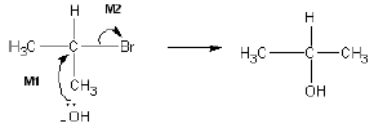
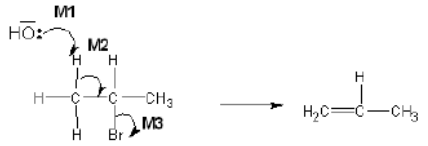
Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	a	i	Reducing agent *OR* Reduce(s) (WO_3 / tungsten oxide) *OR* electron donor *OR* to remove oxygen (from WO_3 / tungsten oxide or to form water);	1	
1	a	ii	$WO_3 + 3H_2 \longrightarrow W + 3H_2O$	1	Or multiples
1	a	iii	*One from* H_2 is • explosive • flammable or inflammable • easily ignited	1	Ignore reference to pressure or temperature
1	b	i	Addition *OR* (catalytic) hydrogenation *OR* Reduction	1	Ignore "electrophilic" Penalise "nucleophilic addition"
1	b	ii	Geometric(al) *OR* cis/trans OR E Z OR E/Z	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	a		NaBr ONLY	1	Penalise incorrect case or additional formulae. Ignore names
	b		NaF ONLY	1	Penalise incorrect case or additional formulae. Ignore names
	c		ONLY one from either NaF *OR* NaCl	1	Penalise incorrect case or additional formulae. Ignore names
	d		NaI ONLY	1	Penalise incorrect case or additional formulae. Ignore names

Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	a		Antacid *OR* to neutralise acidity *OR* eases indigestion	1	Credit suitable reference to indigestion or to laxative or to relief of constipation
	b		**M1** Decrease in T decreases the energy of the particles / ions / H^+ / molecules **M2 (also scores M1)** Decrease in the number of / less particles / ions / H^+ / molecules with $E \geq E_{Act}$ or $E \geq$ minimum energy to react **M3** Few(er) / Less effective / productive / successful collisions	3	In **M1** and **M2**, credit "atoms" but ignore "calcium carbonate", ignore "calcium", ignore any ion formula except H^+ QoL
	c	i	Strontium has a higher melting point than barium, because **Correct reference to size of cations/proximity of electrons** **M1** (For Sr) delocalised electrons closer to cations / positive ions / atoms / nucleus *OR* cations / positive ions / atoms are smaller *OR* cation / positive ion / atom or it has fewer (electron) shells / levels **Relative strength of metallic bonding** **M2** (Sr) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons *OR* stronger metallic bonding (assume argument refers to Sr but accept converse argument for Ba)	2	Ignore general Group 2 statements Penalise M1 if Sr or Ba is said to have more or less delocalised electrons Ignore reference to shielding CE = 0 for reference to molecules or intermolecular forces or covalent bonds Ignore "Van der Waals forces (between atoms)" but penalise if "between molecules"
	c	ii	$Sr + 2H_2O \longrightarrow Sr(OH)_2 + H_2$	1	Or multiples
	d	i	$2Mg + TiCl_4 \longrightarrow 2MgCl_2 + Ti$	1	Or multiples
	d	ii	It or $MgSO_4$ is soluble OR forms a solution (and is washed away) OR dissolves	1	Credit reference to $MgSO_4$ being the most soluble Group 2 sulfate. Ignore "disappears"

Q	Part	Sub Part	Marking Guidance	Mark	*Comments*
4	a	i	Oxidation *OR* Oxidised ONLY	1	
	a	ii	Any one from • to provide / overcome activation energy • to provide the minimum energy to make the reaction go / start	1	NOT simply to increase the (initial) reaction rate.
	a	iii	The reaction is exothermic OR releases heat (energy)	1	
	a	iv	**M1** Catalysts provide an alternative route / pathway OR an alternative mechanism *OR* (in this case) surface adsorption occurs (or a description of adsorption) **M2** Lowers the activation energy *OR* of lower activation energy	2	Ignore reference to "surface" alone
	b		**M1** The (forward) reaction is exothermic OR the (forward) reaction releases heat *OR* The reverse reaction is endothermic or absorbs heat **M2** – Direction of change N.B. **M2** depends on correct **M1** At lower temperatures, • the equilibrium yield of NO2 is greater • more NO2 is formed • equilibrium shifts (left) to right • (equilibrium) favours the forward reaction (*OR* converse for higher temperatures)	2	
	c		NO_2 (+) 4 $NO3^-$ (+) 5 HNO_2 (+) 3	3	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
5	a		Functional group (isomerism)	1	
	b		**M1** Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)* **M2** silver mirror OR black solid/precipitate *(NOT silver precipitate)* **M3** (stays) colourless or no change or no reaction **M1** Fehling's (solution) or Benedict's solution *(Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3)* **M2** Red solid/precipitate *(Credit orange or brown solid)* **M3** (stays) blue or no change or no reaction Mark on from an incomplete / incorrect attempt at the correct reagent, penalising M1	3	No reagent, CE=0 Allow the following alternatives **M1** (acidified) potassium dichromate(VI) (solution) **M2** (turns) green **M3** (stays) orange / no change OR **M1** (acidified) potassium manganate(VII) (solution) **M2** (turns) colourless **M3** (stays) purple / no change For M3 Ignore "nothing (happens)" Ignore "no observation"
	c		(Both have) C=O *OR* a carbonyl (group)	1	
	d	i	(Free-) radical substitution ONLY	1	Penalise "(free) radical mechanism"
	d	ii	**Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **First propagation** $Cl\bullet + CH_3CH_2CH_3 \longrightarrow \bullet CH_2CH_2CH_3 + HCl$ OR C_3H_8 **Second propagation** $Cl_2 + \bullet CH_2CH_2CH_3 \longrightarrow CH_3CH_2CH_2Cl + Cl\bullet$ *OR* C_3H_7Cl **Termination (must make C_6H_{14})** $2 \bullet CH_2CH_2CH_3 \longrightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$	4	Penalise absence of dot once only. Penalise incorrect position of dot on propyl radical once only. Penalise $C_3H_7\bullet$ once only Accept $CH_3CH_2CH_2\bullet$ with the radical dot above / below / to the side of the last carbon. Use of the secondary free radical might gain 3 of the four marks
	e		M_r = 44.06352 (for propane) M_r = 43.98982 (for carbon dioxide) **M1** a correct value for both of these M_r values. **M2** a statement or idea that two peaks appear (in the mass spectrum) *OR* two molecular ions are seen (in the mass spectrum).	2	Mark independently

Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	a	i	Nucleophilic substitution  **M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. **M2** must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.	1 2	Penalise M1 if covalent KOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks" Ignore product
	a	ii	2-bromopropane ONLY	1	
	a	iii	Polar C–Br *OR* polar carbon–bromine bond *OR* dipole on C–Br *OR* C—Br C atom of carbon–bromine bond is δ+ / electron deficient *OR* δ+ (δ–) (Credit carbon–halogen bond as an alternative to carbon–bromine bond)	1	It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule. Ignore X for halogen
	b		Elimination  **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom **M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 **M3** is independent. Award full marks for an E1 mechanism in which M2 is on the correct carbocation.	1 3	Credit "base elimination" but NOT "nucleophilic elimination" No other prefix. Mechanism Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks **for the mechanism** for wrong reactant and/or "sticks" Ignore product
	c		*Any one condition from this list to favour elimination;* • alcohol(ic) / ethanol(ic) (solvent) • high concentration of KOH / alkali / hydroxide OR concentrated KOH / hydroxide • high temperature or hot or heat under reflux or T = 78 to 100°C	1	Apply the list principle Ignore "aqueous" Ignore "excess"
	d	i	Addition (polymerisation) ONLY	1	Penalise "additional"
	d	ii	But-2-ene ONLY (hyphens not essential)	1	Ignore references to cis and trans or E/Z Ignore butene

Question	Marking Guidance	Mark	Comments
7 (a)(i)	**M1** c(oncentrated) phosphoric acid / c(onc.) H_3PO_4 ***OR*** c(oncentrated) sulfuric acid / c(onc.) H_2SO_4 **M2** Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants ***OR*** pass the gases over the catalyst several / many times	2	In **M1**, the acid must be concentrated. Ignore an incorrect attempt at the correct formula that is written in addition to the correct name. In **M2**, ignore "remove the ethanol". Credit "re-use".
(a)(ii)	**M1** (By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction **M2 depends on a correct statement of M1** The equilibrium moves / shifts to • oppose the addition of / increased concentration of / increased moles/ increased amount of water / steam • to decrease the amount of steam / water **Mark M3 independently** **M3** Yield of product / conversion increase ***OR*** ethanol increases / goes up / gets more	3	

(a)(iii)	**M1** Poly(ethene) / polyethene / polythene / HDPE / LDPE **M2 At higher pressures** More / higher cost of electrical energy to pump / pumping cost ***OR*** Cost of higher pressure equipment / valves / gaskets / piping etc. ***OR*** expensive equipment	2	Credit all converse arguments for **M2**
(b)	**M1** for balanced equation **M2** for state symbols in a correctly balanced equation $2C(s / graphite) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2OH(l)$ (C_2H_5OH)	2	Not multiples but credit correct state symbols in a correctly balanced equation. Penalise C_2H_6O but credit correct state symbols in a correctly balanced equation.
(c)(i)	**M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element **M2** is burned / combusts / reacts completely in oxygen ***OR*** burned / combusted / reacted in excess oxygen **M3** with (all) reactants and products / (all) substances in standard / specified states ***OR*** (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K	3	If standard enthalpy of formation **CE=0** For **M3** Ignore reference to 1 atmosphere.
(c)(ii)	**M1** Σ B(**reactants**) – Σ B(**products**) = ΔH OR Sum of bonds broken – Sum of bonds formed = ΔH OR B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS) – 4B(C=O) – 6B(O–H) (RHS) = ΔH **M2** (also scores **M1**) 348+360+463+5(412)+3(496) **[LHS = 4719]** (2060) (1488) – 4(805) – 6(463) **[RHS = – 5998]** = ΔH (3220) (2778) OR using only bonds broken and formed (**4256 – 5535**) **M3** ΔH = **– 1279** (kJ mol^{-1}) Award 1 mark for +1279 **Candidates may use a cycle and gain full marks**	3	Correct answer gains full marks Credit 1 mark for (+) 1279 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1** Allow a maximum of one mark if the only scoring point is LHS = 4719 ***OR*** RHS = 5998
(d)(i)	Reducing agent ***OR*** reductant ***OR*** electron donor ***OR*** to reduce the copper oxide	1	Not "reduction". Not "oxidation". Not "electron pair donor".
(d)(ii)	CH_3COOH	1	