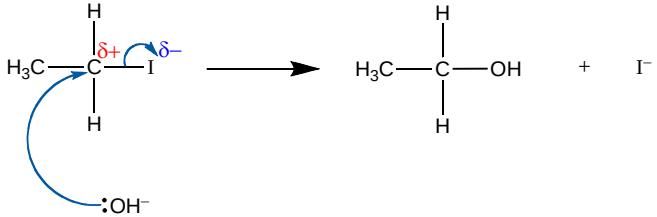
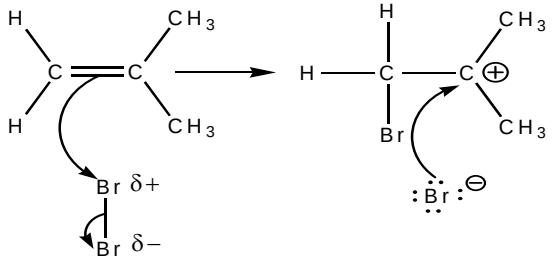
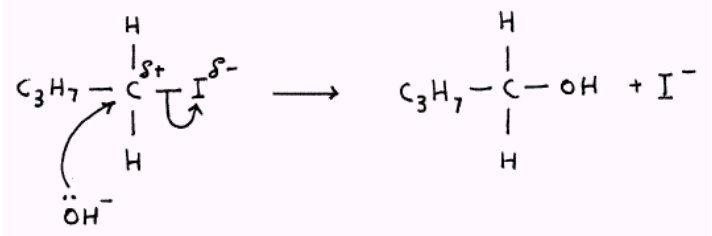
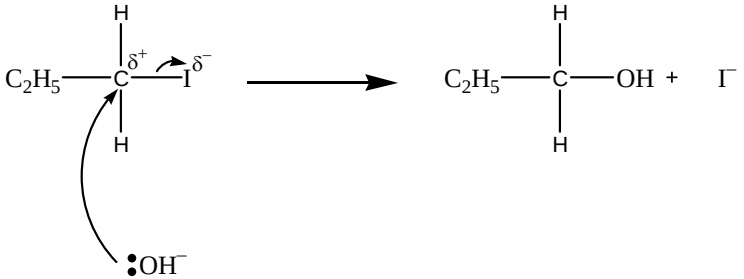
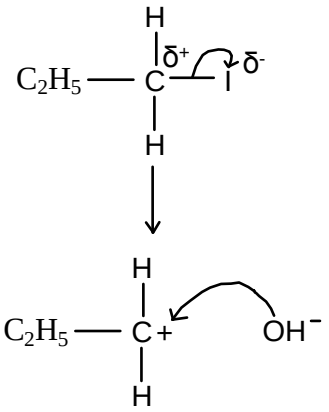
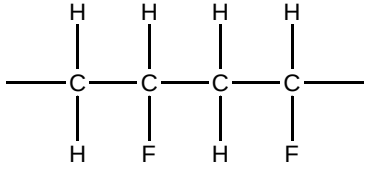
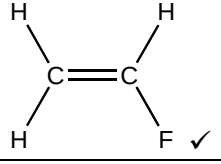
Question			Expected Answers	Marks	Additional Guidance
1	(a)	(i)	$CH_4 + Br_2 \longrightarrow CH_3Br + HBr$ ✓	1	**ALLOW** any correct multiple **IGNORE** state symbols
		(ii)	Dibromomethane **OR** tribromomethane **OR** tetrabromomethane ✓	1	**ALLOW** 1,1-dibromomethane **OR** 1,1,1-tribromomethane etc **ALLOW** 1-dibromomethane **DO NOT ALLOW** 2,2-dibromomethane etc **ALLOW** correct formulae e.g. CH_2Br_2
		(iii)	$Br_2 \longrightarrow 2Br$ **OR** homolytic fission of bromine ✓ $Br + CH_4 \longrightarrow HBr + CH_3$ ✓ $CH_3 + Br_2 \longrightarrow CH_3Br + Br$ ✓ $Br + CH_3 \longrightarrow CH_3Br$ **OR** $Br + Br \longrightarrow Br_2$ ✓ Ethane made when two methyl radicals react **OR** $CH_3 + CH_3 \longrightarrow C_2H_6$ ✓ **Quality of Written Communication** – Consists of initiation step linked to correct equation propagation step linked to one equation in which there is a radical on the left and a radical on the right termination step linked to correct equation: 2 names of steps linked to correct equations ✓ **BUT** 3 names of steps linked to correct equations ✓✓	7	**All equations can be described in words** Radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** any other suitable termination If no equations are given to link the names of the step then award one mark for mention of all three steps

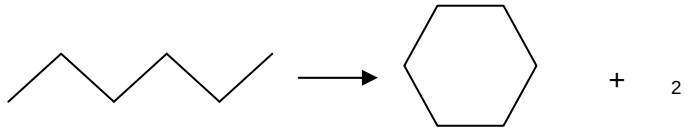
Question	Expected Answers	Marks	Additional Guidance
(b)	**EITHER** Nucleophilic substitution ✓ Example of nucleophilic substitution ✓ Heterolytic fission ✓ C–I curly arrow ✓ Correct dipole on C— I bond ✓ OH^- curly arrow from one lone pair on O of OH^- ion **OR** from minus sign on OH^- ion ✓ **OR** Electrophilic addition ✓ Example of electrophilic addition ✓ Heterolytic fission ✓ Curly arrow from C=C bond to Br—Br bond and Dipole and curly arrow associated with Br_2 ✓ Correct carbocation ion ✓ Curly arrow from one lone pair on Br^- ion **OR** from minus sign on Br^- ion ✓	6	The example mark can be awarded as an example of the name of the mechanism given or if the name is wrong can be given as an example of a reasonably correct drawn mechanism *If **curly half arrows** drawn do not give a mark the first time used and then apply ECF*  **ALLOW** mechanisms for other halogenoalkaes  **ALLOW** mechanisms for other halogens and hydrogen halides
	ALLOW Electrophilic substitution ✓ Example of electrophilic substitution ✓ Heterolytic fission ✓ Curly arrow from benzene ring to the electrophile (i.e. NO_2^+ OR Br^+) ✓ Correct intermediate ✓ Curly arrow to show loss of hydrogen ion ✓		**ALLOW** Nucleophilic addition ✓ Example of nucleophilic addition ✓ Heterolytic fission ✓ Correct dipole on carbonyl group ✓ Curly arrow from lone pair on H^- ion **OR** from minus sign on H^- to C=O carbon and breaking of C=O bond ✓ Curly arrow from carbonyl oxygen to either H^+ or H_2O ✓
	Total	**15**	

Question			Expected Answers	Marks	Additional Guidance
2	**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

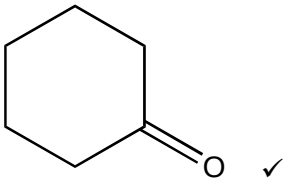
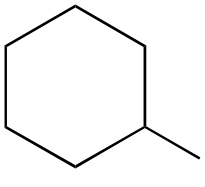
Question			Expected Answers	Marks	Additional Guidance
	b	**i**	Nucleophilic substitution ✓ Heterolytic ✓ Dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ Curly arrow from OH^- to carbon atom of C–I bond ✓ Curly arrow from C–I bond to the iodine atom ✓	5	**ANNOTATE WITH TICKS AND CROSSES** **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**	

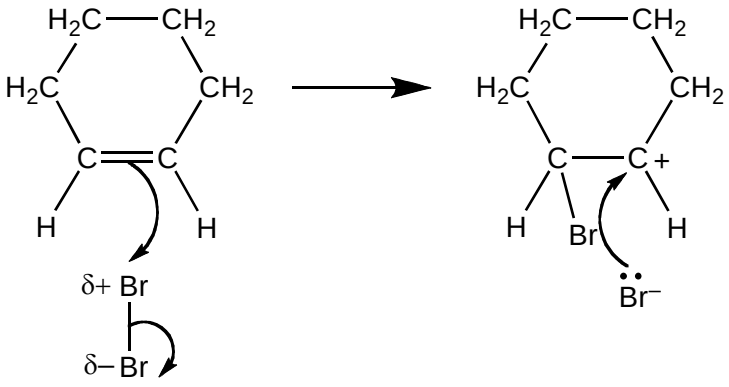
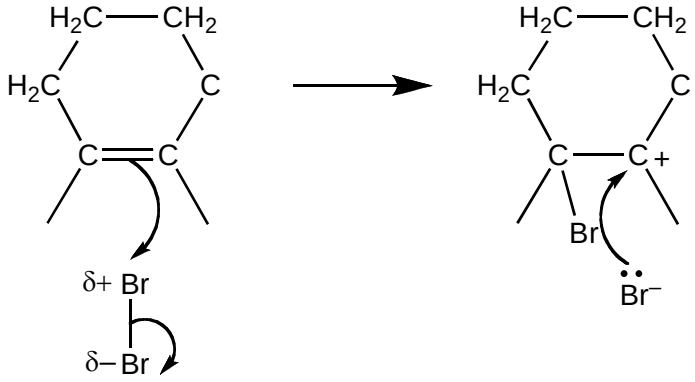
Question			Expected Answers	Marks	Additional Guidance
3	(a)	(i)	 C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- ✓ correct partial charges on C—I ✓	3	no need to show any lone pairs on oxygen but must have a clear negative sign rather than partial negative charge **IGNORE** lone pairs **IGNORE** products of this reaction **ALLOW** curly arrow from a negative charge or from any part of hydroxide ion If S_N1 mechanism is given then use the mark scheme below correct partial charges on C—I ✓ C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- to the **correct** carbocation ✓ 
		(ii)	nucleophilic substitution ✓	1	
	(b)		C–I bonds broken more easily ✓ C–I bonds are weaker **OR** have less bond enthalpy **OR** C–I bonds are longer ✓	2	**ALLOW** ora e.g. C—Br bonds are stronger **OR** broken less easily

Question			Expected Answers	Marks	Additional Guidance
	(c)		**Any TWO from:** CFCs take many years to reach the ozone layer **OR** long residence time ✓ CFCs are still being used ✓ there are other ozone depleting substances ✓	**2**	 **IGNORE** because chlorine radicals stay in the stratosphere **ALLOW** other named ozone depleting substances e.g. NO and HFCs
	(d)	(i)	 ✓	**1**	Free bonds at bond ends must be present **ALLOW** minor slip e.g. missing one hydrogen and left as a stick **ALLOW** more than two repeat units but must be a whole number of repeat units **IGNORE** brackets, use of numbers and n in the drawn structure
		(ii)	 ✓	**1**	**ALLOW** skeletal formula **ALLOW** CH_2CHF
	(e)		**Any two from:** separation into types and recycling **OR** sort plastics, melt and remould ✓ combustion for energy generation ✓ used for cracking **OR** feedstock for plastics or chemicals ✓	**2**	**IGNORE** biodegradable used as a fuel is insufficient releases energy is insufficient **ALLOW** burning plastics to release energy **ALLOW** organic feedstock / raw materials to make organic compounds
			Total	**12**	

Question			Answer	Mark	Guidance
4	(a)		(The hydrocarbons have) different boiling points ✓ The larger the molecules the stronger the van der Waals' forces ✓	2	**PLEASE READ COMMENT ON PAGE 3** **ALLOW** longer chains have higher boiling points **OR** separation based on boiling point **OR** condense at different temperatures **ALLOW** the larger molecular size more van der Waals' forces **OR** longer chains have stronger van der Waals' force **OR** the more electrons, the stronger the van der Waals' forces **OR** the more surface contact the more van der Waals' forces **IGNORE** surface area **ALLOW ORA** van der Waals must be seen at least once in correct context **ALLOW** any 'recognisable' spelling of van der Waals', use of VDW is **not** sufficient **DO NOT ALLOW** intermolecular force unless qualified as van der Waals' somewhere
	(b)	(i)	C_nH_{2n} ✓	1	
		(ii)	$C_6H_{14} \rightarrow C_6H_{12} + H_2$ ✓	1	**ALLOW** displayed, skeletal or structural formulae or combination in the equation 

Question			Answer	Mark	Guidance
	(b)	(iii)	cyclohexane has more efficient combustion ✓	1	Assume comments refer to cyclohexane unless specified otherwise **ALLOW** cyclohexane allows smoother burning **OR** cyclohexane increases octane number **OR** cyclohexane reduces knocking **OR** cyclohexane is less likely to produce pre-ignition **OR** cyclohexane is a more efficient fuel **OR** cyclohexane burns better **OR** easier to burn **OR** cyclohexane combusts more easily **OR** improves combustion **DO NOT ALLOW** cyclohexane ignites more easily **ALLOW** ORA for hexane **IGNORE** cyclohexane increases volatility of fuel **IGNORE** cyclohexane has a lower boiling point cyclohexane is a better fuel on its own is **NOT** sufficient cyclohexane burns more cleanly on its own is **NOT** sufficient
	(c)	(i)	*Unsaturated:* Contains (at least one) **carbon–carbon** double bond **OR** C=C **OR** multiple carbon–carbon bond ✓ *hydrocarbon*: Contains hydrogen and carbon **only** ✓	2	**DO NOT ALLOW** just 'contains a double bond' **DO NOT ALLOW** 'a mixture of carbon and hydrogen' **OR** 'contains carbon and hydrogen' **OR** carbon and hydrogen molecules only
		(ii)	More than one hydrogen atom is substituted **OR** 'multisubstitution' (by chlorine) **OR** further substitution occurs ✓	1	**ALLOW** can get dichloro-compounds (**IGNORE** numbering) **ALLOW** reaction forms more than one **organic** product **DO NOT ALLOW** 'forms termination products' on its own Reaction is not specific **OR** reaction is difficult to control is **NOT** sufficient

Question			Answer	Mark	Guidance
	(c)	(iii)	Contains a lone pair that can be donated ✓	1	**ALLOW** it can donate an electron pair 'lone pair' on its own is **NOT** sufficient
		(iv)	**A**  ✓ **B**  ✓	2	**ALLOW** skeletal, displayed or structural formulae for **A** and **B** **ALLOW** combination of types of formulae as long as it is unambiguous **DO NOT ALLOW** molecular formula For **A**, **ALLOW** carbonyl group on any carbon atom as it is still cyclohexanone For **B**, **ALLOW** bromine atom on any carbon atom as it is still bromocyclohexane

Question			Answer	Mark	Guidance
	(c)	(v)	Correct dipole on Br_2 / correct partial charges on Br_2 ✓ Correct curly arrow from double bond to attack bromine atom and correct curly arrow to show heterolytic fission of Br–Br ✓ Correct carbocation / carbonium ion drawn with the **full** positive charge shown: C^+ ✓ Correct curly arrow from lone pair of Br^- to correct carbon atom **OR** correct curly arrow from negative charge of Br^- to correct carbon atom ✓  	4	**ANNOTATE WITH TICKS AND CROSSES** Curly arrow must come from covalent bonds and not atoms **DO NOT ALLOW** $C^{\delta+}$ for charge on carbonium ion Curly arrow from bromide ion can come from the negative charge or the lone pair **DO NOT ALLOW** $Br^{\delta-}$ instead of Br^- Lone pair does not need to be shown on Br^- or used in mechanism Treat missing hydrogens on the CH_2 as a slip Treat missing hydrogens on the double bond or carbonium ion as a slip providing a bond is shown ie  **ALLOW** use of skeletal formulae in mechanism
			Total	**15**	