Calorimetry

Mark Scheme

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	The Core Principles of Chemistry
Sub Topic	Calorimetry
Booklet	Mark Scheme

Time Allowed: **75 minutes**

Score: **/62**

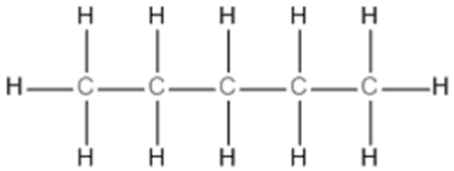
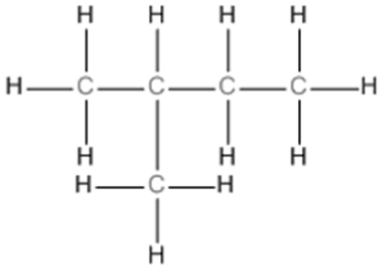
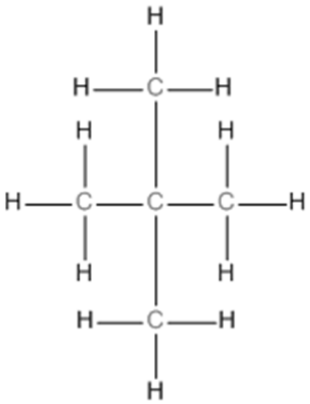
Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

Question Number	Correct Answer	Reject	Mark
1	B		1
	Incorrect Answers: A – The change is not to the extrapolated peak C - The change starts at zero and not 20 and goes to only the observed peak D- The c nge starts at zero and not 20		

Question Number	Correct Answer	Mark
2	A	**1**

Question Number	Acceptable Answers	Reject	Mark
3(a)	   All 3 correct **(2)** Any 2 correct **(1)** ALLOW CH_3 groups If no other marks are scored, ALLOW 3 correct isomers as structural, skeletal or any other combination of formulae except molecular for **(1)** mark IGNORE bond angles and bond lengths IGNORE structural or skeletal formulae in addition to displayed formulae / names, even if incorrect If 4 or more isomers drawn, max 1	Missing H once only Only structural or skeletal formulae once only	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)(i)	(Free) radical **(1)** Substitution **(1)** IGNORE homolytic fission/ initiation / propagation /termination	Heterolytic /electrophilic /nucleophilic	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)(ii)	$C_5H_{12} + Cl\bullet \rightarrow C_5H_{11}\bullet + HCl$ **(1)** $C_5H_{11}\bullet + Cl_2 \rightarrow C_5H_{11}Cl + Cl\bullet$ **(1)** ALLOW equations in either order / displayed formulae / structural formulae NO TE on incorrect free radical IGNORE size and position of dot / any type of curly arrows	Missing dots once only in (b)(ii) and (b)(iii) Additional incorrect equations once only Formation of H• scores **(0)** overall	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)(iii)	Any one from $Cl\bullet + Cl\bullet \rightarrow Cl_2$ $Cl\bullet + C_5H_{11}\bullet \rightarrow C_5H_{11}Cl$ $C_5H_{11}\bullet + C_5H_{11}\bullet \rightarrow C_{10}H_{22}$ IGNORE any type of curly arrows	Additional incorrect equation	**1**

Question Number	Acceptable Answers	Reject	Mark
3(c)(i)	Correct answer with or without working scores the mark 100.0 x 4.18 x 14.5 (**=** 6061 J) **=** 6.061/6.06/6.1 (kJ) ALLOW 6061 **J** IGNORE sign (+/-) / kJ mol^{-1}	6 / 6061 (kJ)	**1**

Question Number	Acceptable Answers	Mark
3(c)(ii)	Correct answer with or without working scores the mark number of moles = $\frac{0.144}{72}$ = 0.002 / $2x10^{-3}$ ALLOW correct working with no answer written	**1**

Question Number	Acceptable Answers	Reject	Mark
3(c)(iii)	Correct answer with or without working scores both marks enthalpy change of combustion = $\frac{\text{answer to (c)(i)}}{\text{answer to (c)(ii)}}$ = −3030.5/−3031 kJ mol^{-1} Or −3030500/−3.0305 x 10^6/−3031000/−3.031 x 10^6 J mol^{-1} Correct number **(1)** Correct sign and units consistent with number **(1)** Mark independently ALLOW −3030/−3050 kJ mol^{-1} and equivalent answers in J mol^{-1} score both marks ALLOW units as kJ/mol or $\frac{\text{kJ}}{\text{mol}}$ or J/mol or $\frac{\text{J}}{\text{mol}}$ IGNORE SF except 1SF ALLOW TE from (c)(i) and (c)(ii)	Incorrect unit e.g. kJ/mol^{-1} or kJ mol^{-}	**2**

Question Number	Acceptable Answers	Reject	Mark
3(c)(iv)	**First mark** Incomplete combustion ALLOW incomplete reaction **(1)** IGNORE not enough oxygen / not all the fuel has reacted **Second mark** Evaporation of the alkane / fuel / reactant / compound ALLOW alkane is volatile / heat capacity of/heat absorbed by container/apparatus was not included **(1)** IGNORE Heat loss to the surroundings / Not measured at standard conditions / Mention of heat capacity/density of water / Evaporation of water / Error in thermometer/balance / Alkane is impure If average bond enthalpies is mentioned, max (1)		**2**

Question Number	Acceptable Answers	Reject	Mark
3(c)(v)	The experimental errors are greater than the differences in the Data Book values OR The experimental value is much lower than all the Data Book values/ the Data Book values are all much more exothermic than the experimental value ALLOW The three Data Book values are (too) close together IGNORE Answer to (c)(iii)/ experimental value is very different to the Data Book values	Average bond enthalpies	**1**

Question Number	Acceptable Answers	Reject	Mark
3(d)	$C_5H_{12}(l) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$ $5C(s, graphite) + 6H_2(g) + 8O_2(g)$ **Cycle** 2 marks $5C(s, graphite) + 6H_2(g) + 8O_2(g)$ **OR** $5C(s) + 6H_2(g) + 8O_2(g)$ Correct species, multiples and all state symbols needed **(1)** Both arrows upwards ALLOW two arrows from elements to products of combustion /downward arrows provided they are labelled with correct value or symbol **(1)** IGNORE additional curved arrows as part of working **Calculation** 2 marks Mark independently of arrows on cycle Correct answer with or without working scores both marks $\Delta H_c = (5x-393.5) + (6x-285.8) -(-173.2)$ **(1)** $= -3509.1/-3509$ (kJ mol^{-1}) **(1)** IGNORE kJ as unit ALLOW TE from incorrect multiple of C and H_2	Other incorrect unit	**4**

(Total for Question 3 = 18 marks)

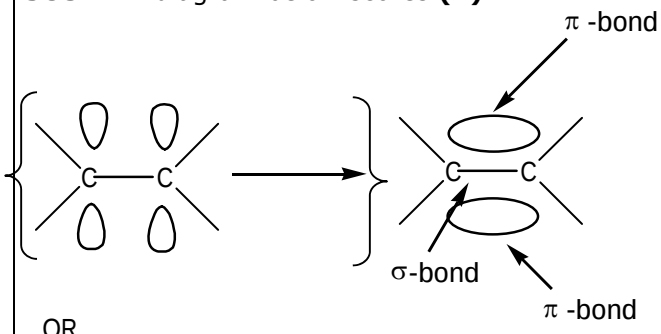
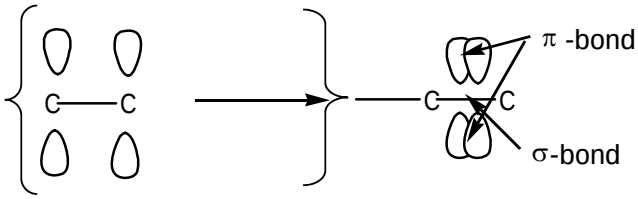
Question Number	Acceptable Answers	Reject	Mark
4(a)	**1st mark – idea of moles / amounts specified** (Enthalpy change when) the number of moles of reactants **ALLOW** (Enthalpy change when) the number of moles of products or substances / just molar quantities / just amounts / just moles **(1)** **2nd mark – idea of an equation** (react as specified in the balanced) **equation** **(1)** **IGNORE** references to (standard) conditions / just 'enthalpy change that occurs during a reaction'	'**One mole** of reactants' / '**One mole** of products' for 1st mark	**2**

Question Number	Acceptable Answers	Reject	Mark
4(b)(i)	(Heat energy absorbed = 100 x 4.2 x 5.5 =) 2310 (J) **ALLOW** 2.3(10) **kJ** IGNORE sign and sf except one sf		**1**

Question Number	Acceptable Answers	Reject	Mark
4(b)(ii)	(Moles NH_4CNS = $\frac{15.22}{76.1}$ =) 0.2(00) (mol) **IGNORE** sf **ALLOW** M_r = 76 for NH_4CNS to give 0.200(3) (mol)		**1**

Question Number	Acceptable Answers	Reject	Mark
4(b)(iii)	$\Delta H_{reaction}$ = +$\frac{2.3(10)}{0.2(00)}$ **x2** = +23.1 (kJ mol^{-1}) = **+**23 (kJ mol^{-1}) to 2 sf **First mark – correct computation of $\Delta H_{reaction}$:** **2 x** [answer to (b)(i) in kJ ÷ answer to (b)(ii) in mol] **(1)** **Second mark – stand alone, for correct rounding:** A final answer to **two** sf **(1)** **Third mark – stand alone, for giving a + sign for endothermic reaction:** **+** sign in front of final answer **(1)** NOTE: **+**12 (kJ mol^{-1}) scores **(2)** (i.e. the 2nd and 3rd marks)	Incorrect units given by the candidate (no 3rd scoring point)	**3**

Question Number	Acceptable Answers	Reject	Mark
4(c)(i)	(Average amount of) energy/enthalpy required to **break one mole** of (covalent) **bonds** **ALLOW** Energy change/enthalpy change to **break one mole** of (covalent) **bonds** **(1)** (in the) **gas / gaseous** (state) **(1)**	Energy/enthalpy **released** OR 'Bonds **formed**/**made**' OR 1 mol of **compound** for 1st mark	**2**

Question Number	Acceptable Answers	Reject	Mark
4(c)(ii)	For a pi/π-bond: Sideways overlap of p-orbitals / overlap of p-orbitals above and below stated or drawn on a diagram **(1)** For a sigma/σ-bond: Head-on overlap of any orbitals, stated or drawn on a diagram **(1)** **MAX (1)** if it is not specified/clear which type of overlap relates to which type of bond **IGNORE** Incorrect diagram **NOTE** **JUST 1st** diagram below scores **(1)** whereas **JUST 2nd** diagram below scores **(2)**  OR  **NOTE:** For the σ-bond, allow any form of 'end-on' overlap of orbitals **MAX (1)** if **only** an UNLABELLED but otherwise correct diagram is given (ie also no words)		**2**

Question Number	Acceptable Answers	Reject	Mark
4(c)(iii)	π-bond is weak(er) OR σ-bond is strong(er) OR The sideways overlap is less effective than the head-on overlap **ALLOW** The two bonds in the (C=C) double bond are not the same strength **IGNORE** References to C=C bond more reactive than C-C bond / 'restricted rotation'	π-bond is stronger than the σ-bond OR C=C bond weaker than C-C bond	**1**

Question Number	Acceptable Answers	Reject	Mark
4(c)(iv)	[FIRST, check the answer on the answer line IF answer = **−1936** (kJ mol^{-1}) award **(3)** marks; **+1936** (kJ mol^{-1}) scores **(2)**] Bonds broken (6 x (C−H) = 6 x 413 + 1 x (C−C) = 1 x 347 + 1 x (C=C) = 1 x 612 + 4½ x (O=O) = 4½ x 498 =) (+)5678 **(1)** Bonds made (6 x (C=O) = 6 x −805 + 6 x (O−H) = 6 x −464 =) (−)7614 **(1)** $\Delta H_{reaction}$ = bonds broken + bonds made = (+)5678 + (−)7614 = −1936 (kJ mol^{-1}) **(1)** **NOTE** 3rd mark CQ on answers calculated for bonds broken and bonds made		**3**

Question Number	Acceptable Answers	Reject	Mark
4(c)*(v)	Under standard conditions/298 K water is a **liquid** OR (Calculations involving) bond energies refer to (water in) **gaseous** state **(1)** Energy released/given out on changing from gas to liquid OR Energy absorbed/taken in on changing from liquid to gas **(1)** **ALLOW max (1)** if state that 'bond energies are average values (from a range of compounds)' **IGNORE** References to 'heat losses' / 'incomplete combustion'		**2**

(Total for Question 4 = 17 marks)

Question Number	Acceptable Answers	Reject	Mark
5(a)(i)	Alkane(s) **IGNORE** Any references to 'branched' / 'aliphatic' / 'hydrocarbons'		**1**

Question Number	Acceptable Answers	Reject	Mark
5(a)(ii)	2,3-**di**methyloctane **IGNORE** Incorrect or missing punctuation		**1**

Question Number	Acceptable Answers	Reject	Mark
5(a)(iii)	**mark:** (Isomers) **A and C** **(1)** **NOTE** If no isomers or isomers other than A & C have been chosen, then award one mark max providing both 2nd and 3rd marking points are evident. **2nd mark:** (They/A and C) have the same **molecular formula** / $C_{10}H_{22}$ / same number of C and H (atoms) **(1)** **3rd mark:** (They/A and C) have different structural formulae/displayed formulae / skeletal formulae / different structures/different arrangement of atoms **IGNORE** Any references to 'in space' / 'spatial' Any references to names Any references to general formulae **(1)**	'Different chemical formulae'	**3**

Question Number	Acceptable Answers	Reject	Mark
5(a)(iv)	$C_{12}H_{24}$ **1st mark:** C_{12} **(1)** **2nd mark:** H_{24} **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
5(b)(i)	OR **B** **ALLOW** lower case letters **IGNORE** any names or formulae		**1**

Question Number	Acceptable Answers	Reject	Mark
5(b)(ii)	OR **D** **ALLOW** lower case letters **IGNORE** any names or formulae		**1**

Question Number	Acceptable Answers	Reject	Mark
5(c)	Any **one** of: (It improves engine performance by) Promoting efficient combustion OR Allowing smoother burning OR Increasing octane number OR Reduces knocking / prevents knocking OR Pre-ignition being less likely OR Being (more) efficient (fuels) OR Better burning / fuels easier to burn OR Combusting more easily OR Improving combustion / complete combustion OR Burns more cleanly OR More miles per gallon **IGNORE** any references to energy density / boiling temperature / volatility		**1**

Question Number	Acceptable Answers	Reject	Mark
5(d)	[FIRST, check the answer on the answer line IF answer = 48000 (kJ kg^{-1}) award **(3)** marks] **1st two marks** $\frac{1000}{170}$ **(1)** x 8086 **(1)** **OR** $\frac{8086}{170}$ **(1)** x 1000 **(1)** NOTE: second mark in both cases dependent on first mark unless one minor transcription error in first mark e.g. use of 110 rather than 170 **3rd mark** = 47564.70588 = 48000 **(1)** Answer must be to 2 sf **Ignore signs and / or incorrect units at any stage** 48 scores **(2)** 47.56 scores **(1)** 1374.6 scores **(0)** even if rounded to 2SF		**3**

(Total for Question 5 = 13 marks)

Question Number	Acceptable Answers	Reject	Mark
6(a)	200 / 2 x 10^2 (ppm)		**1**

Question Number	Acceptable Answers	Reject	Mark
6(b)(i)	$CH_3OH(l) + 3/2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ Formulae **(1)** Balancing and state symbols **(1)** Allow multiples 2nd mark dependent on 1st	CH_3OH(**aq**) / (**g**) / $2H_2O$(**g**)	**2**

Question Number	Acceptable Answers	Reject	Mark
6(b)(ii)	Carbon / C / soot AND carbon monoxide / CO **Both needed**	Graphite	**1**

Question Number	Acceptable Answers	Reject	Mark
6(c)(i)	(150 x 4.18 x 15.8) = 9906.6 / 9907 / 9910 (J) / 9.9066 **kJ** Ignore sf except 1 sf / Ignore signs here	kJ **mol^{-1}**	**1**

Question Number	Acceptable Answers	Reject	Mark
6(c)(ii)	(0.64/32) = 0.02(00) (mol)		**1**

Question Number	Acceptable Answers	Reject	Mark
6(c)(iii)	(9.9066/0.0200) = 495.33 ΔH = -495 (kJ mol^{-1}) Value **(1)** Sign and 3sf **(1)** Allow TE from (c)(i) and / or (c)(ii) (answer to (c)(i) in kJ/ answer to (c)(ii)) No 2nd mark if units given are incorrect e.g. kJ mol or kJ/mol^{-1}		**2**

Question Number	Acceptable Answers	Reject	Mark
6(c)(iv)	Mark the two points **independently** **1st mark:** Evaporation of alcohol (from burner) / alcohol is volatile /CH_3OH is volatile ALLOW H_2O forms as steam, not water **IGNORE** Water evaporates (from apparatus) **(1)** **2nd mark:** (Actual) mass/moles (methanol) burned is less **and** (so) enthalpy change will be less negative/less exothermic / less / smaller **OR** Estimate of mass/moles (methanol) burned is too high **and** (so) enthalpy change will be less negative/less exothermic / less / smaller **OR** Temperature rise will be less than it should be **and** (so) enthalpy change will be less negative/less exothermic / less / smaller **(1)** **IGNORE** Any mention of specific heat capacity	Weighing errors / Other equipment errors (eg distance between calorimeter and spirit burner) Any answers that suggest lab value more exothermic / greater value of enthalpy change	**2**

Question Number	Acceptable Answers	Reject	Mark
6(d)	**Mark each point independently** **1st mark:** **ANY ONE OF:** Bond enthalpies vary with environment Mean bond enthalpies do not equal actual bond enthalpies (for these reactants) / mean bond enthalpies are not exact values Bond enthalpies used are average values (from a range of compounds) **(1)** **2nd mark:** **ANY ONE OF:** Bond enthalpies refer to gases OR Bond enthalpies refer to gaseous bonds OR Methanol is a liquid OR Water is a liquid (under standard conditions) **(1)** IGNORE References to 'non-standard conditions' / 'incomplete combustion' / 'not in same state'		**2**

Total for Question 6 = 12 marks