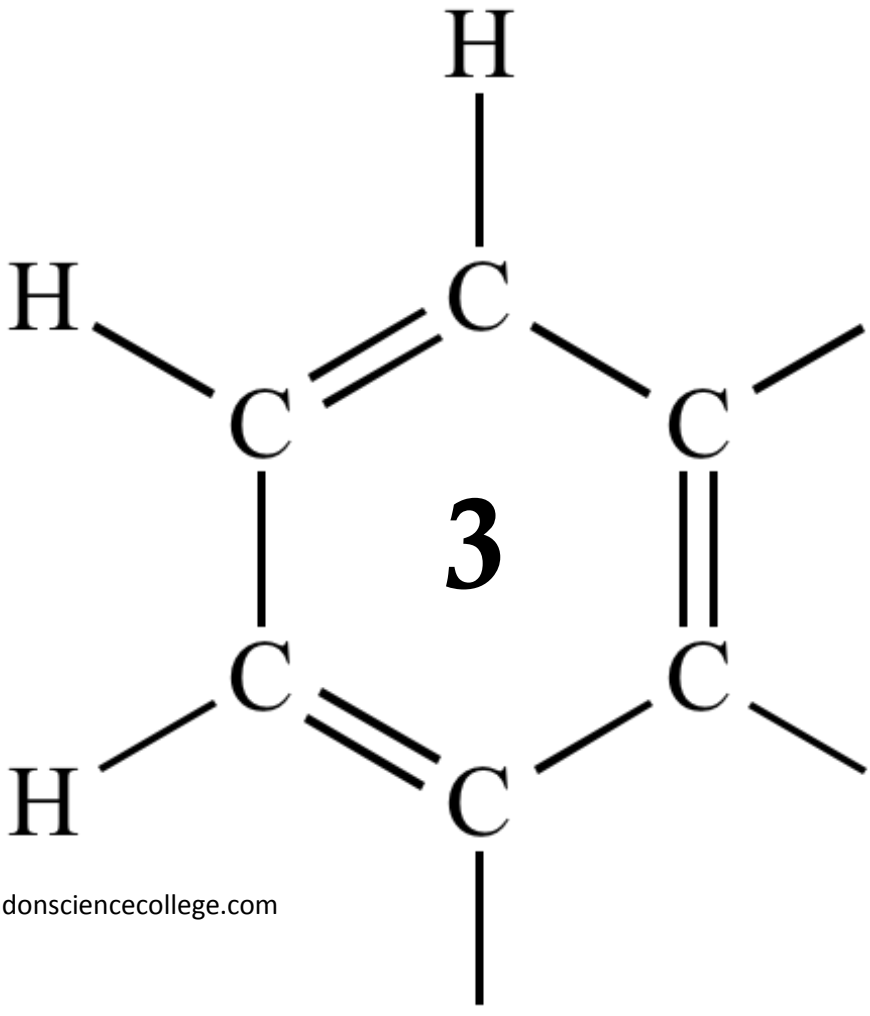
LONDON SCIENCE COLLEGE

OCR AS CHEMISTRY

MODULE 2

REDOX



1 Copper is extracted from the ore chalcopyrite ($CuFeS_2$) in a three-stage process.

(a) In the first stage of this extraction, the chalcopyrite is heated with silicon dioxide and oxygen.

(i) Balance the following equation for this first stage in which copper(I) sulfide is formed.

.....$CuFeS_2$ + ...SiO_2 + ...O_2 → Cu_2S + ...$FeSiO_3$ + ...SO_2

(1)

(ii) Give **one** environmental reason why the SO_2 gas formed in this reaction is not allowed to escape into the atmosphere.

.....

.....

(1)

(iii) State **one** use for the sulfur dioxide formed in this reaction.

.....

.....

(1)

(b) In the second stage of this extraction, the copper(I) sulfide is converted into copper(II) oxide. This occurs by roasting the sulfide with oxygen at high temperature.
Write an equation for this reaction.

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(1)

(c) In the third stage of this extraction, copper(II) oxide is reduced to copper by its reaction with carbon. Write an equation for this reaction.

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(1)

(d) Scrap iron can be used to extract copper from dilute aqueous solutions containing copper(II) ions.

(i) Explain why this is a low-cost method of extracting copper.

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(1)

(ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

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(1)

(Total 7 marks)

2 This question is about the extraction of metals.

(a) Coke is mainly carbon and is a raw material used in the extraction of iron from iron(III) oxide.

(i) Write an equation for the formation of carbon monoxide from carbon.

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(1)

(ii) Write an equation for the reduction of iron(III) oxide to iron by carbon monoxide.

.....

(1)

(iii) The Earth's resources of iron(III) oxide are very large and commercial ores have a high iron content. Give **one** economic and **one** environmental reason for recycling scrap iron and steel.

Economic reason .....

.....

Environmental reason .....

.....

(2)

(b) Pure titanium is extracted by the reduction of titanium(IV) chloride, but not by the direct reduction of titanium(IV) oxide using carbon.

(i) Write an equation for the conversion of titanium(IV) oxide into titanium(IV) chloride.

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(2)

(ii) Write an equation for the extraction of titanium from titanium(IV) chloride.

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(2)

(iii) State why titanium is not extracted directly from titanium(IV) oxide using carbon.

.....

(1)

(c) Aluminium is extracted by the electrolysis of a molten mixture containing aluminium oxide.

(i) State why the electrolysis needs to be of a *molten* mixture.

.....

(1)

(ii) Write an equation for the reaction of oxide ions at the positive electrode during the electrolysis.

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(1)

(iii) State why the positive electrodes need frequent replacement.

.....

(1)

(iv) Give the major reason why it is less expensive to recycle aluminium than to extract it from aluminium oxide by electrolysis.

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(1)

(Total 13 marks)

3 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**

$$2KBr + MnO_2 + 2H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$$

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 MnO_2 in acid solution into Mn^{2+} 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.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

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)

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

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

.....

(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.

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

In warm, concentrated acid, NO_2 is formed.

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

(i) Give the oxidation states of nitrogen in NO_3^-, NO and NO

Oxidation state in NO_3^- .....

Oxidation state in NO_2 .....

Oxidation state in NO .....

(ii) Identify, as oxidation or reduction, the formation of NO_2 from NO_3^- ions in the presence of H^+ ions. Deduce the half-equation for the reaction.

NO from NO_3^- .....

Half-equation .;.....

(iii) Deduce the half-equation for the formation of NO_2 from NO_3^- ions in the presence of H+ ions.

.....

.....

(iv) Deduce the overall equation for the reaction of copper with NO_3^- ions and H^+ ions to produce Cu^{2+} ions, NO_2 and water.

.....

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(8)
(Total 9 marks)

5 Which one of the following is the electron arrangement of the strongest reducing agent?

A $1s^2\ 2s^2\ 2p^5$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(Total 1 mark)

6 Which one of the following is **not** a redox reaction?

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

B $SnCl_2 + HgCl_2 \rightarrow Hg + SnCl_4$

C $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$

D $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

(Total 1 mark)

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

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H^{\ominus} = +180\ kJ\ mol^{-1}$$

(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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.....

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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_3^- in acid solution.

(i) Deduce the oxidation state of nitrogen in NO and in NO_3^-

NO.....

NO_3^- .....

(ii) Write a half-equation for the reduction of NO_3^- ions in acid solution to form nitrogen monoxide and water.

.....

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

.....

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

.....

(5)
(Total 12 marks)

8 Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^{+}(s) + Ag^{+}(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass dark glass

When the photochromic glass darkens

A the Ag^{+} ion is acting as an electron donor.

B the Cu^{+} ion is acting as a reducing agent.

C the Ag^{+} ion is oxidised.

D the Cu^{+} ion is reduced.

(Total 1 mark)

9 (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*.

.....

(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_3^{2-}	
Phosphorus	in PCl_4^{+}	
Nitrogen	in Mg_3N_2	

(3)

(d) In acidified aqueous solution, nitrate ions, NO_3^{-}, 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.

.....

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

.....

(iii) Write an overall equation for this reaction.

.....

(3)
(Total 8 marks)

10 Chlorine and bromine are both oxidising agents.

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

.....

(1)

(b) In aqueous solution, bromine oxidises sulphur dioxide, SO_2, to sulphate ions, SO_4^{2-}

(i) Deduce the oxidation state of sulphur in SO_2 and in SO_4^{2-}

SO_2 .....

SO_4^{2-} .....

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

.....

(iii) Deduce a half-equation for the oxidation of SO_2 in aqueous solution forming SO_4^{2-} and H^+ ions.

.....

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

.....

(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.

.....

.....

(3)

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

.....

(1)

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

.....

(1)

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

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

.....

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

.....

(2)
(Total 13 marks)

11 In which one of the following reactions does hydrogen **not** act as a reducing agent?

A $H_2 + Ca \rightarrow CaH_2$

B $2H_2 + O_2 \rightarrow 2H_2O$

C $H_2 + CH_2{=}CH_2 \rightarrow CH_3CH_3$

C $2H_2 + CH_3COCH_3 \rightarrow CH_3CH_2CH_3 + H_2O$

(Total 1 mark)

12 Which one of the following is a redox reaction?

A $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

B $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$

C $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

D $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

(Total 1 mark)

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

.....

(1)

(b) Consider the following redox reaction.

$SO_2(aq) + 2H_2O(l) + 2Ag^+(aq) \rightarrow 2Ag(s) + SO_4^{2-}(aq) + 4H^+(aq)$

(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) Fe^{2+} ions are oxidised to Fe^{3+} ions by ClO_3^- ions in acidic conditions. The ClO_3^- ions are reduced to Cl^- ions.

(i) Write a half-equation for the oxidation of Fe^{2+} ions in this reaction.

.....

(ii) Deduce the oxidation state of chlorine in ClO_3^- ions.

.....

(iii) Write a half-equation for the reduction of ClO_3^- ions to Cl^- ions in acidic conditions.

.....

(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)

14 Which one of the following is **not** a redox reaction?

A $TiO_2 + 2Cl_2 + C \rightarrow TiCl_4 + CO_2$

B $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

C $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

D $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$

(Total 1 mark)

15 In which one of the following reactions is H_2O_2 behaving as a reducing agent?

A $H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$

B $H_2O_2 + 2[Co(NH_3)_6]^{2+} \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

C $5H_2O_2 + - 2MnO_4^- + 6H+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

D $3H_2O_2 + 2[Cr(OH)_6]^{3-} \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$

(Total 1 mark)

16 In which one of the following reactions do two H ions and one electron have to be added to the left-hand side in order to balance the equation?

A $CH_3CHO \rightarrow CH_3CH_2OH$

B $VO^{2+} \rightarrow V^{3+} + H_2O$

C $NO_3^- \rightarrow HNO_2 + H_2O$

D $HOCl \rightarrow \frac{1}{2}Cl_2 + H_2O$

(Total 1 mark)

17 Which equation does **not** involve the reduction of a transition metal compound?

A $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

B $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$

C $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$

D $TiCl_4 + 4Na \rightarrow Ti + 4NaCl$

(Total 1 mark)

18 (a) Concentrated sulphuric acid can be reduced by some solid sodium halides to H_2S

(i) Give the oxidation state of sulphur in H_2S

.....

(ii) Give **one** solid sodium halide which will reduce concentrated sulphuric acid, forming H_2S

.....

(iii) State **one** way in which the presence of H_2S could be recognised.

.....

(iv) Write a half-equation for the formation of H_2S from sulphuric acid.

.....

(4)

(b) A different solid sodium halide reacts with concentrated sulphuric acid without reduction forming a halogen-containing product **X**.

(i) Suggest an identity for **X**.

.....

(ii) Identify the solid sodium halide which produces **X**.

.....

(iii) State the role of sulphuric acid in the formation of **X**.

.....

(iv) Write an equation for the reaction with concentrated sulphuric acid in which **X** is formed.

.....

(4)
(Total 8 marks)

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

.....

(1)

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

.....

(1)

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

(i) NCl_3 .....

(ii) Mg_3N_2 .....

(iii) NH_2OH .....

(3)

(d) Lead(IV) oxide, PbO_2, reacts with concentrated hydrochloric acid to produce chlorine, lead(II) ions, Pb^{2+}, and water.

(i) Write a half-equation for the formation of Pb^{2+} and water from PbO_2 in the presence of H^+ ions.

.....

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

.....

(iii) Hence deduce an equation for the reaction which occurs when concentrated hydrochloric acid is added to lead(IV) oxide, PbO_2

.....

(3)
(Total 8 marks)

20 Which one of the following is the electronic configuration of the strongest reducing agent?

A $1s^2\ 2s^2\ 2p^5$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(Total 1 mark)

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

$$2NO + 12H^+ + 10I^- \rightarrow 2NH_4^+ + 2H_2O + 5I_2$$

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

.....

(ii) Deduce the oxidation state of nitrogen in NO and of nitrogen in NH_4^+

Oxidation state of nitrogen in NO .....

Oxidation state of nitrogen in NH_4^+ .....

(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.

.....

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

.....

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

.....

(3)
(Total 7 marks)

22 (a) Samples of solid sodium fluoride, sodium chloride, sodium bromide and sodium iodide are each warmed separately with concentrated sulphuric acid. All four compounds react with concentrated sulphuric acid but only two can reduce it.

(i) Identify the **two** halides which do **not** reduce concentrated sulphuric acid. Write an equation for the reaction which does occur with **one** of these two halides.

(ii) Identify the **two** halides which reduce concentrated sulphuric acid to sulphur dioxide. Using half-equations for the oxidation and reduction processes, deduce an overall equation for the formation of sulphur dioxide when concentrated sulphuric acid reacts with **one** of these halides.

(iii) In addition to sulphur dioxide, two further reduction products are formed when one of these two halides reacts with concentrated sulphuric acid. Identify the two reduction products and write a half-equation to show the formation of **one** of them from concentrated sulphuric acid.

(9)

(b) How would you distinguish between separate solutions of sodium chloride, sodium bromide and sodium iodide using solutions of silver nitrate and ammonia?

(6)
(Total 15 marks)

23 Which one of the following contains the metal with the lowest oxidation state?

A CrO_2F_2

B $[Cr_2O_7]^2$

C $[MnCl_6]^{2-}$

D $[Mn(CN)_6]^{3-}$

(Total 1 mark)