**IRON**

Atomic Number 26

Electronic configuration: 1S22s22p63s23p63d64s2

|  |  |
| --- | --- |
| +2 | 1S22s22p63s23p63d6 |
| +3 | 1S22s22p63s23p63d5 |
| +6 | 1S22s22p63s23p63d4 |

Possible oxidation states and their electronic configurations:

The most stable oxidation state is +3 because the electrons

in 3d subshell are partially filled and is thermodynamically

stable.

Fe2+ can easily be oxidized to Fe3+ while Fe3+ cannot easily be reduced to Fe2+

*Chemical properties of Iron*

1. *Reaction with air*

Heated iron combines with oxygen to form triirontetraoxide which is a black mixed oxide.

Fe (s) + 2O2 (g) Fe3O4 (s)

1. *Reaction with water*
2. *Rusting*

Iron reacts with moist cold air to form a brown hydrated iron (iii)oxide called rust.

2Fe (s) + 6H2O (l) + 3O2 (g) 2Fe2O3.3H2O (s)

*How rusting occurs*

Rusting is an electrochemical process which takes place when different parts of iron act as anode and cathode.

At the Cathode region:

Fe (s) Fe2+ (aq) + 2e

 At the Anode region:

2H2O (l) + O2 (g) + 4e 4OH (aq)

If the cathodic and anodic regions are near enough iron (II) hydroxide is formed.

Fe2+ (aq) + 2OH (aq) Fe(OH)­­2 (s)

Moist air then oxidises the iron (II) hydroxide to rust

 4Fe(OH)2 (s) + 2H2O (l) + O2 (g) 2Fe2O3.3H2O (s)

1. *With steam*

Heated iron reacts with steam to form black tri-iron tetra oxide

3Fe (s) + 4H2O (l) Fe3O4 (s) + 4H2 (g)

1. *Reaction with mineral acids*

*Dilute HCl and H2SO4*

Iron reacts with dilute *Dilute HCl and H2SO4* to form Fe2+ salts & hydrogen gas.

Fe (s) + 2HCl (aq) FeCl2 (aq) + H2(g)

Fe (s) + H2SO4 (aq) FeSO4 (aq) + H2

* With dilute nitric acid iron dissolves with evolution of hydrogen gas forming iron (II) nitrate

Fe (s) + HNO3(aq) Fe(NO3)2 (aq) + H2 (g)

* Iron is rendered passive by hot concentrated nitric acid because of protective film layer formed at the surface of iron.
* With hot concentrated sulphuric acid oxidises iron to iron (III) sulphate and itself reduced to Sulphur dioxide and water

2Fe (s) + 6H2SO4 (l) Fe2(SO4)3 (aq) + 3SO2(g) + 6H2O (l)

1. *Reaction with Chlorine*

Heated iron combines with dry chlorine to form iron (III) chloride which is dark brown/black.

2Fe (s) + 3Cl2 (g) 2FeCl3 (s)

***Qtn: (a) List ores of iron***

 ***(b) Describe the process of extraction of iron from a named ore***

Solution

1. Haematite which is iron (III) oxide – Fe2O3

Magnetite which is Tri-iron tetra oxide - Fe3O4

Siderite/spathic iron ore ie iron(II) carbonate - FeCO3

1. *Extraction from spathic iron ore*

The ore is roasted in air to convert it to anhydrous iron (III) oxide as in the equation below:

4FeCO3 (s) + O2 (g) 2Fe2O3 (s) + 4CO2 (g)

*Reduction in the blast furnace*

The furnace is charged with ore, coke and limestone in weighted proportions in the furnace. The following reactions occur.

Near the base coke burns in oxygen blast to produce carbon dioxide.

|  |
| --- |
| This reactions are exothermic |

C (s) + O2 (g) CO2 (g)

CO2 (g) + C (s) 2CO (g)

Near the top of the furnace at 900k iron (III) oxide is reduced to iron as a spongy solid.

Fe2O3 (s) + 3CO (g) 2Fe (s) + 3CO2 (g)

Some reduction also takes place directly by carbon

Fe2O3 (s) + C (s) 2Fe (s) + 3CO (g)

*Functions of limestone*

Limestone in the furnace is decomposed by heat to quicklime (calcium oxide)

CaCO3 (s) CaO (s) + CO2 (g)

Calcium oxide (quick lime) reacts with silicon dioxide and other earthly materials which would silt up the furnace as follows:

CaO (s) + SiO2 (s) CaSiO3(l)

The iron melts as it sinks to the hotter parts of the furnace and with molten slag above it. Iron and slag are tapped off separately at intervals and iron is allowed to solidify in molds in wet sand. This is called cast iron or pig iron.

*Diagram/illustration*



*Forms of Iron*

*Cast Iron*

* It is very impure containing Mn, S, Si, etc
* It has a low melting point and solidifies on expansion
* It is used for casting objects eg gas rings, street lamp stands

*Wrought Iron.*

* Its most pure form of individual iron
* It’s produced by melting cast iron on hearth lined with hematite. The carbon in the cast iron is oxidized away as Carbon monoxide

Fe2O3 (s) + 3C (s) 2Fe (s) + 3CO (g)

**COMPOUNDS OF IRON (II) – Fe2+**

1. ***Iron (II) oxide (FeO)***

Is a black oxide, basic and prepared by heating iron (II) oxalate in air.

FeC2O4 (s) FeO (s) + CO (g) + CO2 (g)

1. ***Iron (II) Chloride***

Is prepared by passing hydrogen chloride gas over heated iron

Fe (s) + 2HCl (g) FeCl2 (s) + H2 (g)

Iron (II) bromide and Iron (II) iodide can be prepared by reacting heated iron with bromine or iodine because bromine & iodine are weak oxidizing agents.

1. ***Iron (II) sulphate***

Is a light green solid prepared by adding dilute sulphuric acid to any soluble salt of iron (II)

Fe2+ (aq) + SO42-  (aq) FeSO4 (aq)

***TEST FOR IRON (II) (Fe2+)***

**Reagents and Observations**

1. *Sodium hydroxide solution*

A dirty green precipitate insoluble in excess sodium hydroxide and turns brown on standing.

Fe2+ (aq) + SO42- (aq) FeSO4 (aq)

1. *Ammonia solution*

A dirty green precipitate insoluble in excess turns brown on standing

Fe2+ (aq) + 2OH (aq) Fe(OH)2 (s)

2Fe(OH)2 (s) + O2 (g) 2Fe(OH)3 (s)

1. *Potassium hexacyanoferate (III)*

Dark blue precipitate

Fe2+ (aq) + [Fe(CN)6]3- (aq) Fe[Fe(CN)6]- (l)

*Ways of converting Iron (II) to iron (III)*

1. *Using concentrated nitric acid*

The dark green solution turns brown

1. *Hydrogen peroxide*

Add acid followed by hydrogen peroxide. The green solution turns brown with evolution of bubbles of a colourless gas that relights a glowing splint

2Fe2+ (aq) + 2H+ (aq) + H2O2 (aq) 2Fe3+ (aq) + 2H2O (l) + ½O2 (g)

1. *Chlorine water or bromine water*

The red brown colour of bromine turns colourless and a brown solution is formed

2Fe2+ (aq) + Br2 (aq) 2Fe3+ (aq) + 2Br- (aq)

1. *Use of acidified KMnO4 and K2Cr2O7*

**COMPOUNDS OF IRON (III) (Fe3+)**

1. ***Iron (III) oxide (Fe2O3)***

Is a dark brown solid, basic and ionic like Al2O3, prepared by heating a Iron (II) sulphate.

2FeSO4 (s) Fe2O3 (s) + SO3 (g) + SO2 (g)

*Observation:* The green solid of iron (II) sulphate turns dark brown with fumes of a colourless gas given off that turns moist blue litmus red.

1. ***Iron (III) hydroxide (Fe(OH)3)***

It’s a brown solid prepared by reacting sodium hydroxide or ammonia solution with soluble salt of Iron (III)

Fe3+ (aq) + 3OH (aq) Fe(OH)3 (s)

1. ***Iron (III) Halides ( FeCl3, FeBr3, FeI3)***

Iron (III) chloride is a dark brown solid prepared by passing dry chlorine gas over heated iron.

2Fe (s) + 3Cl2 (g) 2 FeCl3 (s)

Iron (III) chloride in vapour phase exists as dimer with formula Fe2Cl6

 In solid state

 Trigonal planar

In solid state it has a trigonal planar structure

Iron (III) chloride is a covalent compound with low melting point.

Due to low electronegativity of chloride ion, Fe3+ ion with its high polarizing power can distort the electron cloud on chloride ion forming a predominantly covalent compound

Iron (III) compounds can be reduced to iron (II) compounds by the following:

1. *By addition of acidified potassium iodide to the solution containing Iron (III)*

2Fe3+ (aq) + 2I- (aq) 2Fe2+ (aq) I2 (s)

*Observation:* The reddish brown solution turns green with a brown solid deposit.

1. *By boiling iron (III) solution with zinc powder*

*Observation:* A green solution of iron (II) is formed

(Fe3+ (aq) + e Fe2+)x2

Zn (s) Zn2+ (aq) + 2e-

2Fe3+ (aq) + Zn (s) Zn2+(aq) + 2Fe2+ (aq) - *Is the overall equation*

1. *By passing a current of hydrogen sulphide through solution of Iron (iii) compound.*

*Observation:* The reddish brown solution turns green with a yellow solid deposit.

2Fe3+ (aq) + S2- (aq) 2Fe2+ (aq) + S (s)

State what would be observed when hydrogen sulphide is passed through a solution of Iron (III) sulphate.

*Acidity of Iron (III) ions*

Aqueous solutions of Fe3+ are acidic, they turn blue litmus paper red.

*Explanation:* This is due to the high charge density on iron (III) ions, its heavily hydrated by water molecules to form a hydrated complex, which undergoes cationic hydrolysis to release hydroxonium ions which turn blue litmus paper red.

[Fe(H2O)6]3+ (aq) + 3H2O (l) Fe(H2O)3.3OH(s) +3H3O3+ (aq)

* When sodium carbonate is added to the aqueous solution of iron (III) sulphate a reddish brown precipitate is formed and bubbles of a colourless gas given out.

*Explanation.* Due to the high charge density on the iron (III) ion, it is heavily hydrated by water molecules and undergoes cationic hydrolysis to produce a brown solid of iron (III) hydroxide with release of hydroxonium ions which then react with carbonate ion to release carbon dioxide gas which is colourless.

[Fe(H2O)6]3+ (aq) + 3H2O (l) Fe(H2O)3.3OH(s) +3H3O3+ (aq)

2H3O+ (aq) + CO32- (aq) CO2 (g) + 3H2O (l)

*Overall equation*

2Fe3+ (aq) + 3H2O (l) + 3CO32- (aq) 2Fe(OH)3 (s) + 3CO2 (g)

Due to the removal of hydroxonium ions the forward reaction is favoured and the concentration of the solution precipitates Iron (III) hydroxide seen as a reddish brown precipitate

**Test for Iron (III)**

1. *Sodium hydroxide solution*

Brown precipitate formed insoluble in excess

Fe3+ (aq) + 3OH (aq) Fe(OH)3 (s)

1. *Ammonia solution*

Reddish brown precipitate insoluble in excess is formed

Fe3+ (aq) + 3OH (aq) Fe(OH)3 (s)

1. *Potassium hexacyanoferate (II)*

Dark blue precipitate is formed

Fe3+ (aq) + [Fe(CN)6]4- (aq) Fe[Fe(CN)6]- (s)

1. *Potassium hexacyanate/thiocyanate*

Intense red colouration

Fe3+ (aq) + SCN-  (aq) [FeSCN]2- (aq)