

Mark schemes

1

(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

$$\Delta H = \mathbf{-2642 \text{ (kJ mol}^{-1}\text{)}}$$
 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]

2

- (a) (i) M1 c(oncetrated) phosphoric acid / c(onc.) H₃PO₄
OR c(oncetrated) sulfuric acid / c(onc.) H₂SO₄

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.

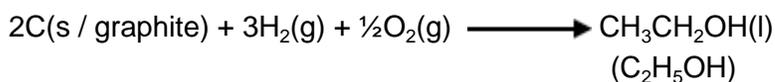
OR expensive equipment

Credit all converse arguments for M2

2

(b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation



Not multiples but credit correct state symbols in a correctly balanced equation.

Penalise C₂H₆O but credit correct state symbols in a correctly balanced equation.

2

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

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

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

(ii) M1

Correct answer gains full marks

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

Credit 1 mark for (+) 1279 (kJ mol⁻¹)

OR

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

OR

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

M2 (also scores **M1**)

$$348+360+463+5(412)+3(496) \text{ [LHS = 4719]}$$

(2060) (1488)

$$- 4(805) - 6(463) \text{ [RHS = - 5998]} = \Delta H$$

(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 only M1*

M3

$$\Delta H = \underline{-1279} \text{ (kJ mol}^{-1}\text{)}$$

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) CH₃COOH

1

[17]

3

(a) **M1 (could be scored by a correct mathematical expression)**

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

$$\text{M1 } \Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$$

Credit 1 mark for - 101 (kJ mol⁻¹)

OR a correct cycle of balanced equations

$$\text{M2} \quad = - 1669 - 3(- 590)$$

$$= - 1669 + 1770$$

(This also scores M1)

$$\text{M3} \quad = + 101 \text{ (kJ mol}^{-1}\text{)}$$

Award 1 mark ONLY for - 101

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 3Sr and 2Al **OR** a clear statement of **M1** which could be in words and scores **only M1***

M4 - Using powders

Any **one** from

- To increase collision frequency / collisions in a given time / rate of collisions
- To increase the surface contact / contact between the solids / contact between (exposed) particles

Ignore dividing final answer by 3

*Penalise **M4** for reference to molecules.*

5

M5 Major reason for expense of extraction

Any **one** from

- Aluminium is extracted by electrolysis **OR** aluminium extraction uses (large amounts of) electricity
- Reaction / process / It / the mixture requires heat
- It is endothermic

- (b) Calcium has a higher melting point than strontium, because

Ignore general Group 2 statements.

Correct reference to size of cations / proximity of electrons

M1 (For Ca) delocalised electrons closer to cations / positive ions / atoms / nucleus

OR cations / positive ions / atoms are smaller

OR cation / positive ion / atom or it has fewer (electron) shells / levels

*Penalise **M1** if either of Ca or Sr is said to have more or less delocalised electrons OR the same nuclear charge.*

Ignore reference to shielding.

Relative strength of metallic bonding

M2 (Ca) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons

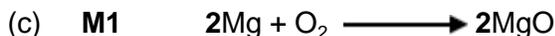
OR

stronger metallic bonding

(assume argument refers to Ca but credit converse argument for Sr)

***CE= 0** for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.*

2



Credit multiples of the equations.

M3 Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative

*Not simply "milk of magnesia" in **M3***

3

[10]

4

- (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).

1

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

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

1

$= (+)13 \text{ (kJ mol}^{-1}\text{)}$

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 = $5/M_r = 5/74.6 = 0.067(0) \text{ mol}$

If moles of KCl not worked out can score M3, M4 only (answer to M4 likely to be 205.7 K)

1

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

Process mark for M1 $\times 17.2$

1

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]

5

- (a) (i) **M1 (could be scored by a correct mathematical expression which must have all ΔH symbols and the Σ or SUM)**

Correct answer gains full marks

Credit 1 mark ONLY if -122 (kJ mol^{-1})

M1 $\Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$

OR a correct cycle of balanced equations

M2 $\Delta H = 3(-394) - 3(-111) - (-971)$
(This also scores M1)

M3 = (+) **122**(kJ mol^{-1})

Award 1 mark ONLY for -122

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 correct method; this requires either a correct cycle of balanced equations OR a clear statement of M1 which could be in words and scores **M1 only***

3

- (ii) By definition

Ignore reference to "standard state"

OR

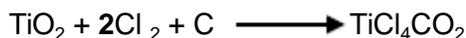
Because it is an element / elemental

1

- (b) (i) $\text{TiO}_2 + 2\text{Cl}_2 + 2\text{C} \longrightarrow \text{TiCl}_4 + 2\text{CO}$

Allow multiples

OR

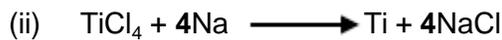


Ignore state symbols

M1 use of Cl_2 and C

M2 a correct balanced equation

2



Allow multiples

OR

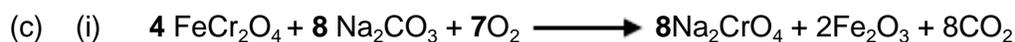


Ignore state symbols

M1 use of Na **OR** Mg

M2 a correct balanced equation

2



Allow multiples

Ignore state symbols

1



Allow multiples

Ignore state symbols

1

[10]

6

- (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

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

OR

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

1

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

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

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

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

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

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

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

$\Delta T = 287$, score $q = m c \Delta T$ 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]

7



Or multiples

Ignore state symbols

1

- (b) M1 enthalpy / heat (energy) change / required / needed to break / dissociate a covalent bond (or a specified covalent bond)

Ignore bond making

Ignore standard conditions

M2 *requires an attempt at M1*

M2 average / mean over different molecules / compounds / substances

2

- (c) M1
 $\sum (\text{bonds broken}) - \sum (\text{bonds formed}) = \Delta H$
M1 could stand alone

OR

Sum of bonds broken – Sum of bonds formed = ΔH
Award full marks for correct answer

M2 (also scores **M1**)
Ignore units

$4(+388) + 163 + 2(146) + 4(463) - 944 - 8(463) = \Delta H$
 OR broken +3859 (2007) formed – 4648 (2796)

M3

$\Delta H = -789$ (kJ mol⁻¹)
Two marks can score with an arithmetic error in the working

Award 1 mark for + 789
*Credit **one mark only** for calculating either the sum of the bonds broken or the sum of the bonds formed provided this is the only mark that is to be awarded*

Students may use a cycle and gain full marks

3
[6]

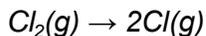
8

- (a) (Enthalpy change to) break the bond in 1 mol of chlorine (molecules)
Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms
Do not allow energy or heat instead of enthalpy, allow heat energy

1

To form (2 mol of) gaseous chlorine atoms / free radicals

Can score 2 marks for 'Enthalpy change for the reaction':



Equation alone gains M2 only

Can only score M2 if 1 mol of chlorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy)

Any mention of ions, CE = 0

1

- (b) (For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing $\frac{1}{2}$ mol chlorine giving 1 mol of atoms

Allow breaking of one bond gives two atoms

Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol

Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation

Any mention of ions, CE = 0

1

- (c) (i) $\frac{1}{2}\text{F}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{ClF}(\text{g})$

1

- (ii) $\Delta H = \frac{1}{2}E(\text{F}-\text{F}) + \frac{1}{2}E(\text{Cl}-\text{Cl}) - E(\text{Cl}-\text{F})$

Allow correct cycle

1

$$E(\text{Cl}-\text{F}) = \frac{1}{2}E(\text{F}-\text{F}) + \frac{1}{2}E(\text{Cl}-\text{Cl}) - \Delta H$$

$$= 79 + 121 - (-56)$$

$$= 256 \text{ (kJ mol}^{-1}\text{)}$$

-256 scores zero

Ignore units even if wrong

1

- (iii) $\frac{1}{2}\text{Cl}_2 + 3/2 \text{F}_2 \rightarrow \text{ClF}_3$

If equation is doubled CE=0 unless correct answer gained by / 2 at end

This would score M1

1

$$\Delta H = \frac{1}{2}E(\text{Cl}-\text{Cl}) + 3/2E(\text{F}-\text{F}) - 3E(\text{Cl}-\text{F})$$

$$= 121 + 237 - 768 \text{ / (or } 3 \times \text{ value from (c)(ii))}$$

This also scores M1 (note = 358 - 768)

1

$$= -410 \text{ (kJ mol}^{-1}\text{)}$$

If given value of 223 used ans = -311

Allow 1 / 3 for +410 and +311

1

- (iv) (Bond enthalpy of Cl-F bond in ClF is different from that in ClF₃)

Allow Cl-F bond (enthalpy) is different in different compounds (QoL)

1

- (d) NaCl is ionic / not covalent

1

[11]

9

(a) (i) **M1** (could be scored by a correct mathematical expression which must have all ΔH_f 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, 3H₂ and 1O₂ 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

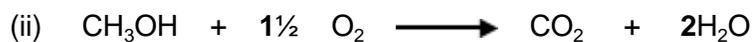
An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

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

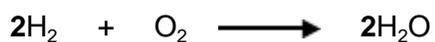
1



Ignore state symbols

OR

Accept multiples



Extra species must be crossed through

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 $\Delta H = -399$ (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]