Smelting is a process of melting and separation of the charge into two or more immiscible liquid layers, which may be slag, matte, speiss or metal.

The different types of smelting are: (i) reduction smelting; (ii) matte smelting; and (iii) flash smelting.
The reduction smelting process involves the reduction of oxidic sources of metals with carbon in the presence of a flux.

\[
\text{mineral + reducing agent + flux} = \text{metal + slag + gases}
\]

Example: blast furnace smelting of iron
The matte smelting process involves the fusion of 
**sulfidic sources** of metals **with a flux** without the use 
of any reducing agent.

\[
sulfidic\ source\ concentrate + flux = matte + slag + gases
\]

**Example:** smelting of Cu or Ni ores

**speiss:** a mixture of molten arsenides and antimonides of 
heavy metals.
The flash smelting process combines into one the flash roasting and the smelting operations.

The sulfide concentrate fines react with oxygen at high temperatures. The oxidation process itself generates sufficient heat for the smelting process to occur simultaneously.
Furnaces used in smelting process: reverberatory, direct electric arc, circular blast, flash smelter, rectangular, etc.
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Flash smelter furnace (Inco technology)
Furnaces used in smelting process: reverberatory, direct electric arc, circular blast, flash smelter, rectangular, etc.

Fluid furnace (Outokumpu technology)
Notes:
1. In smelting choice of slag composition to give the optimum balance of basicity and fluidity is important: maximum removal of impurities.

2. Matte smelting can be conducted at lower melting point than metal oxide smelting.

3. Matte smelting is normally carried out in a reverberatory furnace; electric arc furnace for higher temp. (1500°C); flash smelting: modern, improved, incorporating flash roasting with smelting.
Example: Matte smelting of Cu$_2$S - FeS

1. stage (removal of FeS) $\rightarrow$ 1350 °C

$\begin{align*}
2 \text{FeS} + 3 \text{O}_2 & \rightarrow 2 \text{FeO} + 2 \text{SO}_2 \\
3 \text{FeS} + 5 \text{O}_2 & \rightarrow \text{Fe}_3\text{O}_4 + 3 \text{SO}_2 + 2 \text{Cu}_2\text{S} \\
2 \text{Cu}_2\text{S} + \text{O}_2 & \rightarrow \text{Cu}_2\text{O} + \text{SO}_2 \\
2 \text{FeO} + \text{SiO}_2 & \rightarrow 2 \text{FeO} \cdot \text{SiO}_2 \text{ fayalite} \\
\text{Cu}_2\text{O} + \text{FeS} & \rightarrow \text{Cu}_2\text{S} + \text{FeO} \\
3 \text{Fe}_3\text{O}_4 + \text{FeS} & \rightarrow 10 \text{FeO} + 3 \text{SO}_2 \\
\text{Cu}_2\text{O} + \text{Cu}_2\text{S} & \rightarrow \text{Cu} + \text{SO}_2
\end{align*}$

2. stage (removal of S) $\rightarrow$ raw Cu (blistr): Ag, Au, Pt-kovy, Se, Te, Pb, Zn, As, Sb, Ni, Co, O$_2$ $\rightarrow$ 1150 °C

$\begin{align*}
2 \text{Cu}_2\text{S} + \text{O}_2 & \rightarrow \text{Cu}_2\text{O} + \text{SO}_2 \\
\text{Cu}_2\text{O} + \text{Cu}_2\text{S} & \rightarrow \text{Cu} + \text{SO}_2
\end{align*}$
Reduction

Metal oxides may be reduced to the metal by carbon, carbon monooxide, hydrogen or other metals which form more stable oxides.

1. $\text{MeO(s)} + \text{C(s)} \leftrightarrow \text{Me(s)} + \text{CO(g)}$
2. $\text{MeO(s)} + \text{CO(g)} \leftrightarrow \text{Me(s)} + \text{CO}_2(g)$
Ellingham diagrams
Ellingham diagrams

- O$_2$ grid
- CO$_2$/CO grid
located below the carbon line), the carbon line lies in the oxide stability field. Carbon, therefore, can not reduce these oxides. When the Ellingham line associated with an oxide intersects the carbon line, the temperature of intersection represents the minimum temperature at which the oxide may be reduced by carbon. Ferrous oxide, for example, can be reduced by carbon only above 675 °C. It can similarly be seen that several important nonferrous metal oxides can be reduced by carbon at temperatures around 1000 °C. These include oxides of tin, lead, copper, nickel, and zinc.

Figure 4.10 The effect of varying the pressures of the product gases of the reactions.