

M1.(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

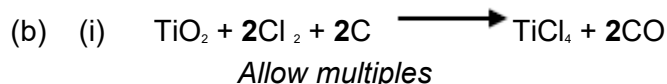
(ii) By definition

Ignore reference to "standard state"

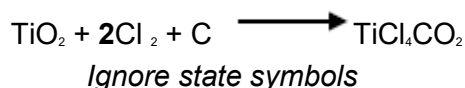
OR

Because it is an element / elemental

1



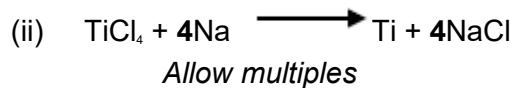
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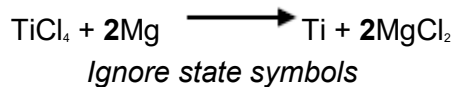
M1 use of Cl_2 and C

M2 a correct balanced equation

2



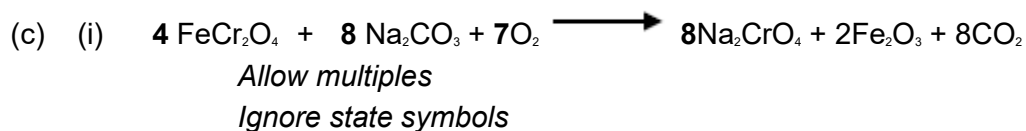
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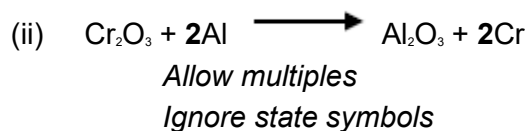
M1 use of Na **OR** Mg

M2 a correct balanced equation

2



1



1

[10]

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

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

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

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

$$\text{M2} = 1463\text{J OR } 1.46 \text{ kJ (This also scores M1)}$$

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

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

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

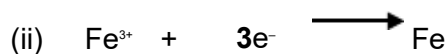
(Copper sulfate) solution will form

1

[8]

- M3.(a)** (i) reduction **OR** reduced **OR** redox **OR** reduction–oxidation
Not "oxidation" alone

1



Ignore state symbols

Do not penalise absence of charge on electron

Credit $\text{Fe}^{3+} \longrightarrow \text{Fe} - 3\text{e}^-$

Credit multiples

1

- (b) (i) **Because (one of the following)**

CO is not the only product **OR**

Reference to "incomplete combustion to form CO" does not answer the question

(Some) complete combustion (also) occurs **OR**

CO₂ is (also) formed

Further oxidation occurs

1

- (ii) 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)

1

- (iii) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

For M1, credit correct reference to molecule/s or atom/s

M2 is burned completely / undergoes complete combustion in (excess) oxygen

M3 with all reactants and products / all substances in standard states

For M3

Ignore reference to 1 atmosphere

OR all reactants and products / all substances in normal / specified states under standard conditions / 100 kPa / 1 bar and specified T / 298 K

3

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

Correct answer gains full marks

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

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

Credit 1 mark ONLY for -27 (kJ mol^{-1}) i.e. assuming value for $\text{Fe}(l) = 0$

OR correct cycle of balanced equations with 2Fe, 3C and 3O₂

M2 $\Delta H_r = 2(+14) + 3(-394) - (-822) - 3(-111)$

$$= 28 - 1182 + 822 + 333$$

(This also scores M1)

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

(Award 1 mark ONLY for -1)

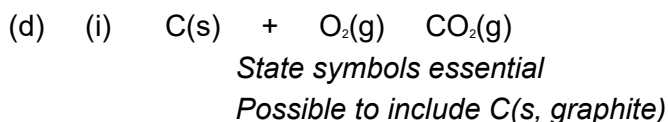
(Award 1 mark ONLY for -27)

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 2Fe, 3C and 3O₂ OR a clear statement of M1 which could be in words and scores only M1

3



1

- (ii) These two enthalpy changes are for the same reaction / same equation / same reactants and products

Penalise reference to CO₂ being produced by a different route

OR

They both make one mole of carbon dioxide only from carbon and oxygen (or this idea clearly implied)

"both form CO₂" is not sufficient (since other products might occur e.g. CO)

OR

The same number and same type of bonds are broken and formed

1

[12]

M4.(a) (Enthalpy change to) break the bond in 1 mol of chlorine (molecules)

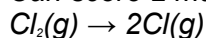
Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms

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

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

This would score M1

1

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

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

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]

- M5.** (a) (i) **M1** (could be scored by a correct mathematical expression which must have all ΔH symbols and the Σ or SUM)

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

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**

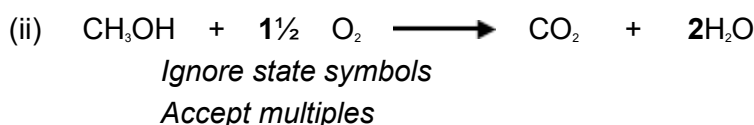
to lower the temperature

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

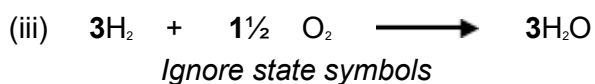
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- (d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere
OR
An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.
OR
There is no change in the total amount / level of carbon 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

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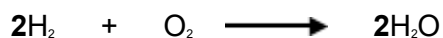


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OR

Accept multiples



Extra species must be crossed through

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(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]