1) A

2) B

3) C

4) A

5) D

6) B

7) A

8) D

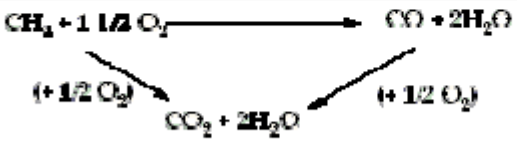
9) C

10) A

11) B

12)

(a)	The heat/enthalpy/energy change (for a reaction) is independent of the path(way)/route IGNORE any extra detail referring to "initial and final states"		1

estion mber	Acceptable Answers	Reject	Mark
(b)(i)	 $CO_2 + 2H_2O$ **(1)** Both arrows in correct direction downwards **(1)** IGNORE state symbols, even if incorrect Mark the two points independently		2

estion mber	Acceptable Answers	Reject	Mark
(b)(ii)	$\Delta H = -890 - (-283)$ **(1)** $= -607$ (kJ mol^{-1}) **(1)** Correct answer with no working scores **(2)** NOTE: +607 (kJ mol^{-1}) scores **(1)** only		2

(b) (iii)	Cannot stop the reaction at CO OR the reaction produces CO_2/complete combustion occurs OR may produce some carbon/soot OR cannot react exact amounts of methane to oxygen	non-standard conditions **Just** incomplete combustion occurs **Just** forming 'other products' /**just** a 'mixture of products' **Just** methane is 'very reactive'/ 'explosive' **Just** heat loss Cannot measure the temperature change	1

(c)	**First mark: State of the H_2O** Water is in the gas phase/water is (formed) as steam/water is not in its standard state/water is not (formed as a) liquid **(1)** **Second mark: Idea of an energy change when there is a change of state** Change of state involves an energy change /energy change (for the reaction given) is less exothermic **(1)** ALLOW 'more endothermic' instead of 'less exothermic' IGNORE references to non-standard conditions	Energy change is more exothermic /less endothermic Heat loss 'Incomplete combustion'	**2**

13)

(a)	C_nH_{2n} ALLOW letters other than *n*		**1**

estion mber	Acceptable Answers	Reject	Mark
(b)	A compound which contains (C=C) double bonds OR A compound that will undergo addition reactions OR Does not contain the maximum number of hydrogen atoms		**1**

estion mber	Acceptable Answers	Reject	Mark
(c)(i)	*E*-3-ethylhex-2-ene **(2)** **(1)** mark for 3-ethylhex-2-ene **(1)** mark for '**E**' IGNORE any missing hyphens or any hyphens replaced by commas Mark independently		**2**

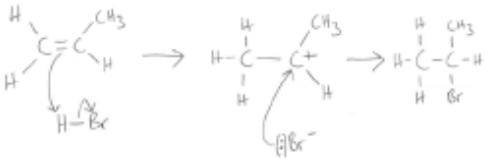
(c)(ii)	The four atoms/four groups around the C=C double bond are different OR No two groups are the same OR There are no common groups on either side of the C=C double bond OR There are two alkyl groups on one of the carbon atoms (in the C=C double bond) OR There are three alkyl groups around the double bond OR An indication of the existence of Priority Rules (for E-Z nomenclature) OR One of the carbon atoms (of the C=C double bond) is not bonded to a hydrogen atom ALLOW 'functional groups' for 'groups'	Each side is not symmetrical	**1**

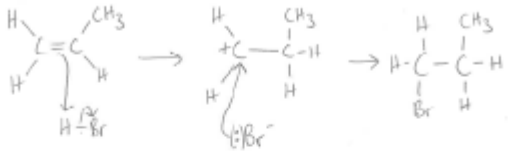
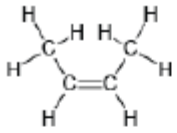
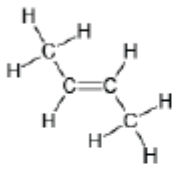
(d)(i)	CH_3CH_3 ALLOW displayed or skeletal formulae throughout 24(d)	C_2H_6	**1**

estion mber	Acceptable Answers	Reject	Mark
(d)(ii)	$ClCH_2CH_2Cl$ / CH_2ClCH_2Cl	$C_2H_4Cl_2$	**1**

estion mber	Acceptable Answers	Reject	Mark
(d)(iii)	$HOCH_2CH_2OH$ / CH_2OHCH_2OH	$C_2H_6O_2$	**1**

estion mber	Acceptable Answers	Reject	Mark
(d)(iv)	$HOCH_2CH_2Br$ / CH_2OHCH_2Br	$BrCH_2CH_2Br$; C_2H_5OBr; $C_2H_4Br_2$	**1**

(e)	Major product route:  **First mark:** Curly arrow from C=C to the H (in H-Br) **AND** curly arrow from the bond in H—Br to the Br **(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 **(1)** NOTE: The bromide ion must have a full negative charge, but the lone pair of electrons on the Br^- NEED NOT be shown **Fourth mark:** Choice of 2-bromopropane as major product **(1)** For showing the major product mechanism correctly **(4)** • both arrows **(1)** • carbocation intermediate **(1)** • attack by bromide ion **(1)** (Bromide ion must show a full negative charge. The lone pair of electrons need not be shown) • choice of 2-bromopropane as major product **(1)**	4

	Single-headed arrows used throughout **max (3)** Minor product route **max (3)**  If the minor product route is shown, the last mark is lost, but the first three marks can be scored consequentially as follows:- • both arrows **(1)** • carbocation intermediate **(1)** • attack of bromide ion **(1)** (NOTE: The bromide ion must show a full negative charge. The lone pair of electrons need not be shown) NOTE: If a correct mechanism for the electrophilic addition of HBr to **ethene** is shown then max **(2)** (i.e. the first and the third marks in the mechanism)		
(f)(i)	 **(1)**  **(1)** NOTE: CH_3 group does not have to be displayed. IGNORE if any connectivity is shown from the **H_3** in a **CH_3** group IGNORE bond angles ALLOW one mark for just but-2-ene's structural formula		**2**

(f)(ii)	**Any ONE of:-** • No atoms lost (or gained) • No elements lost (or gained) • (Only) one product (is formed) • (Produced by) an addition reaction • Addition polymer(ization) • Polymer is a repeat of the monomer • No small molecules (formed) • No co-products • No waste products • Same C:H ratio • Same ratio of carbon:hydrogen atoms • Same ratio of each element • Same ratio of atoms	(Monomer and polymer have) '**same number** of carbon and hydrogen atoms'	**1**
(f)(iii)	**100% AND** some correct justification is needed **ONE answer from:-** 100% as addition reaction 100% because all the atoms are incorporated into the polymer 100% because (only) one product is formed 100% because (only) one desired product is formed 100% because no atoms are lost 100% because no waste products 100% because no small molecules (formed) 100% as no co-products 100% as no by-products	Statements such as 'the atom economy is **almost** 100%' OR **Just** "it has a high atom economy"	**1**

14)

5(a)(i)	Amount Na = 1.73 (g) ÷ 23 (g mol^{-1}) = 0.075(22) (mol) Amount O = 1.20 (g) ÷ 16 (g mol^{-1}) = 0.075 (mol) **(1)** IGNORE sf, even if 1 sf NaO **(1)** Correct answer no working **(2)** NOTE: Correct answer can be obtained via incorrect working and all responses should be read carefully e.g. Amount Na = 23 ÷ 1.73 = 13.3 Amount O = 16 ÷ 1.20 = 13.3 scores second mark only for NaO if obtained by incorrect working OR e.g. Use of atomic numbers gives the Na : O ratio as 0.157 : 0.150 and an empirical formula of NaO. This scores (1) overall (i.e. the 2nd mark). OR e.g Use of atomic number ONLY for Na (i.e. Na = 11) gives the Na : O ratio as 0.157 : 0.075 and an empirical formula of Na_2O. This scores (1) overall (i.e. the 2nd mark). NOTE: Use of **O** = 32 gives Na_2O and scores second mark	Na_2O_2	**2**

Question Number	Acceptable Answers	Reject	Mark
5(a)(ii)	(NaO = 39 hence molar mass twice that of NaO ∴) so **Na_2O_2**	'2NaO'	**1**

Number			
5(a)(iii)	$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$ All species correct **(1)** State symbols and balancing **(1)** NOTE: 2nd mark is conditional on correct species. NOTE: $2Na(s) + O_2(g) \rightarrow 2NaO(s)$ scores **(1)** $Na(s) + O_2(g) \rightarrow NaO_2(s)$ scores **(1)** $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$ scores **(2)**		**2**

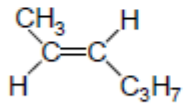
(a)(iv)	Moles of O_2 = 0.075 ÷ 2 = 0.0375 OR 1.2 ÷ 32 = 0.0375 (mol) **(1)** 0.0375 mol x 24 dm^3 mol^{-1} = 0.9(0) (dm^3) **(1)** ALLOW 900 **cm^3 (units must be present here)** Correct answer no working **(2)** OR Moles of Na = 1.73 ÷ 23 = 0.075217 = moles of O Moles of O_2 = 0.075217 ÷ 2 = 0.0376085 0.0376085 x 24 = 0.903 (dm^3) or 903 **cm^3** IGNORE s.f., including ONE s.f. NOTE: If number of moles x 24 (dm^3 mol^{-1}) is clearly evident and correctly calculated in stated units, award second mark		**2**

estion mber	Acceptable Answers	Reject	Mark
(a)(v)	0.0375 x 6.02 x 10^{23} (= 2.2575 x 10^{22} (molecules)) = 2.26 x 10^{22} (molecules) IGNORE s.f. unless 1 s.f.		**1**

(b)	Sodium might react with nitrogen in the air/sodium forms a nitride/ nitrogen (gas) is present in the air (which reacts with the sodium) OR sodium might form a different oxide (e.g. Na_2O or allow NaO_2) NOTE: If nitrogen / N_2 is mentioned as part of a 'list' of substances that can be present in air, award the mark	**Just** 'very reactive' OR 'very explosive' sodium forms Na_2O_2 alone References to hydrogen in the air **Just** 'reacts with other substances in the air' (as nitrogen not identified Sodium nitrate formation **Just** sodium hydroxide formation	**1**

15)

(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**

estion mber	Acceptable Answers	Reject	Ma
(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**

(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

estion mber	Acceptable Answers	Reject	Mark
(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

(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

(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

(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

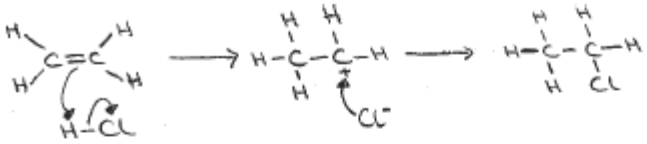
estion mber	Acceptable Answers	Reject	Ma
(d) (i)	Nickel / Ni Finely divided nickel/ Raney nickel ALLOW Platinum /Pt Palladium/ Pd Rhodium/ Rh Accept one of the above answers combined with a comment such as "at high temperature", "heat also needed", "under pressure", "lumps of", "powdered" Accept combinations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

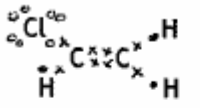
(d) (ii)	Left hand arrow, pointing down, labelled ΔH_c hex-1-ene + ΔH_c hydrogen/ -4003-286/-4289 OR Pointing up with signs given above reversed (1) Right hand arrow pointing down labelled ΔH_c hexane / -4163 OR Pointing up with signs given above reversed (1) Ignore oxygen on both arrows Arrows may be 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

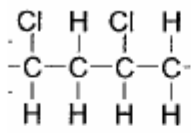
estion mber	Acceptable Answers	Reject	Mar
(d) (iii)	Same (number and type of) bonds are broken and made in each reaction / one C=C (and one H-H) are broken and two C-H made ALLOW reaction is -CH=CH- + $H_2 \rightarrow$ -CH_2-CH_2- each time (Similar energy change) as in each case H_2 reacts with C=C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

16)

(a) (ii)	(free) radical (1) Substitution (1) Mark independently		2
(b) (i)	Hydrogen chloride / HCl	Hydrochloric acid Chlorine HCl (aq) Cl_2	1

(b) (ii)	Curly (not half headed) arrow from C=C to H (1) Curly arrow from bond in H-Cl to Cl (1) Curly arrow from Cl^- to C^+ (1)  Partial charges on HCl not required Lone pairs on Cl^- not required It should be clear if arrows are to/ from a bond or an atom, but give allowance for precise position Correct intermediate without arrows (1) Correct addition of HBr max 2 Correct addition of HCl to propene max 2 Max 2 for addition of Cl_2 instead of HCl (forming 1,2 - dichloroethane) Max 1 for addition of Cl_2 instead of HCl forming chloroethane	Attack by $Cl^{\delta-}$ or $Cl\cdot$ loses 3rd mark only Correct free radical mechanism from ethane and chlorine scores 0	3

estion mber	Acceptable Answers	Reject	Mark
(c)	Higher atom economy from ethene /by electrophilic addition Higher yield from ethene Both correct for (1) From ethene only one product / all atoms are used **making product** /no unwanted products (1) For ethene yield high as no di-, tri- etc substituted products form /only one product / no by-products OR no side reactions occur OR no C_4 compounds can form (1) [Or reverse argument]	 Not much product is lost	3
(d) (i)	 Double bond and electrons around C correct (1) Other electrons correct (1) Can be all dots or all crosses First mark can be given if C_2H_4 drawn correctly Second mark can be given if C_2H_5Cl drawn correctly Don't penalise if bonds shown as well as electrons		2

(d) (ii)	 ALLOW H and Cl below C chain; Cl on C2 and C3 or C1 and C4; formula above with brackets at each end and n outside end bracket End bonds should be shown, but don't penalise if these don't go through brackets H atoms should be shown	Formula not displayed One monomer unit shown in bracket with the number 2 outside bracket Cl on C1 and C2 Cl onC3 and C4	1
(d) (iii)	QWC Any 2 Answers could consider the following factors: • energy for manufacture • availability / abundance of raw materials • lifetime of product/ how often will it need to be replaced /metal rusts/plastic more easily punctured etc • ease of recycling /steel an excellent recyclable material • consequences of disposal / is it biodegradable? • Is it from a non-renewable resource? • Atom economy in manufacture Allow answers comparing specific properties (if correct) illustrating the relevant property Examples PVC will last longer than iron due to lack of corrosion (1) PVC comes from oil which is non-renewable (1) PVC and metals come from non-renewable sources (1) Credit any two valid points	Ignore if other answers given: cost PVC biodegradable its carbon footprint Is it environmentally friendly? Pollution comments without reference to resources needed to clean up	2