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

M1 $\Delta H = \sum \Delta H_f$ **(products)** − $\sum \Delta H_f$ **(reactants)**

OR a correct cycle of balanced equations

M2 = 5(−635) − (−1560)

= − 3175 + 1560

(This also scores M1)

M3 = **− 1615** (kJ mol^{-1})

Award 1 mark ONLY for (+) 1615

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

Credit 1 mark for(+) 1615 (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 V_2O_5 and 5CaO OR a clear statement of **M1** which could be in words and scores **only M1***

M4 Type of reaction is

- reduction
- redox
- (or accept) V_2O_5 / it / V(V) has been reduced

*In **M4** not "vanadium / V is reduced"*

M5 Major reason for expense of extraction − the answer must be about calcium

Calcium is produced / extracted by electrolysis
OR calcium is expensive to extract
OR calcium extraction uses electricity
OR calcium extraction uses large amount of energy
OR calcium is a (very) reactive metal / reacts with water or air
OR calcium needs to be extracted / does not occur native

QoL

Accept calcium is expensive "to produce" but not "to source, to get, to obtain, to buy" etc.

*In **M5** it is neither enough to say that calcium is "expensive" nor that calcium "must be purified"*

5

(b) **M1**

$2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$

Ignore state symbols

Credit multiples of the equation

M2

(Change in oxidation state) **0** to (+)**3**

OR

(changed by) **+3**

*In **M2** if an explanation is given it must be correct and unambiguous*

2

(c) **M1**

$VCl_2 + H_2 \longrightarrow V + 2HCl$

*In **M1** credit multiples of the equation*

M2 and **M3**

Two hazards in either order

- HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous
- Explosion risk with hydrogen (gas) OR H_2 is flammable

*For **M2 / M3** there must be reference to hydrogen; it is not enough to refer simply to an explosion risk*

*For **M2 / M3** with HCl hazard, require reference to acid(ic) / corrosive / toxic only*

M4

The only other product / the HCl is easily / readily removed / lost / separated because it is a gas *OR* will escape (or this idea strongly implied) as a gas

OR vanadium / it is the only solid product (and is easily separated)

OR vanadium / it is a solid and the other product / HCl is a gas

*In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.*

4

[11]

M2.(a) $C(s) + 2F_2(g) \longrightarrow CF_4(g)$

State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma\ \Delta_f H$ products $- \Sigma\ \Delta_f H$ reactants or a correct cycle

1

Hence = (2 × –680) + (6 × –269) – (x) = –2889

1

x = 2889 – 1360 – 1614 = –85 (kJ mol^{-1})

1

Score 1 mark only for +85 (kJ mol^{-1})

(d) Bonds broken = 4(C–H) + 4(F–F) = 4 × 412 + 4 × F–F

Bonds formed = 4(C–F) + 4(H–F) = 4 × 484 + 4 × 562

Both required

1

–1904 = [4 × 412 + 4(F–F)] – [4 × 484 + 4 × 562]

4(F–F) = –1904 – 4 × 412 + [4 × 484 + 4 × 562] = 632

1

F–F = 632 / 4 = 158 (kJ mol^{-1})

1

The student is correct because the F–F bond energy is much less than the C–H or other covalent bonds, therefore the F–F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F–F bond)

1

[10]

M3.(a) (i) **3**Fe + Sb_2S_3 ⟶ **3**FeS + **2**Sb

Or multiples.
Ignore state symbols.

1

(ii) $Fe \longrightarrow Fe^{2+} + 2e^-$

Ignore charge on the electron unless incorrect.
Or multiples.
Credit the electrons being subtracted on the LHS.
Ignore state symbols.

1

(b) (i) $Sb_2S_3 + \mathbf{4.5}O_2 \longrightarrow Sb_2O_3 + \mathbf{3}SO_2$

Or multiples.
Ignore state symbols.

1

(ii) SO_3 or sulfur trioxide / sulfur (VI) oxide

Credit also the following ONLY.
H_2SO_4 or sulfuric acid.
OR
Gypsum / $CaSO_4$ or plaster of Paris.

1

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

Correct answer gains full marks.

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

OR a <u>correct cycle of balanced equations / correct numbers of moles</u>

Credit 1 mark for +104 (kJ mol^{-1}).

M2 $= 2(+20) + 3(-394) - (-705) - 3(-111)$

$= 40 - 1182 + 705 + 333$

$= -1142 - (-1038)$

(This also scores M1)

M3 $= \mathbf{\underline{-104}}$ (kJ mol^{-1})

(Award 1 mark ONLY for + 104)

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.*

• *If no AE, check for a correct method; this requires either a correct cycle with 3CO, 2Sb and $3CO_2$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

3

(ii) It / Sb is <u>not in its standard state</u>

OR

<u>Standard state</u> (for Sb) <u>is solid / (s)</u>

OR

<u>(Sb) liquid is not its standard state</u>

Credit a correct definition of standard state as an alternative to the words 'standard state'.

QoL

1

(iii) Reduction **OR** reduced **OR** redox

1

(d) Low-grade ore extraction / it

- uses (cheap) <u>scrap / waste</u> <u>iron / steel</u>
- is a single-step process

uses / requires <u>less / low(er) energy</u>

Ignore references to temperature / heat or labour or technology.

1

[10]

M4.(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

= **5706 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

Moles = mass / M_r

= 0.22 / 74(.0)

= **0.00297 moles**

1

ΔH = –5706 / (0.002970 × 1000)

= **–1921 (kJ mol^{-1})**

If 0.22 is used in part (a), answer = –8.45 kJ mol^{-1} scores 3

(Allow –1920, –1919)

If uses the value given (5580 J), answer = –1879 kJ mol^{-1} scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) ΔH = ΣΔH products – ΣΔH reactants
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

ΔH = −(−360) + (4 × −393) + (5 × −286)

M2 also implies M1 scored.

1

ΔH = **–2642** (kJ mol^{-1}) This answer only.

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) (–2422 – part (b)) × 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]

M5.(a) **M1 (could be scored by a correct mathematical expression**

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

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

Credit 1 mark for − 101 (kJ mol^{-1})

OR a <u>correct cycle of balanced equations</u>

M2 = − 1669 − 3(− 590)
= − 1669 + 1770
(This also scores M1)

M3 = **+ 101** (kJ mol^{-1})

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 <u>and</u> 2Al OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M4 - Using powders
Any **one** from

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

Ignore dividing final answer by 3

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

5

M5 Major reason for expense of extraction
Any **one** from

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

(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 <u>electrons closer to cations / positive ions / atoms / nucleus</u>
OR <u>cations / positive ions / atoms are smaller</u>
OR <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u>

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

Ignore reference to shielding.

Relative strength of metallic bonding
M2 (Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / atoms / nucleus</u> and the <u>delocalised electrons</u>
OR
<u>stronger metallic</u> 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

(c) **M1** $\mathbf{2}Mg + O_2 \longrightarrow \mathbf{2}MgO$

M2 $Mg + \mathbf{2}H_2O \longrightarrow Mg(OH)_2 + H_2$

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]