Q6.

This question is about redox reactions.

(a) State, in terms of electrons, the meaning of the term oxidising agent.

_____

(1)

(b) $Cr_2O_7^{2-}$ can oxidise SO_3^{2-} in acidic conditions to form Cr^{3+} and SO_4^{2-}

Deduce a half-equation for the oxidation of SO_3^{2-} to SO_4^{2-}

Deduce a half-equation for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}

Deduce the overall equation for the oxidation of SO_3^{2-} by $Cr_2O_7^{2-}$

Half-equation for the oxidation of SO_3^{2-} to SO_4^{2-}

_____

Half-equation for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}

_____

Overall equation

_____

(3)

(Total 4 marks)

Q7.

This question is about Group 2 elements and their compounds.

(a) Explain why the melting point of magnesium is higher than the melting point of sodium.

_____

_____

_____

_____

_____

_____

(2)

(b) Give an equation to show how magnesium is used as the reducing agent in the extraction of titanium.

Explain, in terms of oxidation states, why magnesium is the reducing agent.

Equation

_____

Explanation _____

_____

_____

_____

_____

(2)

(c) State what is observed when dilute aqueous sodium hydroxide is added to separate solutions of magnesium chloride and barium chloride.

Observation with magnesium chloride _____

Observation with barium chloride _____

(2)

(Total 6 marks)

Q8.

This question is about emissions of oxides of nitrogen from petrol and diesel engines.

(a) Explain how oxides of nitrogen are formed in engines.

_____

_____

_____

_____

(2)

(b) State why it is desirable to decrease emissions of oxides of nitrogen from vehicles.

_____

_____

_____

(1)

(c) Modern diesel vehicles use diesel exhaust fluids, such as AdBlue, to decrease emissions of oxides of nitrogen.

AdBlue reacts with water in the hot exhaust gases to form ammonia.
In the presence of a catalyst the ammonia reacts with oxides of nitrogen to form nitrogen and water.

Give the oxidation state of nitrogen in each of NO_2, NH_3 and N_2

Complete the equation for the reaction between NO_2 and NH_3

Oxidation state of nitrogen in

NO_2_____ NH_3_____ N_2_____

Equation

_____ NO_2 + _____ NH_3 → _____ N_2 + _____ H_2O

(2)

(d) Petrol vehicles have a catalytic converter which decreases emissions of oxides of nitrogen.
Platinum in the catalytic converter acts as a heterogeneous catalyst.

State the meaning of the term heterogeneous catalyst.

_____

_____

_____

_____

(2)

(e) Some carbon particulates are also formed in both diesel and petrol vehicles.

Explain why carbon particulates are formed.

_____

_____

(1)

(Total 8 marks)

Q9.

This question is about the element iodine and its compounds.

(a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.

Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

_____

_____

_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✓) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

NH_4I_3 ☐

(1)

(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$ _____

$[H_4IO_6]^-$ _____

(2)

(Total 14 marks)

Q10.

A student oxidised a solution of hydrochloric acid with a few drops of sodium chlorate(I) solution. The reaction mixture effervesced and turned pale green. The gas formed bleached universal indicator paper.

(a) Write a half-equation for the oxidation of chloride ions.

_____

(1)

(b) Write a half-equation for the reduction of chlorate(I) ions to chlorine in acidic conditions.

_____

(1)

(c) Write an overall equation for the redox reaction of chlorate(I) ions with hydrochloric acid.

_____

(1)

(d) A solution of sodium chlorate(I) was added to a colourless solution of potassium iodide. Suggest what is observed.

Explain the reaction that leads to this observation.

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q11.

The halogens are the elements in Group 7.

(a) The electronegativities of the halogens are shown in the table.

Halogen	**Fluorine**	**Chlorine**	**Bromine**	**Iodine**
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

_____

_____

_____

_____

(2)

(b) The halogens can all behave as oxidising agents in reactions.

(i) Explain, in terms of electron transfer, the meaning of the term oxidising agent.

_____

_____

(1)

(ii) An equation for the reaction that takes place when chlorine gas is bubbled through aqueous potassium bromide is shown.

$$Cl_2(g) + 2KBr(aq) \longrightarrow Br_2(aq) + 2KCl(aq)$$

Explain, with reference to the oxidation states, why this is a redox reaction.

_____

_____

_____

(1)

(c) Solid sodium halides react with concentrated sulfuric acid.

(i) A sample of solid sodium iodide is reacted with concentrated sulfuric acid.
A black solid forms and hydrogen sulfide gas is produced.

Write a half-equation for the reaction of sulfuric acid to form hydrogen sulfide.

_____

(1)

(ii) Write a half-equation for the formation of the black solid.

_____

(1)

(iii) Use your answers to parts (c) (i) and (c) (ii) to write an overall equation for the reaction of sodium iodide with concentrated sulfuric acid.

_____

(1)

(iv) Give the role of sulfuric acid in its reaction with sodium iodide.

Tick (✓) **one** box.

Acid	☐
Oxidising agent	☐
Reducing agent	☐
Electrophile	☐

(1)

(v) Write an equation for the reaction of concentrated sulfuric acid with solid sodium fluoride.

_____

(1)

(vi) Suggest **one** reason why the reaction of sodium fluoride with concentrated sulfuric acid is different from the reaction with sodium iodide.

_____

(1)

(d) Chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and chloric(I) acid.

(i) Write an equation for the formation of this equilibrium mixture.

_____

(1)

(ii) Household bleach contains sodium chlorate(I) and sodium chloride.
State and explain, with reference to your equation in part **(d)(i)**, why it is dangerous to acidify an aqueous mixture of sodium chlorate(I) and sodium chloride.

_____

_____

_____

(2)

(Total 13 marks)

Q12.

Chlorine is an important industrial chemical.

(a) Chlorine is formed when $KMnO_4$ reacts with hydrochloric acid.
The ionic equation for this redox reaction is

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

(i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

_____

(1)

(ii) Give the oxidation state of manganese in the MnO_4^- ion.

_____

(1)

(iii) Deduce the half-equation for the reduction of the MnO_4^- ions in acidified solution to manganese(II) ions and water.

_____

(1)

(b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

(i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

_____

(1)

(ii) Give **one** observation that would be made during this reaction.

_____

_____

(1)

(iii) In terms of electrons, state the meaning of the term **oxidising agent**.

_____

_____

(1)

(c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.
Give the oxidation state of chlorine in the chlorine-containing species that is formed.

Equation

_____

Oxidation state of chlorine in the species formed _____

(2)

(d) Explain why chlorine has a lower boiling point than bromine.

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 10 marks)

Q6.

(a) Electron acceptor

Do not allow electron pair acceptor

1

(b) $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$

Allow multiples in each case

1

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

1

$3SO_3^{2-} + Cr_2O_7^{2-} + 8H^+ \rightarrow 3SO_4^{2-} + 2Cr^{3+} + 4H_2O$

1

[4]

Q7.

(a) Mg^{2+} has a higher charge than Na^+ / Mg^{2+} ions are smaller / Mg^{2+} has a greater charge density / Mg atoms smaller than Na atoms / Mg has more delocalised electrons than Na

Allow
Mg has a higher nuclear charge

1

Stronger attraction to delocalised sea of electrons / stronger metallic bonding

Not attraction for outer electrons

1

(b) $2Mg + TiCl_4 \rightarrow 2MgCl_2 + Ti$

Allow multiples

1

Mg changes oxidation state from 0 to +2 so electrons are lost / Ti changes oxidation state from +4 to 0 , so gains electrons

Allow
Oxidation state of Mg increases so it is a reducing agent

1

(c) Observation with $MgCl_2$: (slight) white ppt

1

Observation with $BaCl_2$: no (visible) change / colourless solution / no reaction

Do not allow nothing / no observation

1

[6]

Q8.

(a) **M1** reaction of nitrogen/N_2 and oxygen/O_2 from the air

Must be at least one reference to air.
NOT reference to nitrogen/oxygen from the fuel.
Allow equation plus a reference to the air.
Allow combustion of nitrogen plus reference to the air.
NOT M1 if reference to reaction taking place in the catalytic

converter.

1

M2 at high temperatures

Allow high energy/heat or very hot.

Allow heat/energy in the engine provides Ea

IGNORE references to pressure/spark

1

(b) Formation of acid rain / causes respiratory problems

Allow (contributes to) ground level ozone / (photochemical) smog / toxic / poisonous

Allow makes water acidic / reacts with water to form nitric acid / (NO_x gases are) acidic

IGNORE greenhouse gases / global warming / damages ozone layer

IGNORE vague answers such as 'harmful to environment'/polluting/harmful

NOT reference to pH rising

1

(c) **M1** $NO_2 = (+)4$ $NH_3 = -3$ $N_2 = 0$

1

M2 $3NO_2 + 4NH_3 \rightarrow 7/2N_2 + 6H_2O$

ALLOW multiples/fractions
($6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$ OR
$1½NO_2 + 2NH_3 \rightarrow 1¾N_2 + 3H_2O$)

1

(d) **M1** Catalyst in different phase/state (to reactants)

*NOT (catalyst in different phase/state to) products allow catalyst in different phase/state to reactants **and** products*

1

M2 Speeds up reaction without being used up

ALLOW speeds up the reaction by (providing alternative route for reaction and) lowering E_a

NOT does not take part in the reaction

1

(e) incomplete combustion

***ignore** equations*

ALLOW description of incomplete combustion (e.g. not enough oxygen)

Allow O_2 but NOT O for oxygen

1

[8]

Q9.

(a) [Kr] $5s^2$ $4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \longrightarrow HI$

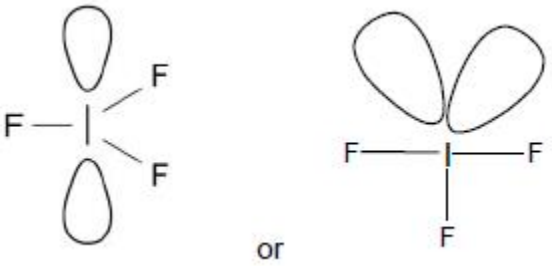
Allow multiples

1

(e) NH_4I_3

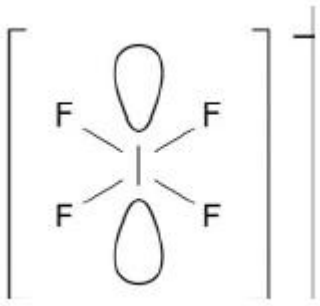
1

(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q10.

(a) $2Cl^- \longrightarrow Cl_2 + 2e^{(-)}$

Allow $2Cl^- - 2e^{(-)} \longrightarrow Cl_2$

Allow correct equation forming ClO^- *but not* Cl^+

1

(b) $2ClO^- + 4H^+ + 2e^- \longrightarrow Cl_2 + 2H_2O$

Allow HClO in correctly balanced equation

1

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

allow $HClO + HCl + \longrightarrow Cl_2 + H_2O$

1

(d) Goes brown (or shades of brown)

Allow black ppt/solid but NOT black solution or purple

1

Due to iodine or I_3^-

Correct ½ equation scores M2 and M3

1

Because I^- oxidised

1

[6]

Q11.

(a) Increasing atomic radius / shielding / number of shells / size (down group) or reverse argument

***NOT** 'molecules'*

1

Decreasing attraction of <u>nucleus/protons</u> for shared (electron) pair / bond electrons

***NOT** if attraction for single electron implied*

1

(b) (i) Electron acceptor / species that accepts electrons / species that gains electrons

***NOT** electron pair*

***NOT** just 'gain of electrons'*

1

(ii) Chlorine 0 to –1 / oxidation state/number of chlorine decreases
AND
Bromine –1 to 0 / oxidation state/number of bromine increases

Penalise if oxidised for chlorine and/or reduced for bromine

Credit oxidation states if labelled on equation

1

(c) (i) $H_2SO_4 + 8H^+ + 8e^{(-)} \longrightarrow H_2S + 4H_2O$

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

***ALLOW** fractions/multiples*

***IGNORE** state symbols*

1

(ii) $2I^- \longrightarrow I_2 + 2e^{(-)}$

***ALLOW** fractions/multiples*

***IGNORE** state symbols*

***ALLOW** $2I^- - 2e^{(-)} \longrightarrow I_2$*

1

(iii) $H_2SO_4 + 8H^+ + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2$

ALLOW

$H_2SO_4 + 8HI \longrightarrow H_2S + 4H_2O + 4I_2$

$SO_4^{2-} + 2H^+ + 8HI \longrightarrow H_2S + 4H_2O + 4I_2$

$SO_4^{2-} + 10H^+ + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2$

$9H_2SO_4 + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2 + 8HSO_4^-$

$9H_2SO_4 + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 8NaHSO_4$

$H_2SO_4 + 8H^+ + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 8Na^+$

$5H_2SO_4 + 8I^- \longrightarrow H_2S + 4H_2O + 4I_2 + 4SO_4^{2-}$

$5H_2SO_4 + 8NaI \longrightarrow H_2S + 4H_2O + 4I_2 + 4Na_2SO_4$

1

(iv) 'Oxidising agent' box ticked

1

(v) $H_2SO_4 + 2NaF \longrightarrow Na_2SO_4 + 2HF$
OR
$H_2SO_4 + NaF \longrightarrow NaHSO_4 + HF$

1

(vi) Fluoride less powerful reducing agent (than iodide)
OR
Fluoride less easily oxidised than iodide
Or reverse argument in either case

***NOT** general group VII trend statement*
***NOT** fluorine/F or iodine/I*
Must be comparative

1

(d) (i) $Cl_2 + H_2O \rightleftharpoons 2H^+ + Cl^- + ClO^-/HCl + HOCl$

***ALLOW** $\longrightarrow$ for $\rightleftharpoons$*

1

(ii) Equilibrium shifts/moves left

1

(Producing) chlorine (which) is toxic/poisonous
Mark independently

1

[13]

Q12.

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

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 only

Ignore state symbols

1

(ii) (Turns to) yellow / orange / brown (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) gains electron(s) / takes electron(s) / accepts electron(s) (from the bromide ions)

OR

(Chlorine) causes another species (Br^-) to lose electron(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 smaller 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 intermolecular force affects energy needed

Ignore shielding

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

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

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

2

[10]