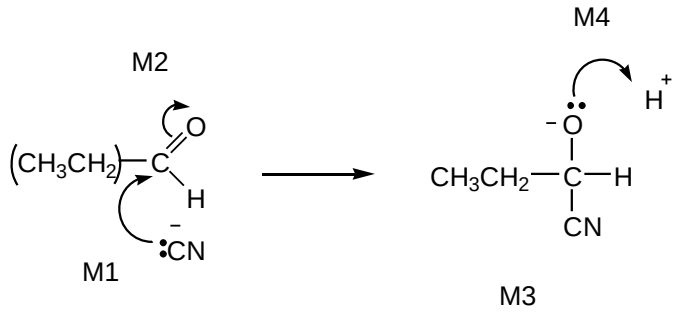
Question	Marking Guidance	Mark	Comments
5(a)	**J** (acid) amide **K** (secondary) amine or amino	1 1	not peptide, not N-substituted amide penalise primary or tertiary allow N-substituted amine
5(b)	(δ =) 3.1-3.9 doublet **OR** duplet	1 1	Not 3.7 – 4.1 Not secondary name required not the number 2
5(c)(i)	Solvent must be proton-free **OR** $CHCl_3$ has protons or has H or gives a peak	1	
5(c)(ii)	$CDCl_3$ is polar **OR** CCl_4 is non-polar	1	
5(d)	11 **OR** eleven	1	
5(e)(i)	$Si(CH_3)_4$ **OR** SiC_4H_{12}	1	ignore TMS
5(e)(ii)	a single number or a range within 21-25	1	penalise anything outside this range
5(e)(iii)		1	allow ring around the C only and also allow 

5(f)(i)	$NaBH_4$	1	ignore name if formula correct ignore solvent allow $LiAlH_4$ Zn/HCl Sn/HCl H_2/Ni H_2/Pt
5(f)(ii)		1	allow ring around the C only
5(f)(iii)	(plane) polarised light **OR** light in a polarimeter polarised light is not rotated or is unaffected	1 1	 penalise bent/diffracted/deflected/reflected Not just solution is optically inactive
5(f)(iv)	**adv** cheaper medicine due to cost or difficulty <u>of separation</u> or both can lower blood pressure **OR** more effective/beneficial <u>with a reason</u> **disadv** may be side effects from one enantiomer in the mixture or only half the product works or one enantiomer may be ineffective or double dose required	1 1	or no need to separate

Question	Marking Guidance	Mark	Comments
6(a)(i)	$C_6H_6 + CH_3CH_2COCl \rightarrow C_6H_5COCH_2CH_3 + HCl$ **OR** $C_6H_6 + CH_3CH_2CO^+ \rightarrow C_6H_5COCH_2CH_3 + H^+$	1	allow C_2H_5 penalise $C_6H_5–CH_3CH_2CO$ allow + on C or O in equation
	phenylpropanone **OR** ethylphenylketone **OR** phenylethylketone	1	Ignore 1 in formula, but penalise other numbers
	$AlCl_3$	1	can score in equation
	$CH_3CH_2COCl + AlCl_3 \rightarrow CH_3CH_2CO^+ + AlCl_4^-$	1	allow C_2H_5 allow + on C or O in equation
	$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$	1	

6(a)(ii)	electrophilic substitution M1 M3  M2 for structure **OR** M1 M3  M2	1 3	can allow in (a)(i) if no contradiction M1 arrow from circle or within it to C or to + on C horseshoe must not extend beyond C2 to C6 but can be smaller + not too close to C1 M2 penalise C_6H_5–CH_3CH_2CO (even if already penalized in (a)(i)) M3 arrow into hexagon unless Kekule allow M3 arrow independent of M2 structure ignore base removing H in M3

6(b)(i)	$CH_3CH_2\underline{CHO}$ + HCN → $CH_3CH_2CH(OH)CN$ **OR** $C_2H_5CH(OH)CN$ 2-hydroxybutan<u>e</u>nitrile **OR** 2-hydroxybutan<u>o</u>nitrile	1 1	aldehyde must be -CHO brackets optional no others

6(b)(ii)	<u>nucleophilic addition</u>  	1 4	 M1 includes lp and arrow to Carbonyl C and minus charge (on either C or N) Not allow M2 before M1, but allow M1 to C^+ after non-scoring carbonyl arrow Ignore $\delta+$, $\delta-$ on carbonyl group, but if wrong way round or full + charge on C lose M2 M3 for correct structure including minus sign. Allow C_2H_5 M4 for lp and curly arrow to H^+
6(b)(iii)	(propanone) slower **OR** <u>propanal</u> faster inductive effects of alkyl groups **OR** C of C=O less $\delta+$ in propanone **OR** alkyl groups in ketone hinder attack **OR** easier to attack at end of chain	1 1	if wrong, no further marks

Question	Marking Guidance	Mark	Comments
7(a)	diethylamine **OR** ethyl ethanamine **OR** ethyl aminoethane	1	ignore N-

7(b)

For 7(b) and (c)

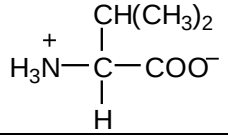
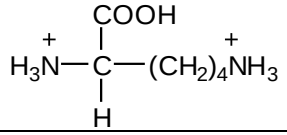
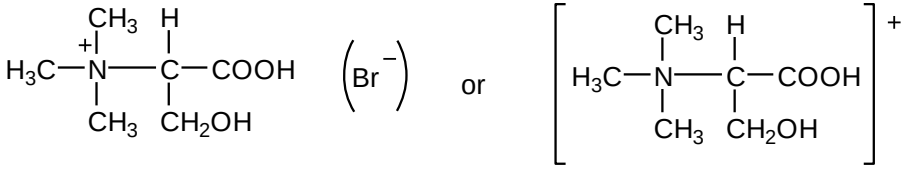
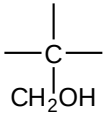
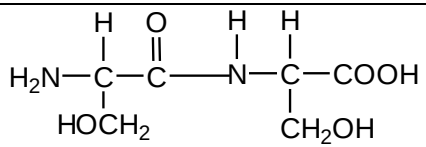
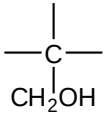
There are three valid routes for this synthesis called Routes **A, B** and **C** below

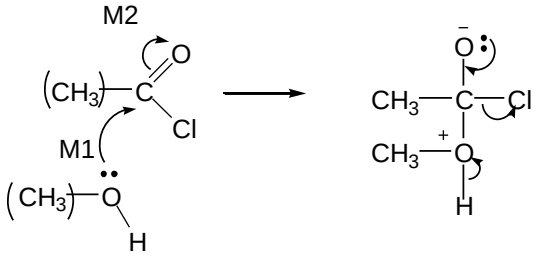
- Decide which route fits the answer best (this may not be the best for part b) to give the candidate the best possible overall mark.
- Mark part (b)
- For this best route mark the mechanism and reagent independently
- Migration from one route to another is not allowed
- Either name or formula is allowed in every case.
- Ignore conditions unless they are incorrect.

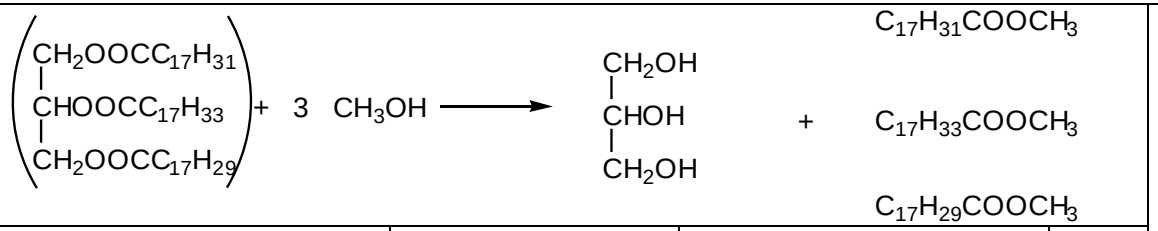
	Route A	Route B	Route C	
F	CH_3CH_2Br or CH_3CH_2Cl	C_2H_6	CH_3CH_2OH	1
G	$CH_3CH_2NH_2$ ethylamine **OR** ethanamine **OR** aminoethane	CH_3CH_2Br **OR** CH_3CH_2Cl	CH_3CH_2Br **OR** CH_3CH_2Cl	1

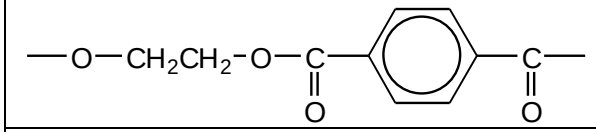
7(c)			**Route A**	**Route B**	**Route C**	
	Step 1	Reagent(s)	HBr **OR** HCl	$\underline{H_2 / Ni}$ (Not $NaBH_4$)	H_2O & H_3PO_4 **OR** H_2O & H_2SO_4	1
		Mechanism	Electrophilic addition	addition (allow electrophilic **OR** catalytic but not nucleophilic) ignore hydrogenation	Electrophilic addition	1
	Step 2	Reagent(s)	NH_3	Cl_2 **OR** Br_2	HBr **OR** KBr & H_2SO_4 **OR** PCl_3 **OR** PCl_5 **OR** $SOCl_2$	1
		Mechanism	Nucleophilic substitution	(free) radical substitution	Nucleophilic substitution	1
	Step 3	Reagent(s)	CH_3CH_2Br **OR** CH_3CH_2Cl	$CH_3CH_2NH_2$ **OR** NH_3 but penalise excess ammonia here	$CH_3CH_2NH_2$ **OR** NH_3 but penalise excess ammonia here	1
		Mechanism	Nucleophilic substitution	Nucleophilic substitution	Nucleophilic substitution	1

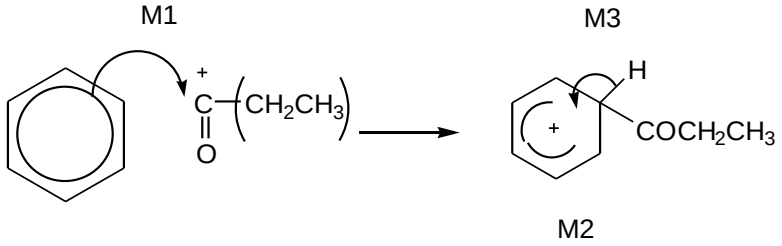
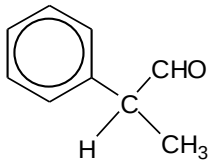
7(d)	tertiary amine **OR** triethylamine **OR** $(CH_3CH_2)_3N$ Quaternary ammonium salt **OR** tetraethylammonium bromide **OR** chloride **OR** ion **OR** $(CH_3CH_2)_4N^+$ (Br^- **OR** Cl^-)	1	
	further substitution will take place **OR** diethylamine is a better nucleophile than ethylamine	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	(a)	(i)	hydrolysis	1	not hydration
8	(a)	(ii)	2-aminopropanoic acid	1	ignore alanine QoL
8	(a)	(iii)		1	allow $-CO_2^-$ allow $^+NH_3-$ don't penalize position of + on NH_3
8	(a)	(iv)		1	allow $-CO_2H$ allow $^+NH_3-$ don't penalize position of + on NH_3
8	(b)	(i)		1	allow $-CO_2H$ allow limit as  + on N or outside [ ]
8	(b)	(ii)		1	allow $-CO_2H$ allow –CONH– or –COHN– allow NH_2- allow limit as 

Q	Part	Sub Part	Marking Guidance		Mark	Comments
9	a		$CH_3CH_2CH_2COOH$	M1	1	not C_3H_7COOH
			CH_3CH_2OH or C_2H_5OH	M2	1	
			$\rightarrow CH_3CH_2CH_2COOCH_2CH_3 + H_2O$	M3	1	allow $C_3H_7COOC_2H_5$ penalise M3 for wrong products and unbalanced equation
			H_2SO_4 or HCl or H_3PO_4 conc or dil or neither	M4	1	not HNO_3
9	b		$CH_3CH_2CH_2CH_2OH$	M1	1	not C_4H_9OH
			$(CH_3CO)_2O$	M2	1	
			$\rightarrow CH_3COOCH_2CH_2CH_2CH_3 + CH_3COOH$	M3	1	allow $CH_3COOC_4H_9$ penalise M3 for wrong products and unbalanced equation
9	c		(nucleophilic) addition-elimination  		5	not acylation alone M2 not allowed indep of M1 but allow M1 for correct attack on C+ +C=O loses M2 only allow M4 after correct or v close M3 ignore Cl^- removing H^+

9	d						ignore errors in initial triester First mark for $3CH_3OH$ Third mark for all three esters
			(1)	(1)	(1)	3	

9	e		not – C_2H_4 – 	First mark for correct ester link second mark for the rest including trailing bonds	2	If ester link wrong, lose second mark also
		Adv	reduces landfill saves raw materials lower cost for recycling than making from scratch reduces CO_2 emissions by not being incinerated		1	not allow cost without qualification ignore energy uses
		Disad	difficulty/cost of collecting/sorting/processing product not suitable for original purpose, easily contaminated		1	not allow cost without qualification ignore energy uses

Q	Part	Sub Part	Marking Guidance	Mark	Comments
10	a		CH_3CH_2COCl OR CH_3CH_2CClO OR propanoyl chloride OR $(CH_3CH_2CO)_2O$ OR propanoic anhydride penalize contradiction in formula and name e.g. propyl chloride	1	could score in equation
			$AlCl_3$ or $FeCl_3$ or names	1	could score in equation
			$CH_3CH_2COCl + AlCl_3 \rightarrow CH_3CH_2CO^+ + AlCl_4^-$ Allow RCOCl in equation but penalise above	1	allow + on C or O in equation
10	b			3	M1 arrow from circle or within it to C or to + on C Horseshoe must not extend beyond C2 to C6 but can be smaller + not too close to C1 M3 arrow into hexagon unless Kekule allow M3 arrow independent of M2 structure Ignore base removing H in M3
10	c		Tollens or ammoniacal silver nitrate	1	penalise wrong formula
				1	

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are <u>required information</u> to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**
-

A. <u>The "List principle" and the use of "ignore" in the mark scheme</u>

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. <u>Incorrect case for element symbol</u>

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. <u>Spelling</u>

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

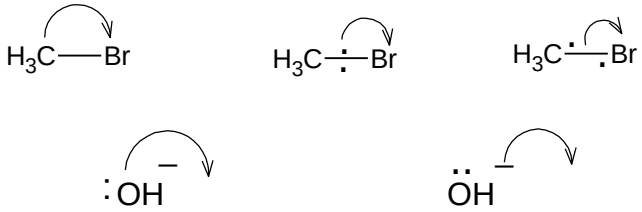
G. Marking calculations

In general

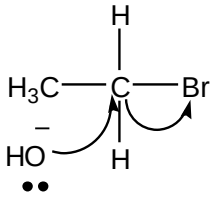
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- An arithmetic error may result in a one mark penalty if further working is correct.
- A chemical error will usually result in a two mark penalty.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

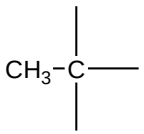
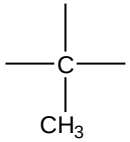
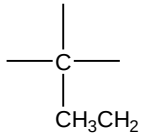
- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms. This principle applies in all cases where the attached functional group contains a carbon atom, e.g nitrile, carboxylic acid, aldehyde and acid chloride. The carbon-carbon bond should be clearly shown. Wrongly bonded atoms will be penalised **on every occasion**. (see the examples below)
- The same principle should also be applied to the structure of alcohols. For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in alkyl groups, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Similar latitude should be given to the representation of amines where NH_2─ C will be allowed, although H_2N─ C would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or vertical C ─ NH_2 bonds should **not** be penalised. For other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply.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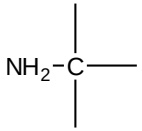	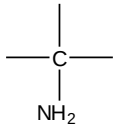	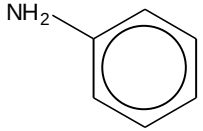	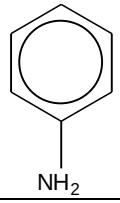	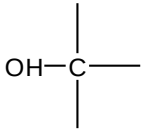	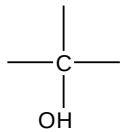
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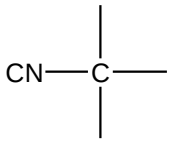	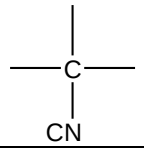	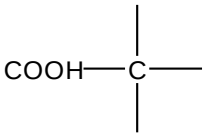	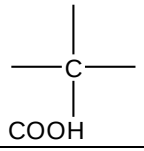	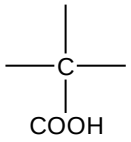	
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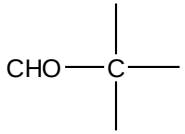	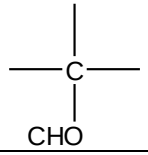	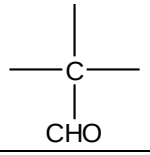	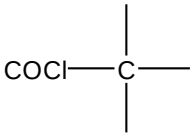	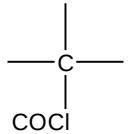	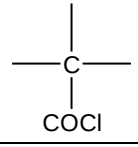
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- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethane

N.B. Exceptions <u>may</u> be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**