M1. D

[1]

M2. D

[1]

M3. (a) (i) Reducing agent

OR

Reduce(s) (WO_3/tungsten oxide)

OR

electron donor

OR

to remove <u>oxygen</u> (from WO_3/tungsten oxide or to form water);

1

(ii) $WO_3 + \mathbf{3}H_2 \rightarrow W + \mathbf{3}H_2O$

Or multiples

1

(iii) *One from*

H_2 is

- explosive
- flammable or inflammable
- easily ignited

Ignore reference to pressure or temperature

1

(b) (i) Addition

Ignore "electrophilic"
Penalise "nucleophilic addition"

OR

(catalytic) hydrogenation

OR

Reduction

1

(ii) Geometric(al)

OR

cis/trans OR E Z OR E/Z

1

(c) (i) (If any factor is changed which affects an equilibrium), the position of <u>equilibrium</u> will <u>shift/move/change/respond/act</u> so as <u>to oppose the change</u>.

OR

(When a system/reaction in equilibrium is disturbed), the <u>equilibrium shifts/moves</u> in a direction which tends <u>to reduce the disturbance</u>

A variety of wording will be seen here and the key part is the last phrase and must refer to <u>movement of the equilibrium</u>.

QoL

1

(ii) **M1 – Statement of number of moles/molecules**

There are <u>more moles/molecules</u> (of gas) on the left/of reactants

OR

<u>fewer moles/molecules</u> (of gas) on the right./products

OR

there are <u>4 moles/molecules</u> (of gas) on the left <u>and 2 moles/ molecules</u> on the right.

Ignore "volumes" for M1
Mark independently

M2 – Explanation of response/movement in <u>terms of pressure</u>

Increase in pressure is opposed (or words to that effect)

OR

pressure is lowered by a shift in the equilibrium (from left) to right/favours forward reaction.

2

(d) ΣB(reactants) – ΣB(products) = Δ*H* (**M1**)

OR

Sum of bonds broken – Sum of bonds formed = ΔH (**M1**)

B(H–H) + ½B(O=O) – 2B(O–H) = – 242 (**M1**)

B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**)

B(H–H) = (+)436 (kJ mol^{-1}) (**M3**)

Award 1 mark for – 436

Candidates may use a cycle and gain full marks.

M1 could stand alone
Award full marks for correct answer.
Ignore units.
Two marks can score with an arithmetic error in the working.

3

[11]

M4. (a) (i) **2**$CuFeS_2$ + **2**SiO_2 + **4**O_2 → Cu_2S + **2**$FeSiO_3$ + **3**SO_2

1

(ii) Acid rain

OR

an effect either from acid rain or from an acidic gas in the atmosphere

1

(iii) SO_2 could be used to make H_2SO_4

OR

to make gypsum/plaster or $CaSO_4$ (xH_2O)

1

(b) $Cu_2S + \mathbf{2}O_2 \rightarrow \mathbf{2}CuO + SO_2$

Or multiples
Ignore state symbols

1

(c) $\mathbf{2}CuO + C \rightarrow \mathbf{2}Cu + CO_2$

OR

$CuO + C \rightarrow Cu + CO$

Or multiples
Ignore state symbols

1

(d) (i) *Any one from the following two ONLY*
Apply the list principle

- (Scrap) iron is cheap
- Low energy requirement

Not "less energy"

1

(ii) $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$

Or multiples
Ignore state symbols

1

[7]

M5. (a) Gain of electrons

1

(b) (i) (+)5 or V or N^{5+} 1

(+)4 or IV or N^{4+} 1

(+)2 or II or N^{2+} 1

(ii) Reduction 1

$4H^{+} + NO_3^{-} + 3e^{(-)} \rightarrow NO + 2H_2O$ 1

(iii) $2H^{+} + NO_3^{-} + e^{(-)} \rightarrow NO_2 + H_2O$ 1

(iv) $Cu + 4H^{+} + 2\,NO_3^{-} \rightarrow Cu^{2+} + 2H_2O + 2NO_2$

species 1

balanced
If electrons included, **mark CE if these are not balanced** 1

[9]

M6. (a) (i) $\mathbf{2}C + O_2 \rightarrow \mathbf{2}CO$
OR
$C + CO_2 \rightarrow 2CO$
Or multiples.
Ignore state symbols. 1

(ii) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
Or multiples
Penalise FE and Fe_2
Ignore state symbols 1

(iii) **Economic:**

- Scrap iron/steel has higher iron content.
- Recycling involves lower energy consumption
- Blast furnace not required

Ignore cost
Assume that "it" means recycling for both reasons

1

Environmental:

- Reduces greenhouse gas / CO_2 / SO_2 emission.
- Reduces acid rain
- Reduces mining
- Reduces landfill
- Removes an eyesore

1

(b) (i) **M1** Use of Cl_2 and C

M2 Balanced equation consequential on correct reactants

EITHER

$TiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \rightarrow TiCl_4 + \mathbf{2}CO$

OR

$TiO_2 + \mathbf{2}Cl_2 + C \rightarrow TiCl_4 + CO_2$

Or multiples
Ignore state symbols

2

(ii) **M1** Use of Na OR Mg

M2 Balanced equation consequential on correct reactants

EITHER

$TiCl_4 + \mathbf{4}Na \rightarrow Ti + \mathbf{4}NaCl$

OR

$TiCl_4 + \mathbf{2}Mg \rightarrow Ti + \mathbf{2}MgCl_2$

Or multiples
Ignore state symbols

2

(iii) One from

- TiC / carbide is produced
- Product is brittle
- Product is a poor engineering material

1

(c) (i) One from

To allow

- ions to move
- current to flow
- it to conduct electricity

1

(ii) $2O^{2-} \rightarrow O_2 + 4e^-$

Or multiples including
$\mathbf{3}O^{2-} \rightarrow \mathbf{1.5}\ O_2 + 6e^-$
Ignore state symbols
Ignore charge on the electron
Credit the electron being subtracted on the LHS

1

(iii) Carbon / graphite / the electrodes oxidise
OR
Carbon / graphite / the electrodes burn in / react with the oxygen formed
OR
carbon dioxide / CO_2 is formed

1

(iv) Recycling involves lower electricity OR less energy consumption
OR
The converse for electrolysis

Ignore references to raw materials
Assume that "it" means recycling
The answer MUST show some evidence of comparison e.g. lower or less

1

[13]

M7. (a) **M1** $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

1

OR multiples

M2 An oxidising agent is an <u>electron acceptor</u> OR <u>receives / accepts / gains electrons</u>

Ignore state symbols

M2 NOT an "electron pair acceptor"

1

M3 MnO_2 is the oxidising agent

Ignore "takes electrons" or "takes away electrons"

1

(b) **M1** Formation of SO_2 and Br_2 (could be in an equation)

1

M2 Balanced equation
Several possible equations
$\mathbf{2}KBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}KHSO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$
OR
$\mathbf{2}KBr + 2H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

1

M3 $\mathbf{2}KBr + Cl_2 \rightarrow \mathbf{2}KCl + Br_2$

M2 Could be ionic equation with or without K^+
$\mathbf{2}Br^- + \mathbf{6}H^+ + \mathbf{3}SO_4^{2-} \rightarrow Br_2 + \mathbf{2}HSO_4^- + SO_2 + \mathbf{2}H_2O$
$(\mathbf{3}H_2SO_4)$

$\mathbf{2}Br^- + \mathbf{4}H^+ + SO_4^{2-} \rightarrow Br_2 + SO_2 + \mathbf{2}H_2O$
$(\mathbf{2}HBr + H_2SO_4)$

Accept HBr and H_2SO_4 in these equations as shown or mixed variants that balance.
Ignore equations for KBr reacting to produce HBr
M3 Could be ionic equation with or without K^+
$\mathbf{2}Br^- + Cl_2 \rightarrow \mathbf{2}Cl^- + Br_2$

1

M4 % atom economy of bromine

$$= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$$

= **51.7%** OR **52%**

M4 Ignore greater number of significant figures

1

M5 One from:

- High atom economy
- Less waste products
- Cl_2 is available on a large-scale
- No SO_2 produced
- Does not use concentrated H_2SO_4
- (Aqueous) KBr or bromide (ion) in seawater.
- Process 3 is simple(st) or easiest to carry out

M5 Ignore reference to cost
Ignore reference to yield

1

(c) **M1** HBr **–1**

1

M2 HBrO **(+)1**

1

M3 Equilibrium will shift to the right
OR
L to R
OR
Favours forward reaction
OR
Produces more HBrO

1

M4 **Consequential on correct M3**
OR
to oppose the loss of HBrO
OR
replaces (or implied) the HBrO (that has been used up)

1

[12]