M1.D

[1]

M2.C

[1]

M3.B

[1]

M4.D

[1]

M5.D

[1]

M6.D

[1]

M7.D

[1]

M8.A

[1]

M9.B

[1]

M10.A

[1]

M11.D

[1]

M12.A

[1]

M13.D

[1]

M14.B

[1]

M15.C

[1]

M16.C

[1]

M17.B

[1]

M18.B

[1]

M19.D

[1]

M20.B

[1]

M21.A

[1]

M22.D

[1]

M1.(a) (i) $\mathbf{2}Cl^- \longrightarrow Cl_2 + \mathbf{2}e^-$

Ignore state symbols
Credit loss of electrons from LHS
Credit multiples
Do not penalise absence of charge on electron

1

(ii) +7 ***OR*** 7 ***OR*** VII ***OR*** +VII

Allow Mn^{+7} and 7+

1

(iii) $MnO_4^- + 8H^+ + 5\mathbf{e}^- \longrightarrow Mn^{2+} + 4H_2O$

Ignore state symbols
Credit loss of electrons from RHS
Credit multiples
Do not penalise absence of charge on electron

1

(b) (i) $Cl_2 + \mathbf{2}Br^- \longrightarrow \mathbf{2}Cl^- + Br_2$

OR

$\frac{1}{2}Cl_2 + Br^- \longrightarrow Cl^- + \frac{1}{2}Br_2$

One of these two equations <u>only</u>
Ignore state symbols

1

(ii) (Turns to) <u>yellow / orange / brown</u> (solution)

Penalise "red / reddish" as the only colour
Accept "red-brown" and "red-orange"
Ignore "liquid"
Penalise reference to a product that is a gas or a precipitate

1

(iii) (Chlorine) <u>gains electron(s)</u> / <u>takes electron(s)</u> / <u>accepts electron(s)</u> (from the bromide ions)

OR

(Chlorine) <u>causes another species</u> (Br^-) <u>to lose electron</u>(s)

Penalise "electron pair acceptor"
Not simply "causes loss of electrons"

1

(c) **M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

$(\mathbf{4}H^+ + \mathbf{4}Cl^-)$

M2 Oxidation state **−1**

Ignore state symbols

Credit multiples

***M2** consequential on HCl or Cl^- which **must** be the only chlorine-containing product in the (un)balanced equation.*

*For **M2** allow Cl^{-1} or Cl^{1-} but **not** Cl^-*

2

(d) **M1 The relative size (of the molecules / atoms)**

Chlorine is <u>smaller</u> than bromine ***OR*** has fewer electrons / electron shells

*For **M1** ignore whether it refers to molecules or atoms.*

OR It is smaller / It has a smaller atomic radius / it is a smaller molecule / atom (or converse)

***CE=0** for the clip for reference to (halide) ions or incorrect statements about relative size*

Ignore molecular mass and M_r

M2 How size of the <u>intermolecular force</u> affects energy needed

Ignore shielding

The <u>forces between</u> chlorine / Cl_2 <u>molecules</u> are weak<u>er</u> (than the forces between bromine / Br_2 <u>molecules</u>)
(or converse for bromine)
OR chlorine / Cl_2 has <u>weaker / fewer / less</u> (VdW) <u>intermolecular forces / forces between molecules</u>
(or converse for bromine)

***QoL in M2** for clear reference to the difference in size <u>of the force between molecules</u>. Reference to Van der Waals forces alone is not enough.*

*Penalise **M2** if (covalent) bonds are broken*

2

[10]

M2.(a) moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150 / 1000 = <u>3.195×10^{-4}</u>

1

$(Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+})$ $Cr_2O_7^{2-}$:Fe^{2+} = 1:6

If 1:6 ratio incorrect cannot score M2 or M3

1

moles of Fe^{2+} = 6 × 3.195 × 10^{-4} = 1.917 × 10^{-3}

Process mark for M1 × 6 (also score M2)

1

original moles in 250 cm^3 = 1.917 × 10^{-3} × 10 = 1.917 × 10^{-2}

Process mark for M3 × 10

1

mass of $FeSO_4.7H_2O$ = 1.917 × 10^{-2} × 277.9 = 5.33 (g)

Mark for answer to M4 × 277.9

(allow 5.30 to 5.40)

*Answer **must** be to at least 3 sig figs*

Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)

1

(b) (Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)

Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$

OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $FeSO_4.7H_2O$

1

[7]

M3.(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]

M4.(a) (i) $\mathbf{3}Fe + Sb_2S_3 \longrightarrow \mathbf{3}FeS + \mathbf{2}Sb$

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 $\Delta H_r = \Sigma \Delta H_f$(**products**) − $\Sigma \Delta H_f$(**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 = **−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) <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]

M5.D

[1]

M6.D

[1]

M7.B

[1]

M8.(a) $Cl_2 + H_2O \rightleftharpoons HOCl + HCl$

Allow the products shown as ions.

1

Cl_2 = 0, HOCl = +1 and HCl = −1

1 mark for all three oxidation states correct. Allow a reaction arrow in this equation.

Oxidation states must match the species

1

(b) Hydroxide / alkali ions react with the acids

Mark independently

1

Equilibrium moves to the right

1

(c) Only used in small amounts

1

The health benefits outweigh the risks

1

[6]

M9.C

[1]

M10.D

[1]

M1.(a) (i) **M1** (+) 4 **OR** IV

M2 (+) 6 **OR** VI

2

(ii) It / Chlorine has gained / accepted electron(s)

OR

Correctly balanced half-equation eg Cl_2 + **2**e^- ⟶ **2**Cl^-

Credit 1 or 2 electrons but not lone pair.
The idea of 'reduction' alone is not enough.

1

(b) (i) **6**KI + **7**H_2SO_4 ⟶ **6**$KHSO_4$ + **3**I_2 + S + **4**H_2O

1

(ii) **2**I^- ⟶ I_2 + **2**e^-

OR

$8I^-$ ⟶ $4\mathbf{I}_2$ + $8e^-$

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

1

(iii) H_2SO_4 + **8**H^+ + **8**e^- ⟶ H_2S + **4**H_2O

OR

SO_4^{2-} + **10**H^+ + **8**e^- ⟶ H_2S + **4**H_2O

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

1

(c) (i) $Ag^+ + I^- \longrightarrow AgI$ ONLY

Ignore state symbols.

Not multiples.

1

(ii) The precipitate / solid / it does not dissolve / is insoluble / remains

OR a white / cream / yellow solid / precipitate

OR stays the same

OR no (visible / observable) change

OR no effect / no reaction

Ignore 'nothing (happens)'.

Ignore 'no observation'.

1

(iii) The silver nitrate is acidified to

- react with / remove (an)ions that would interfere with the test

  Credit a correct reference to ions that give a 'false positive'.

- prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test

  Do not penalise an incorrect formula for an ion that is written in addition to the name.

- remove (other) ions that react with the silver nitrate

  If only the formula of the ion is given, it must be correct.

- react with / remove carbonate / hydroxide / sulfite (ions)

  Ignore 'sulfate'.

1

(iv) HCl would form a (white) precipitate / (white) solid (with silver nitrate and this would interfere with the test)

*It is not sufficient simply to state either that it will interfere **or** simply that the ions / compounds react to form AgCl*

1

(d) (i) Any **one** from

Ignore 'to clean water'.

- to sterilise / disinfect water

Ignore 'water purification' and 'germs'.

- to destroy / kill microorganisms / bacteria / microbes / pathogens
  Credit 'remove bacteria etc' / prevent algae.

1

(ii) The (health) benefit outweighs the risk

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

1

(iii) $Cl_2 + H_2O \longrightarrow HClO + HCl$

OR

$Cl_2 + H_2O \longrightarrow \mathbf{2}H^+ + ClO^- + Cl^-$

OR

$\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

Credit HOCl or ClOH
Or multiples.
Credit other ionic or mixed representations.
Ignore state symbols.

1

(e) **In either order - Both required for one mark only**

Credit correct ionic formulae.

NaClO (OR NaOCl) **and** NaCl

Give credit for answers in equations unless contradicted.

1

[14]

M2.(a) $Pt|H_2|H^+||Fe^{2+}|Fe$

Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS,

additional phase boundary

Note, allow one mark only for correct symbol in reverse:

$Fe|Fe^{2+}||H^+|H_2|Pt$

Allow dashed lines for salt bridge
Ignore state symbols
Ignore 2 if used before H^+

2

(b) Electron donor

Allow (species that) loses electrons
Do not allow reference to electron pairs

1

(c) Cl_2 / chlorine

If M1 blank or incorrect cannot score M2

1

(Species on RHS / electron donor) has most positive / largest $E^{\ominus}$ / has highest potential

Do not allow reference to e.m.f. or E(cell)

1

(d) (i) Cl / chlorine

1

(ii) Chlorine +1 to chlorine 0

CE if chlorine not identified in part (i)
Allow chlorine +1 to chlorine –1 (in Cl^-)
Allow oxidation state decreases by one OR two
Allow oxidation state changes by –1 OR –2

1

(e) $4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$

OR

$4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$

Allow one mark for any incorrect equation that shows

$HOCl \rightarrow Cl_2 + O_2$

Allow multiples

Ignore state symbols

Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ instead of $2H_2O$)

2

(f) (i) e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)

Allow –1.65 (V)

1

(ii) $2Zn + O_2 \rightarrow 2ZnO$

Allow multiples

Ignore state symbols

Do not allow uncancelled species

If more than one equation given, choose the best

1

(iii) **A** / stainless lid

If M1 incorrect or blank CE=0

1

<u>O_2</u> (electrode) has a more positive $E^{\ominus}$ / <u>oxygen</u> (electrode) requires / gains electrons from external circuit

Or reference to the overall equation and a link to electrons going into A

Allow oxygen is reduced and reduction occurs at the positive electrode

OR <u>Zinc</u> (electrode) has more negative $E^{\ominus}$

Do not allow reference to e.m.f. or E(cell)

1

(iv) (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated

Allow danger from production of gas / oxygen produced / hydrogen produced

1

[14]

M3.(a) (i) $SiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \longrightarrow SiCl_4 + \mathbf{2}CO$

Ignore state symbols

Credit multiples of either equation

OR

$SiO_2 + \mathbf{2}Cl_2 + C \longrightarrow SiCl_4 + CO_2$

1

(ii) (fractional) distillation

OR

G(L)C or gas (–liquid–) chromatography

1

(b) (i) $SiCl_4 + \mathbf{2}H_2 \longrightarrow Si + \mathbf{4}HCl$

Ignore state symbols

Credit multiples

Penalise ionic HCl

1

(ii) Reducing agent / reductant / reduces $SiCl_4$ / reduces (silicon) / electron donor

1

(iii) Explosion / explosive

OR

(highly) flammable / inflammable

OR

<u>readily</u> / <u>easily</u> ignites / burns / combusts

1

(c)

$\mathbf{2}MgO + Si \longrightarrow \mathbf{2}Mg + SiO_2$

Ignore state symbols
Credit multiples

1

[6]

M4.(a) (i) $3CuS(s) + \mathbf{8}HNO_3(aq) \longrightarrow \mathbf{3}CuSO_4(aq) + \mathbf{8}NO(g) + \mathbf{4}H_2O(l)$

1

(ii) **(+) 5**
(+) 2

2

(iii) $\mathbf{4}H^+ + NO_3^- + \mathbf{3}e^- \longrightarrow \mathbf{2}H_2O + NO$
Ignore state symbols.
*Credit multiples of **this equation only**.*
Ignore absence of charge on the electron.

1

(iv) $S^{2-} + \mathbf{4}H_2O \longrightarrow SO_4^{2-} + \mathbf{8}e^- + \mathbf{8}H^+$
Ignore state symbols.
*Credit multiples of **this equation only**.*
Ignore absence of charge on the electron.

1

(b) M1 add <u>scrap / recycled / waste iron (or steel)</u> to the aqueous solution
*If **M1** refers to iron / steel, but does not make it clear in the text that it is "scrap" / "waste" / "recycled", penalise **M1** but mark on.*

M2 the iron is a <u>more reactive</u> metal ***OR*** <u>Fe is a better reducing agent</u>
*Credit zinc or magnesium as an alternative to iron for **M2**, **M3** and **M4** only, penalising **M1***

M3 <u>Cu^{2+} / copper ions</u> are <u>reduced</u> / <u>gain electrons</u>
OR $Cu^{2+} + 2e^- \longrightarrow Cu$
OR <u>copper / Cu is displaced by Fe</u>
Ignore absence of charge on the electron.

M4 $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$ ONLY

*For **M4**, ignore state symbols*

4

[9]

M5. (a) Ti is not produced

OR

TiC / carbide is produced OR titanium reacts with carbon

OR

Product is brittle

OR

Product is a poor engineering material

Penalise "titanium carbonate"
Ignore "impure titanium"
Credit "it / titanium is brittle"

1

(b) (i) $FeTiO_3 + 3\frac{1}{2}Cl_2 + 3C \longrightarrow FeCl_3 + TiCl_4 + 3CO$

Ignore state symbols
Credit multiples

1

(ii) $FeCl_3 + TiCl_4 + 7Na \longrightarrow 7NaCl + Fe + Ti$

OR (for example)

$2FeCl_3 + TiCl_4 + 10Na \longrightarrow 10NaCl + 2Fe + Ti$

Ignore state symbols
Credit multiples including ratios other than 1:1
Ignore working

1

(c) Either order

*Penalise reference to incorrect number of electrons in **M1***

M1 The Cu^{2+} / copper(II) ions / they have gained (two) electrons

OR $Cu^{2+} + 2e^- \longrightarrow Cu$

*For **M1**, accept "copper" if supported by correct half-equation or simplest ionic equation*

OR oxidation state / number decreases (or specified from 2 to 0)

Ignore charge on the electron

M2 The Cu^{2+} / copper(II) ions / they have been reduced

*For **M2** do **not** accept "copper" alone*

2

(d) $2O^{2-} \longrightarrow O_2 + \mathbf{4}e^-$

Or multiples including

$\mathbf{3}O^{2-} \longrightarrow \mathbf{1.5}\ O_2 + \mathbf{6}e^-$

Ignore state symbols

Ignore charge on the electron

Credit the electrons being subtracted on the LHS

1

[6]

M6. (a) $\mathbf{2}Ca_5F(PO_4)_3 + 9SiO_2 + \mathbf{15}C \longrightarrow 9CaSiO_3 + CaF_2 + \mathbf{15}CO + \mathbf{6}P$

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

and

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH=CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

M1. (a) (i) **M1** iodine ***OR*** I_2 OR I_3^-

Ignore state symbols

*Credit **M1** for "iodine solution"*

M2 $Cl_2 + \mathbf{2}I^- \longrightarrow \mathbf{2}Cl^- + I_2$

OR

$\frac{1}{2} Cl_2 + I^- \longrightarrow Cl^- + \frac{1}{2} I_2$

Penalise multiples in M2 except those shown

***M2** accept correct use of I_3^-*

M3 redox or reduction-oxidation or displacement

3

(ii) **M1** (the white precipitate is) <u>silver chloride</u>

***M1** <u>must be named</u> and for <u>this mark</u> ignore incorrect formula*

M2 $Ag^+ + Cl^- \longrightarrow AgCl$

*For **M2** ignore state symbols*

Penalise multiples

M3 (white) precipitate / <u>it dissolves</u>

OR <u>colourless solution</u>

Ignore references to "clear" alone

3

(b) (i) **M1** $H_2SO_4 + \mathbf{2}Cl^- \longrightarrow \mathbf{2}HCl + SO_4^{2-}$

*For **M1** ignore state symbols*

OR $H_2SO_4 + Cl^- \longrightarrow HCl + HSO_4^-$

Penalise multiples for equations and apply the list principle

OR $H^+ + Cl^- \longrightarrow HCl$

M2 hydrogen chloride ***OR*** HCl ***OR*** hydrochloric acid

2

(ii) **M1 and M2 in either order**

*For **M1** and **M2**, ignore state symbols and credit multiples*

M1 $\mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}e^-$

OR

$8I^- \longrightarrow 4I_2 + 8e^-$

Do not penalise absence of charge on the electron

Credit electrons shown correctly on the other side of each equation

M2 $H_2SO_4 + 8H^+ + 8e^- \longrightarrow H_2S + 4H_2O$

OR

$SO_4^{2-} + 10H+ + 8e^- \longrightarrow H_2S + 4H_2O$

Additional equations should not contradict

M3 <u>oxidising agent</u> / <u>oxidises the iodide</u> (ions)

OR

<u>electron acceptor</u>

M4 sulfur *OR* S *OR* S_2 *OR* S_8 *OR* sulphur

4

(iii) **M1** The <u>NaOH / OH^- / (sodium) hydroxide reacts with / neutralises the H^+ / acid / HBr</u> (lowering its concentration)

OR a correct neutralisation equation for H^+ or HBr with NaOH or with hydroxide ion

Ignore reference to NaOH reacting with bromide ions

Ignore reference to NaOH reacting with HBrO alone

M2 Requires a correct statement for M1

The (position of) <u>equilibrium moves / shifts</u>(from L to R)

- to <u>replace the H^+ / acid / HBr that has been removed / lost</u>
- *OR* to <u>increase the H^+ / acid / HBr concentration</u>
- *OR* to <u>make more H^+ / acid / HBr / product(s)</u>
- *OR* to <u>oppose the loss of H^+ / loss of product(s)</u>
- *OR* to <u>oppose the decrease in concentration</u> of product(s)

In M2, answers must refer to the (position of) <u>equilibrium shifts / moves</u> and is not enough to state simply that it / the system / the reaction shifts to oppose the change.

M3 The (health) benefit outweighs the risk or wtte

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

3

[15]

M2. **(a)** **(i)** **$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$**

Or multiples

Ignore state symbols

1

(ii) **M1** **HNO_3 (+) 5**

M2 **NO_2 (+) 4**

Ignore working out

M1 Credit (V)

M2 Credit (IV)

2

(iii) **$HNO_3 + H^+ + e^- \longrightarrow NO_2 + H_2O$**

OR

$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$

Or multiples

Ignore state symbols

Ignore charge on the electron unless incorrect and accept loss of electron on the RHS

1

(b) **(i)** **In either order**

M1 <u>Concentration(s)</u> (of reactants and products) <u>remain(s) constant / stay(s) the same / remain(s) the same / do(es) not change</u>

M2 <u>Forward rate = Reverse / backward rate</u>

For M1 accept [ ] for concentration

NOT "equal concentrations" and NOT "concentration(s) <u>is/are</u> the same"

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(ii) M1

The (forward) reaction / to the right is endothermic or takes in / absorbs heat

OR

The reverse reaction / to the left is exothermic or gives out / releases heat

M2 depends on correct M1 and must refer to temperature/heat

The equilibrium shifts / moves left to right to oppose the increase in temperature

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves

to absorb the heat OR

to lower the temperature OR

to cool the reaction

2

(iii) M1 refers to number of moles

There are fewer moles (of gas) on the left OR more moles (of gas) on the right.
OR there is one mole (of gas) on the left and 2 moles on the right.

M2 depends on correct M1 and must refer to pressure
The equilibrium shifts / moves right to left to oppose the increase in pressure

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves to lower the pressure.

2

[10]

M3.(a) **(i)** **M1** **0**

M2 **(+) 5**

Accept Roman V for M2

2

(ii) $I_2 + 10HNO_3 \longrightarrow 2HI + 10NO_3 + 4H_2O$

Accept multiples

1

(b) **M1** $IO_3^- + 6H^+ + 5I^- \longrightarrow 3I_2 + 3H_2O$

For M1, ignore state symbols

Credit multiples

Accept $2\frac{1}{2}I_2 + \frac{1}{2}I_2$ as alternative to $3I_2$

Electrons must be cancelled

M2 $NaIO_3$ ***OR*** IO_3^- ***OR*** **iodate ions** ***OR*** **iodate(V) ions etc.**

For M2 Do not penalise an incorrect name for the correct oxidising agent that is written in addition to the formula.

Accept "the iodine in iodate ions" but NOT "iodine" alone

Accept "the iodine / I in iodate ions" but NOT "iodine" alone

2

(c) **(i)** **Iodine** ***OR*** I_2

Insist on correct name or formula

1

(ii) $H_2SO_4 + 6H^+ + 6e^- \longrightarrow S + 4H_2O$

Ignore state symbols

$SO_4^{2-} + 8H^+ + 6e^- \longrightarrow S + 4H_2O$

Credit multiples

Do not penalise absence of charge on the electron

1

(d) **hydrogen sulfide**

OR **H_2S**

OR **hydrogen sulphide**

1

(e) (i) $Ag^+ + I^- \longrightarrow AgI$ **ONLY**

Ignore state symbols
No multiples

1

(ii) **The (yellow) precipitate / solid / it does not dissolve / is insoluble**
ignore "nothing (happens)"

OR **turns to a <u>white solid</u>**
ignore "no observation"

OR **stays the same**

OR **no (visible/ observable) change**

OR **no effect / no reaction**

1

(iii) **The silver nitrate is acidified to**

- **react with / remove <u>(an)ions that would interfere</u> with the test**
  Ignore reference to "false positive"
- **prevent the formation of other <u>silver precipitates / insoluble silver compounds</u> that would interfere with the test**
  Do not penalise an incorrect formula for an ion that is written in addition to the name.
- **remove (other) <u>ions that react with the silver nitrate</u>**
- **react with / remove carbonate / hydroxide / sulfite (ions)**
  If only the formula of the ion is given, it must be correct

1

(f) (i) An <u>electron donor</u>

Penalise "electron pair donor"

***OR* (readily) <u>donates / loses / releases / gives (away) electron(s)</u>**

Penalise "loss of electrons" alone

Accept "electron donator"

1

(ii) $Cl_2 + 2e^- \longrightarrow 2Cl^-$

Ignore state symbols

Do not penalise absence of charge on electron

Credit $Cl_2 \longrightarrow 2Cl^- - 2e^-$

Credit multiples

1

(iii) For M1 and M2, iodide ions are stronger reducing agents than chloride ions,
because

Ignore <u>general statements</u> about Group VII trends or about halogen molecules or atoms. Answers must be specific

M1 Relative size of <u>ions</u>

CE=0 for the clip if "iodine ions / chlorine ions" QoL

Iodide ions / they are <u>larger</u> /have more <u>electron levels(shells)</u>(than chloride ions) / <u>larger atomic / ionic radius</u>

CE=0 for the clip if "iodide ions are bigger molecules / atoms" QoL

***OR* <u>electron to be lost/outer shell/level</u> (of the iodide ion) is <u>further</u> the nucleus**

***OR* <u>iodide ion(s)</u> / they have <u>greater / more shielding</u>**

Insist on <u>iodide</u> ions in M1 and M2 or the use of it / they / them, in the correct context (or <u>chloride</u> ions in the converse argument)

***OR* converse for <u>chloride ion</u>**

M2 Strength of attraction for electron(s)

Must be comparative in both M1 and M2

<u>The electron(s) lost /outer shell/level electron from (an) iodide</u> ion(s) <u>less</u>

strongly held by the nucleus compared with that lost from a **chloride** ion

OR converse for a **chloride ion**

2

[15]

M4. **(a)** **(i)** $2MoS_2 + 7O_2 \rightarrow 2MoO_3 + 4SO_2$

OR

$MoS_2 + 3\frac{1}{2}O_2 \rightarrow MoO_3 + 2SO_2$

Allow multiples

Ignore state symbols

1

(ii) **M1 Environmental problem**

Acid rain

OR

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

M2 Use

SO_2 could be used to make / to form / to produce (or wtte) H_2SO_4 / sulfuric acid

OR

To make / to form / to produce (or wtte) gypsum / $CaSO_4$ or plaster of Paris / plaster board

Ignore references to the greenhouse effect

Penalise reference to the ozone layer using the list principle

2

(iii) $MoO_3 + 3H_2 \rightarrow Mo + 3H_2O$

Allow multiples

Ignore state symbols

1

(iv) One from

H_2 is

- **Explosive**
- **(in)flammable**
- **<u>easily</u> ignited**

Ignore "burns"

1

(b) (i) To allow <u>ions</u> to <u>move</u> (when molten)

OR

<u>Ions cannot move in the solid</u>

1

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

Or multiples

Ignore state symbols

Ignore charge on the electron unless incorrect and accept loss of two electrons on the RHS

1

(iii) (High) <u>electricity</u> / <u>electrical energy</u> (cost)

Ignore "energy" and ignore "current"

[8]

M5.(a) (i) reduction OR reduced OR redox *OR* reduction–oxidation

Not "oxidation" alone

1

(ii) $Fe^{3+} + 3e^- \longrightarrow Fe$

Ignore state symbols
Do not penalise absence of charge on electron
Credit $Fe^{3+} \longrightarrow Fe - 3e^-$
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_2 is (also) formed

Further oxidation occurs

1

(ii) **The <u>enthalpy change</u> / <u>heat (energy) change at constant pressure</u> in a reaction**
is <u>independent of the route / path taken</u> (and depends only on the initial and
final states)

1

(iii) **M1 The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u>of a compound / substance / element**
For M1, credit correct reference to molecule/s or atom/s

M2 is <u>burned completely</u> / <u>undergoes complete combustion</u> in (excess) <u>oxygen</u>

M3 with <u>all reactants and products / all substances in standard states</u>
For M3
Ignore reference to 1 atmosphere

OR **<u>all reactants and products / all substances in normal / specified states</u>**
<u>under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

3

(c) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> <u>ΔH</u> symbols and the ∑)**

Correct answer gains full marks

Credit 1 mark ONLY for –1 (kJ mol^{-1})

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

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

***OR* <u>correct cycle of balanced equations with 2Fe, 3C and $3O_2$</u>**

M2 ΔH_r **= 2(+14) + 3(– 394) – (– 822) – 3(–111)**

= 28 –1182 + 822 + 333

(This also scores M1)

M3 = (+) 1 (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 2Fe, 3C and $3O_2$ OR a clear statement of M1 which could be in words and scores <u>only M1</u>***

3

(d) **(i)** **C(s) + O_2(g) CO_2(g)**

State symbols essential

Possible to include C(s, graphite)

1

(ii) **These two enthalpy changes are for <u>the same reaction / same equation / same reactants and products</u>**

Penalise reference to CO_2 being produced by a different route

OR

They <u>both make one mole of carbon dioxide only from carbon and oxygen</u>
(or this idea clearly implied)

"both form CO_2" is not sufficient (since other products might occur e.g.CO)

OR

The <u>same number and same type of bonds are broken and formed</u> 1

[12]

M1. (a) **M1** The yield of zinc oxide <u>increases/greater</u>

If M1 is given as "decrease" OR "no effect" then CE= 0

M2 Removal of the carbon dioxide results in the **<u>equilibrium</u>**

Either

Shifting/moving/goes to the right
shifting/moving/goes L to R
favours the forward reaction/towards the products

M3 (By Le Chatelier's principle) the reaction/equilibrium will respond so as <u>to replace the CO_2/lost product</u>
OR <u>to make more CO_2</u>
OR <u>to increase concentration of CO_2</u>

For M3, not simply "to oppose the change/to oppose the loss of CO_2/to oppose the removal of carbon dioxide."

3

(b) **M1** Process 2 produces/releases SO_2
OR Process 2 produces/releases CO

M2 It/Process 3 avoids the release of SO_2 OR CO
OR It/Process 3 (captures and) converts SO_2 to H_2SO_4

M3 SO_2 causes acid rain OR is toxic/poisonous
OR CO is toxic/poisonous

3

Ignore "global warming" and "greenhouse gases" and "the ozone layer"

If both CO and SO_2 claimed to form acid rain, treat as contradiction

(c) **M1** Process 3 (is expensive because it) uses <u>electrolysis</u>
OR due to high <u>electricity/electrical</u> consumption

M2 this is justified because the product/zinc is pure

Ignore "energy"

Penalise "pur<u>er</u>"

2

(d) **M1** $Zn^{2+} + 2e^- \longrightarrow Zn$

Ignore state symbols

M2 the negative electrode OR the cathode

Ignore absence of negative charge on electron

Accept electrons subtracted from RHS

2

(e) **M1** The reaction of ZnO with sulfuric acid
OR the second reaction in Extraction process 3

M2 neutralisation or acid-base

OR alternatively

M1 The reaction of zinc carbonate in Extraction process 1

M1 could be the equation written out in both cases

M2 (thermal) decomposition

M2 depends on correct M1

M3 It/carbon is <u>oxidised/gains oxygen/changes oxidation state/number from 0 to +2/increase in oxidation state/number</u> in Process 2

Do not forget to award this mark

Ignore reference to electron loss but penalise electron gain

Ignore "carbon is a reducing agent"

3

(f) **M1** $Zn + H_2O \longrightarrow ZnO + H_2$

M2 <u>Zinc oxide and hydrogen</u>

OR as an alternative

M1 $Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2$

M2 <u>Zinc hydroxide and hydrogen</u>

Mark independently

If ZnO_2 is given for zinc oxide in the equation, penalise M1 and mark on

If ZnOH is given for zinc hydroxide in the equation, penalise M1 and mark on

Ignore state symbols

Credit multiples of the equation

If M1 is blank, either of the M2 answers could score

To gain <u>both</u> marks, the names must match the correct equation given.

2

[15]

M2. (a) Hydrogen/H_2 gas/bubbles

1

1.0 mol dm^{-3} HCl/H^+

1

At 298K and 100kPa

Allow 1 bar instead of 100 kPa
Do not allow 1 atm

1

Pt (electrode)

1

(b) $Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$

Ignore state symbols

1

–0.13(V)

1

(c) Fe^{3+} ions reduced to Fe^{2+}

Can score from equation/scheme

1

Because $E(Fe^{3+}/Fe^{2+}) > E(H^+/H_2)$/$E$(hydrogen)

Allow emf/E_{cell} +ve/0.77V
Allow Fe^{3+} better oxidising agent than H^+
Allow H_2 better reducing agent than Fe^{2+}
Only award this explanation mark if previous mark given

1

(d) Moles $Cr_2O_7^{2-}$ = $\underline{23.7 \times 0.01/1000}$ = 2.37×10^{-4}

1

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles Fe^{2+} in 25 cm^3 = $6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$

1

M1 × 6

Moles Fe^{2+} in 250 cm^3 = 1.422×10^{-2}

M2 × 10 or M4/10

1

Original moles Fe^{2+} = 10.00/277.9 = 0.0360

Independent mark

1

Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218

M4 – M3

1

% oxidised = (0.0218 × 100)/0.0360 = 60.5%

(M5 × 100)/M4
Allow 60 to 61
Note Max 3 if mol ratio for M2 wrong
eg 1:5 gives 67.1%
1:1 gives 93.4%
Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)

1

[14]

M3.(a) (i) Propanone evaporates (or similar)

1

Removes water (from the precipitate)

Accept 'removes impurities / excess reagents'.
Accept 'salt insoluble in propanone'.

1

(ii) Add NaOH / NH_3 / Na_2CO_3

1

No green ppt

Accept 'no visible change'.
Must have correct reagent to score this mark.

1

(iii) Some salt dissolves (in propanone) **or** some lost in filtration **or** some Fe^{2+}

gets oxidised (to Fe^{3+} in air)

Do not accept 'reaction reversible' or 'incomplete reaction' or similar.

1

(iv) Moles $Fe^{2+} = 2.50 \times 10^{-2}$

Accept 2.5×10^{-2}

1

M_r of salt = 179.8

Allow 180

Allow if 179.8 or 180 appears in a calculation.

1

Mass of salt = $179.8 \times 2.5 \times 10^{-2} \times 0.95 = 4.27$ (g)

Correct answer with no working scores this mark only.

Allow range 4.2 to 4.3 (g)

1

(v) 1.67 mol or correct ratio of $5FeC_2O_4 : 3MnO_4^-$

1

(b) $Ca^{2+} + C_2O_4^{2-} \rightarrow CaC_2O_4$

Accept multiples.

1

(c) (Insoluble) calcium ethanedioate coats surface

Allow 'calcium ethanedioate is insoluble'.

Do not allow answers based on ethanedioic acid being a weak acid.

Do not accept 'acid used up' or 'reaction very fast'.

1

(d) Small amount of tea used **or** concentration of the acid in tea is low

Accept 'high temperature decomposes the acid'.

Accept 'calcium ions in milk form a precipitate with the acid'.

Do not accept 'do not drink tea often' or similar.

1

(e) Mass of acid = 180.0 and mass of reagents = 450.0

Accept 180 and 450.

1

(180 / 450 ×100 =) 40.0%

Do not penalise precision.

Correct answer without working scores this mark only.

1

[14]

M4. (a) (i) Oxidation

OR

Oxidised ONLY

1

(ii) Any one from

- to provide/overcome activation energy
- to provide the minimum energy to make the reaction go/start

NOT simply to increase the (initial) reaction rate.

1

(iii) The reaction is exothermic OR releases heat (energy)

1

(iv) M1
Catalysts provide an alternative route/pathway OR an alternative mechanism

OR

(in this case) surface adsorption occurs (or a description of adsorption)

Ignore reference to "surface" alone

M2
Lowers the activation energy

OR

of lower activation energy

2

(b) M1
The (forward) reaction is exothermic OR the (forward) reaction releases heat

OR

The reverse reaction is endothermic or absorbs heat

M2 – Direction of change N.B. M2 depends on correct M1
At lower temperatures,

- the equilibrium yield of NO_2 is greater
- more NO_2 is formed
- equilibrium shifts (left) to right
- (equilibrium) favours the forward reaction

(***OR*** converse for higher temperatures)

2

(c) NO_2 (+) 4

NO_3^- (+) 5

HNO_2 (+) 3

3

[10]

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 equilibrium will shift/move/change/respond/act so as to oppose the change.

OR

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

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

QoL

1

(ii) **M1 – Statement of number of moles/molecules**
There are more moles/molecules (of gas) on the left/of reactants

OR

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

OR

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

Ignore "volumes" for M1
Mark independently

M2 – Explanation of response/movement in terms of pressure

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) **2**C + O_2 → **2**CO
OR
C + CO_2 → 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 <u>lower energy</u> 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

- <u>ions</u> to <u>move</u>
- <u>current</u> to <u>flow</u>
- it to <u>conduct electricity</u>

1

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

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

1

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

1

(iv) Recycling involves <u>lower electricity</u> OR <u>less energy</u> 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 <u>to the right</u>
OR
<u>L to R</u>
OR
Favours forward reaction
OR
Produces more HBrO

1

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

1

[12]

M1.D

[1]

M2.A

[1]

M3.A

[1]

M4. (a) Gains electrons (or removes electrons)

1

(b) (i) +4

1

+6

1

(ii) $Br_2 + 2e^- \rightarrow 2Br^-$

1

(iii) $SO_2 + 2H_2O \rightarrow 4H^+ + SO_4^{2-} + 2e^-$

1

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

1

(c) $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$

1

Chloride: –1

1

Chlorate(I): +1

1

(d) Chloride ions cannot reduce sulphuric acid

(Or chloride ions are weak reducing agents
Or sulphuric acid is not a strong enough oxidising agent
Or sulphuric acid is a weaker oxidising agent than chlorine)

1

(e) $KCl + H_2SO_4 \rightarrow HCl + KHSO_4$

(Allow $2KCl + H_2SO_4 \rightarrow 2HCl + K_2SO_4$)

1

(f) (i) Bromine

1

(ii) Sulphur dioxide

1

[13]

M5. D

[1]

M6. (a) (i) HgO

1

(ii) $Hg^{2+} + 2e^- \rightarrow Hg$

1

(iii) $2H_2O + SO_2 \rightarrow H_2SO_4 + 2e^-$ etc

1

(iv) $Cl_2 + 2e^- \rightarrow 2Cl^-$

1

(b) (i) Vanadium species: VO_2^+

1

Oxidation state: 5

1

Half-equation: $V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 3e^-$

1

(ii) Cell e.m.f 0.06 V

1

Change in e.m.f , Increases

1

More Fe^{3+} ions to accept electrons

1

Fe^{3+}/Fe^{2+} electrode becomes more positive

1

(c) (i) $2H_2 \rightarrow 4H^+ + 4e^-$

1

$4e^- + O_2 + 2H_2O \rightarrow 4OH^-$

1

Overall equation $2H_2 + O_2 \rightarrow 2H_2O$

(ii) Unchanged

1

(d) Economic disadvantage; Use of CH_4 or cost of producing or high temp

1

Environmental disadvantage; Makes CO_2

1

(e) Cost of manufacture of solar cells

1

[17]

M7. (a) Accepts electrons

1

(b) Charge on the ion (or element or atom)

1

(c) +4

1

+5

1

–3

1

(d) (i) $Cu^{-} \rightarrow Cu^{2+} + 2e^{-}$

1

(ii) $NO_3^- + 4H^+ \, 3e^- \rightarrow NO_2 \, H_2O$

1

(iii) $3Cu + 2NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

1

[8]

M8. B

[1]

M9. A

[1]

M10. (a) removal/loss of electrons

1

(b) no change

1

equal number of gaseous moles on either side

1

both sides affected equally

1

increases

1

equilibrium moves to lower the temperature/oppose the change

1

endothermic reaction favoured /forward reaction is endothermic

1

(c) (i) +2

1

+5

1

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

1

(iii) $Ag \rightarrow Ag^+ + e^-$

1

(iv) $NO_3^- + 4H^+ + 3Ag \rightarrow NO + 2H_2O + 3Ag^+$

1

[12]

M1.(a) (i) Loss (of electrons) **(1)**

(ii) *Oxidation state of nitrogen in NO:* (+) 2 **(1)**

Oxidation state of nitrogen in NH^+: –3 **(1)**

(iii) I_2 **(1)**

4

(b) (i) $Cl_2 + 2e^- \rightarrow 2Cl^-$ **(1)**

(ii) $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ **(1)**

(iii) $SO_2 + 2H_2O + Cl_2 \rightarrow SO_4^{2-} + 2Cl^- + 4H^+$ **(1)**
or H_2SO_4 + 2HCl etc

Ignore state symbols in equation

Allow multiples of all equations

3

[7]

M2.D

[1]

M3.D

[1]

M4. (a) (i) Halides:- Fluoride
Chloride **(1)**

Equation:- $H^+ + F^- \rightarrow HF$ *(or molecular / for a correct halide)* **(1)**

(ii) Halides:- Bromide and iodide **(1)**

Equation:- H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* + $2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ **(1)**

$2Br^- \rightarrow Br_2 + 2e^-$ **(1)**

$H_2SO_4 + 2H^+ + 2Br^-$ (or 2HBr) $\rightarrow Br_2 + SO_2 + 2H_2O$ **(1)**

Q of L penalise wrong symbol for fluoride or bromide once
Ignore state symbols in equations

(iii) Products Sulphur (or S_8 not S_4) **(1)**
Hydrogen sulphide **(1)**
Equation:- H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* $+6H^+ + 6e^- \rightarrow S + 4H_2O$ **(1)**
OR
H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* $+ 8H^+ + 8e^- \rightarrow H_2S + 4H_2O$

9

Ignore halide if given even if incorrect
Do not allow elements, molecules or atoms in part (a)

(b) Addition of silver nitrate
Chloride gives white precipitate / solid **(1)**
Bromide gives cream precipitate / solid **(1)**
Iodide gives yellow precipitate / solid **(1)**
Addition of ammonia
Chloride precipitate soluble in dilute **(1)**
Bromide precipitate soluble in concentrated **(1)**
Iodide precipitate insoluble **(1)**

Do not allow halogen or sodium halide

6

[15]

M5.A

[1]

M6.B

[1]

M7.D

[1]

M8.B

[1]

M9. (a) A reducing agent gives electrons **(1)**

Not electron pairs

1

(b) Zero **(1)**

1

(c) (i) (+)3 **(1)**

(ii) –3 **(1)**

(iii) –1 **(1)**

Allow answers in roman

3

(d) (i) $PbO_2 + 4H^+ + 2e^- \rightarrow Pb_2^+ + 2H_2O$ **(1)**

(ii) $2Cl^- \rightarrow Cl_2 + 2e^{(-)}$ **(1)**

(iii) $PbO_2 + 4H^+ + 2Cl^- \rightarrow Pb^{2+} + Cl_2 + 2H_2O$ **(1)**

Or molecular

3

[8]

M10. (a) (i) –2 OR 2–

(ii) NaI or NaAt or I^- or iodide or At^-or Astatide **(1)**

<u>Not</u> atoms or molecules

(iii) Smell of bad eggs **(1)**

Allow $PbAc_2$ goes black and $K_2Cr_2O_7/H^+$ goes cloudy green

(iv) $8\ e^- + 8\ H^+ + H_2SO_4 \rightarrow H_2S + 4H_2O$ **(1)**

OR $10\ H^+ + SO_4^{2-}$

4

(b) (i) HF or HCl **(1)**

CE = 0 if redox answer given

If wrong halide given allow max one in b(iii)

If NaF or NaCl, or F^- or Cl^- given lose mark in (i)

Mark on if X is e.g. HF_2 or H_2F

(ii) NaF or NaCl or F^- or Cl^- **(1)**

(iii) A proton donor or an acid **(1)**

(iv) $H^+ + F^- \rightarrow HF$

OR $H_2SO_4 + NaF \rightarrow NaHSO_4 + HF$

OR $H_2SO_4 + 2\ NaF \rightarrow Na_2SO_4 + 2\ HF$

OR for chloride

4

[8]

M11. (a) gains electrons **(1)**
or accepts/takes electrons

Allow an electron
or just 'gains'
or reduction is gain of electrons, but NOT OILRIG even if stated
Do not allow mention of electron pair(s)

1

(b) (i) *Oxidising agent*: Ag^+ **(1)** (*or Ag I*)

Reducing agent: SO_2 **(1)** (*or S^{VI}, not sulphur*)

(ii) $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ **(1)** (*or* $H_2SO_4 + 2H^+ + 2e^-$)

allow e i.e. no charge
penalise E^- once only
allow $-e^-$ on LHS

3

(c) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ **(1)**

(ii) 5 **(1)** (*or V or +5*)

(iii) $ClO_3^- + 6H^+ + 6e^- \rightarrow Cl^- + 3H_2O$ **(1)**

(iv) $ClO_3^- + 6H^+ + 6Fe^{2+} \rightarrow Cl^- + 3H_2O + 6Fe^{3+}$ **(1)**
Mark parts (i) to (iv) independently

4

(d) *Equation*: Mg + S → MgS **(1)**

allow FeS + Mg → MgS + Fe
allow Ca

Oxidising agent: S **(1)**

Only award mark if first answer given unless no first answer then can allow

2

[10]

M12.B

[1]

M13.B

[1]

M14.C

[1]

M15.C

[1]