

1

(ii) to speed up the reaction

**OR**

(provide a) catalyst or catalyses the reaction or biological catalyst

**OR**

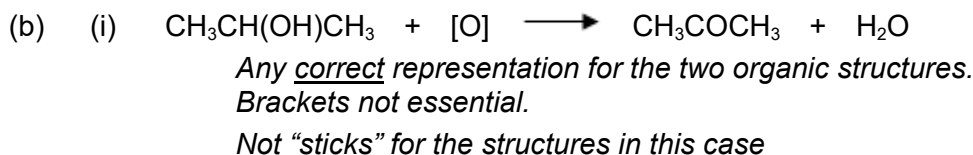
release / contain / provides an enzyme

*Ignore "fermentation"*

*Ignore "to break down the glucose"*

*Not simply "enzyme" on its own*

1



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  $\Delta H = - \underline{1115}$  (kJ mol<sup>-1</sup>)

**OR**  $- \underline{1114.6}$  to  $- \underline{1120}$  (kJ mol<sup>-1</sup>)

**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  $\Delta T = 281$ ; score  $q = m c \Delta T$  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<sup>-1</sup> 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**

$\sum B(\text{reactants}) - \sum B(\text{products}) = \Delta H$

**OR**

Sum of bonds broken – Sum of bonds formed =  $\Delta H$

**OR**

2B(C–C) + B(C=O) + 6B(C–H) + 4B(O=O) (LHS)

– 6B(C=O) – 6B(O–H) (RHS) =  $\Delta H$

**M2** (also scores **M1**)

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

(696)            (2472) (1984)

– 6(805) – 6(463) [RHS = (–) **7608**] =  $\Delta H$

(4830)    (2778)

OR using only bonds broken and formed (5152 – 6803)

**M3**

$\Delta H = -1651$  (kJ mol<sup>-1</sup>)

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

*Correct answer gains full marks*

*Credit 1 mark for (+) 1651 (kJ mol<sup>-1</sup>)*

*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<sub>2</sub>, 3CO<sub>2</sub> and 3H<sub>2</sub>O 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.** Increase in volume

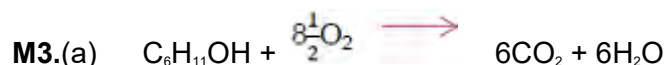
If a volume is quoted it must be less than 300

1

Smaller increase in T above room temperature  
Or increased contact between calorimeter and water  
Or smaller heat loss by evaporation / from the surface

1

[2]



1

(b) Temperature rise = 20.1

$$q = 50.0 \times 4.18 \times 20.1 = 4201 \text{ (J)}$$

1

Mass of alcohol burned = 0.54 g and  $M_r$  alcohol = 100.0

$$\therefore \text{mol of alcohol} = n = 0.54 / 100 = 0.0054$$

1

Heat change per mole =  $q / 1000n$  **OR**  $q / n$

$$= 778 \text{ kJ mol}^{-1} \text{ **OR** } 778\,000 \text{ J mol}^{-1}$$

1

$$\Delta H = -778 \text{ kJ mol}^{-1} \text{ **OR** } -778\,000 \text{ J mol}^{-1}$$

*M4 is for answer with negative sign for exothermic reaction*

*Units are tied to the final answer and must match*

1

(c) Less negative than the reference

1

Heat loss **OR** incomplete combustion **OR** evaporation of alcohol **OR** heat transferred to beaker not taken into account

(d) Water has a known density (of  $1.0 \text{ g cm}^{-3}$ )

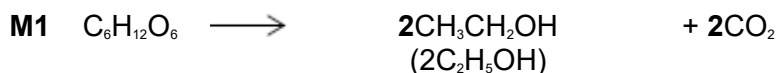
1

Therefore, a volume of  $50.0 \text{ cm}^3$  could be measured out

1

[9]

**M4.(a)**



*Penalise C<sub>2</sub>H<sub>6</sub>O for ethanol in M1.*

**M2 and M3**

*Mark M2 and M3 independently.*

Any **two** conditions in any order for **M2** and **M3** from

- (enzymes from) yeast or zymase
- $25 \text{ }^\circ\text{C} \leq T \leq 42 \text{ }^\circ\text{C}$  OR  $298 \text{ K} \leq T \leq 315 \text{ K}$
- anaerobic / no oxygen / no air OR neutral pH

*A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.*

*Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.*

**M4** (fractional) distillation or GLC

*Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).*

**M5** Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO<sub>2</sub> emission to the atmosphere

**OR**

There is no change in the total amount / level of carbon dioxide / CO<sub>2</sub> present, in the atmosphere

For **M5** – must be about  $\text{CO}_2$  and the atmosphere.  
The idea that the carbon dioxide /  $\text{CO}_2$  given out equals the carbon dioxide /  $\text{CO}_2$  that was taken in from the atmosphere.

5

- (b) **M1**  $q = m c \Delta T$  (this mark for correct mathematical formula)  
Full marks for **M1**, **M2** and **M3** for the correct answer.  
In **M1**, do not penalise incorrect cases in the formula.

$$\mathbf{M2} = (75 \times 4.18 \times 5.5)$$

$$1724 \text{ (J) OR } 1.724 \text{ (kJ) OR } 1.72 \text{ (kJ) OR } 1.7 \text{ (kJ)}$$

(also scores **M1**)

Ignore incorrect units in **M2**.

**M3** Using 0.0024 mol

therefore  $\Delta H = \underline{-718}$  (kJ mol<sup>-1</sup>)

(Accept a range from -708 to -719 but do not penalise more than 3 significant figures)

Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718** gains two marks.

If units are quoted in **M3** they must be correct.

If  $\Delta T = 278.5$ , CE for the calculation and penalise **M2** and **M3**.

**M4** and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the ( $2.40 \times 10^{-3}$  mol) ethanol is burned / reaction is incomplete  
If  $c = 4.81$  (leads to 1984) penalise **M2** ONLY and mark on for **M3** = - 827

5

- (c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in breaking / dissociating (a) covalent bond(s)  
Ignore bond making.

**M2** averaged for that type of bond over different / a range of molecules /

compounds

*Ignore reference to moles.*

2

(ii) **M1**

$$\underline{\sum B(\text{reactants}) - \sum B(\text{products}) = \Delta H}$$

**OR**

$$\underline{\text{Sum of bonds broken} - \text{Sum of bonds formed} = \Delta H}$$

**OR**

$$\begin{aligned} & B(\text{C-C}) + B(\text{C-O}) + B(\text{O-H}) + 5B(\text{C-H}) + 3B(\text{O=O}) \\ & - 4B(\text{C=O}) - 6B(\text{O-H}) = \Delta H = -1279 \end{aligned}$$

*Correct answer gains full marks.*

*Credit 1 mark for - 496 (kJ mol<sup>-1</sup>)*

*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 2CO<sub>2</sub> and 3H<sub>2</sub>O OR a clear statement of M1 which could be in words and scores **only M1**.*

**M2** (also scores **M1**)

$$348+360+463+5(412)+ 3B(\text{O=O})$$

$$\begin{aligned} & \quad \quad \quad (3231) \quad \quad \quad (\text{or } 2768 \text{ if O-H cancelled}) \\ & - 4(805) - 6(463) = \Delta H = -1279 \end{aligned}$$

$$\quad \quad \quad (5998) \quad \quad \quad (\text{or } 5535 \text{ if O-H cancelled})$$

$$3B(\text{O=O}) = \underline{1488} \text{ (kJ mol}^{-1}\text{)}$$

*Credit a maximum of one mark if the only scoring point is bonds formed adds up to 5998 (or 5535) OR bonds broken includes the calculated value of 3231 (or 2768).*

**M3**

$$B(\text{O=O}) = \underline{496} \text{ (kJ mol}^{-1}\text{)}$$

Award 1 mark for -496

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

3

[15]

**M5.(a)** Start a clock when KCl is added to water 1

Record the temperature every subsequent minute for about 5 minutes

*Allow record the temperature at regular time intervals  
until some time after all the solid has dissolved for M2*

1

Plot a graph of temperature vs time

1

Extrapolate back to time of mixing = 0 and determine the temperature

1

(b) Heat taken in =  $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6 \text{ J}$

*Max 2 if 14.6 °C used as  $\Delta T$*

1

Moles of KCl =  $5.00 / 74.6 = 0.0670$

1

Enthalpy change per mole =  $+1128.6 / 0.0670 = 16\,839 \text{ J mol}^{-1}$

1

=  $+16.8 \text{ (kJ mol}^{-1}\text{)}$

*Answer must be given to this precision*

1

(c)  $\Delta H_{\text{solution}} = \Delta H_{\text{lattice}} + \Delta H(\text{hydration of calcium ions}) + 2 \times \Delta H(\text{hydration of chloride ions})$

$\Delta H_{\text{lattice}} = \Delta H_{\text{solution}} - \Delta H(\text{hydration of calcium ions}) - 2 \times \Delta H(\text{hydration of chloride ions})$

1



$$\Delta H_{\text{lattice}} = -82 - 9 - (-1650 + 2 \times -364) = +2295 \text{ (kJ mol}^{-1}\text{)}$$

1

(d) Magnesium ion is smaller than the calcium ion

1

Therefore, it attracts the chloride ion more strongly / stronger ionic bonding

1

**[12]**