22.3: Metallurgy

Most metals are chiefly useful in elemental form, but they usually occur in compounds on the earth's surface. An **ore** is a naturally occurring material from which one or more useful elements or compounds may be obtained at a cost that is economically feasible. As can be seen from the table, most metal ores are oxides, carbonates, or sulfides. A few of the least electropositive metals occur as the element.

Table 22.3.1: Occurrence of Metals.

Type of Ore	Examples
Native Metals	Cu, Ag, Au, As, Sb, Bi, Pd, Pt
Oxides	Al_2O_3, Fe_2O_3, Fe_3O_4, SnO_2, MnO_2, TiO_2, $FeO•Cr_2O_3$, $FeO•WO_3$, Cu_2O, ZnO
Carbonates	$CaCO_3$, $CaCO_3•MgCO_3$,$MgCO_3$, $FeCO_3$, $PbCO_3$, $BaCO_3$, $SrCO_3$, $ZnCO_3$, $MnCO_3$, $CuCO_3•Cu(OH)_2$
Sulfides	Ag_2S, Cu_2S, CuS, PbS, ZnS, HgS, $FeS•CuS$, FeS_2, Sb_2S_3, Bi_2S, MoS_2, NiS, CdS
Halides	NaCl, KCl, AgCl, $KCl•MgCl_2•6H_2O$, NaCl and $MgCl_2$ in seawater
Sulfates	$BaSO_4$, $SrSO_4$, $PbSO_4$, $CaSO_4•2H_2O$, $CuSO_4•2Cu(OH)_2$
Silicates	$Be_3Al_2Si_6O_{18}$, $ZrSiO_4$, $Sc_2Si_2O_7$
Phosphates	$LaPO_4$, $LiF•AlPO_4$

Whether a mineral can usefully be regarded as an ore or not depends on such factors as how *concentrated* it is, its exact *location*, and whether there is a suitable *process* for extracting the metal. As the more accessible higher-grade ores become exhausted, less accessible and lower-grade ores are becoming increasingly utilized with a consequent shift in the meaning of the word ore. It is conceivable that many silicates could become sources of metals, notably aluminum. Currently, though, silicates are expensive decompose chemically, and silicates form ores only for relatively expensive metals like zirconium and beryllium.

The processing of ores may be divided into three steps. Often concentration or other **beneficiation** is required to remove worthless material (**gangue**) or to convert the mineral into an appropriate form for subsequent processing. The second and most-important step is **reduction** of the metal from a positive oxidation state. This may involve elevated temperatures, chemical reducing agents, electrolysis, or some combination of these treatments. Usually a third step, **refining**, is required to achieve the purity (or precise mixed composition in the case of an alloy) desired in the final product.