M1. (a) (i) MnO_2 (+) 4

1

(ii) $MnO_2 + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$

Or multiples

Ignore state symbols

Credit electrons subtracted from RHS

Ignore absence of charge on e

1

(iii) Iodide ion(s) is/are oxidised because they have <u>lost electron(s)</u>

Do not penalise reference to iodine; the mark is for electron loss

1

(b) (i) **M1** Cl_2 0

M2 HClO (+) 1

2

(ii) **M1** Equilibrium will shift/move <u>to the right</u>

OR <u>L to R</u>

OR to favour the <u>forward reaction</u>

OR to produce <u>more HClO</u>

M2 **<u>Consequential on correct M1</u>**

To <u>oppose the loss of HClO</u>

OR <u>replaces the HClO</u> (that has reacted)

for M2

NOT just "to oppose the change"

2

(c) (i) The answers can be in **<u>either order</u>**

M1 $2Br^- \longrightarrow Br_2 + 2e^-$

M2 $4H^+ + SO_4^{2-} + 2e^- \longrightarrow SO_2 + 2H_2O$

OR

$\mathbf{2}H^+ + H_2SO_4 + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$

NOT multiples

Ignore state symbols

Credit electrons subtracted from incorrect side

Ignore absence of charge on e

2

(ii) $KCl + H_2SO_4 \longrightarrow KHSO_4 + HCl$

OR

$\mathbf{2}KCl + H_2SO_4 \longrightarrow K_2SO_4 + \mathbf{2}HCl$

Credit ionic equations

1

(iii) For M1 and M2, chloride ions are weaker reducing agents than bromide ions, because

M1 Relative size of ions

Chloride ions are <u>smaller</u> than bromide ions OR chloride ion electron(s) are <u>closer</u> to the nucleus OR chloride ion has fewer (electron) shells/levels OR chloride ion has less shielding (or converse for bromide ion)

M2 Strength of attraction for electron being lost

Outer shell/level electron(s) OR electron(s) lost from a chloride ion is more strongly held by the nucleus compared with that lost from a bromide ion (or converse for bromide ion)

If the forces are described as intermolecular or Van der Waals then CE = 0

Ignore general reference to Group 7 trend

For M1 accept reference to chlorine/bromine or reference to atoms of these but NOT "chloride/bromide atoms" or "chlorine/bromine molecules"

For M2 insist on reference to the correct ions

This is the expected answer, but award credit for a candidate who gives a correct explanation in terms of hydration enthalpy, electron affinity and atomisation enthalpy.

2

[12]

M2. (a) (i) **M1 Initiation**

$Cl_2 \longrightarrow 2Cl\bullet$

M2 First propagation

$Cl\bullet + CH_3CH_3 \longrightarrow \bullet CH_2CH_3 + HCl$

C_2H_6

M3 Second propagation

$Cl_2 + \bullet CH_2CH_3 \longrightarrow CH_3CH_2Cl + Cl\bullet$

C_2H_5Cl

M4 Termination (must make C_4H_{10})

$2 \bullet CH_2CH_3 \longrightarrow C_4H_{10}$ or $CH_3CH_2CH_2CH_3$

Penalise absence of dot once only.

Penalise + or – charges <u>every time</u>

Penalise incorrect position of dot on ethyl radical once only.

Penalise $C_2H_5\bullet$ once only

Accept $CH_3CH_2\bullet$ with the radical dot above/below/to the side of <u>the CH_2</u>

Mark independently

4

(ii) **M1** ultra-violet/uv/sun light

OR (very) high temperature OR 500 °C ≥ T ≤1000 °C

M2 (free-)<u>radical substitution</u>

Ignore "heat" for M1

Both words needed for M2

For M2, ignore the word "mechanism"

2

(b) (i) $Cl_2 + H_2O \longrightarrow HClO + HCl$

OR

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

Accept HOCl or ClOH

Accept other ionic or mixed representations

Ignore state symbols

1

(ii) **M1** Any one from
- in swimming pools
- in drinking water
- to sterilise/disinfect/sanitise water
- in water treatment

Ignore the manufacture of bleach
Ignore "to clean water"
Ignore "water purification"

M2 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

Mark independently but M1 can score from (M2) explanation

2

(iii) Sodium chlorate(I) or sodium hypochlorite

Must be named
Ignore (in)correct formulae
Insist on the (I) in the name

1

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

Or half this equation
Ignore state symbols

1

(ii) **M1** **The relative size (of the molecules/atoms)**
Bromine is larger than chlorine OR has more electrons/electron shells
OR It is larger/It has a larger atomic radius/it is a larger molecule/atom

M2 **How size of the intermolecular force affects energy needed**
The forces between bromine/Br_2 molecules are stronger (than the forces between chlorine/Cl_2 molecules leading to more energy needed to separate the molecules) (or converse)
OR bromine/Br_2 has stronger/more (VdW) intermolecular forces.
(or converse)

For M1 ignore whether it refers to molecules or atoms.

CE = 0 for reference to (halide) ions

Ignore molecular mass

***QoL** for clear reference to the difference in size <u>of the force between molecules</u>*

Penalise M2 if covalent bonds are broken

2

[13]

M3. (a) **M1** Cl_2 (provides the pale green colour)

M1 <u>requires the formula</u>

M2 NaOH reacts with the acid(s)/the HCl/the HClO/H^+

Ignore "reacts with the products"

Ignore "reacts with chloride ion"
Ignore "reacts with chlorine"

M3 <u>requires a correct answer in M2</u>
Equilibrium shifts (from left) <u>to right</u> ***OR*** wtte

3

(b) **M1** A reducing agent is an <u>electron donor</u> OR (readily) <u>loses/ gives away electrons</u>

Penalise M1 if "electron pair donor"

M2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

For M3 and M4, **i**odide ions are stronger reducing agents than chloride ions, because

Ignore state symbols in M2 Accept no charge on the electron
Credit the electrons being lost on the RHS

M3 Relative size of ions/atomic radius/ionic radius
<u>Iodide ions</u> are <u>larger</u>/have more (electron) shells/levels than chloride ions (or converse for chloride ion) OR <u>electron(s) to be lost/outer shell/level</u> is <u>further</u> from the nucleus (or converse for chloride ion) OR greater/more shielding

For M3 insist on "<u>iodide ions</u>"

M4 Strength of attraction for <u>electron(s) being lost</u>
<u>Electron(s) lost</u> from an iodide ion is <u>less strongly held by the nucleus</u> compared with that lost from a chloride ion

M3 and M4 must be comparative and should refer to electrons.

(assume argument refers to iodide ions but accept converse argument for chloride ions)

4

(c) **M1** **2**Cl_2 + **2**H_2O → **4**HCl + O_2

Or multiples

M2 silver chloride ONLY

<u>M2 requires a name</u>

M3 The solid/precipitate would dissolve
OR is soluble
OR (It) forms a (colourless) solution

Mark M3 independently

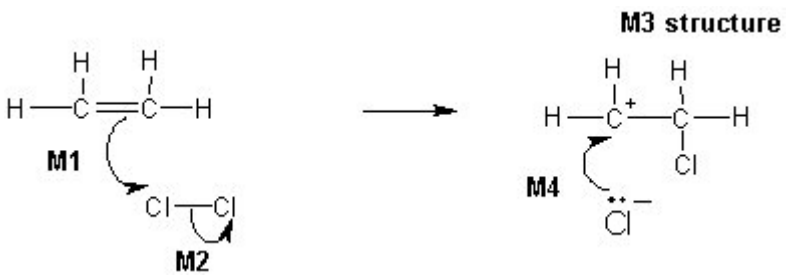
Ignore "disappears"

3

(d) <u>Electrophilic addition</u>

1

Mechanism:



M2 Penalise partial charges if wrong way around, otherwise ignore

*Max 3 marks **<u>for the mechanism</u>** for wrong reactant and/or "sticks" (wrong reactant could be HBr or Br_2 or incorrect alkene)*

M1 must show an arrow from the double bond towards one of the Cl atoms on a Cl–Cl molecule.

M2 must show the breaking of the Cl–Cl bond.

M3 is for the structure of the carbocation with Cl substituent.

M4 must show an arrow from the lone pair of electrons on a negatively charged chloride ion towards the positively charged carbon atom.

4

[15]