M1. (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** ΔH_r **=** $\sum\Delta H_f$ **(products) -** $\sum\Delta H_f$ **(reactants)**

M2 ΔH_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* $2Cl_2$ *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 $TiCl_4$

OR electron donor

1

[7]

M2. (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**)

$\Delta H =$ **–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

[5]

M3. (a) (i) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / product

1

M2 Is formed from its (constituent) elements

1

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 specified T / 298 K

Ignore reference to 1 atmosphere

1

(ii) By definition

OR

Because they are elements

1

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

1

M2 = –1669 – 3(–558)
(This also scores M1)

1

M3 = **(+) 5** (kJ mol^{-1})
Correct answer gains full marks.
Assume the value is positive unless specifically stated as negative.
Credit 1 mark if – 5 (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 a correct cycle with 3BaO OR a clear statement of M1 which could be in words and scores only M1*

1

(b) (i) *One from*

- Aluminium is expensive (to extract *OR* due to electrolysis)
- High energy cost
- The cost of heating strongly
  This requires a clear statement about cost

1

(ii) *One from*

- increase collision frequency
- OR more collisions
- OR more chance of colliding
  The answer MUST refer to more collisions.
  Ignore "more available to collide"

1

(c) (i) Ba + **2**$H_2O \rightarrow Ba(OH)_2 + H_2$
Ignore state symbols
Allow multiples and correct ionic equations

1

(ii) **M1** $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
(or the ions together)
Allow crossed out Na^+ ions, but penalise if not crossed out

1

M2 White precipitate / white solid
Ignore state symbols
Ignore "milky"

1

(iii) **M1** Barium meal or (internal) X-ray or to block X-rays

1

M2 $BaSO_4$ / barium sulfate is insoluble (and therefore not toxic)
Accept a correct reference to M1 written in the explanation in M2, unless contradictory.
For M2 NOT barium ions
NOT barium
NOT barium meal and NOT "It".
Ignore radio-tracing.

1

[14]

M4.(a) Enthalpy change when 1 mol of compound (1)

Is formed from it's elements (1)

All substances in their standard state (1)

3

(b) $\Delta H = \Sigma \Delta H^{\ominus}_c$ (reactants) – $\Sigma \Delta H^{\ominus}_c$ (products) (1)

= $(7x - 394) + (4x - 286) - (-3909)$ (1)

= + 7 $kJmol^{-1}$ (1)

3

(c) Heat change = m c ΔT (1)

= 250 × 4.18 × 60 = 62700J = 62.7kJ (1)

Moles C_7H_8 = 2.5 /92 = 0.0272 (1)

ΔH = 62.7 / 0.0272 = – 2307 kJ mol^{-1} (1)
(allow –2300 to –2323)

4

(d) Mass of water heated = 25 + 50 = 75g
Temp rise = 26.5 – 18 = 8.5 °C
*both for **(1)** mark*

Heat change = 75 × 4.18 × 8.5 = 2665 J = 2.665 kJ (1)

Moles HCl = 0.05 (1)

ΔH = – 2.665 / 0.05 = –53.3 $kJmol^{-1}$ (1)
(allow –53 to –54)

4

(e) Less heat loss (1)

1

[15]

M5. (a) The enthalpy change when 1 mol of a compound

1

is completely burnt in oxygen

1

under standard conditions, or 298K and 100kPA

1

(b) (i) $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$

1

(ii) $\Delta H = 2 \times \Delta H_f^\ominus (CO_2) + 3 \times \Delta H_f^\ominus (H_2O) – \Delta H_f^\ominus (C_2H_6)$

1

= – 788 – 858 – (–85)

1

= – 1561 kJ mol^{-1}

1

(c) moles methane = $\frac{0.10}{16}$ = 6.25×10^{-3}

1

kJ evolved = $6.25 \times 10^{-3} \times 890 = 5.56$

1

5.56×10^{3} joules = (mc)ΔT

1

$\Delta T = \frac{5.56 \times 10^{3}}{120}$ = 46.4 K

1

[11]