Chapter 1
Roshetta

* Roasting process

a) In this process the ore is strongly heated in air.

convert siderite to hematite

1. $FeCO_{3\,(s)(48.5\%\,Fe)} \xrightarrow{\Delta} FeO_{(s)} + CO_{2\,(g)}$
2. $2\,FeO_{(s)} + \frac{1}{2}\,O_{2\,(g)} \xrightarrow{\Delta} Fe_2O_{3(s)\,(69.6\%Fe)}$

lemonite to hematite

3. $2\,Fe_2O_3.3H_2O_{(s)(40\,\%\,Fe)} \xrightarrow{\Delta} 2\,Fe_2O_{3\,(s)\,(69.6\%Fe)} + 3H_2O_{(v)}$

b) Oxidation of some impurities such as Sulphur and phosphorus.

4. $S_{(s)} + O_{2\,(g)} \xrightarrow{\Delta} SO_{2\,(g)}$
5. $4\,P_{(s)} + 5\,O_{2\,(g)} \xrightarrow{\Delta} 2\,P_2O_{5(s)}$

* Blast furnace

Formation of reducing agent (Carbon Monoxide) (CO):

6. $C_{(s)} + O_{2\,(g)} \xrightarrow{\Delta} CO_{2\,(g)}$
7. $CO_{2\,(g)} + C_{(s)} \xrightarrow{\Delta} 2\,CO_{(g)}$

Reduction process:

8. $Fe_2O_{3\,(s)} + 3\,CO_{(g)} \xrightarrow[>\,700]{\Delta} 2\,Fe_{(s)} + 3\,CO_{2\,(g)}$

* Midrex furnace

Formation of reducing agent (water gas) ($CO+H_2$):

9. $2\,CH_{4\,(g)} + CO_{2\,(g)} + H_2O_{(v)} \xrightarrow{\Delta} 3\,CO_{(g)} + 5\,H_{2\,(g)}$

Reduction process:

10. $2\,Fe_2O_{3\,(s)} + 3\,CO_{(g)} + 3\,H_{2\,(g)} \xrightarrow{\Delta} 4\,Fe_{(s)} + 3\,CO_{2\,(g)} + 3\,H_2O_{(V)}$

* Iron

1.Effect of air

11. $3\,Fe_{(s)} + 2\,O_{2\,(g)} \xrightarrow{\Delta} Fe_3O_{4\,(s)}$

2. Effect of Water vapor (Steam)

12. $3\,Fe_{(s)} + 4\,H_2O_{(v)} \xrightarrow{500\ ^oC} Fe_3O_{4\,(s)} + 4H_{2\,(g)}$

3. Iron with Non-metals

13. $2\,Fe_{(s)} + 3\,Cl_{2\,(g)} \xrightarrow{\Delta} 2\,FeCl_{3\,(aq)}$
14. $Fe_{(s)} + S_{(s)} \xrightarrow{\Delta} FeS_{(s)}$

4. Iron with acids:

15. $Fe_{(s)} + H_2SO_{4\,(aq)} \xrightarrow{Dil} FeSO_{4\,(aq)} + H_{2\,(g)}$
16. $Fe_{(s)} + 2HCl_{(aq)} \xrightarrow{Dil} FeCl_{2(aq)} + H_{2\,(g)}$
17. $3\,Fe_{(s)} + 8\,H_2SO_{4\,(l)} \xrightarrow[Conc.]{\Delta} FeSO_{4\,(aq)} + Fe_2(SO_4)_{3\,(aq)} + 4SO_{2\,(g)} + 8H_2O_{(v)}$
18. $Fe_{(s)} + HNO_{3\,(l)} \xrightarrow[Conc.]{\Delta}$ Passivity

* Iron (II) oxide FeO

Preparation

19. $\begin{matrix} COO \\ | \\ COO \end{matrix}\!\!\diagdown\!\!\diagup Fe \xrightarrow[\text{in absence of air}]{\Delta} FeO_{\,(S)} + CO_{\,(g)} + CO_{2\,(g)}$
20. $Fe_2O_{3\,(s)} + H_{2\,(g)} \xrightarrow{400\text{-}700^o\,C} 2\,FeO_{\,(S)} + H_2O_{(v)}$
21. $Fe_3O_{4\,(s)} + H_{2\,(g)} \xrightarrow{400\text{-}700^o\,C} 3\,FeO_{\,(S)} + H_2O_{\,(V)}$
22. $2\,FeCO_{3\,(s)} \xrightarrow{\Delta} 2\,FeO_{(s)} + 2\,CO_{2\,(g)}$

Properties

23. $4\,FeO_{\,(S)} + O_{2\,(g)} \xrightarrow{\Delta} 2\,Fe_2O_{3\,(S)}$
24. $FeO_{\,(s)} + H_2SO_{4\,(aq)} \xrightarrow{Dil.} FeSO_{4\,(aq)} + H_2O_{\,(l)}$
25. $FeO_{\,(s)} + 2\,HCl_{\,(aq)} \xrightarrow{Dil.} FeCl_{2\,(aq)} + H_2O_{\,(l)}$

* Iron (III) oxide Fe_2O_3

Preparation

26. $FeCl_{3\,(aq)} + 3\,NH_4OH_{\,(aq)} \longrightarrow 3\,NH_4Cl_{\,(aq)} + Fe(OH)_{3\,(S)}\downarrow$ reddish-brown
27. $2\,Fe(OH)_{3\,(s)} \xrightarrow[200\ ^oC]{\text{above}} Fe_2O_{3\,(s)} + 3\,H_2O_{\,(v)}$
28. $2\,FeSO_{4\,(S)} \xrightarrow{\Delta} Fe_2O_{3\,(s)} + SO_{2\,(g)} + SO_{3(g)}$
29. $4\,FeO_{(s)} + O_{2\,(g)} \xrightarrow{\Delta} 2\,Fe_2O_{3\,(s)}$
30. $2\,Fe_3O_{4\,(s)} + \frac{1}{2}\,O_{2\,(g)} \xrightarrow{\Delta} 3\,Fe_2O_{3\,(s)}$

Properties

31. $Fe_2O_{3\,(s)} + 3H_2SO_{4\,(l)} \xrightarrow[Conc.]{\Delta} Fe_2(SO_4)_{3\,(aq)} + 3H_2O_{(v)}$
32. $Fe_2O_{3\,(s)} + 6\,HCl_{\,(l)} \xrightarrow[Conc.]{\Delta} 2\,FeCl_{3\,(aq)} + 3H_2O_{\,(v)}$

* The black oxide (magnetic iron oxide) Fe_3O_4

Preparation

33. $3\,Fe_{(s)} + 2\,O_{2\,(g)} \xrightarrow{\Delta} Fe_3O_{4\,(s)}$
34. $3\,Fe_{(s)} + 4\,H_2O_{(aq)} \xrightarrow{500\ ^oC} Fe_3O_{4\,(s)} + 4\,H_{2\,(g)}$
35. $3\,Fe_2O_{3\,(s)} + CO_{\,(g)} \xrightarrow{230\text{-}300\ ^oC} 2Fe_3O_4 + CO_{2(g)}$

Properties

36. $Fe_3O_{4\,(s)} + 4\,H_2SO_{4\,(l)} \xrightarrow[\Delta]{Conc.} FeSO_{4\,(aq)} + Fe_2(SO_4)_{3\,(aq)} + 4\,H_2O_{(v)}$
37. $Fe_3O_{4\,(s)} + 8\,HCl_{\,(l)} \xrightarrow[\Delta]{Conc.} FeCl_{2\,(aq)} + 2\,FeCl_{3\,(aq)} + 4\,H_2O_{(v)}$
38. $2\,Fe_3O_{4\,(s)} + \frac{1}{2}\,O_{2\,(g)} \xrightarrow{\Delta} 3\,Fe_2O_{3\,(s)}$

Chapter 1
Roshetta

TRANSITION ELEMENTS

Siderite
"Iron II Carbonate"

$FeCO_3$

$- CO_2$ (absence of air)

Iron II Oxalate

$(COO)_2Fe$ = 

$-CO_2$, **CO** (absence of air)

GR

400°c - 700°c

$+H_2$ $-H_2O$

FeO
Iron II Oxide

+ dil or Conc HCl → $FeCl_2 + H_2O$

+ dil or Conc H_2SO_4 → $FeSO_4 + H_2O$

air

+ ½ O_2

$+H_2$ $-H_2O$

400°c - 700°c

+ Conc 8HCl → $FeCl_2 + 2FeCl_3 + 4H_2O$

GR

Fe_3O_4
Magnetite
Black oxide

$FeSO_4 + Fe_2(SO_4)_3 + 4H_2O$

+ Conc $4H_2SO_4$

+ ½ O_2

230°c - 300°c

+ CO , $-CO_2$

Fe_2O_3
Hematite
Iron III Oxide

$K_2Cr_2O_7$
$-SO_2$, $-SO_3$

Iron II Sulphate

$2FeSO_4$

>200°c

$- 3H_2O$

$2Fe(OH)_3$

Iron III Hydroxide

+ $4H_2O$ $- 4H_2$

GR

+ $2O_2$

500°c

Fe
Iron

> 700°c

+ CO CO_2
+ H_2 H_2O
+ CO CO_2

Paints

GR

Conc. 6 HCl +

+ NH_4OH

$- NH_4Cl$

$2FeCl_3 + 3H_2O$

Conc. 3 H_2SO_4

$Fe_2(SO_4)_3 + 3H_2O$

+ 3 Cl_2 Chlorine gas → 2 $FeCl_3$

+ S Sulfur → FeS

Iron II Sulphide

GR

Hydrochloric acid Dil.2HCl → $H_2 + FeCl_2$

Sulphuric acid Dil.H_2SO_4 → $H_2 + FeSO_4$

$K_2Cr_2O_7$

+8 Conc. H_2SO_4 → $4SO_2 + 8H_2O + Fe_2(SO_4)_3 + FeSO_4$

GR

+ Conc. HNO_3

Nitric acid

GR

No reaction

Passivity

-Removed by :
Abrasion or
Dil HCl

Chapter 1
Roshetta

Metallurgy

TRANSITION ELEMENTS

1. ORE DRESSING

This process is carried for **2 main reasons:**

1) Improving physical and mechanical properties (3 Processes)

A) Crushing Process

- the large sized ore to small particles to be easily reduced

-There is no change in (the mass - percentage of iron or impurities)

B) Sintering Process

-fine particles resulted from crushing process to large suitable size to be easily reduced

-There is no change in (the mass - percentage of iron or impurities)

C) Concentrating Process

- Remove impurities by 3 methods **"Surface Tension, Magnetic Separation & Electric Separation"**

- The mass of Ore decreases
- The percentage of iron in ore increases

2) Improving chemical properties (Roasting Processes)

ore is strongly heated and left to dry in air

1)convert siderite to hematite

$FeCO_{3(s)}$ (48.5% Fe) $\rightarrow FeO_{(s)}+CO_{2(g)}$

$2FeO_{(s)}+ ½O_{2(g)} \rightarrow Fe_2O_3$ (69.6% Fe)

2)convert limonite to hematite

$2Fe_2O_3.3H_2O_{(40\%Fe)} \rightarrow 2Fe_2O_{3(s)\,(69.6\%\,Fe)}+3H_2O_{(v)}$

3) convert magnetite to hematite

$2\,Fe_3O_{4(s)} + ½\,O_{2(g)} \xrightarrow{\Delta} 3\,Fe_2O_{3(s)}$

Oxidation of some impurities such as Sulphur and phosphorus.

$S_{(s)}+O_{2(g)} \rightarrow SO_{2(g)}$

$4P_{(s)}+5O_{2(g)} \rightarrow 2P_2O_{5(s)}$

-The mass of Ore decreases

-The percentage of iron in ore increases

2. REDUCTION OF IRON ORES

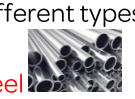
The reduction of iron oxides to iron is carried out by one or two methods depending on the Reducing agent:

	Blast furnace	Midrex furnace
Reducing agent:	★ **Carbon monoxide (CO) Resulting from coke (C)**	By carbon monoxide and hydrogen gas ($CO+H_2$) known as water gas resulting from natural gas **(93% methane CH_4)**
Formation of reducing agent :	$C_{(S)}+O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$ $CO_{2(g)}+C_{(s)} \xrightarrow{\Delta} 2CO_{(g)}$	$2CH_{4(g)}+CO_{(g)}+H_2O_{(V)} \xrightarrow{\Delta} 3CO_{(g)}+5H_{2(g)}$
Reduction process:	$Fe_2O_3+3CO_{(g)} \xrightarrow{\Delta} 2Fe+3CO_{2(g)}$	$2Fe_2O_{3(s)}+3CO_{(g)}+H_{2(g)} \xrightarrow{\Delta} 4Fe_{(s)}+3CO_{(g)}+3H_2O_{(V)}$

Confusion

Coke (C)	**Source** of reducing agent in **blast** furnace
Carbon monoxide (CO)	Reducing agent in **blast** furnace
natural gas (methane CH_4)	**Source** of reducing agent in **midrex** furnace
Water gas ($CO+H_2$)	Reducing agent in **midrex** furnace

3. IRON PRODUCTION

After the reduction of Hematite in the blast furnace or midrex furnace the third step is production of different types of iron such as cast iron and steel 

note that: in the production stage we use pure iron Fe.

Steel (Alloy) :

Steel production depends on two essential processes:

1. Removal of impurities from iron resulting from furnaces to get pure iron

2. Addition of some elements to iron to produce steel with the required properties for industrial purposes (formation it to what we need)

The furnaces that produce steel:

1. The oxygen converters
2. Open-hearth furnace
3. Electric furnace

Note that:

Steel: is an alloy from iron and carbon (Fe-C) interstitial alloy

Stainless steel: is an alloy from iron and chromium (Fe-Cr) substitutional alloy