Question Number	Answer	Mark
20	**The only correct answer is D** (2,5-dichlorohex-3-ene) ***A*** *is not correct because this does not form E-Z isomers* ***B*** *is not correct because this does not form E-Z isomers* ***C*** *is not correct because this does not form E-Z isomers*	**(1)**

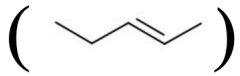
Question Number	Answer	Mark
18	**The only correct answer is D** ($C_3H_7^{\bullet} + HCl \rightarrow C_3H_7Cl + H^{\bullet}$) ***A*** *is not correct because this is a termination step in the reaction* ***B*** *is not correct because this is a termination step in the reaction* ***C*** *is not correct because this is a propagation step in the reaction*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is B** (a compound containing of carbon and hydrogen only) ***A*** *is not correct because hydrocarbons do not contain oxygen* ***C*** *is not correct because not all hydrocarbons have only single carbon to carbon bonds* ***D*** *is not correct because it does not suggest that the hydrogen and carbon atoms are bonded together*	**(1)** **Computer**

Question Number	Answer	Mark
19	**The only correct answer is C** (further substitution products are formed) ***A*** *is not correct because this is not true* ***B*** *is not correct because ultraviolet radiation is used in industrial reactions* ***D*** *is not correct because termination products are formed in low concentrations*	**(1)**

Question Number	Answer	Mark
18	**The only correct answer is D** ((i), (ii) and (iii)) ***A*** *is incorrect because all three are true* ***B*** *is incorrect because all three are true* ***C*** *is incorrect because all three are true*	**(1)**

Question Number	Answer	Mark
16	**The only correct answer is A** (*E* | *E*) ***B*** *is incorrect because double bond 2 is an E configuration* ***C*** *is incorrect because double bond 1 is an E configuration* ***D*** *is incorrect because both double bonds are E configuration*	**(1)**

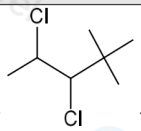
Question Number	Answer	Mark
18	**The only correct answer is D**  *A is incorrect because this molecule has two methyl groups at one end of the carbon to carbon double bond* *B is incorrect because this molecule has two methyl groups at one end of the carbon to carbon double bond* *C is incorrect because this molecule has two methyl groups at each end of the carbon to carbon double bond*	(1)

Question Number	Answer	Mark
13	**The only correct answer is D** (thermal decomposition) *A is incorrect because the alkane has not been burned* *B is incorrect because the alkane has not been hydrolysed* *C is incorrect because the alkane has not been neutralised*	(1)

Question Number	Answer	Mark
17	**The only correct answer is C** (water, carbon dioxide and sulfur dioxide) *A is not correct because no hydrogen can be produced* *B is not correct because no hydrogen chloride can be produced* *D is not correct because no hydrogen can be produced*	(1)

Question Number	Answer	Mark
13	**The only correct answer is B** (Isomer X and Isomer Z only) *A is incorrect because Isomer Y only forms two isomeric monochlorination products* *C is incorrect because Isomer Y forms two isomeric monochlorination products and Isomer X forms four* *D is incorrect because Isomer Z also forms four isomeric monochlorination products*	(1)

Question Number	Answer	Mark
16	**The only correct answer is A** (butene, pentane and propene) *B is not correct because there are too many hydrogen atoms in the products* *C is not correct because there are too few carbon atoms in the products* *D is not correct because there are too many carbon atoms in the products*	(1)

Question Number	Answer	Mark
16	 **The only correct answer is A** ( ) ***B*** *is not correct because this is 2,4-dichloro-2,3-dimethylpentane* ***C*** *is not correct because this is 2,3-dichloro-2,4-dimethylpentane* ***D*** *is not correct because this is 2,2-dichloro-3,4-dimethylpentane*	**(1)**

Question Number	Answer	Mark
16	**The only correct answer is D** (decreases the average number of carbon atoms per molecule) ***A*** *is incorrect because cracking converts alkanes into smaller alkanes and alkenes* ***B*** *is incorrect because this is fractional distillation* ***C*** *is incorrect because cracking converts alkanes into smaller alkanes and alkenes*	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(a)	An answer that makes reference to the following points: • (Molecular formula) C_8H_{18} **(1)** • (Empirical formula) C_4H_9 **(1)** • (IUPAC name) 2,2,4-trimethylpentane **(1)**	Ignore incorrect punctuation and a gap between trimethyl and pentane If MP1 and 2 are not scored allow a molecular formula which is a multiple of the empirical formula given and which has 8 carbons for (1).	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(b)(i)	An answer that makes reference to the following point: • fractional distillation / fractionation	Do not award simple distillation or just distillation	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)	An answer that makes reference to the following points: • isooctane boils first **(1)** • isooctane condenses (in the condenser) **and** is collected **(1)**	Allow isooctane evaporates / vaporises before octane or first or faster Allow isooctane evaporates / vaporises below 125°C Allow octane remains in the flask / container	**(2)**

Question Number	Answer	Additional Guidance	Mark
18(c)(i)	An answer that makes reference to the following point: • correct balanced equation	Example of equation: $C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$ Allow multiples Do not penalise incorrect formula of octane (as this may have been penalised in (a). Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(c)(ii)	An answer that makes reference to the following points: • carbon monoxide is formed by incomplete combustion **(1)** • due to insufficient oxygen / too much hydrocarbon **(1)** • nitrogen monoxide is formed by the reaction of nitrogen and oxygen (from the air) **(1)** • due to high temperature (in the engine) / high pressure (in the engine) / a spark **(1)**	**Do not award unbalanced equations** $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ Allow any **balanced** equation for an alkane or carbon reacting with oxygen to form carbon monoxide, water and any other appropriate products such as CO_2. If an equation is give there is no need to mention incomplete combustion Ignore $C_8H_{18} + 17[O] \rightarrow 8CO + 9H_2O$ Allow $N_2 + O_2 \rightarrow 2NO$ Do not award if nitrogen from / in the fuel	**(4)**

Question Number	Answer	Additional Guidance	Mark
18(c)(iii)	An answer that makes reference to the following point: • nitrogen dioxide / NO_2 / sulfur dioxide / SO_2 / sulfur trioxide / SO_3 / carbon (particulates) / soot / unburnt hydrocarbons	Allow dinitrogen tetroxide / N_2O_4 Allow oxides of sulfur / SOx Allow oxides of nitrogen / NOx Allow PM10 or PM2.5 Allow formula for a feasible hydrocarbon Ignore water Do not award CO_3, SO, NO_3,	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(d)(i)	An answer that makes reference to the following point: • free radical substitution		(1)

Question Number	Answer	Additional Guidance	Mark
18(d)(ii)	An answer that makes reference to the following point: • uv (light) / ultra-violet (light) / uv radiation / ultra-violet radiation	Allow sunlight Ignore just light	(1)

Question Number	Answer	Additional Guidance	Mark
18(d)(iii)	• calculation of percentage of **chlorine** (1) • calculation of number of moles of each element (1) • calculation of ratio and molecular formula (1)	Example of calculation: 100 − 44.1 − 6.90 = 49.0 C 44.1 ÷ 12 = 3.675 H 6.9 ÷ 1 = 6.9 Cl 49.0 ÷ 35.5 = 1.38 C:H:Cl = 2.66 : 5 : 1 = 8 : 15 : 3 Therefore $C_8H_{15}Cl_3$ Allow TE on each step, but final answer must have 8 carbons to score MP3 Ignore SF	(3)

(Total for Question 18 = 17 marks)

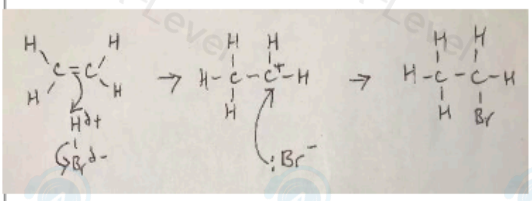
Question Number	Answer	Additional Guidance	Mark
22(c)(ii)	An answer that makes reference to the following points: • fossil fuels are non-renewable/ will run out/ are finite / biofuels are renewable **(1)** • fossil fuels contribute to global warming / biofuels release the carbon dioxide absorbed while growing **(1)**	Do not award biodegradable Allow fossil fuels contribute to climate change Allow biofuels (don't release net carbon dioxide so) are carbon neutral/ net zero Allow biofuels have a lower carbon footprint Ignore references to acid rain / NOx / Do not award references to hydrogen	**(2)** **Expert**

Question Number	Answer	Additional Guidance	Mark
22(c)(iii)	An answer that makes reference to the following point: • (catalytic) reforming/reformation	Allow isomerisation Do not award catalytic conversion	**(1)** **Clerical**

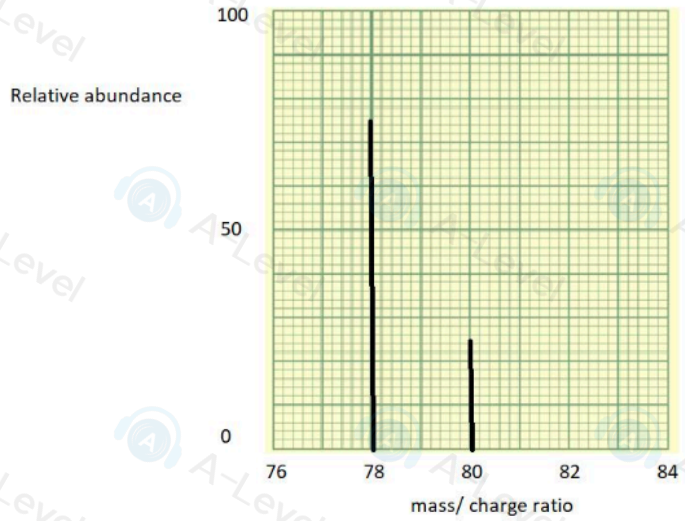
Question Number	Answer	Additional Guidance	Mark
22(c)(iv)	An answer that makes reference to the following point: • 	Allow structural methyl groups shown on branches and ignore vertical connectivity Ignore bond angles Ignore molecular / structural / displayed formulae Ignore state symbols even if incorrect Ignore references to reaction conditions/ catalysts	**(1)** **Graduate**

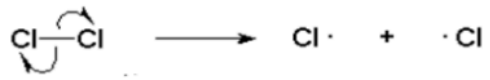
Question Number	Answer	Additional Guidance	Mark
22(d)(i)	An answer that makes reference to the following point: • to prevent combustion/ oxidation / explosion (of the mixture) or oxygen reacts with hydrocarbons/ ethene /hydrogen	Allow hydrocarbons are flammable/ can catch fire Allow to prevent formation of CO_2/ CO /C/ alcohols/diols/aldehydes Ignore references to side reactions/ (unwanted) products/ incorrect / toxic products Do not award (oxygen) reacts with steam	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
22(d)(ii)	An answer that makes reference to one of the following points: • **making** polymers / poly(ethene) / polythene / polyethylene/ plastics • ripening / maturing fruit e.g. bananas • **making** ethanol / ethane-1,2-diol / antifreeze/ haloethane /	Ignore to make alcohol Ignore polymerisation Ignore references to fuels Do not award making bioethanol	**(1)** **Expert**

Question Number	Answer	Additional Guidance	Mark
22(e)	An answer that makes reference to the following points: • dipole on HBr • curly arrow from C=C bond to H $^{(\delta+)}$ • curly arrow from H−Br bond to Br or just beyond • correct intermediate • lone pair on Br^- • curly arrow from lone pair (if shown) on Br^- to C+	Do not award partial charge on C=C Do not award partial charge on Br Penalise incorrect or missing charge on Br once only If lp shown and M5 scored, arrow must come from lp Penalise half arrows once only  All 6 points scores 3 4 or 5 points scores 2 2 or 3 points scores 1	(3) Expert

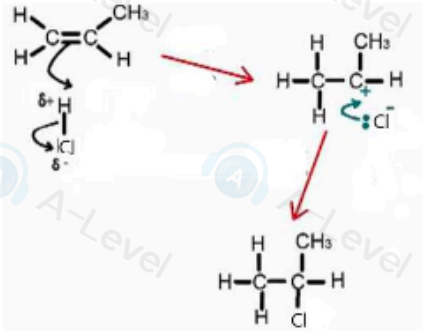
(Total for Question 22 = 20 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)	A description that makes reference to the following points: • two peaks at 78 and 80 **(1)** • peak at 78, 3 x higher than peak at 80 **(1)** 	If there are more than 2 peaks score 0 Allow within 1small square If the peaks are wrong but the lower mass/ charge one is 3x higher than the other, M2 can be scored as a TE. Ignore any labels on the peaks	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(i)	An answer that makes reference to the following points:  • diagram showing curly half-arrows forming 2 free radicals **(1)** • uv (radiation / light) or sunlight **(1)**	Both arrows can come from the same side of the bond Ignore just light	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	An answer that makes reference to the following points: • homolytic: each atom gets one electron/ the electron pair splits evenly **(1)** • free radical: species with an unpaired electron **(1)**	Allow equal splitting of the electrons (in the bond) Allow atom/ element Allow lone electron Ignore free electron	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(iii)	An answer that makes reference to the following point: • multiple substitutions can occur/ more than one (organic) product	Allow more products formed//more waste products Allow termination products Allow side products/reactions Allow further reactions Ignore chain reaction Ignore poor yield/atom economy Ignore forms impurities Ignore references to HCl being formed/toxic	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	An answer that makes reference to the following points: • 1 dipole on H–Cl • 2 curly arrow from H–Cl bond to Clδ– • 3 curly arrow from double bond to H(δ+) • 4 correct carbocation intermediate • 5 curly arrow from lone pair on Cl • 6 arrow to C+ on intermediate • 7 charge on chloride ion All 7 marking points score 4 marks, 5/6 points score 3 marks, 3/4 points score 2, 2 points score 1 mark	 Arrows must start from the covalent bond or lone pair From the H—Cl bond it must go to the Cl or beyond. From the C=C bond it must go to the H or in the space. From the lone pair on the Cl it must go to the C+ on the intermediate. If wrong alkene used just penalise 1 marking point. If primary carbocation is formed just penalise marking point 4 If half curly arrows used penalise 1 marking point If HBr/HI used penalise 1 marking point	(4)

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	An answer that makes reference to the following points: • (the formation of 1-chloropropane goes via a) primary carbocation **(1)** • (which is) less stable than the secondary carbocation (formed when of 2-chloropropane is produced) **(1)**	Do not award 1-chloropropane is a primary carbocation or 2-chloropropane is a secondary carbocation but only penalise once, Allow the correct comparison between a tertiary and primary or secondary carbocation for 1 mark Allow reverse argument	**(2)**

(Total for Question 19 = 13 marks)