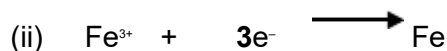


- M1.(a) (i) reduction **OR** reduced **OR** redox **OR** reduction–oxidation  
*Not “oxidation” alone*

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**

CO<sub>2</sub> 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  $\Delta H$  symbols and the  $\Sigma$ )**

*Correct answer gains full marks*

*Credit 1 mark ONLY for  $-1$  ( $\text{kJ mol}^{-1}$ )*

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

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

**OR** correct cycle of balanced equations with  $2\text{Fe}$ ,  $3\text{C}$  and  $3\text{O}_2$

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

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

(This also scores M1)

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

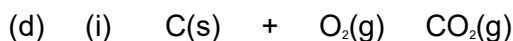
**(Award 1 mark ONLY for  $-1$ )**

**(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  $2\text{Fe}$ ,  $3\text{C}$  and  $3\text{O}_2$  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  $\text{CO}_2$  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 CO<sub>2</sub>” 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<sup>-1</sup>)

*Correct answer gains full marks*

**Credit 1 mark for + 936** (kJ mol<sup>-1</sup>)

**Credit 1 mark for - 924** (kJ mol<sup>-1</sup>) 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 2Cl<sub>2</sub> 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 TiCl<sub>4</sub>

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<sup>-1</sup>)  
 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)  $2(14.00307) + 15.99491 = 44.00105$   
*A sum is needed to show this*

1

(ii) Propane/C<sub>3</sub>H<sub>8</sub> and carbon dioxide/CO<sub>2</sub> (and N<sub>2</sub>O) 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 10<sup>5</sup> 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]