**M1.**(a) (i) $2C_6H_{12}O_6 \longrightarrow 3CH_3COCH_3 + 3CO_2 + 3H_2O$

*Or multiples*

**1**

(ii) to speed up the reaction
***OR***
(provide a) catalyst or catalyses the reaction or biological catalyst
***OR***
release / contain / provides an enzyme

*Ignore "fermentation"*

*Ignore "to break down the glucose"*

*Not simply "enzyme" on its own*

**1**

(b) (i) $CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

*Any correct representation for the two organic structures.*
*Brackets not essential.*

*Not "sticks" for the structures in this case*

**1**

(ii) Secondary (alcohol) OR 2° (alcohol)

**1**

(c) **M1** $q = m\ c\ \Delta T$

***OR*** $q = 150 \times 4.18 \times 8.0$

*Award full marks for correct answer*

*In **M1**, do not penalise incorrect cases in the formula*

**M2** = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ)
(also scores M1)

**M3** This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown.
Using 0.00450 mol

therefore $\Delta H$ = **− 1115** (kJ $mol^{-1}$)

***OR*** **− 1114.6 to − 1120** (kJ $mol^{-1}$)

**Range (+)1114.6 to (+)1120 gains 2 marks**

**BUT − 1110 gains 3 marks and +1110 gains 2 marks**

**AND − 1100 gains 3 marks and +1100 gains 2 marks**

*Award full marks for correct answer*

*In **M1**, do not penalise incorrect cases in the formula*

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **(+)1114.6 to (+)1120 gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

*If ΔT = 281; score q = m c ΔT only*

*If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = − 1283*

*Ignore incorrect units in **M2***

*If units are given in **M3** they must be either kJ or kJ mol$^{-1}$ in this case*

**3**

(d) **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

*For **M3***

*Ignore reference to 1 atmosphere*

**3**

(e) **M1**
$\sum$ B **(reactants)** − $\sum$ B **(products)** = Δ*H*
***OR***
Sum of bonds broken − Sum of bonds formed = Δ*H*
***OR***
2B(C−C) + B(C=O) + 6B(C−H) + 4B(O=O) (LHS)

− 6B(C=O) − 6B(O−H) (RHS) = Δ*H*

**M2** (also scores **M1**)
2(348)+805+6(412)+4(496) [LHS = **5957**]

(696) (2472) (1984)

− 6(805) − 6(463) [RHS = (−) **7608**] = Δ*H*

(4830) (2778)

***OR*** using only bonds broken and formed (**5152 − 6803**)

**M3**
Δ*H*= **− 1651** (kJ $mol^{-1}$)

**Candidates may use a cycle and gain full marks.**

*Correct answer gains full marks*

*Credit 1 mark for (+) 1651 (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 / addition error; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ 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 = 5957 (or 5152) OR RHS = 7608 (or 6803)*

*Award 1 mark for + 1651*

**3**

(f) **For the two marks M1 and M2, any two from**

- heat loss or not all heat transferred to the apparatus or heat absorbed by the apparatus or (specific) heat capacity of the apparatus not considered
- incomplete combustion / not completely burned / reaction is not complete
- The idea that the water may end up in the gaseous state (rather than liquid)
- reactants and / or products may not be in standard states.
- MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states
- MBE do not refer to specific compounds OR MBE values vary with different compounds / molecules OR are average / mean values taken from a range of compounds / molecules

*Apply the list principle but ignore incomplete reasons that contain correct chemistry*

*Ignore "evaporation"*

*Ignore "faulty equipment"*

*Ignore "human error"*

*Not enough simply to state that "MBE are mean / average values"*

**2**

**[15]**

**M2.**(a) (i) M1 c(oncentrated) phosphoric acid / c(onc.) $H_3PO_4$
***OR*** c(oncentrated) sulfuric acid / c(onc.) $H_2SO_4$

*In **M1**, the acid must be concentrated.*
*Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.*

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants
***OR*** pass the gases over the catalyst several / many times

*In **M2**, ignore "remove the ethanol".*
*Credit "re-use".*

**2**

(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**

(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

*Credit all converse arguments for **M2***

**2**

(b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation

$$2C(s \text{ / graphite}) + 3H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow CH_3CH_2OH(l)\ (C_2H_5OH)$$

*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.*

**2**

(c) (i) M1 The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is <u>burned / combusts / reacts completely</u> in <u>oxygen</u>
***OR*** <u>burned / combusted / reacted in excess oxygen</u>

M3 with (all) <u>reactants and products /</u> (all) <u>substances in standard / specified states</u>
***OR*** (all) <u>reactants and products /</u> (all) <u>substances in normal states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

*For **M3***
*Ignore reference to 1 atmosphere*

**3**

(ii) M1

*Correct answer gains full marks*

<u>ΣB(**reactants**) − ΣB(**products**) = *ΔH*</u>

*Credit 1 mark for (+) 1279 (kJ mol$^{-1}$)*

OR
<u>Sum of bonds broken − Sum of bonds formed = ΔH</u>
OR
B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS)
− 4B(C=O) − 6B(O−H) (RHS) = <u>*ΔH*</u>

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**)

*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 **<u>only M1</u>***

M3
ΔH= **<u>− 1279</u>** (kJ mol$^{-1}$)

*Allow a maximum of one mark if the only scoring point is LHS = 4719 **OR** RHS = 5998*

Award 1 mark for +1279

**Candidates may use a cycle and gain full marks**

**3**

(d) (i) Reducing agent ***OR*** reductant ***OR*** electron donor ***OR*** to reduce the copper oxide

*Not "reduction".*
*Not "oxidation".*
*Not "electron pair donor".*

**1**

(ii) $CH_3COOH$

**1**

**[17]**

**M3.**(a) $q = 500 \times 4.18 \times 40$

*Do not penalise precision.*

**1**

$= 83600$ J

*Accept this answer only.*
*Ignore conversion to 83.6 kJ if 83600 J shown.*
*Unit not required but penalise if wrong unit given.*
*Ignore the sign of the heat change.*
*An answer of 83.6 with no working scores one mark only.*
*An answer of 83600 with no working scores both marks.*

**1**

(b) Moles (= 83.6 / 51.2) = 1.63

*Using 77400 alternative gives 1.51 mol*
*Allow (a) in kJ / 51.2*
*Do not penalise precision.*

**1**

Mass = 1.63 × 40(.0) = 65.2 (g)

*Allow 65.3 (g)*

*Using 77400 alternative gives 60.4 to 60.5*

*Allow consequential answer on M1.*

*1 mark for $M_r$ (shown, not implied) and 1 for calculation.*

*Do not penalise precision.*

**2**

(c) Molarity = 1.63 / 0.500 = 3.26 mol dm–3

*Allow (b) M1 × 2*

*Using 1.51 gives 3.02*

**1**

(d) Container splitting and releasing irritant / corrosive chemicals

*Must have reference to both aspects; splitting or leaking (can be implied such as contact with body / hands)* ***and*** *hazardous chemicals.*

*Allow 'burns skin / hands' as covering both points*

*Ignore any reference to 'harmful'.*

*Do not allow 'toxic'.*

**1**

(e) (i) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

*Allow fractions / multiples in equation.*

*Ignore state symbols.*

**1**

(ii) Iron powder particle size could be increased / surface area lessened

*Decrease in particle size, chemical error = 0 / 3*

*Change in oxygen, chemical error = 0 / 3*

**1**

Not all the iron reacts / less reaction / not all energy released / slower release of energy / lower rate of reaction

*Mark points M2 and M3 independently.*

**1**

Correct consequence of M2

*An appropriate consequence, for example*

- *too slow to warm the pouch effectively*

- *lower temperature reached*
- *waste of materials*

**1**

(f) (i) Conserves resources / fewer disposal problems / less use of landfill / fewer waste products

*Must give a specific point.*

*Do not allow 'does not need to be thrown away' without qualification.*

*Do not accept 'no waste'.*

**1**

(ii) Heat to / or above 80 °C (to allow thiosulfate to redissolve)

*Accept 'heat in boiling water'.*

*If steps are transposed, max 1 mark.*

**1**

Allow to cool before using again

*Reference to crystallisation here loses this mark.*

**1**

**[14]**