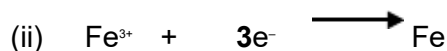


- M1.(a) (i) reduction **OR** reduced **OR** redox **OR** reduction–oxidation
Not “oxidation” alone

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 3O_2

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

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

(This also scores M1)

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

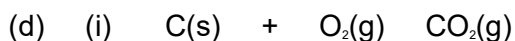
(Award 1 mark ONLY for -1)

(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 3O_2 OR a clear statement of M1 which could be in words and scores only M1*

3



State symbols essential

Possible to include $\text{C}(s, \text{graphite})$

1

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

Penalise reference to CO_2 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]

M2. (a) One from

- Ti is not produced
- TiC / carbide is produced OR titanium reacts with carbon
- Product is brittle
- Product is a poor engineering material
Penalise “titanium carbonate”
Ignore “impure titanium”
Credit “titanium is brittle”

1

(b) Heat (energy) change at constant pressure
QoL

1

(c) The enthalpy change in a reaction is independent of the route taken (and depends only on the initial and final states)
Credit “heat change at constant pressure” as an alternative to “enthalpy change”

1

(d) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / product

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

M2 is formed from its (constituent) elements

M3 with all reactants and products / all substances in

standard states

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

Ignore reference to 1 atmosphere

3

- (e) (i) Na / it is not in its standard state / normal state under standard conditions

OR

Standard state / normal state under standard conditions
for Na is solid / (s)

QoL

Ignore "sodium is a liquid or sodium is not a solid"

1

- (ii) **M1** $\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$

M2 $\Delta H_r = 4(-411) - (-720) - 4(+3) = -1644 + 720 - 12$ (This
also scores M1)

M3 = **-936** (kJ mol⁻¹)

Correct answer gains full marks

Credit 1 mark for + 936 (kJ mol⁻¹)

Credit 1 mark for - 924 (kJ mol⁻¹) i.e. assuming value for Na(l) = 0

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 2Cl₂ and 4Na OR a clear complete statement of M1 which could be in words and scores only M1*

3

- (iii) Reducing agent

Ignore "reduces titanium"

OR reductant OR reduces TiCl₄

OR electron donor

1

- M3.** (a) Heat (energy) change at constant pressure
Ignore references to standard conditions, but credit specified pressure. 1
- (b) 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
- (c) $\Delta H + 963 = -75 - 432$ OR $\Delta H + 963 = - 507$ (**M1**)
 $\Delta H = -75 - 432 - 963$ (**M1** and **M2**)
 $\Delta H = \underline{-1470}$ (kJ mol⁻¹)
 Award 1 mark for + 1470
Award full marks for correct answer
Ignore units.
Ignore numbers on the cycle
M1 and **M2** can score for an arithmetic error 3
- M4.** (a) Enthalpy change for the formation of 1 mol of gaseous atoms
allow heat energy change for enthalpy change 1
- From the element (in its standard state)
ignore reference to conditions 1

Enthalpy change to separate 1 mol of an ionic lattice/solid/compound
enthalpy change not required but penalise energy

1

Into (its component) gaseous ions
mark all points independently

1

(b) $\Delta H_L = -\Delta H_f + \Delta H_a + \text{I.E.} + 1/2E(\text{Cl-Cl}) + \text{EA}$
Or correct Born-Haber cycle drawn out

1

$$= +411 + 109 + 494 + 121 - 364$$

1

$$= +771 \text{ (kJ mol}^{-1}\text{)}$$

-771 scores 2/3

+892 scores 1/3

-51 scores 1/3

-892 scores zero

+51 scores zero ignore units

1

(c) (i) Ions are perfect spheres (or point charges)

1

Only electrostatic attraction/no covalent interaction
mention of molecules/intermolecular forces/covalent bonds
CE = 0
allow ionic bonding only
If mention of atoms CE = 0 for M2

1

(ii) Ionic
Allow no covalent character/bonding

1

(iii) Ionic with additional covalent bonding
Or has covalent character/partially covalent
Allow mention of polarisation of ions or description of
polarisation

1

[11]

M5. (a) The molecular ion is

- The molecule with one/an electron knocked off/lost
Ignore the highest or biggest m/z peak

OR

- The molecule with a (single) positive charge

OR

- the ion with/it has the largest/highest/biggest m/z (value/ratio)
Ignore "the peak to the right"

OR

- the ion with/it has an m/z equal to the M_r
Ignore "compound"

1

(b) (i) $\frac{2(14.00307) + 15.99491}{}$ = 44.00105
A sum is needed to show this

1

- (ii) Propane/C₃H₈ and carbon dioxide/CO₂ (and N₂O) or they or both the gases/molecules or all three gases/molecules have an (imprecise) M_r of 44.0 (OR 44)

OR

they have the same M_r or molecular mass (to one d.p)

This could be shown in a calculation of relative masses for propane and carbon dioxide

1

- (iii) By definition

OR

The standard/reference (value/isotope)
Ignore "element"

Ignore "atom"

1

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

$$\Delta H = \sum \Delta H_{\text{products}} - \sum \Delta H_{\text{reactants}}$$

OR a correct cycle of balanced equations

M1 and M2 can be scored with correct moles as follows

$$\Delta H + 2(-46) = +82 + 3(-286)$$

$$\Delta H - 92 = -776$$

$$\Delta H = 92 - 776 \text{ OR } 92 + 82 - 858$$

M3

$$\Delta H = \underline{-684} \text{ (kJ mol}^{-1}\text{) (This is worth 3 marks)}$$

Award 1 mark ONLY for + 684

Full marks for correct answer.

Ignore units.

Deduct one mark for an arithmetic error.

3

- (ii) The value is quoted at a pressure of 100 kPa OR 1 bar or 10⁵ Pa

OR

All reactants and products are in their standard states/their normal states at 100 kPa or 1 bar

Ignore 1 atmosphere/101 kPa

Ignore "constant pressure"

1

[8]