Digital Teachers
Digitalteachers.co.ug

O-level chemistry

General principles of extraction of metals

Occurrence of elements in nature

Elements occur in two state

1. Native or free especially less reactive, Au, Ag, Cu, Pt.
2. Combined state: generally, the reactive metals occur as oxides, sulphide, phosphates, silicates, carbonates, phosphates, chlorides and nitrates

Minerals and ores

Minerals are compound of metals which are found in the earth and in which the metals are present in combined state. Minerals have a chemical composition and structure. Ores are those minerals from which the metals can be extracted economically and conveniently. Thus, all minerals are not ores but all ores are minerals.

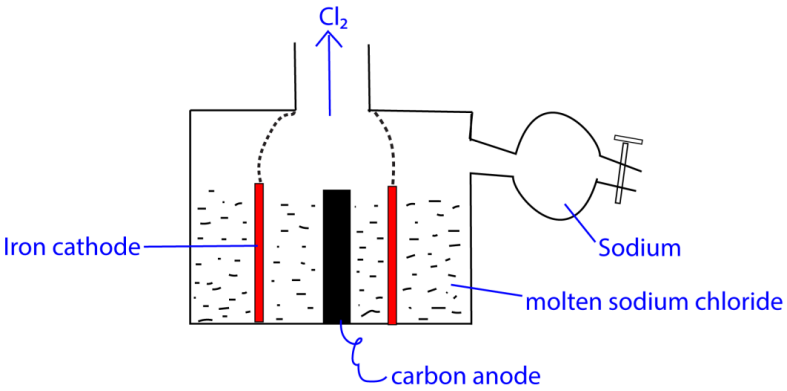
Methods of extraction of metals

The method of extraction of metals depends on metal's position in electrochemical series.

i.e. Potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, copper

Elements above carbon are extraction are extracted by electrolysis while those below carbon are extracted by reduction with carbon of carbon monoxide.

Extraction of Sodium



It is manufactured by electrolysis of fused sodium chloride in the Downs' cell) (MPt. 800^0C)

At first there were four difficulties

(i) It was expensive to keep the electrolyte over 800^0C
(ii) The molten sodium chloride was corrosive
(iii) Sodium is fairly soluble in its molten chloride at 800^0C
(iv) The vapor pressure of sodium at 800^0C is very high, about ½ atmosphere of 400mmHg.

The difficulties were all overcome by adding calcium chloride to sodium chloride to form a mixture that melts below 600^0C. It is cheaper to maintain this temperature, the mixture is non corrosive, sodium is almost insoluble and the vapor pressure is about 15mmHg.

The iron gauze cylinder between anode and cathode prevent the sodium and chlorine from mixing. Liquid sodium leaves the cell in a raised pipe high enough for the low density metal but not high enough for the higher density chloride mixture to overflow continuously into the receiver

The reactions are

At cathode: $Na^+(l) + e \rightarrow Na(l)$

Anode; $2Cl^- - 2e \rightarrow Cl_2(g)$

Sodium is collected in dry nitrogen to protect it from reacting with air.

Uses of sodium

- Molten sodium is used as a coolant in some types of nuclear reactor because of its good thermal conductivity, low melting point and its higher boiling point than that of water
- Sodium wire is used in electrical circuit for special application
- Sodium vapor lamps are used for street lighting
- Sodium cyanide is used in extraction of silver and gold

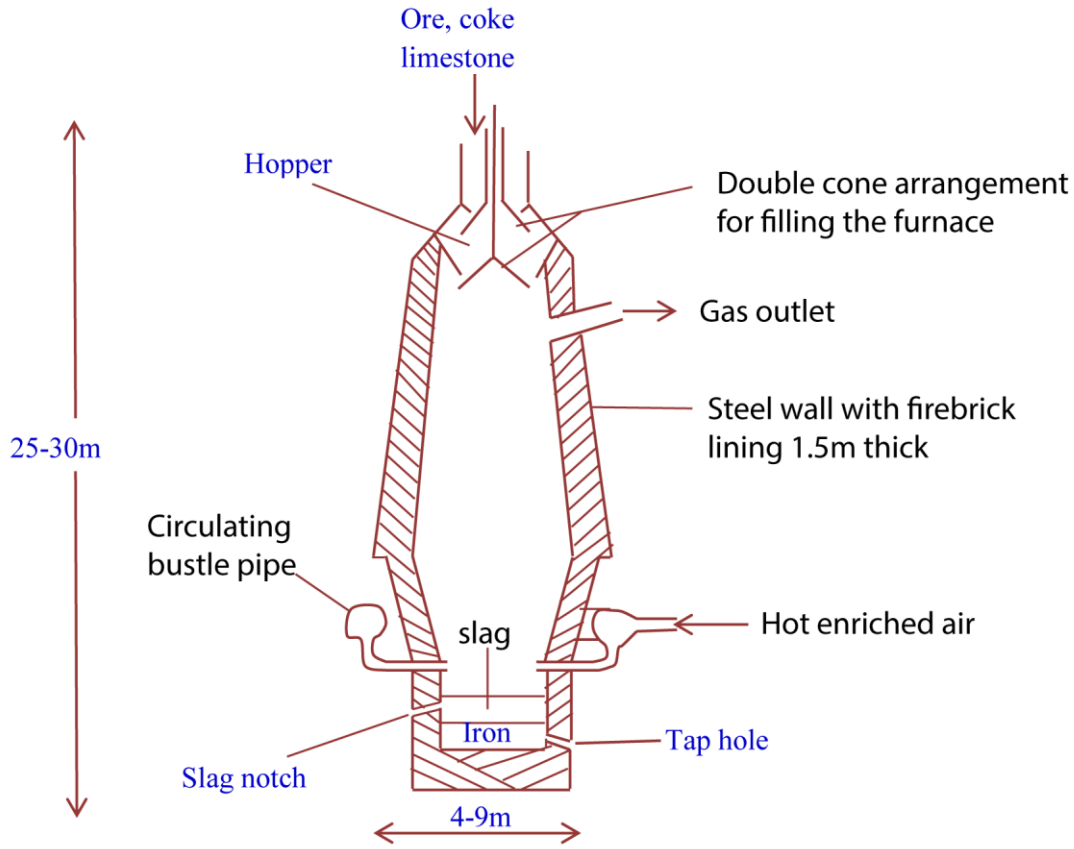
Iron and its compounds

Iron, which is the second most abundant metal occurring in the earth crust, is extracted from its oxides, haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite, $FeCO_3$. Iron pyrites, FeS_2, is not considered an important ore of iron.

The extraction of iron is carried out in a blast furnace that can vary in size between 2 and 600 metres high and up to 10 meters in diameter.

It is constructed from steel with the inner region lined with bricks. Iron ore, lime stone and coke in the correct proportions are fed into the top of the furnace through a cone and hopper arrangement. Preheated air at a temperature of about 600^0C is injected into the furnace through a number of pipes called tyères (pronounced "Tweers"). The tuyères are fed from a "bustle" pipe encircling the blast

furnace. The blast furnace is provided with two holes which are plugged with clay; molten iron is tapped from the lower one and molted slag from the upper one. The production of iron is continuous process and depending on its size, a blast furnace can be producing from 1000 to 1800 tons of iron every 24 hours.



The Blast Furnace

The energy and reducing agent required for the smelting of iron are obtained by the combustion of coke, the temperature of the charge increasing steadily as it falls through the ascending combustion gases:

$$2C\ (s) + O_2\ (g) \rightarrow 2CO\ (g)$$

At a temperature of about 700 ^{0}C the iron ore is reduced to spongy iron by the carbon monoxide.

$$Fe_2O_3\ (s) + 3CO\ (g) \leftrightarrow 2Fe\ (s) + 3CO_2\ (g)$$

The limestone decomposes at 500 ^{0}C and the calcium oxide reacts with sandy impurities to form a slag of calcium silicate. More carbon monoxide is produced by the reduction of carbon dioxide:

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

$CaO\ (s) + SiO_2\ (s) \rightarrow CaSiO_3\ (l)$

impurity slag

$C\ (s) + CO_2\ (g) \rightarrow 2CO\ (g)$

Uses of iron

In form of steel it used to make bridges, doors and window flame, cutlery and so on

Properties of iron

1. It reacts with oxygen to form iron (III) oxide.
   $2Fe\ (s) + 2O2(g) \rightarrow 2Fe_2O_3(s)$
2. It reacts with sulphur to form black iron (II) sulphide
   $Fe(s) + S(s) \rightarrow FeS(s)$
3. It reacts with chlorine to form iron (III) chloride
   $2Fe(s) + 3Cl_2\ (g) \rightarrow FeCl_3(s)$
4. It reacts with hydrogen chloride gas to form iron (II) chloride
   $Fe(s) + 2\ HCl(g) \rightarrow FeCl_2(s)$
5. Reacts reversibly with steam to form hydrogen and triirontetroxide
   $3Fe\ (s) + H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$
6. It reacts with dilute acid to liberate hydrogen
   $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$

Exercise

1. Which one of the following can be extracted from its ore by reduction method?
   A. Zn B. Al C. Ca D. Na
2. Which one of the following substances is made the anode during the extraction of sodium from molten sodium chloride?
   A. Carbon B. iron C. mercury D. Copper
3. The substance formed when iron rusts is
   A. Hydrated iron (II) oxide
   B. Anhydrous iron (II) oxide
   C. Hydrated iron (III) oxide
   D. Anhydrous iron (III) oxide
4. The suitable method of preparing anhydrous iron (II) chloride is by
   A. Passing dry chlorine over heated iron
   B. Reacting iron (II) oxide with dilute hydrochloric acid
   C. Pass dry hydrogen chloride gas over heated iron
   D. Reacting iron with dilute hydrochloric acid
5. The metal which can be extracted from its ore only by electrolysis is
   A. Zinc
   B. Copper
   C. Iron
   D. Magnesium
6. The hydroxide which turn brown when exposed to air from the list is
   A. Copper (II) hydroxide
   B. Iron (II) hydroxide
   C. Lead (II) hydroxide
   D. Iron (III) hydroxide
7. The reaction of iron and chlorine
   A. Occur at ordinary temperature
   B. Requires platinum catalyst
   C. Produces iron (II) chloride
   D. Produces (III) chloride

Section B

8. (a) carbon monoxide was passed over heated iron (II) oxide

   (i) Write equation for the reaction that took Place.
   (ii) Write equation for the reaction between the solid product in (a)(i) and dilute sulphuric acid.
   (b) Chlorine was bubbled through the product in (a)(i)

(i) State what was observed

(ii) Write equation for the reaction that took place

9. (a) Name the raw materials which are used in extraction of iron using a blast furnace (02mark)

(b) Briefly describe the reactions that lead to the formation of iron during extraction using a blast furnace. (Your answer should include equations for the reactions)

(c) state what would be observed and write equations for the reactions that would take place when the following gases are passed over heated iron

(i) dry chloride

(ii) steam

(d) Dilute hydrochloric acid was added to iron filling and a mixture warmed. Write the equation for the reaction that took place.

10. In extraction of cast iron using a blast furnace, spathic iron ore, which contain some impurities, is first roasted in air. It is then mixed with some other substance and finally introduced into the blast furnace. Cast Iron can be obtained from iron (II) carbonate ore.

(a) Name the major impurity in the iron ore (1mark)

(b)(i) Give the chemical name of spathic ore (1mark)

(ii) Write an equation for the reaction which takes place when iron (II) carbonate is roasted in air (2 ½ mark)

(c) Name the substances that are fed into the blast furnace

(i) From the top

(ii) From the bottom

(d) Outline the reactions leading to

(i) The formation of cast ion

(ii) The removal of the major impurity you have named in (a)

(e) State the major components of steel

11. (a) Name one ore of iron and write its formula (1mark)

(b) During extraction of iron ore, lime stone and coke are added into the blast furnace. Explain the roles

(i) coke (5marks)

(ii) lime stone (4marks)

(use equations to illustrate your answers)

(c) write equation for the reaction leading to iron (II) sulphate (2marks)

(d) Iron (II) sulphate was heated strongly

(i) state what is observed (1½ marks)

(ii) write equation for the reaction that took place (1½ mark)

12. Iron forms compounds in which it shows a valence of two and three

(a) state the general color of iron compounds in which iron is

(i) divalent

(ii) trivalent

(b) write the formula and name of the sulphates of iron in which iron is in (b)(i) and (ii).

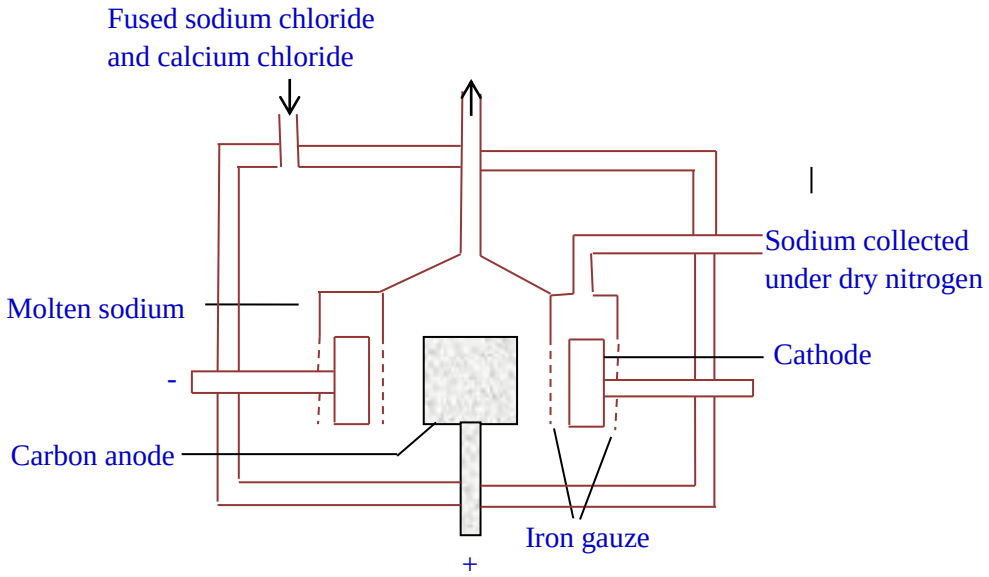
(c) (i) Name a reagent that can be used to distinguish between the sulphates in (b)(i) and (ii).

(ii) state what would be observed when the iron sulphates are reacted with the reagent in (c)(i).

(iii)Write equation for the reaction in (c)(ii).

(d) starting from iron wool, state how the anhydrous chloride of Iron (III) can be prepared and write equation to illustrate your answer. (diagram not required)

13. Sodium is manufactured by electrolysis of molten sodium chloride as shown in the figure below



(a) Name the materials of which the cathode is made

(b) Write an equation for the reaction for the reaction that takes place at

(i) The cathode

(ii) anode

(c) What is the purpose of calcium chloride?

(d) State why sodium is collected under dry nitrogen.

Answers

1. A 2. A 3.C 4. C 5. D 6. B 7. D

8. (a) (i) $FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$
   (ii) $Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$
   (b) (i) black crystals formed
   (ii) $2Fe(s) + 3Cl2(g) \rightarrow 2FeCl_3(g)$
9. (a) haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite, $FeCO_3$
   (b) (i) Reduction of the ore
   the roasted is mixed with coke and lime stone in a blast furnace and heated with hot air
   coke or carbon burns in oxygen to form carbon dioxide
   $C(s) + O_2(g) \rightarrow CO_2(g)$
   Carbon dioxide reacts with carbon to form carbon monoxide
   $CO_2(s) + C(s) \rightarrow 2CO(g)$
   Carbon monoxide reduces iron (III) oxide to iron
   $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
   (ii) Removal of impurities of silicon dioxide, SiO_2.
   Lime stone or calcium carbonate decompose on heating
   $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
   Calcium oxide reacts with impurities to form slag of calcium silicate that is pour away
   $CaO(s) + SiO_2(s) \rightarrow CaSiO_3$
   (b) (i) iron glow red forming black crystals and purple vapor
   $2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$
   (ii) a black solid forms
   $3Fe(s) + 4H_2O(l) \rightarrow Fe_3O_4(l) + 4H_2$
   (c) $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(g) + H_2(g)$
10. (a) silicon dioxide, SiO_2
   (b) (i) Iron (II) carbonate
   (ii) $FeCO_3 \xrightarrow{heat} FeO(s) + CO_2(g)$
   (c) (i) iron ore, coke and lime stone
   (ii) Hot air
   (d) (i) coke or carbon burns in oxygen to form carbon dioxide
   $C(s) + O_2(g) \rightarrow CO_2(g)$
   Carbon dioxide reacts with carbon to form carbon monoxide
   $CO_2(s) + C(s) \rightarrow 2CO(g)$
   Carbon monoxide reduces iron (III) oxide to iron
   $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$
   (ii) the impurity is silicon dioxide, SiO_2.
   Lime stone or calcium carbonate decompose on heating
   $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
   Calcium oxide reacts with impurities to form slag of calcium silicate that is pour away
   $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

(e) Iron and carbon

11. (a) Haematite, Fe_2O_3 and magnetite, Fe_3O_4, and from the siderite (spathic ore), $FeCO_3$

(b) (i) coke or carbon burns in oxygen to form carbon dioxide

$C(s) + O_2(g) \rightarrow CO_2(g)$

Carbon dioxide reacts with carbon to form carbon monoxide

$CO_2(s) + C(s) \rightarrow 2CO(g)$

Carbon monoxide reduces iron (III) oxide to iron

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$

(ii) Lime stone or calcium carbonate

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Calcium oxide reacts with impurities to form slag of calcium silicate that is pour away

$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

(c) $Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g$

(d) Green crystals turn white with liberation of water of crystallization, then decompose into brown residue giving off chocking gases.

$FeSO_4.7H_2O\ (s) \rightarrow FeSO_4(s) + 7H_2O(l)$

Then

$2FeSO_4(s) \rightarrow Fe_2O_3\ (s) + SO_2(g) + SO_3(g)$

12 (a) (i) divalent : green

(ii) trivalent: brown

(b) (i) divalent: $FeSO_4$ – iron (II) sulphate

(ii) trivalent: $Fe_2(SO_4)_3$ – iron (III) sulphate

(c) (i) aqueous sodium hydroxide

(ii) Iron (II)sulphate – dirty green precipitate insoluble in excess

Iron (III) sulphate – brown precipitate insoluble in excess

(iii) $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$

$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

(d) By heating iron with dry hydrogen chloride gas

$Fe(s) + 2HCl(g) \rightarrow FeCl_2(s) + H_2(g$

13. (a) Iron or steel

(b) Cathode: $Na^+(l) + e \rightarrow Na(l)$

Anode $2Cl^-(g) - 2e \rightarrow Cl_2\ (g)$

(c) Lower melting point of sodium chloride

(d) To prevent sodium from reacting with air