

M1.(a) ($Q = mc\Delta T$)

$$= 50 \times 4.18 \times 27.3$$

If incorrect (eg mass = 0.22 or 50.22 g) CE = 0 / 2

1

$$= \mathbf{5706 \text{ J}}$$
 (accept 5700 and 5710)

Accept 5.7 kJ with correct unit. Ignore sign.

1

(b) M_r of 2-methylpropan-2-ol = 74(.0)

For incorrect M_r , lose M1 but mark on.

1

$$\text{Moles} = \text{mass} / M_r$$

$$= 0.22 / 74(.0)$$

$$= \mathbf{0.00297 \text{ moles}}$$

1

$$\Delta H = -5706 / (0.002970 \times 1000)$$

$$= \mathbf{-1921 \text{ (kJ mol}^{-1}\text{)}}$$

If 0.22 is used in part (a), answer = $-8.45 \text{ kJ mol}^{-1}$ scores 3

(Allow -1920 , -1919)

If uses the value given (5580 J), answer = $-1879 \text{ kJ mol}^{-1}$ scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) $\Delta H = \Sigma\Delta H \text{ products} - \Sigma\Delta H \text{ reactants}$
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

$$\Delta H = -(-360) + (4 \times -393) + (5 \times -286)$$

M2 also implies M1 scored.

1

$$\Delta H = -2642 \text{ (kJ mol}^{-1}\text{) This answer only.}$$

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) $(-2422 - \text{part (b)}) \times 100 / -2422$

Ignore negative sign.

Expect answers in region of 20.7

If error carried forward, 0.22 allow 99.7

If 5580 J used earlier, then allow 22.4

1

- (e) Reduce the distance between the flame and the beaker / put a sleeve around the flame to protect from drafts / add a lid / use a copper calorimeter rather than a pyrex beaker / use a food calorimeter

Any reference to insulating material around the beaker must be on top.

Accept calibrate the equipment using an alcohol of known enthalpy of combustion.

1

- (f) Incomplete combustion

1

[11]

- M2.(a)** The enthalpy change / heat (energy) change (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)

Ignore the use of ΔH for enthalpy

1

(b) $\Delta H_{\text{exp}} + \Delta H_2 - \Delta H_1 = 0$

Any correct mathematical statement that uses all three terms

OR

$$\Delta H_{\text{exp}} + \Delta H_2 = \Delta H_1 \text{ OR } \Delta H_1 = \Delta H_{\text{exp}} + \Delta H_2$$

OR

$$\Delta H_{\text{exp}} = \Delta H_1 - \Delta H_2 \text{ OR } \Delta H_{\text{exp}} = \Delta H_1 + (-\Delta H_2)$$

1

(c) $\Delta H_{\text{exp}} = \Delta H_1 - \Delta H_2$

$$\Delta H_{\text{exp}} = -156 - 12 = \mathbf{-168} \text{ (kJ mol}^{-1}\text{)}$$

Ignore units

Award the mark for the correct answer without any working

1

(d) (i) M1 $q = m c \Delta T$ OR calculation (25.0 x 4.18 x 14.0)

Award full marks for correct answer

M2 = **1463J** OR **1.46** kJ (This also scores **M1**)

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

M3 must have both the correct value within the range specified **and** the minus sign

*Penalise **M3** ONLY if correct numerical value but sign is incorrect; e.g. **+69.5 to +69.7 gains 2 marks** (ignore +70 after correct answer)*

For 0.0210 mol, therefore

$$\Delta H_1 = \mathbf{- 69.67} \text{ to } \mathbf{- 69.52} \text{ (kJ mol}^{-1}\text{)}$$

$$\text{OR } \Delta H_1 = \mathbf{- 69.7} \text{ to } \mathbf{- 69.5} \text{ (kJ mol}^{-1}\text{)}$$

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

Accept answers to 3sf or 4sf in the range - 69.7 to - 69.5

$$\Delta T = 287, \text{ score } q = m c \Delta T \text{ only}$$

Ignore -70 after correct answer

*If $c = 4.81$ (leads to 1684J) penalise **M2** ONLY and mark on for **M3** = -80.17 (range - 80.0 to - 80.2)*

Ignore incorrect units

3

(ii) The idea of heat loss

NOT impurity

OR

Incomplete reaction (of the copper sulfate)

NOT incompetence

OR

Not all the copper sulfate has dissolved

NOT incomplete combustion

1

(e) Impossible to add / react the exact / precise amount of water

Not just "the reaction is incomplete"

OR

Very difficult to measure the temperature rise of a solid

OR

Difficult to prevent solid dissolving

OR

(Copper sulfate) solution will form

1

[8]

M3. (a) (i) **M1 (could be scored by a correct mathematical expression which must have**

all ΔH symbols and the Σ or SUM)

M1 $\Delta H_r = \Sigma \Delta H_f$ (products) - $\Sigma \Delta H_f$ (reactants)

OR a correct cycle of balanced equations with 1C, 3H₂ and 1O₂

M2 $\Delta H_r = -201 + (-242) - (-394)$

$\Delta H_r = -201 - 242 + 394$

$\Delta H_r = -443 + 394$

(This also scores M1)

M3 = -49 (kJ mol⁻¹)

(Award 1 mark ONLY for + 49)

Correct answer gains full marks

Credit 1 mark ONLY for + 49 (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; this would score 2 marks (**M1** and **M2**)
- If no AE, check for a correct method; this requires either
correct cycle of balanced equations with $1C$, $3H_2$ and $1O_2$
OR a clear statement of **M1** which could be in words
and scores only M1

3

- (ii) It is an element / elemental
Ignore reference to "standard state"

OR

By definition

1

- (b) **M1** (The yield) increases / goes up / gets more
If M1 is given as "decreases" / "no effect" / "no change" then
CE= 0 for clip, but mark on only **M2** and **M3** from a blank M1

M2 There are more moles / molecules (of gas) on the left / of reactants

OR fewer moles / molecules (of gas) on the right
/ products

OR there are 4 moles / molecules (of gas) on the left and 2 moles / molecules on the right.

OR (equilibrium) shifts / moves to the side with less moles / molecules
Ignore "volumes", "particles" "atoms" and "species" for **M2**

M3: Can only score M3 if M2 is correct

The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in pressure

For **M3**, not simply "to oppose the change"

For **M3** credit the equilibrium shifts / moves (to right) to lower / decrease the pressure

(There must be a specific reference to the change that is opposed)

3

- (c) **M1** Yield increases goes up

M2 The (forward) reaction / to the right is endothermic OR takes in/ absorbs

heat

OR

The reverse reaction / to the left is exothermic OR gives out / releases heat

*If M1 is given as “decrease” / “no effect” / “no change” then
CE= 0 for clip, but mark on only **M2** and **M3** from a blank **M1***

Can only score M3 if M2 is correct

M3 The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in temperature (QoL)

*For **M3**, not simply “to oppose the change”*

*For **M3**, credit the (position of) equilibrium shifts / moves (QoL)*

to absorb the heat OR

to cool the reaction OR

to lower the temperature

(There must be a specific reference to the change that is opposed)

3

- (d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere

OR

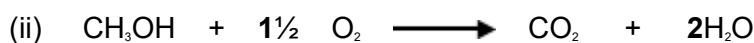
An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

OR

There is no change in the total amount / level of carbon dioxide /CO₂ carbon /greenhouse gas present in the atmosphere.

The idea that the carbon /CO₂ given out equals the carbon /CO₂ that was taken in from the atmosphere

1



Ignore state symbols

Accept multiples

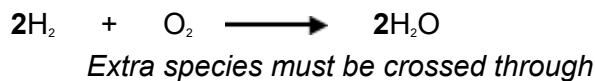
1



Ignore state symbols

OR

Accept multiples



1

- (e) **M1** $q = m c \Delta T$
Award full marks for correct answer
Ignore the case for each letter
- OR** $q = 140 \times 4.18 \times 7.5$
- M2** = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores M1)
- M3** Using 0.0110 mol
 therefore $\Delta H = \underline{-399}$ (kJmol⁻¹)
 OR -400
*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; +399 gains 2 marks*
*Penalise **M2** for arithmetic error and mark on*
*In **M1**, do not penalise incorrect cases in the formula*
If $\Delta T = 280.5$; score $q = m c \Delta T$ only
*If $c = 4.81$ (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = - 459*
- +399 or +400 gains 2 marks**
Ignore incorrect units

3

[16]

- M4.(a)** Chloride (ions) are smaller (than bromide ions)
Must state or imply ions.
Allow chloride has greater charge density (than bromide).
Penalise chlorine ions once only (max 2 / 3).

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So the force of attraction between chloride ions and water is stronger
This can be implied from M1 and M3 but do not allow intermolecular forces.

1

Chloride ions attract the $\delta+$ on H of water / electron deficient H on water
Allow attraction between ions and polar / dipole water.
Penalise H^+ (ions) and mention of hydrogen bonding for M3
Ignore any reference to electronegativity.
Note: If water not mentioned can score M1 only.

1

(b) $\Delta H_{\text{solution}} = \Delta H_L + \Delta H_{\text{hyd}} K^+ \text{ ions} + \Delta H_{\text{hyd}} Br^- \text{ ions} / = 670 - 322 - 335$

Allow $\Delta H_{\text{solution}} = \Delta H_L + \Sigma \Delta H_{\text{hyd}}$

1

= (+)13 (kJ mol⁻¹)

Ignore units even if incorrect.

+13 scores M1 and M2

-13 scores 0

-16 scores M2 only (transcription error).

1

- (c) (i) The entropy change is positive / entropy increases
 ΔS is negative loses M1 and M3

1

Because 1 mol (solid) \rightarrow 2 mol (aqueous ions) / no of particles increases
Allow the aqueous ions are more disordered (than the solid).
Mention of atoms / molecules loses M2

1

Therefore $T\Delta S > \Delta H$

1

- (ii) Amount of KCl = $5/M_r = 5/74.6 = \underline{0.067(0)} \text{ mol}$
If moles of KCl not worked out can score M3, M4 only
(answer to M4 likely to be 205.7 K)

1

$$\text{Heat absorbed} = 17.2 \times 0.0670 = 1.153 \text{ kJ}$$

Process mark for M1 \times 17.2

1

$$\text{Heat absorbed} = \text{mass} \times \text{sp ht} \times \Delta T$$

$$(1.153 \times 1000) = 20 \times 4.18 \times \Delta T$$

If calculation uses 25 g not 20, lose M3 only (M4 = 11.04, M5 = 287)

1

$$\Delta T = 1.153 \times 1000 / (20 \times 4.18) = 13.8 \text{ K}$$

If 1000 not used, can only score M1, M2, M3

M4 is for a correct ΔT

Note that 311.8 K scores 4 (M1, M2, M3, M4).

1

$$T = 298 - 13.8 = 284(.2) \text{ K}$$

If final temperature is negative, M5 = 0

Allow no units for final temp, penalise wrong units.

1

[13]