

22.6: Refining of Metals

Once a metal is reduced, it is still not necessarily pure enough for all uses to which it might be put. An obvious example is the brittleness and low tensile strength of pig iron, characteristics which make it suitable for casting, but little else. These adverse properties are due to the presence of impurities, a typical analysis of blast-furnace iron showing about 4% C, 2% P, 2.5% Si, 2.5%Mn, and 0.1% S by weight. Further refining to remove these impurities (especially carbon) produces **steel**, a much stronger and consequently more useful material.

Steel making involves oxidation of the impurities in basic oxygen, open hearth, or electric furnaces. Some oxidation products (CO, CO₂, and SO₂) are volatile and easily separated. The others end up, along with some iron oxides, in a slag which floats on the surface of the molten steel.

In the **open-hearth furnace** oxidation is due to air at the surface of the molten metal. This method of steel refining was developed in the mid 1800s, contemporaneous with the industrial revolution. This method requires up to 12 hours—and natural gas or other fuel must be burned to keep the metal liquid. Thus the open hearth wastes large amounts of free energy. The use of fossil fuel does make it possible to recycle as much as 50 percent scrap iron, however, and the longer melting time allows somewhat greater control over the composition of a batch of steel.

Developed in the 1950s, the **basic oxygen furnace** has replaced the open-hearth furnace as the primary steel making method. In this process, pure oxygen is directed onto the surface of molten pig iron in a large crucible. Some of the iron is oxidized to Fe₃O₄ and Fe₂O₃, forming an oxidizing slag. The impurities, namely, C, P, Si, Mn, and S, are all oxidized at the same time. Since all these reactions are spontaneous and exothermic, they provide enough heat so that up to 25 percent solid scrap iron may be melted in the crucible without cooling it to the point where solid iron would remain. Oxidation of one batch of pig iron and scrap normally takes slightly more than half an hour. Thus, this method is far quicker than the open-hearth furnace, is three times more efficient.

Computers are now used to interpret spectroscopic analyses of steel in basic oxygen furnaces, indicating in a few minutes what metals must be added to obtain the desired composition. This has largely eliminated the last advantage of the open hearth and speeded up changeovers to basic oxygen. It has also decreased recycling of iron because the latter furnace cannot handle as much scrap. Much recycling of iron is now done in **electric-arc furnaces** which can melt a charge of 100 percent scrap.

In addition to the chemical oxidations used in steel making, electrolytic oxidation and reduction is quite important in refining metals. The electrolytic [refining of copper](#), and [aluminum production](#) has already been described.

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