**Q1.**(a)     The following is an equation for a redox reaction.

2NO   +   12H+   +   10I–   →   2NH4+   +   2H2O   +   5I2

(i)      Define *oxidation* in terms of electrons.

.............................................................................................................

(ii)     Deduce the oxidation state of nitrogen in NO and of nitrogen in NH4+

*Oxidation state of nitrogen in NO* .......................................................

*Oxidation state of nitrogen in NH4+* ......................................................

(iii)     Identify the species formed by oxidation in this reaction..........................

**(4)**

(b)     When chlorine gas is bubbled into an aqueous solution of sulphur dioxide, hydrogen ions, sulphate ions and chloride ions are formed.

(i)      Write a half-equation for the formation of chloride ions from chlorine.

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(ii)     Write a half-equation for the formation of hydrogen ions and sulphate ions from sulphur dioxide and water.

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(iii)     Hence, deduce an overall equation for the reaction which occurs when chlorine is bubbled into aqueous sulphur dioxide.

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**(3)**

**(Total 7 marks)**

**Q2.**          (a)     In terms of electron transfer, what does the reducing agent do in a redox reaction?

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**(1)**

(b)     What is the oxidation state of an atom in an uncombined element?

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**(1)**

(c)     Deduce the oxidation state of nitrogen in each of the following compounds.

(i)      NCl3 ...................................................................................................

(ii)     Mg3N2 .................................................................................................

(iii)     NH2OH ................................................................................................

**(3)**

(d)     Lead(IV) oxide, PbO2, reacts with concentrated hydrochloric acid to produce chlorine, lead(II) ions, Pb2+, and water.

(i)      Write a half-equation for the formation of Pb2+ and water from PbO2 in the presence of H+ ions.

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(ii)     Write a half-equation for the formation of chlorine from chloride ions.

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(iii)     Hence deduce an equation for the reaction which occurs when concentrated hydrochloric acid is added to lead(IV) oxide, PbO2

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**(3)**

**(Total 8 marks)**

**Q3.**          (a)     In acidic conditions, hydrogen peroxide, H2O2, oxidises iodide ions to iodine. The hydrogen peroxide is reduced to water. In H2O2, oxygen has an oxidation state of –1.

(i)      Construct a half-equation for the reduction of hydrogen peroxide to water in acidic conditions.

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(ii)     Construct a half-equation for the oxidation of I– ions to iodine.

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(iii)     Construct an equation for the overall reaction.

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**(3)**

(b)     The concentration of an aqueous iodine solution can be determined by titration with aqueous sodium thiosulphate. In a titration, 25.0 cm3 of an aqueous iodine solution reacted with exactly 19.5 cm3 of a 0.120 mol dm–3 solution of sodium thiosulphate.

(i)      Write an equation for the reaction between iodine and thiosulphate ions.

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(ii)     Calculate the concentration of the iodine solution.

(If you are unable to answer part (b)(i), assume that one mole of iodine reacts with three moles of thiosulphate ions. This is not the correct ratio.)

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**(5)**

(c)     Chlorine reacts with water as shown in the following equation.

Cl2  +  H2O    Cl–  +  HClO  +  H+

In this reaction, chlorine acts both as an oxidising agent and as a reducing agent.

(i)      Construct a half-equation for the reduction of chlorine to chloride ions.

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(ii)     Deduce the oxidation state of chlorine in HCIO.

.............................................................................................................

(iii)     Construct a half-equation for the oxidation of chlorine, in reaction with water, to form HCIO and H+ ions.

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(iv)    Give **one** reason why chlorine is used in the water industry

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**(4)**

**(Total 12 marks)**

**Q4.**          (a)     In terms of electrons, what happens to an oxidising agent during a redox reaction?

......................................................................................................................

**(1)**

(b)     Consider the following redox reaction.

SO2(aq) + 2H2O(l) + 2Ag+(aq) → 2Ag(s) + (aq) + 4H+(aq)

(i)      Identify the oxidising agent and the reducing agent in this reaction.

*Oxidising agent* ...................................................................................

*Reducing agent* ...................................................................................

(ii)     Write a half-equation to show how sulphur dioxide is converted into sulphate ions in aqueous solution.

.............................................................................................................

**(3)**

(c)     Fe2+ ions are oxidised to Fe3+ ions by  ions in acidic conditions. The  ions are reduced to Cl– ions.

(i)      Write a half-equation for the oxidation of Fe2+ ions in this reaction.

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(ii)     Deduce the oxidation state of chlorine in  ions.

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(iii)     Write a half-equation for the reduction of  ions to Cl– ions in acidic conditions.

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(iv)    Hence, write an overall equation for the reaction.

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**(4)**

(d)     Write an equation to show how sulphur is removed from impure iron obtained from the Blast Furnace. Identify the oxidising agent in this reaction.

*Equation* ......................................................................................................

*Oxidising agent* ............................................................................................

**(2)**

**(Total 10 marks)**

**Q5.**          The extraction of metals involves redox reactions.

(a)     In terms of electrons, state what happens in a redox reaction.

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**(1)**

(b)     Titanium is extracted from titanium(IV) oxide in a two-step batch process.

(i)      Write an equation for the first step in this process in which titanium(IV) oxide is converted into titanium(IV) chloride. Identify the oxidising and reducing agents in this step.

*Equation* .............................................................................................

*Oxidising agent* ...................................................................................

*Reducing agent* ...................................................................................

(ii)     Write an equation for the second step in this process in which titanium(IV) chloride is converted into titanium metal. State two important conditions for this step and in each case explain why the conditions are necessary.

*Equation* ..............................................................................................

*Condition 1* ..........................................................................................

*Explanation .*........................................................................................

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*Condition 2* ..........................................................................................

*Explanation* ..........................................................................................

.............................................................................................................

**(10)**

(c)     Give the major reason why recycling aluminium is economically viable.

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**(1)**

**(Total 12 marks)**

**Q6.**          Chlorine and bromine are both oxidising agents.

(a)     Define an *oxidising agent* in terms of electrons.

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**(1)**

(b)     In aqueous solution, bromine oxidises sulphur dioxide, SO2, to sulphate ions, 

(i)      Deduce the oxidation state of sulphur in SO2 and in 

*SO2*  .....................................................................................................

 ...................................................................................................

(ii)     Deduce a half-equation for the reduction of bromine in aqueous solution.

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(iii)     Deduce a half-equation for the oxidation of SO2 in aqueous solution forming
 and H+ ions.

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(iv)    Use these two half-equations to construct an overall equation for the reaction between aqueous bromine and sulphur dioxide.

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**(5)**

(c)     Write an equation for the reaction of chlorine with water. Below each of the chlorine-containing products in your equation, write the oxidation state of chlorine in that product.

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**(3)**

(d)     Give a reason why chlorine is not formed when solid potassium chloride reacts with concentrated sulphuric acid.

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**(1)**

(e)     Write an equation for the reaction between solid potassium chloride and concentrated sulphuric acid.

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**(1)**

(f)      Solid potassium bromide undergoes a redox reaction with concentrated sulphuric acid.

(i)      Give the oxidation product formed from potassium bromide.

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(ii)     Give the reduction product formed from sulphuric acid.

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**(2)**

**(Total 13 marks)**

**Q7.**          (a)     By referring to electrons, explain the meaning of the term *oxidising agent*.

......................................................................................................................

**(1)**

(b)     For the element **X** in the ionic compound **MX**, explain the meaning of the term *oxidation state*.

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**(1)**

(c)     Complete the table below by deducing the oxidation state of each of the stated elements in the given ion or compound.

|  |  |
| --- | --- |
|   | Oxidation state |
| Carbon               in CO |   |
| Phosphorus       in PCl |   |
| Nitrogen             in Mg3N2 |   |

**(3)**

(d)     In acidified aqueous solution, nitrate ions, NO, react with copper metal forming nitrogen monoxide, NO, and copper(II) ions.

(i)      Write a half-equation for the oxidation of copper to copper(II) ions.

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(ii)     Write a half-equation for the reduction, in an acidified solution, of nitrate ions to nitrogen monoxide.

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(iii)     Write an overall equation for this reaction.

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**(3)**

**(Total 8 marks)**

**Q8.**          At high temperatures, nitrogen is oxidised by oxygen to form nitrogen monoxide in a reversible reaction as shown in the equation below.

N2(g)  + O2(g)  2NO(g)        ∆*H*~~ο~~   =   +180 kJ mol–1

(a)     In terms of electrons, give the meaning of the term *oxidation*.

......................................................................................................................

**(1)**

(b)     State and explain the effect of an increase in pressure, and the effect of an increase in temperature, on the yield of nitrogen monoxide in the above equilibrium.

*Effect of an increase in pressure on the yield* .............................................

*Explanation* ..................................................................................................

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*Effect of an increase in temperature on the yield* ........................................

*Explanation* ..................................................................................................

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**(6)**

(c)     Nitrogen monoxide, NO, is formed when silver metal reduces nitrate ions, NO in acid solution.

(i)      Deduce the oxidation state of nitrogen in NO and in NO

NO.......................................................................................................

NO....................................................................................................

(ii)     Write a half-equation for the reduction of NOions in acid solution to form nitrogen monoxide and water.

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(iii)     Write a half-equation for the oxidation of silver metal to Ag+(aq) ions.

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(iv)    Hence, deduce an overall equation for the reaction between silver metal and nitrate ions in acid solution.

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**(5)**

**(Total 12 marks)**

**Q9.**          Oxidation and reduction can de defined in terms of electron transfer.

(a)     Define the term *reduction* in terms of electrons.

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**(1)**

(b)     The oxide of nitrogen formed when copper reacts with nitric acid depends upon the concentration and the temperature of the acid. The reaction of copper with cold, dilute acid produces NO as indicated by the following equation.

3Cu + 8H+ +  → 3Cu2+ + 4H2O + 2NO

In warm, concentrated acid, NO2 is formed.

Oxidation states can be used to understand electron transfer in these reactions.

(i)      Give the oxidation states of nitrogen in , NO and NO

*Oxidation state in * ......................................................................

*Oxidation state in NO2* ........................................................................

*Oxidation state in NO* ..........................................................................

(ii)     Identify, as oxidation or reduction, the formation of NO2 from  ions in the presence of H+ ions. Deduce the half-equation for the reaction.

*NO from * .....................................................................................

*Half-equation .;*.....................................................................................

(iii)     Deduce the half-equation for the formation of NO2 from  ions in the presence of H+ ions.

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(iv)    Deduce the overall equation for the reaction of copper with  ions and H+ ions to produce Cu2+ ions, NO2 and water.

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**(8)**

**(Total 9 marks)**

**Q10.**          In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

2KBr + MnO2 + 2H2SO4 → MnSO4 + K2SO4 + 2H2O + Br2

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a)     Write a half-equation for the conversion of MnO2 in acid solution into Mn2+ ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

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**(3)**

(b)     Write an equation for Extraction Process **2** and an equation for Extraction Process **3**.
Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

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**(5)**

(c)     Bromine has been used for more than 70 years to treat the water in swimming pools.
The following equilibrium is established when bromine is added to water.

Br2   +   H2O      HBrO + HBr

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

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**(4)**

**(Total 12 marks)**

**Q11.**          Hydrogen–oxygen fuel cells can operate in acidic or in alkaline conditions but commercial cells use porous platinum electrodes in contact with concentrated aqueous potassium hydroxide. The table below shows some standard electrode potentials measured in acidic and in alkaline conditions.

|  |  |
| --- | --- |
| **Half-equation** | ***E*~~ο~~/V** |
|   O2(g) + 4H+(aq) + 4e–  →      2H2O(l) | +1.23 |
|   O2(g) + 2H2O(l) + 4e–   →      4OH–(aq) | +0.40 |
| 2H+(aq) + 2e–   →      H2(g) | 0.00 |
| 2H2O(l) + 2e–   →      2OH–(aq) + H2(g) | – 0.83 |

(a)     State why the electrode potential for the standard hydrogen electrode is equal to 0.00V.

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**(1)**

(b)     Use data from the table to calculate the e.m.f. of a hydrogen–oxygen fuel cell operating in alkaline conditions.

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**(1)**

(c)     Write the conventional representation for an alkaline hydrogen–oxygen fuel cell.

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**(2)**

(d)     Use the appropriate half-equations to construct an overall equation for the reaction that occurs when an alkaline hydrogen–oxygen fuel cell operates. Show your working.

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**(2)**

(e)     Give **one** reason, other than cost, why the platinum electrodes are made by coating a porous ceramic material with platinum rather than by using platinum rods.

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**(1)**

(f)      Suggest why the e.m.f. of a hydrogen–oxygen fuel cell, operating in acidic conditions, is exactly the same as that of an alkaline fuel cell.

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**(1)**

(g)     Other than its lack of pollution, state briefly the main advantage of a fuel cell over a re-chargeable cell such as the nickel–cadmium cell when used to provide power for an electric motor that propels a vehicle.

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**(1)**

(h)     Hydrogen–oxygen fuel cells are sometimes regarded as a source of energy that is carbon neutral. Give **one** reason why this may **not** be true.

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**(1)**

**(Total 10 marks)**

**Q12.**          Nickel–cadmium cells are used to power electrical equipment such as drills and shavers.
The electrode reactions are shown below.

                              NiO(OH) + H2O + e–  →  Ni(OH)2 + OH–       *E*~~ο~~= +0.52 V

                                       Cd(OH)2 + 2e–  →  Cd + 2OH–             *E*~~ο~~= –0.88 V

(a)     Calculate the e.m.f. of a nickel–cadmium cell.

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**(1)**

(b)     Deduce an overall equation for the reaction that occurs in the cell when it is used.

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**(2)**

(c)     Identify the oxidising agent in the overall cell reaction and give the oxidation state of the metal in this oxidising agent.

Oxidising agent ............................................................................................

Oxidation state .............................................................................................

**(2)**

**(Total 5 marks)**

**Q13.**          Nitric acid is manufactured from ammonia in a process that involves several stages.

(a)     In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

4NH3(g) + 5O2(g)  4NO(g) + 6H2O(g)              ∆*H* = –905 kJ mol–1

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

(i)      In terms of redox, state what happens to the ammonia in the forward reaction.

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**(1)**

(ii)     Suggest a reason why the catalyst must be hot.

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**(1)**

(iii)     Suggest a reason why the catalyst remains hot during the reaction.

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**(1)**

(iv)    State how a catalyst increases the rate of a reaction.

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**(2)**

(b)     In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

2NO(g) + O2(g)  2NO2(g)                  ∆*H* = –113 kJ mol–1

Explain why the equilibrium mixture is cooled during this stage of the process.

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**(2)**

(c)     In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

2NO2(g) + H2O(l) → H+(aq) + NO3–(aq) + HNO2(aq)

Give the oxidation state of nitrogen in each of the following.

NO2 ...............................................................................................................

NO3– …...........................................................................................................

HNO2 .............................................................................................................

**(3)**

**(Total 10 marks)**

**Q14.**          Sulfuric acid is an important chemical in many industrial and laboratory reactions.
Consider the following three reactions involving sulfuric acid.

Reaction **1**                    Mg(OH)2 + H2SO4 → MgSO4 + 2H2O

Reaction **2**                    The reaction of solid sodium bromide with concentrated
sulfuric acid

Reaction **3**                    H2C=CH2 + H2O  CH3CH2OH

(a)     Give a use for magnesium hydroxide in medicine.

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**(1)**

(b)     Sulfuric acid behaves as an oxidising agent in Reaction **2**.

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

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**(1)**

(ii)     Give the formula of the oxidation product that is formed from sodium bromide in Reaction **2**.

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**(1)**

(iii)     Deduce the half-equation for the reduction of H2SO4 to SO2 in Reaction **2**.

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**(1)**

(c)     The formation of ethanol in Reaction **3** uses concentrated sulfuric acid and proceeds in two stages according to the following equations.

Stage **1**                    H2C=CH2 + H2SO4 → CH3CH2OSO2OH

Stage **2**                    CH3CH2OSO2OH + H2O → CH3CH2OH + H2SO4

(i)      State the overall role of sulfuric acid in Reaction **3**.

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**(1)**

(ii)     Outline a mechanism for Stage **1** of this reaction.

**(4)**

(iii)     State the class of alcohols to which ethanol belongs.

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**(1)**

(iv)    Draw the displayed formula of the carboxylic acid formed when ethanol is oxidised by an excess of acidified potassium dichromate(VI) solution.

**(1)**

**(Total 11 marks)**

**Q15.**          Sulfuric acid is made from SO3 which can be manufactured in a series of stages from iron(II) disulfide (FeS2), found in the mineral iron pyrites.

(a)     In the first stage, FeS2 is roasted in air to form iron(III) oxide and sulfur dioxide.

(i)      Balance the following equation for this reaction.

..........FeS2 + ..........O2 → ..........Fe2O3 + ..........SO2

**(1)**

(ii)     Deduce the oxidation state of sulfur in each of the following compounds.

SO2 .....................................................................................................

FeS2.....................................................................................................

**(2)**

(b)     In the second stage of the manufacture of sulfuric acid, sulfur dioxide reacts with oxygen. The equation for the equilibrium that is established is shown below.

SO2(g)  +  O2(g)    SO3(g)        *ΔH* = –98 kJ mol–1

State and explain the effect of an increase in temperature on the equilibrium yield of SO3

Effect of increase in temperature on yield ..................................................

Explanation …..............................................................................................

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**(3)**

(c)     In the extraction of iron, carbon monoxide reacts with iron(III) oxide. Write an equation for this reaction and state the role of the carbon monoxide.

Equation ......................................................................................................

Role of the carbon monoxide .......................................................................

**(2)**

**(Total 8 marks)**

**Q16.**          Reactions that involve oxidation and reduction are used in a number of important industrial processes.

(a)     Iodine can be extracted from seaweed by the oxidation of iodide ions.
In this extraction, seaweed is heated with MnO2 and concentrated sulfuric acid.

(i)      Give the oxidation state of manganese in MnO2

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**(1)**

(ii)     Write a half-equation for the reaction of MnO2 in acid to form Mn2+ ions and water as the only products.

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**(1)**

(iii)     In terms of electrons, state what happens to the iodide ions when they are oxidised.

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**(1)**

(b)     Chlorine is used in water treatment. When chlorine is added to cold water it reacts to form the acids HCl and HClO
The following equilibrium is established.

Cl2(aq) + H2O(I) H+(aq) + Cl–(aq) + HClO(aq)

(i)      Give the oxidation state of chlorine in Cl2 and in HClO

Cl2 …....................................................................................................

HClO ...................................................................................................

**(2)**

(ii)     Deduce what happens to this equilibrium as the HClO reacts with bacteria in the water supply. Explain your answer.

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**(2)**

(c)     Concentrated sulfuric acid is reduced when it reacts with solid potassium bromide.
Concentrated sulfuric acid is **not** reduced when it reacts with solid potassium chloride.

(i)      Write the two half-equations for the following redox reaction.

2H+ + 2Br– + H2SO4  Br2 + SO2 + 2H2O

Half-equation 1

.............................................................................................................

Half-equation 2

.............................................................................................................

**(2)**

(ii)     Write an equation for the reaction of solid potassium chloride with concentrated sulfuric acid.

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**(1)**

(iii)     Explain why chloride ions are weaker reducing agents than bromide ions.

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**(2)**

**(Total 12 marks)**

**Q17.**          A sample of nitrogen dioxide gas (NO2) was prepared by the reaction of copper with concentrated nitric acid.

(a)     (i)      Balance the equation for the reaction of copper with concentrated nitric acid.

Cu + ........ HNO3 → Cu(NO3)2 + ........ NO2 + ........ H2O

**(1)**

(ii)     Give the oxidation state of nitrogen in each of the following compounds.

HNO3 ........................................................

NO2 ..........................................................

**(2)**

(iii)     Deduce the half-equation for the conversion of HNO3 into NO2 in this reaction.

.............................................................................................................

**(1)**

(b)     The following equilibrium is established between colourless dinitrogen tetraoxide gas (N2O4) and dark brown nitrogen dioxide gas.

N2O4(g)  2NO2(g)               Δ*H* = 58 kJ mol–1

(i)      Give two features of a reaction at equilibrium.

Feature 1 ............................................................................................

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Feature 2 ............................................................................................

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**(2)**

(ii)     Use Le Chatelier’s principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

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**(2)**

(iii)     Use Le Chatelier’s principle to explain why the amount of NO2 decreases when the pressure is increased at constant temperature.

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**(2)**

**(Total 10 marks)**

**Q18.**          (a)     Give the **formula** of a Group 2 metal hydroxide used in agriculture.

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**(1)**

(b)     Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

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**(1)**

(c)     Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.

Give the **formula** of **X**.

.....................................................................................................................

**(1)**

(d)     Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

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**(1)**

(e)     Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.

Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product ......................................................

Formula of the oxidation product ................................................................

**(2)**

(f)      Draw the structure of each of the following organic compounds.

(i)      The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

**(1)**

(ii)     The alcohol that is a position isomer of butan-2-ol.

**(1)**

(iii)     The hydrocarbon that has a peak, due to its molecular ion, at *m/z* = 44 in its mass spectrum.

**(1)**

(iv)    The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

**(1)**

**(Total 10 marks)**

**Q19.**Iodine reacts with concentrated nitric acid to produce nitrogen dioxide (NO2).

(a)     (i)      Give the oxidation state of iodine in each of the following.

I2 .......................................................................

HIO3..................................................................

**(2)**

(ii)     Complete the balancing of the following equation.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| l2 | + | 10HNO3 |  | ..........HIO3 | + | ..........NO2 | + | ..........H2O |

**(1)**

(b)     In industry, iodine is produced from the NalO3 that remains after sodium nitrate has been crystallised from the mineral Chile saltpetre.
The final stage involves the reaction between NalO3 and Nal in acidic solution.
Half-equations for the redox processes are given below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IO3– | + | 5e– | + | 6H+ |  | 3H2O | + | l2 |
|   |   |   |   |     l – |  | l2 | + | e– |

Use these half-equations to deduce an overall ionic equation for the production of iodine by this process. Identify the oxidising agent.

Overall ionic equation

The oxidising agent .......................................................................................

**(2)**

(c)     When concentrated sulfuric acid is added to potassium iodide, solid sulfur and a black solid are formed.

(i)      Identify the black solid.

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**(1)**

(ii)     Deduce the half-equation for the formation of sulfur from concentrated sulfuric acid.

...............................................................................................................

**(1)**

(d)     When iodide ions react with concentrated sulfuric acid in a different redox reaction, the oxidation state of sulfur changes from +6 to –2. The reduction product of this reaction is a poisonous gas that has an unpleasant smell.
Identify this gas.

........................................................................................................................

**(1)**

(e)     A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

(ii)     Write the **simplest ionic** equation for the formation of the yellow precipitate.

...............................................................................................................

**(1)**

(ii)     State what is observed when concentrated ammonia solution is added to this precipitate.

...............................................................................................................

...............................................................................................................

**(1)**

(iii)    State why the silver nitrate is acidified when testing for iodide ions.

...............................................................................................................

...............................................................................................................

**(1)**

(f)     Consider the following reaction in which iodide ions behave as reducing agents.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cl2(aq) | + | 2I–(aq) |  | I2(aq) | + | 2Cl–(aq) |

(i)      In terms of electrons, state the meaning of the term *reducing agent*.

...............................................................................................................

...............................................................................................................

**(1)**

(ii)     Write a half-equation for the conversion of chlorine into chloride ions.

...............................................................................................................

**(1)**

(iii)    Suggest why iodide ions are stronger reducing agents than chloride ions.

...............................................................................................................

...............................................................................................................

...............................................................................................................

...............................................................................................................

*(Extra space)* ........................................................................................

...............................................................................................................

**(2)**

**(Total 15 marks)**

**Q20.**The price of copper is increasing as supplies of high-grade ores start to run out.
The mineral covellite (CuS), found in low-grade ores, is a possible future source of copper.

(a)     When copper is extracted from covellite, a reaction occurs between copper(II) sulfide and nitric acid to form a dilute solution of copper(II) sulfate.

(i)      Balance the equation for this reaction.

   3CuS(s)   +    .......HNO3(aq)       ........CuSO4(aq)   +    .......NO(g)   +  ...H2O(I)

**(1)**

(ii)     Give the oxidation state of nitrogen in each of the following.

HNO3..............................................

NO .................................................

**(2)**

(iii)    Deduce the redox half-equation for the reduction of the nitrate ion in acidified solution to form nitrogen monoxide and water.

...............................................................................................................

**(1)**

(iv)    Deduce the redox half-equation for the oxidation of the sulfide ion in aqueous solution to form the sulfate ion and H+(aq) ions.

...............................................................................................................

**(1)**

(b)     Use your knowledge of metal reactivity to state and explain a low-cost method for the extraction of copper from a dilute aqueous solution of copper(II) sulfate.
Write the **simplest ionic** equation for the reaction that occurs during this extraction process.

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

Simplest ionic equation

........................................................................................................................

**(4)**

**(Total 9 marks)**

**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)     I2 **(1)**

**4**

(b)     (i)      Cl2 + 2e– → 2Cl– **(1)**

(ii)     SO2 + 2H2O → SO42– + 4H+ + 2e– **(1)**

(iii)     SO2 + 2H2O + Cl2 → SO42– + 2Cl– + 4H+ **(1)** or H2SO4 + 2HCl etc

*Ignore state symbols in equation*

*Allow multiples of all equations*

**3**

**[7]**

**M2.**          (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)      PbO2 + 4H+ +2e– → Pb2+ + 2H2O **(1)**

(ii)     2Cl– → Cl2 +2e(–) **(1)**

(iii)     PbO2 + 4H+ +2Cl– → Pb2+ + Cl2 + 2H2O **(1)**

*Or molecular*

**3**

**[8]**

**M3.**          (a)     (i)      H2O2 + 2H+ + 2e– → 2H2O **(1)**

(ii)     2I– → I2 +2e– **(1)**

(iii)     H2O2 + 2H+ + 2I– → I2 + 2H2O **(1)**

**3**

(b)     (i)      I2 + 2S2O32–→ 2I– + 2S4O62–Correct formula of reactants and products **(1)**Balanced **(1)**

*Allow Na+ ions etc*

(ii)     moles thiosulphate =  × 0.120 = 0.00234

moles iodine =  **(1)** = 0.00117

moles iodine in 1000 cm3 = 0.00117 ×  = 0.0468 **(1)**

*Allow 0.0466 to 0.047(0)*

*Allow conseq. on wrong equation*

*If use 3:1 moles I2 = moles thio /3* ***(1)*** *= 0.000780
moles I in 1000 cm3 = 0.000780 × 40 = 0.0312* ***(1)****Allow 0.031(0) – 0.0314*

**5**

(c)     (i)      Cl2 + 2e– → 2Cl– **(1)**

(ii)     +1 **(1)**

*Allow 1, 1+, Cl+*

(iii)     Cl2 + 2H2O → 2HClO + 2H+ +2e– **(1)**

(iv)    kill bacteria / germs / microorganisms / bugs

*allow sterilise, disinfect
Not allow purify, safe to drink*

**4**

**[12]**

**M4.**          (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*: SO2 **(1)** (*or SVI, not sulphur*)

(ii)     SO2 + 2H2O → SO42– + 4H+ + 2e– **(1)** (*or H2SO4 + 2H+ + 2e–*)

*allow e i.e. no charge
penalise E– once only
allow –e– on LHS*

**3**

(c)     (i)      Fe2+ → Fe3+ + e– **(1)**

(ii)     5 **(1**) (*or V or +5*)

(iii)     ClO3– + 6H+ + 6e– → Cl– + 3H2O **(1)**

(iv)    ClO3– + 6H+ + 6Fe2+ → Cl– + 3H2O +6Fe3+ **(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]**

**M5.**          (a)     electrons transferred **(1)**OR some lose e–, some gain e–s
OR oxidation is loss of e–OR reduction is gain of e–

**1**

(b)     (i)      *Equation*: TiO2 + 2C + 2Cl2 → TiCl4 + 2CO balance **(1)**               or TiO2 + C + 2Cl2 → TiCl4 + CO2,

*C + Cl2* ***(1)****balance* ***(1)***

*Oxidising agent*: Cl2 **(1)**

*Con = 0 marks if more than (species)*

*Reducing agent*: C **(1)**

*allow coke, not coal*

(ii)     *Equation*: TiCl4 + 4Na / 2Mg → Ti + 4NaCl / 2MgCl2

*Na/Mg* ***(1)****Balance* ***(1)***

*Condition 1*: high temp **(1)** (500 – 1000)

*Explanation*: to speed up reaction **(1)** OR otherwise too slow OR makes
 more reactants with E>Ea

*Condition 2*: Argon **(1)**

*NOT inert atmosphere but mark*

Explanation: prevents oxidation of Mg / Na / Ti **(1)**OR prevents contamination of Ti with O/N
OR prevents H2O reacting with TiCl4 / Na / Mg

**10**

(c)     electrolysis / electricity is expensive **(1)**OR large energy cost to reduce Al2O3

**1**

**[12]**

**M6.**          (a)     Gains electrons (or removes electrons)

**1**

(b)     (i)      +4

**1**

+6

**1**

(ii)     Br2 + 2e– → 2Br–

**1**

(iii)     SO2 + 2H2O → 4H+ +  + 2e–

**1**

(iv)    Br2 + SO2 + 2H2O → 2Br– + 4H+ + 

**1**

(c)     Cl2 + H2O → 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 + H2SO4 → HCl + KHSO4

*(Allow 2KCl + H2SO4 → 2HCl + K2SO4)*

**1**

(f)      (i)      Bromine

**1**

(ii)     Sulphur dioxide

**1**

**[13]**

**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– → Cu2+ + 2e–

**1**

(ii)     

**1**

(iii)     

**1**

**[8]**

**M8.**          (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)     NO3– + 4H+ + 3e– → NO +2H2O

**1**

(iii)     Ag → Ag+ + e–

**1**

(iv)    NO3– + 4H+ + 3Ag → NO + 2H2O + 3Ag+

**1**

**[12]**

**M9.**          (a)     Gain of electrons

**1**

(b)     (i)      (+)5 or V or N5+

**1**

(+)4 or IV or N4+

**1**

(+)2 or II or N2+

**1**

(ii)     Reduction

**1**

         4H+ + NO3– + 3e(–) → NO + 2H2O

**1**

(iii)     2H+ + NO3– + e(–) → NO2 + H2O

**1**

(iv)    Cu + 4H+ + 2 NO3– → Cu2+ + 2H2O + 2NO2

         species

**1**

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

**1**

**[9]**

**M10.**          (a)     **M1**    MnO2 + 4H+ + 2e– → Mn2+ + 2H2O

**1**

*OR multiples*

**M2**    An oxidising agent is an electron acceptor OR
receives / accepts / gains electrons

*Ignore state symbols*

*M2 NOT an “electron pair acceptor”*

**1**

**M3**    MnO2 is the oxidising agent

*Ignore “takes electrons” or “takes away electrons”*

**1**

(b)     **M1**    Formation of SO2 and Br2 (could be in an equation)

**1**

**M2**    Balanced equation
**Several possible equations
2**KBr + **3**H2SO4 → **2**KHSO4 + Br2 + SO2 + **2**H2O
**OR
2**KBr + 2H2SO4 → K2SO4 + Br2 + SO2 + **2**H2O

**1**

**M3**    **2**KBr + Cl2 → **2**KCl + Br2

*M2 Could be ionic equation with or without K+****2****Br– +* ***6****H+ +* ***3****SO42– → Br2 +* ***2****HSO4– + SO2 +* ***2****H2O
(****3****H2SO4)*

***2****Br– +* ***4****H+ + SO42– → Br2 + SO2 +* ***2****H2O
(****2****HBr + H2SO4)*

*Accept HBr and H2SO4 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+****2****Br– + Cl2 →* ***2****Cl– + Br2*

**1**

**M4**    % atom economy of bromine

          = 

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

*M4 Ignore greater number of significant figures*

**1**

**M5**    One from:

•        High atom economy

•        Less waste products

•        Cl2 is available on a large-scale

•        No SO2 produced

•        Does not use concentrated H2SO4

•        (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]**

**M11.**          (a)     By definition

*allow ‘set to this value’*

**1**

(b)     1.23 V

*Allow + or –*

**1**

(c)     Pt|H2(g)|OH–(aq),H2O(l)||O2(g)|H2O(l),OH–(aq)|Pt

*H2O not essential, allow reverse order*

Correct but with Pt missing

**1**

Includes Pt with correct representation

**1**

(d)     Uses O2 + 2H2O + 4e– → 4OH–

And (2×) 2OH– + H2 → 2H2O + 2e–

**1**

2H2 + O2 → 2H2O

**1**

(e)     Increases the surface area (so reaction faster)

**1**

(f)      Overall reaction is the same (2H2 + O2 → 2H2O)

*Or shows e.m.f. is the same*

**1**

(g)     Hydrogen and oxygen supplied continuously

***OR***

Can be operated without stopping to recharge

*Or can be refuelled quickly
Allow any one mark*

**1**

(h)     Hydrogen may need to be made using an energy source that is
not ‘carbon neutral’

**1**

**[10]**

**M12.**          (a)     1.4 V

*Allow + or –*

**1**

(b)     2NiO(OH) + 2H2O + Cd → 2Ni(OH)2 + Cd(OH)2

*Mark for species, Deduct a mark for additional species
(eg OH–) but allow balance mark*

**1**

Balanced

*If equation is reversed CE=0*

**1**

(c)     NiO(OH) or Ni(III) or nickel

**1**

+3

*Allow conseq on wrong species*

**1**

**[5]**

**M13.**          (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 NO2 is greater

•        more NO2 is formed

•        equilibrium shifts (left) to right

•        (equilibrium) favours the forward reaction

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

**2**

(c)     NO2           (+) 4

NO3-        (+) 5

HNO2         (+) 3

**3**

**[10]**

**M14.**          (a)     to neutralise stomach acidity

***OR***

as an antacid

OR

eases indigestion/heartburn

*Ignore milk of magnesia*

*Credit suitable reference to indigestion/laxative/relief of constipation*

**1**

(b)     (i)      an electron acceptor

***OR***

(readily) gains/accepts/receives electron(s)

*NOT an electron pair acceptor*

*Ignore removes/takes away/attracts electrons*

**1**

(ii)     Br2 ONLY

*Ignore “bromine”*

*Apply the list principle*

**1**

(iii)     H2SO4 + **2**H+ + **2**e–  SO2 + **2**H2O

***OR***

SO42– + 4H+ + **2**e–  SO2 + **2**H2O

*Ignore state symbols*

*Ignore absence of negative charge on electron*

*Or multiples of equations*

**1**

(c)     (i)      (acid) catalyst

***OR***

catalyses (the reaction)

***OR***

to speed up the reaction/increase the rate (of reaction)

*Ignore “provides H+ ions”*

*Accept phonetic spelling*

**1**

(ii)



**M1** must show an arrow from the double bond towards the
H atom of the H – O bond OR HO on a compound with
molecular formula for H2SO4 (or accept H2SO3 here)
M1 could be to an H+ ion and M2 an independent
O – H bond break on a compound with molecular
formula for H2SO4 or H2SO3

**M2** must show the breaking of the O ─ H bond.

**M3** must show an arrow from the lone pair of electrons on the
correct oxygen of the negatively charged ion towards the
positively charged carbon atom.

**M4** is for the structure of the carbocation.

**NB The arrows here are double-headed**

*M2 Ignore partial charges unless wrong*

*M3 NOT HSO4–*

*For M3, credit as shown or ―:OSO3H ONLY with the negative charge anywhere on this ion*

*OR correctly drawn out with the negative charge placed correctly on oxygen*

*Max 3 marks for wrong reactant*

*Do not penalise the use of “sticks”*

**4**

(iii)     Primary ***OR*** 1° (alcohol)

**1**

(iv)    Displayed formula for ethanoic acid, CH3COOH



*All the bonds must be drawn out and this includes the O ─ H bond*

*Ignore bond angles.*

**1**

**[11]**

**M15.**          (a)     (i)      **4**FeS2 + **11**O2  **2**Fe2O3 + **8**SO2

**2**             **5**½                      **(1)**              **4**

*Or multiples of this equation*

**1**

(ii)     **M1**    **(+) 4**

**M2    – 1**

*Ignore working*

*M1, credit (+) IV*

*M2, credit – I*

**2**

(b)     **M1** Lower/smaller/decreases/reduced yield
***OR*** equilibrium shifts (right) to left

**M2** (Forward) reaction is exothermic OR reverse reaction is endothermic

**M3** (By Le Chatelier’s principle) equilibrium responds/shifts/moves
(R to L)
to lower the temperature
***OR*** to absorb the heat
***OR*** to cool the reaction

*If M1 is blank, mark on and credit M1 in the text.*

*If M1 is incorrect, only credit correct M2*

*Mark M2 independently – it may be above the arrow in the equation*

*For M3, not simply “to oppose the change/temperature”*

**3**

(c)     **M1** Fe2O3 + 3CO  **2**Fe + **3**CO2

*Or multiples*

*Ignore state symbols*

**M2** Reducing agent
***OR*** Reduce(s) (Fe2O3/iron(III) oxide)
***OR*** Electron donor
***OR*** to remove the oxygen (from iron(III) oxide to form CO2)
***OR*** reductant

*For M2, credit “reduction”*

**2**

**[8]**

**M16.**          (a)     (i)      MnO2 (+) 4

**1**

(ii)     MnO2 + **4**H+ + **2**e–  Mn2+ + **2**H2O

*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 lost electron(s)

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

**1**

(b)     (i)      **M1**       Cl2         0

**M2** HClO   (+) 1

**2**

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

OR    L to R

OR    to favour the forward reaction

OR    to produce more HClO

**M2**    **Consequential on correct** **M1**

          To oppose the loss of HClO

OR    replaces the HClO (that has reacted)

*for M2*

*NOT just “to oppose the change”*

**2**

(c)     (i)      The answers can be in **either order**

**M1**    **2**Br–  Br2 + **2**e–

**M2    4**H+ + SO42– + **2**e–  SO2 + **2**H2O

OR

**2**H+ + H2SO4 + **2**e–  SO2 + **2**H2O

*NOT multiples*

*Ignore state symbols*

*Credit electrons subtracted from incorrect side*

*Ignore absence of charge on e*

**2**

(ii)     KCl + H2SO4  KHSO4 + HCl

OR

**2**KCl + H2SO4  K2SO4 + **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 smaller than bromide ions OR
chloride ion electron(s) are closer 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]**

**M17.**          (a)     (i)      Cu + **4**HNO3 → Cu(NO3)2 + **2**NO2 + **2**H2O

*Or multiples*

*Ignore state symbols*

**1**

(ii)     **M1**     HNO3 (+) **5**

**M2**     NO2 (+) **4**

*Ignore working out*

*M1 Credit (V)*

*M2 Credit (IV)*

**2**

(iii)     HNO3 + H+ + e– → NO2 + H2O

OR

NO3– + 2H+ + e– → NO2 + H2O

*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** Concentration(s) (of reactants and products)
remain(s) constant / stay(s) the same / remain(s)
the same / do(es) not change

**M2** Forward rate = Reverse / backward rate

*For M1 accept [ ] for concentration*

*NOT “equal concentrations” and NOT “concentration(s) is/are 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]**

**M18.**          (a)     Ca(OH)2 OR Mg(OH)2

*Ignore name*

*Could be ionic*

**1**

(b)     NaF or sodium fluoride

OR

NaCl or sodium chloride

*Either formula or name can score*

*Do not penalise the spelling “fluoride”*

*When both formula and name are written,*

*•    penalise contradictions*

*•    if the attempt at the correct* ***formula*** *is incorrect, ignore
     it and credit* ***correct name*** *for the mark unless
     contradictory*

*•    if the attempt at the correct name is incorrect, ignore it
     and credit* ***correct formula*** *for the mark unless contradictory*

**1**

(c)     NaClO OR NaOCl

*Ignore name (even when incorrect)*

*The correct formula must be clearly identified if an equation is written*

**1**

(d)     **Br2** (ONLY)

*Only the correct formula scores;*

*penalise lower case “b”, penalise upper case “R”, penalise superscript*

*Ignore name*

*The correct formula must be clearly identified if an equation is written*

**1**

(e)     **M1** S OR S8 OR S2

**M2** I2 (ONLY)

*Ignore names*

*penalise lower case “i” for iodine,*

*penalise superscripted numbers*

*Mark independently*

*The correct formula must be clearly identified in each case if an equation is written*

**2**

(f)      (i)      CH3CH2CH=CH2

*Structure of but-1-ene. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(ii)     CH3CH2CH2CH2OH

*Structure of butan-1-ol. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(iii)     CH3CH2CH3

*Structure of propane. Ignore name*

*Ignore calculations and molecular formula*

*Credit “sticks” for C-H bonds*

*Ignore the molecular ion*

**1**

(iv)    CH3CH2Br OR C2H5Br

*Structure of bromoethane.*

*Ignore name and structure of nitrile*

*Credit “sticks” for C-H bonds*

**1**

**[10]**

**M19.**(a)      (i)     **M1     0**

**M2     (+) 5**

*Accept Roman V for M2*

**2**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (ii) | I2 | + | 10HNO3 |  | **2**HIO3 | + | **10**NO2 | + | **4**H2O |

*Accept multiples*

**1**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (b) | **M1** | IO3– | + | **6**H+ | + | **5**I – |  | **3**I2 | + | **3**H2O |

*For M1, ignore state symbols*

*Credit multiples*

*Accept 2½I2 + ½I2 as alternative to 3I2*

*Electrons must be cancelled*

**M2**    NaIO3 ***OR*** IO3– ***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*** I2

*Insist on correct name or formula*

**1**

(ii)     H2SO4   +   **6**H+   +   **6**e–      S   +   **4**H2O

*Ignore state symbols*

SO42–   +   **8**H+   +   **6**e–      S   +   **4**H2O

*Credit multiples*

*Do not penalise absence of charge on the electron*

**1**

(d)     hydrogen sulfide

***OR*** H2S

***OR*** hydrogen sulphide

**1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| (e)    (i) | Ag+ | + | I – |  | 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 white solid

*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 (an)ions that would interfere with the test

*Ignore reference to “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

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

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

**1**

(f)     (i)     An electron donor

*Penalise “electron pair donor”*

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

*Penalise “loss of electrons” alone*

*Accept “electron donator”*

**1**

(ii)     Cl2    +    **2**e–        **2**Cl–

*Ignore state symbols*

*Do not penalise absence of charge on electron*

*Credit Cl2 * ***2****Cl – –* ***2****e –*

*Credit multiples*

**1**

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

*Ignore general statements about Group VII trends or about halogen molecules or atoms. Answers must be specific*

**M1   Relative size of ions**

*CE=0 for the clip if “iodine ions / chlorine ions”* ***QoL***

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

*CE=0 for the clip if “iodide ions are bigger molecules / atoms”* ***QoL***

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

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

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

         ***OR*** converse for chloride ion

**M2   Strength of attraction for electron(s)**

*Must be comparative in both M1 and M2*

         The electron(s) lost /outer shell/level electron from (an) iodide ion(s) less
strongly held by the nucleus compared with that lost from a chloride ion

         ***OR*** converse for a chloride ion

**2**

**[15]**

**M20.**(a)     (i)      3CuS(s) + **8**HNO3(aq)   **3**CuSO4(aq) + **8**NO(g) + **4**H2O(l)

**1**

(ii)     **(+) 5
(+) 2**

**2**

(iii)    **4**H+ + NO3− + **3**e−   **2**H2O + NO

*Ignore state symbols.*

*Credit multiples of* ***this equation only****.*

*Ignore absence of charge on the electron.*

**1**

(iv)    S2− + **4**H2O   SO 42− + **8**e− + **8**H+

*Ignore state symbols.*

*Credit multiples of* ***this equation only****.*

*Ignore absence of charge on the electron.*

**1**

(b)     M1 add scrap / recycled / waste iron (or steel) 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 more reactive metal ***OR*** Fe is a better reducing agent

*Credit zinc or magnesium as an alternative to iron for* ***M2****,* ***M3*** *and* ***M4*** *only, penalising* ***M1***

M3 Cu2+ / copper ions are reduced / gain electrons
***OR*** Cu2+ + 2e−   Cu
***OR*** copper / Cu is displaced by Fe

*Ignore absence of charge on the electron.*

M4 Fe + Cu 2+   Fe 2+ + Cu ONLY

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

**4**

**[9]**