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(ii) to speed up the reaction

OR

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

OR

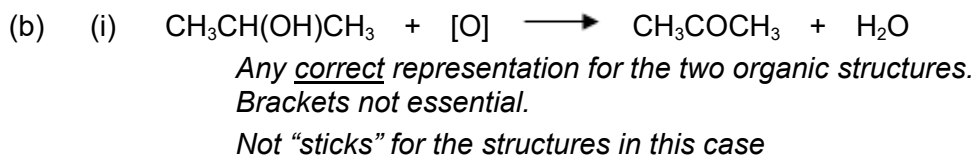
release / contain / provides an enzyme

Ignore "fermentation"

Ignore "to break down the glucose"

Not simply "enzyme" on its own

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

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(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⁻¹)

OR $\underline{-1114.6}$ to $\underline{-1120}$ (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 $\Delta T = 281$; 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⁻¹ in this case

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(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

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(e) **M1**

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

OR

Sum of bonds broken – Sum of bonds formed = ΔH

OR

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

– 6B(C=O) – 6B(O–H) (RHS) = ΔH

M2 (also scores **M1**)

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

(696) (2472) (1984)

– 6(805) – 6(463) [RHS = (–) **7608**] = ΔH

(4830) (2778)

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

M3

$\Delta H = -1651$ (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 4O₂, 3CO₂ and 3H₂O 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

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(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"

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M2.(a) The enthalpy (change) to break 1 mol of H—O / bonds

Allow heat energy

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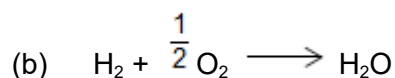
Averaged over a range of compounds / molecules

Penalise energy but mark on

ignore states

CE = 0 for ionic bonds

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$$\Delta H = (\text{H-H}) + \frac{1}{2} (\text{O}=\text{O}) - 2(\text{H-O}) / \text{sum of (bonds broken)} - \text{sum of (bonds formed)}$$

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$$= 436 + 496 / 2 - 2 \times 464$$

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$$= -244 \text{ (kJ mol}^{-1}\text{)}$$

Allow 1 mark only for +244 and -488

Units not essential but penalise incorrect units

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- (c) (i) same reaction / same equation / same number / same reactants and same products / same number and type of bonds broken and formed

Do not allow similar

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- (ii) There must be a slight difference between the actual bond enthalpy (in water) and mean bond enthalpies for the O-H bond (in other molecules)

Allow bond enthalpy value for enthalpy of formation may not be under standard conditions.

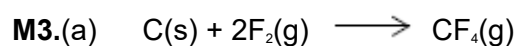
Allow reference to bond energy rather than bond enthalpy

Do not allow heat loss or experimental error

Do not allow mean bond enthalpies are not accurate

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State symbols essential

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(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

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Therefore, these repel equally and spread as far apart as possible

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(c) $\Delta H = \sum \Delta_f H \text{ products} - \sum \Delta_f H \text{ reactants}$ or a correct cycle

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$$\text{Hence} = (2 \times -680) + (6 \times -269) - (x) = -2889$$

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$$x = 2889 - 1360 - 1614 = -85 \text{ (kJ mol}^{-1}\text{)}$$

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Score 1 mark only for +85 (kJ mol⁻¹)

(d) Bonds broken = 4(C-H) + 4(F-F) = 4 × 412 + 4 × F-F

Bonds formed = 4(C-F) + 4(H-F) = 4 × 484 + 4 × 562

Both required

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$$-1904 = [4 \times 412 + 4(\text{F-F})] - [4 \times 484 + 4 \times 562]$$

$$4(\text{F-F}) = -1904 - 4 \times 412 + [4 \times 484 + 4 \times 562] = 632$$

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$$\text{F-F} = 632 / 4 = 158 \text{ (kJ mol}^{-1}\text{)}$$

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The student is correct because the F-F bond energy is much less than the C-H or other covalent bonds, therefore the F-F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F-F bond)

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M4.(a) Bonds broken = $2(\text{C}=\text{O}) + 3(\text{H}-\text{H}) = 2 \times 743 + 3 \times \text{H}-\text{H}$

Bonds formed = $3(\text{C}-\text{H}) + (\text{C}-\text{O}) + 3(\text{O}-\text{H}) = 3 \times 412 + 360 + 3 \times 463$

Both required

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$$-49 = [2 \times 743 + 3 \times (\text{H}-\text{H})] - [3 \times 412 + 360 + 3 \times 463]$$

$$3(\text{H}-\text{H}) = -49 - 2 \times 743 + [3 \times 412 + 360 + 3 \times 463] = 1450$$

Both required

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$$\text{H}-\text{H} = 483 \text{ (kJ mol}^{-1}\text{)}$$

Allow 483.3(3)

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- (b) Mean bond enthalpies are not the same as the actual bond enthalpies in CO_2 (and / or methanol and / or water)

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- (c) The carbon dioxide (produced on burning methanol) is used up in this reaction

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- (d) 4 mol of gas form 2 mol

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At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure

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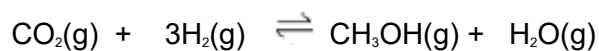
This increases the yield of methanol

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- (e) Impurities (or sulfur compounds) block the active sites
Allow catalyst poisoned

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- (f) Stage 1: moles of components in the equilibrium mixture
Extended response question



Initial moles	1.0	3.0	0	0
Eqm moles	(1-0.86) = 0.14	(3-3×0.86) = 0.42	0.86	0.86

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Stage 2: Partial pressure calculations

Total moles of gas = 2.28

Partial pressures = mol fraction × p_{total}

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$$p_{\text{CO}_2} = \text{mol fraction} \times p_{\text{total}} = 0.14 \times 500 / 2.28 = 30.7 \text{ kPa}$$

$$p_{\text{H}_2} = \text{mol fraction} \times p_{\text{total}} = 0.42 \times 500 / 2.28 = 92.1 \text{ kPa}$$

M3 is for partial pressures of both reactants

Alternative M3 =

$$pp_{\text{CO}_2} = 0.0614 \times 500$$

$$pp_{\text{H}_2} = 0.1842 \times 500$$

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$$p_{\text{CH}_3\text{OH}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500 / 2.28 = 188.6 \text{ kPa}$$

$$p_{\text{H}_2\text{O}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500 / 2.28 = 188.6 \text{ kPa}$$

M4 is for partial pressures of both products

Alternative M4 =

$$pp_{\text{CH}_3\text{OH}} = 0.3772 \times 500$$

$$pp_{\text{H}_2\text{O}} = 0.3772 \times 500$$

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Stage 3: Equilibrium constant calculation

$$K_p = p_{\text{CH}_3\text{OH}} \times p_{\text{H}_2\text{O}} / p_{\text{CO}_2} \times (p_{\text{H}_2})^3$$

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$$\text{Hence } K_p = 188.6 \times 188.6 / 30.7 \times (92.1)^3 = 1.483 \times 10^{-3} = 1.5 \times 10^{-3}$$

Answer must be to 2 significant figures

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$$\text{Units} = \underline{\text{kPa}^{-2}}$$

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