

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

M1 $\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$

OR a correct cycle of balanced equations

$$\mathbf{M2} = 5(-635) - (-1560)$$

$$= -3175 + 1560$$

(This also scores M1)

$$\mathbf{M3} = -1615 \text{ (kJ mol}^{-1}\text{)}$$

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 V₂O₅ 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) V₂O₅ / 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

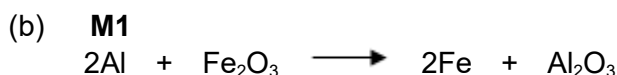
OR calcium is a (very) reactive metal / reacts with water or air

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”*



Ignore state symbols
Credit multiples of the equation

M2

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

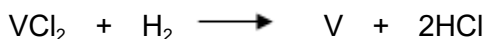
OR

(changed by) +3

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

2

(c) **M1**



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 H₂ 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

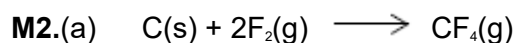
OR vanadium / it is the only solid product (and is easily separated)

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]



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) $\Delta H = \Sigma \Delta_f H \text{ products} - \Sigma \Delta_f H \text{ reactants}$ or a correct cycle

1

$$\text{Hence} = (2 \times -680) + (6 \times -269) - (x) = -2889$$

1

$$x = 2889 - 1360 - 1614 = -85 \text{ (kJ mol}^{-1}\text{)}$$

1

Score 1 mark only for +85 (kJ mol⁻¹)

(d) Bonds broken = $4(\text{C-H}) + 4(\text{F-F}) = 4 \times 412 + 4 \times \text{F-F}$

Bonds formed = $4(\text{C-F}) + 4(\text{H-F}) = 4 \times 484 + 4 \times 562$

Both required

1

$$-1904 = [4 \times 412 + 4(\text{F-F})] - [4 \times 484 + 4 \times 562]$$

$$4(\text{F-F}) = -1904 - 4 \times 412 + [4 \times 484 + 4 \times 562] = 632$$

1

$$\text{F-F} = 632 / 4 = 158 \text{ (kJ mol}^{-1}\text{)}$$

1

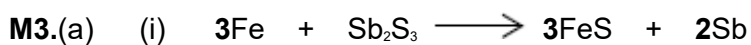
The student is correct because the F-F bond energy is much less than the C-H or other covalent bonds, therefore the F-F bond is weak / easily broken

Relevant comment comparing to other bonds

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

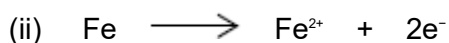
1

[10]



Or multiples.
Ignore state symbols.

1



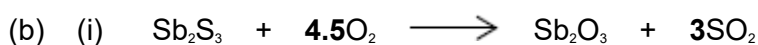
Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the LHS.

Ignore state symbols.

1



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 $\underline{\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})}$

OR a correct cycle of balanced equations / correct numbers of moles

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 $= \underline{-104}$ (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 not in its standard state

OR

Standard state (for Sb) is solid / (s)

OR

(Sb) liquid is not its standard state

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) scrap / waste iron / steel
- is a single-step process

uses / requires less / low(er) energy

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

$\Delta H = -5706 / (0.002970 \times 1000)$
= **-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) $\Delta H = \Sigma \Delta H$ products – $\Sigma \Delta H$ reactants
OR a correct cycle
Correct answer with no working scores 1 mark only.

1

$\Delta H = -(-360) + (4 \times -393) + (5 \times -286)$
M2 also implies M1 scored.

1

$\Delta H =$ **-2642 (kJ mol⁻¹)** This answer only.

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

1

- (d) $(-2422 - \text{part (b)}) \times 100 / -2422$
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 $\underline{\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})}$

Credit 1 mark for $-101 \text{ (kJ mol}^{-1}\text{)}$

OR a correct cycle of balanced equations

$$\text{M2} = -1669 - 3(-590)$$

$$= -1669 + 1770$$

(This also scores M1)

$$\text{M3} = +101 \text{ (kJ mol}^{-1}\text{)}$$

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

M4 - Using powders

Any **one** from

- To increase collision frequency / collisions in a given time / rate of collisions
- To increase the surface contact / contact between the solids / contact between (exposed) particles
Ignore dividing final answer by 3
*Penalise **M4** for reference to molecules.*

5

M5 Major reason for expense of extraction

Any **one** from

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

- (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 electrons closer to cations / positive ions / atoms / nucleus

OR cations / positive ions / atoms are smaller

OR cation / positive ion / atom or it has fewer (electron) shells / levels

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

Ignore reference to shielding.

Relative strength of metallic bonding

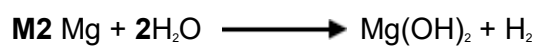
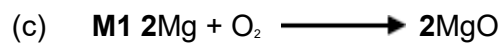
M2 (Ca) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons

OR

stronger metallic 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.



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

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