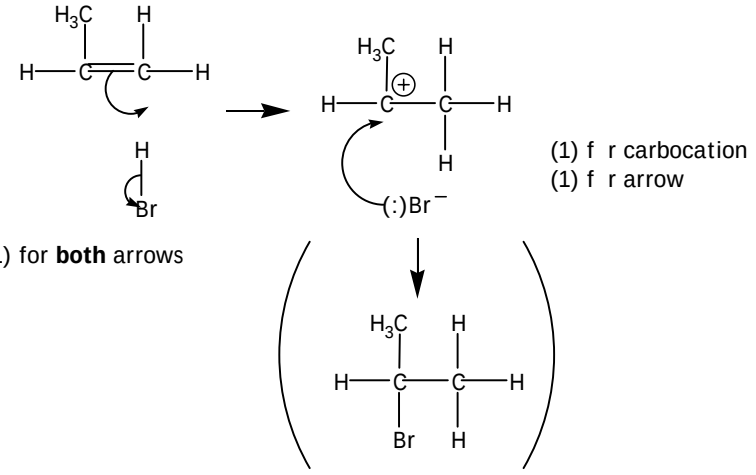
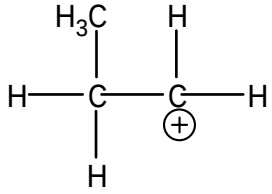
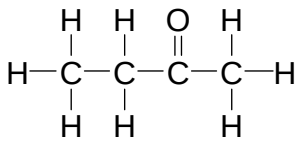
Question Number	Acceptable Answers	Mark
1 (a)(i)	 (1) for **both** arrows (1) f r carbocation (1) f r arrow **1st mark:** • top arrow must start from the double bond / close to the double bond and **not** from either of the C atoms of the C=C bond • top arrow can end on, or close to, the H in HBr • lower arrow must start from the bond and **not** the H atom in HBr *REJECT* **full** charges on the HBr **2nd mark:** the carbocation must have a full + and **not** δ+ **3rd mark:** • the bromide ion must have a full $^-$ and **not** δ$^-$ • the lone pair need not be shown on the Br^- • arrow from bromide ion can start anywhere on the Br^- or from the minus sign or the lone pair (if shown) on Br^- and can go to the C or the + sign on the intermediate 3rd mark available even if an incorrect intermediate has been drawn	**3**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	 OR $CH_3\,CH_2\,CH_2^+$		**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)(i)	B /$CH_3CH_2CH(OH)CH_3$ /butan-2-ol **(1)** Because the C atom bearing the OH is attached to two other C atoms / C with OH group attached to one H (atom) **(1)** *ALLOW* Because the C atom bearing the OH is attached to two alkyl groups **These marks are stand alone**	**Just** "OH is on the second C atom" / "OH is in the chain, not on the end" OR "OH attached to two **methyl** / two **CH_3** groups" OH^- (instead of –OH	**2**

Question Number	Acceptable Answers	Reject	Mark
1(b)(ii)	C /$(CH_3)_3COH$ /(2-)methylpropan-2-ol **(1)** Because it is a **tertiary** (alcohol)/no C-H bonds to break **(1)** *ACCEPT* a description of a tertiary alcohol **These marks are stand alone**	"tertiary **structure"** / **"**tertiary **carbon"** / "tertiary **carbocation"**	**2**

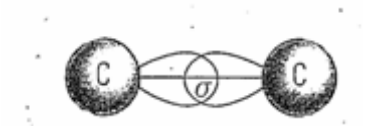
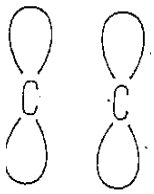
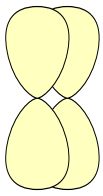
Question Number	Acceptable Answers	Reject	Mark
1(b)(iii)	**BOTH** B / $CH_3CH_2CH(OH)CH_3$ / butan-2-ol **AND**  **BOTH required for the one mark**	Structural / skeletal formula	**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)(iv)	A / $CH_3CH_2CH_2CH_2OH$ / butan-1-ol **and** D / $CH_3CH(CH_3)CH_2OH$ / (2-)methylpropan-1-ol **BOTH needed for one mark**		**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)(v)	Steamy fumes / misty fumes / white mist	White **smoke**	**1**

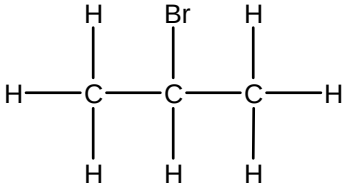
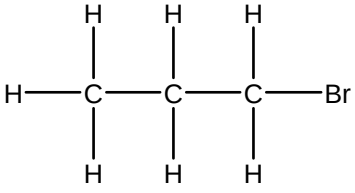
Question Number	Acceptable Answers	Reject	Mark
1(b)(vi)	(C_4H_9OH + PCl_5 →) **C_4H_9Cl + $POCl_3$ + HCl** **(1)** for HCl **(1)** for rest of the equation correct *NOTE:* Equation must be completely correct for the second mark. *ACCEPT* "PCl_3O" instead of $POCl_3$		**2**

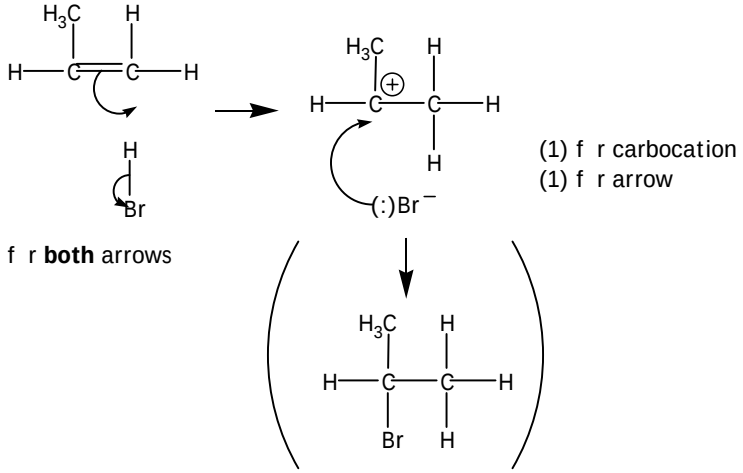
Question Number	Acceptable Answers	Reject	Mark
2 (a)	$C_{10}H_{22} \rightarrow C_7H_{16} + C_3H_6$ *ALLOW* structural or displayed formulae instead of molecular formulae *IGNORE* any state symbols, even if incorrect		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (b) (i)	**diagram for the σ-bond** e.  **First Mark:** *EITHER* Diagram shows **overlap** of **any-shaped orbitals** along the line between the two nuclei *OR* Mentions/implies rotation around a sigma/single bond **(1)** **Second Mark:** Any written mention, or clear evidence from the diagram (e.g. shading), of the resultant (high) electron density (along the line) **between** the two nuclei **(1)** **diagram for the π-bond** e. *EITHER*  *OR*  **Third Mark:** *EITHER* Diagram shows two dumb-bell shaped (p-) orbitals(these can be separate dumb-bells or the diagram can show the p-orbitals overlapping sideways) *OR* Restricted /lack of /no rotation about a pi/double bond **(1)** **Fourth Mark:** Any written mention, or clear evidence from the diagram (e.g. shading), of the resultant (high) electron density **above and below (**the line between) the two nuclei **(1)**	Just a line between the two nuclei Just curved lines above and below the two nuclei	**4**

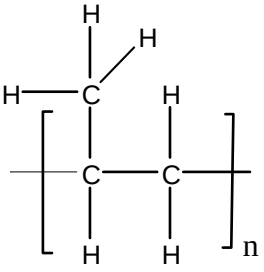
Question Number	Acceptable Answers	Reject	Mark
2 (b) (ii)	Electrophilic addition *BOTH words needed* *ALLOW* "heterolytic" before electrophilic addition		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (b) (iii)	π bond weaker than σ (bond) / less energy needed to break π bond *ALLOW* π bond weak(er) / π bond easy to break **(1)** π – electrons / π bonds (more) accessible (to electrophilic attack) *ALLOW* high/higher/more electron density in π bond (so alkenes more susceptible to electrophilic attack) **(1)** **Mark the two points independently**		**2**

Question Number	Acceptable Answers	Reject	Mark
2 (c) (i)	 **and**  (main product) both DISPLAYED structures, with ALL bonds and atoms shown **(1)** major product identified or shown as product in (c)(ii) if NOT identified in (c)(i) **(1)** **NOTE**: if only one isomer of C_3H_7Br is named, assume this is the required "labelling" of the major product **Mark the two points independently**	CH_3 not fully displayed Incorrect name of isomer for 2nd mark	**2**

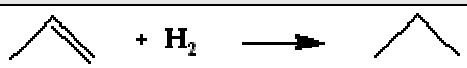
Question Number	Acceptable Answers	Reject	Mark
2 (c) (ii)	 (1) for carbocation (1) for arrow (1) for **both** arrows **1st mark:** Curly arrows must start from the bonds NOT the atoms **3rd mark**: Bromide ion must clearly have a 1^- charge to get this mark **NOTE**: The arrow from the bromide ion can start from anywhere on the Br^- ion (including the minus sign) or from a lone pair on Br^- if shown Curly arrow can go to the C or the + sign on the intermediate TE for mechanism on the isomer identified in (c)(i) or either mechanism if no major product has been identified in (c)(i) **Mark the three points independently**	**half** arrow-heads $Br^{\delta-}$	**3**

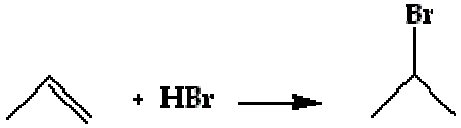
Question Number	Acceptable Answers	Reject	Mark
2 (c) (iii)	Secondary carbocation (named or described or drawn) **(1)** more stable (than primary) **(1)** **Mark the two points independently** **NOTE:** Zero awarded if primary carbocation thought to be more stable	Answers just in terms of Markownikoff's rule	**2**

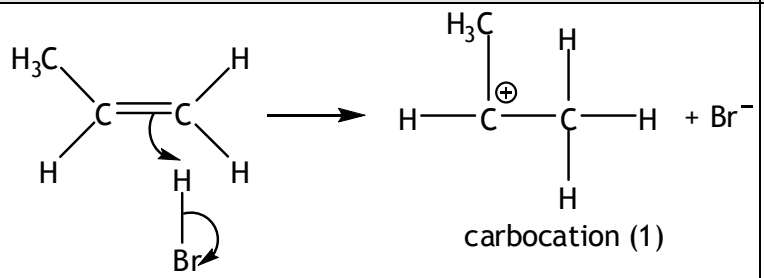
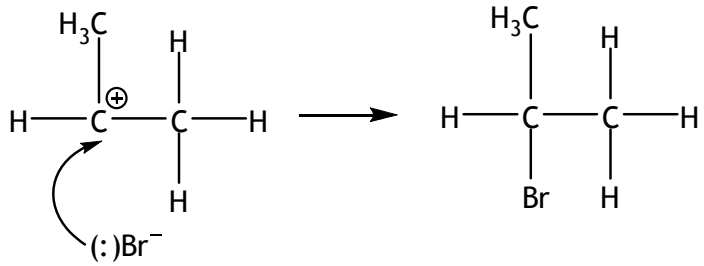
Question Number	Acceptable Answers	Reject	Mark
2 (d) (i)	$nC_3H_6 \rightarrow$  **Two** "*n*'s" in the equation **and** a correct formula (molecular or structural) for propene on left hand side of the equation **(1)** Correct repeating unit, with a methyl branch shown **(1)** A*LLOW* CH_3 fully displayed or just as CH_3 Continuation bond at each end (with or without bracket shown in equation) **(1)** Unsaturated polymer scores max **(1)** **Mark the three points independently**	"x" instead of "n"	**3**

Question Number	Acceptable Answers	Reject	Mark
2 (d) (ii)	**(Advantage)**: polypropene will decompose (naturally) *ALLOW* "rot" or "break down" *OR* polypropene will not require landfill (as it can decompose in sunlight) *OR* no need to incinerate /burn *IGNORE* "good for environment" / "no pollution" **(1)** **(Disadvantage)**: poly(propene) cannot be used when exposed to (bright) sunlight / UV / outdoors *OR* cannot be recycled / cannot be reused **(1)** **Mark the two points independently**	"Can be recycled" (0) for first scoring point Biodegradable for 1st mark Answers which do not imply exposure to UV/sunlight Biodegradable for 2nd mark	**2**

Question Number	Acceptable Answers	Reject	Mark
3(a)	(C_nH_{2n} could be a) ring / cyclic (compound) ALLOW identification of any specific cyclic compound (e.g. cyclohexane) IGNORE any reference to "fewer hydrogen atoms"		**1**

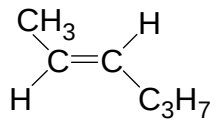
Question Number	Acceptable Answers	Reject	Mark
3(b)(i)	 All must be correct for the mark		**1**

Question Number	Acceptable Answers	Reject	Mark
3(b)(ii)	 **First mark:-** An equation with the reactants shown correctly and EITHER 2-bromopropane OR 1-bromopropane shown as the product NOTE: The C-Br bond MUST be shown in the skeletal formula for the first mark **(1)** **Second mark (stand alone, even if no equation attempted or left-hand side of equation incorrect):-** Correct skeletal formula of **2-bromopropane** **(1)** Penalise lack of skeletal formulae once only in (b)(i) and (b)(ii) when taken together		**2**

Question Number	Acceptable Answers	Reject	Mark
3(c)	 carbocation (1) both arrows (1)  attack of bromide ion (1) **First mark:** Curly arrow from C=C to H (in H-Br) **AND** curly arrow from bond in H-Br to the Br IGNORE polarity of HBr even if incorrect **(1)** **Second mark:** Structure of correct secondary carbocation **(1)** **Third mark:** Curly arrow from anywhere on the bromide ion towards the C+ on the carbocation **NOTE:** The bromide ion must have a full negative charge, but the lone pair of electrons on the Br^- NEED NOT be shown **NOTE:** A correct mechanism leading to the formation of 1-bromopropane scores the **first** and **third** marks only (so max **(2)**) Skeletal formulae can be used	**Full** + and - charges on HBr Extra / spare bond dangling from the C+ carbon δ^- on bromide ion instead of Br^-	3

	If but-2-ene is the starting alkene, only 3rd mark can be awarded If but-1-ene is the starting alkene, 2nd and 3rd marks can be awarded ***If single-headed arrows used throughout but all else correct, then max (2) can be awarded for mechanism***		

Question Number	Acceptable Answers	Reject	Mark
4(a)	Allow formulae throughout instead of names **Test** : add bromine (water) /bromine solution ALLOW bromine gas /bromination (1) **Result**: no change with hexane / stays orange brown/ stays red brown/ stays yellow and goes colourless with hex-1-ene(1) 2nd mark cq on 1st OR **Test** : add (acidified) potassium manganate((VII)) (solution) (1) ALLOW potassium permanganate for potassium manganate(VII) **Result:** no change with hexane/stays purple and goes colourless / brown with hex-1-ene (1) OR **Test** : add alkaline potassium manganate((VII)) (solution) (1) ALLOW potassium permanganate for potassium manganate(VII) **Result**: no change with hexane/stays purple and goes green with hex-1-ene (1)	Smokiness of flame Bromide Iodine Goes clear	**2**

Question Number	Acceptable Answers	Reject	Mark
4(b)(i)	 ALLOW Partially or fully displayed as long as the two H are trans Allow bonds which go closer to the H than to C of alkyl groups on l.h.s.		**1**

Question Number	Acceptable Answers	Reject	Mark
4(b)(ii)	QWC C=C restricts rotation/ C=C prevents twisting /C=C can't rotate/ lack of free rotation round C=C (so the groups can't change position relative to the bond) (1) Hex-2-ene has different groups on the C at each end of C=C / hex-1-ene has 2 hydrogens on the C at one end of C=C / hex-1-ene doesn't have different groups on the C at one end of C=C / hex-1-ene has no group which takes priority on the C at one end of C=C (1) (answer can be considered from either hex -1-ene or hex-2-ene)	Alkenes can't rotate Double bond is fixed Bonds can't rotate Double bond is on first carbon (unless further explanation)	**2**

Question Number	Acceptable Answers	Reject	Mark
4(c)(i)	ignore signs (50 x 46 x 4.18) = 9614(J)/ 9.614 kJ (if converted to kJ units must be stated) ALLOW 9610 / 9600 /9.61 kJ /9.6 kJ	(50.32 x 46 x 4.18) = 9676(J)	**1**

Question Number	Acceptable Answers	Reject	Mark
4(c)(ii)	One mark each for moles of hexane energy change sign, units, 2 sig figs (for energy change calculated) Moles hexane = **0.32/86** = (3.72×10^{-3}) (1) (9614/ 3.72×10^{-3}) = 2584000 J/ 2584 kJ (1) ΔH **= -2600 kJ mol^{-1}** /-2 600 000 J mol^{-1} / -2.6×10^{6} J mol^{-1} (1) Allow TE: **0.32g** in (i) (gives 61.53J), ΔH **= -17 kJ mol^{-1}** /-17 000 J mol^{-1} /-1.7×10^{4} J mol^{-1} **50.32g** in (i) (gives 9676J) ΔH **= -2600 kJ mol^{-1}** /-2 600 000 J mol^{-1} /-2.6×10^{6} J mol^{-1} **Rounding of moles to 4×10^{-3}** gives –**2400 kJ mol^{-1} or-15 kJ mol^{-1}** max 2 (loses moles mark) Answer alone (3) Max 2 if negative sign missing and/or more than 2 sf or error in units		**3**

Question Number	Acceptable Answers	Reject	Mark
4(c)(iii)	Any 2 from: • Heat losses (from calorimeter)/ poor insulation • Incomplete combustion/burning • Incomplete transfer of heat/ loss by convection • Evaporation of fuel (after weighing) • Heat capacity of calorimeter (not included)/ heat absorbed by calorimeter • Measurements not carried out under standard conditions /H_2O is gas, not liquid, in this experiment	Just “energy losses” Not all hexane burns Data books give average values Hexane is impure Human error	**2**

Question Number	Acceptable Answers	Reject	Mark
4(c)iv)	Error in reading temperature is less than the effect of ignoring heat loss etc ALLOW Other errors are greater than error in temperature reading / Readings are within margins of error/ The accuracy with the thermometer is not significantly different from other measurement errors / 0.1°C is insignificant compared to temperature change / Using 0.1°C thermometer does not change significant figures in final answer / Using 0.1°C thermometer does not reduce errors	Using 0.1°C thermometer gives a more precise reading but does not improve accuracy	**1**

Question Number	Acceptable Answers	Reject	Mark
4(d)(i)	Nickel / Ni Finely divided nickel/ Raney nickel ALLOW Platinum /Pt Palladium/ Pd Rhodium/ Rh Accept one of the above answers combined with a comment such as “at high temperature”, “heat also needed”, “under pressure”, “lumps of”, “powdered” Accept combinations of above answers eg Pt and Pd	Zeolite Carbon Hydrogen Uv light	**1**

Question Number	Acceptable Answers	Reject	Mark
4(d)(ii)	Left hand arrow, pointing down, labelled ΔH_c hex-1-ene + ΔH_c hydrogen/ -4003-286/-4289 OR Pointing up with signs given above reversed (1) Right hand arrow pointing down labelled ΔH_c hexane / -4163 OR Pointing up with signs given above reversed (1) Ignore oxygen on both arrows Arrows may be labelled ΔH_1 etc if key given or use of numbers in calculation makes this obvious. ($\Delta H_{reaction}$ – 4163 = -4003 – 286 / or words applying Hess' law correctly) $\Delta H_{reaction}$ = **-126** however obtained(1) TE: If arrows point up and signs are **not** reversed $\Delta H_{reaction}$ = **+126** Max (1)		**3**

Question Number	Acceptable Answers	Reject	Mark
4(d)(iii)	Same (number and type of) bonds are broken and made in each reaction / one C=C (and one H-H) are broken and two C-H made ALLOW reaction is –CH=CH- + $H_2 \rightarrow$ -CH_2-CH_2- each time (Similar energy change) as in each case H_2 reacts with C=C	All are alkenes going to alkanes all have the same double bond which reacts in the same way	**1**

Question Number	Acceptable Answers	Reject	Mark
4(a)(i)	Reagent: chlorine/ Cl_2 (1) Condition: uv/ sunlight (1) ALLOW light Mark independently Ignore reference to temp and pressure if given with uv light. If answers reversed/both on one line 1 out of 2	Cl Just "heat"	**2**

Question Number	Acceptable Answers	Reject	Mark
4(a)(ii)	(free) radical (1) Substitution (1) Mark independently		**2**