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Al-Fe-Ni-O (Aluminum-Iron-Nickel-Oxygen)

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Extraction of nickel laterite ores requires an understanding of the phase equilibria of this quaternary system. For the first time, [2009Rha] reported experimental results of the isothermal equilibria at 1600, 1500 and 1400 °C in the Al_2O_3-FeO-Fe_2O_3-NiO region.

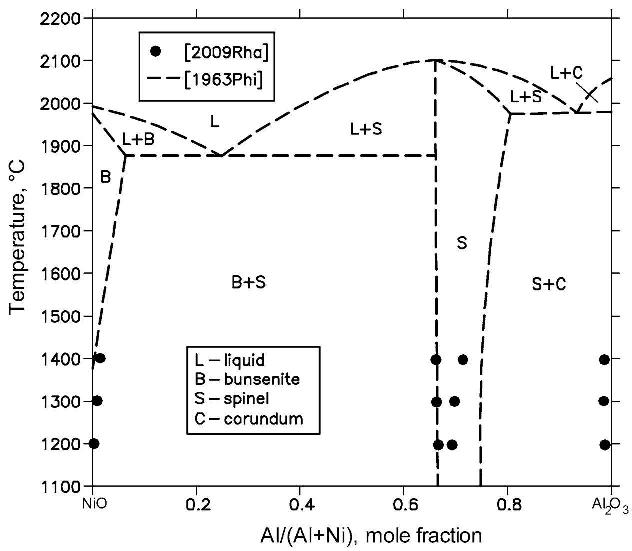

Fig. 1 NiO-Al_2O_3 pseudo-binary section in air

Lower Order Systems

Updates on the Al-Fe-O and Fe-Ni-O systems appear in this issue. The phase equilibria with emphasis on the metal-rich region of these systems were reviewed earlier by [1989Rag1] and [1989Rag2] respectively. During the course of their quaternary investigations, [2009Rha] determined a pseudo-binary section in air of the Al-Ni-O system along the NiO-Al_2O_3 join, using the same experimental procedures as outlined below for the quaternary equilibria. This section is shown in Fig. 1. In the temperature range studied (1400-1200 °C), the solubility of Al in the bunsenite (NiO) phase is slightly higher than that reported earlier by [1963Phi] and does not change significantly with temperature. The solubility of Al in the spinel phase was found to be smaller than that found by [1963Phi], see Fig. 1. The most recent update on the Al-Fe-Ni system is by [2009Rag].

Quaternary Phase Equilibria

With starting powders of 99.99% Al_2O_3, 99.98% Fe_2O_3, 99.99% NiO, 99.99% Fe and 99.8% Ni, [2009Rha] prepared pellets of powder mixtures, which were broken into smaller pieces and annealed in air between 1400 and 1200 °C for 72-168 h and quenched. The approach to equilibrium was from two opposite directions, by employing both

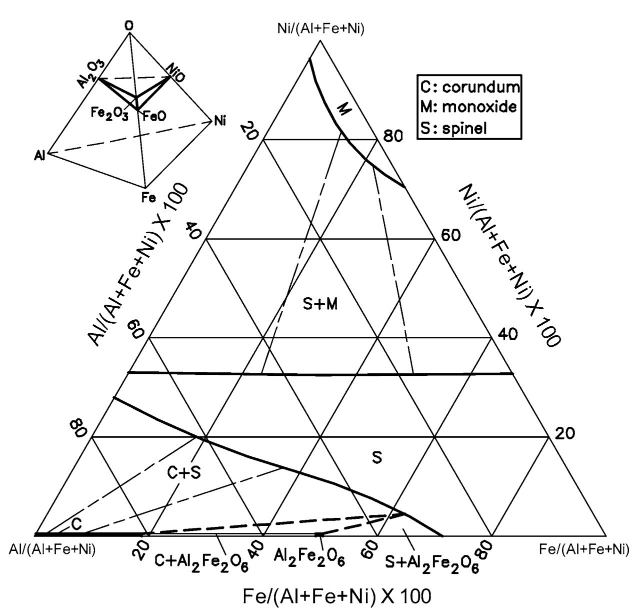

Fig. 2 Al-Fe-Ni-O isothermal equilibria in air at 1400 °C projected on to the Al-Fe-Ni plane [2009Rha]

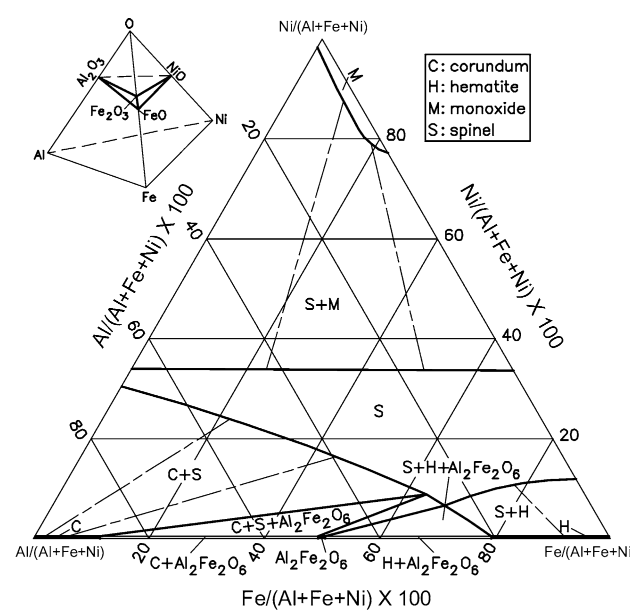

Fig. 3 Al-Fe-Ni-O isothermal equilibria in air at 1300 °C projected on to the Al-Fe-Ni plane [2009Rha]

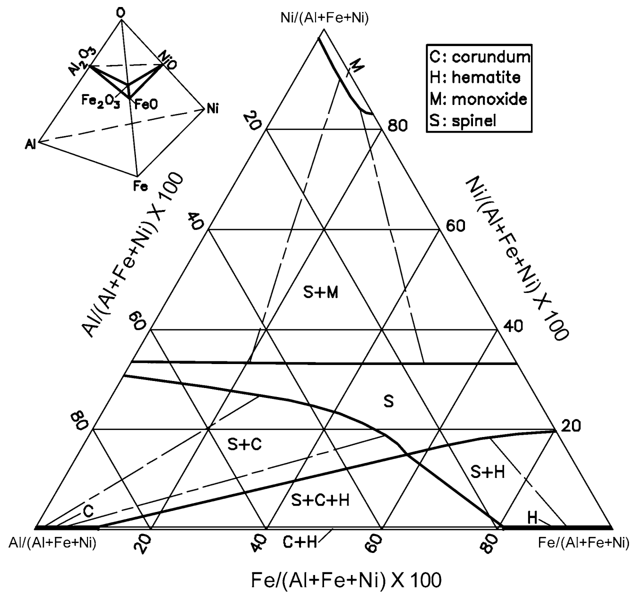

Fig. 4 Al-Fe-Ni-O isothermal equilibria in air at 1200 °C projected on to the Al-Fe-Ni plane [2009Rha]

more-oxidized and more-reduced starting compositions. The final phase compositions were measured with an electron probe microanalyzer and listed. The isothermal equilibria at 1400, 1200 and 1300 °C plotted as projections on the Al-Fe-Ni plane are shown in Fig. 2, 3, and 4. The ternary phase $Al_2Fe_2O_6$ was found by [2009Rha] at 1400 and 1300 °C. Earlier reports, however, placed the lower temperature limit of stability of $Al_2Fe_2O_6$ at 1318 °C. Hematite (Fe_2O_3) is stable at 1300 and 1200 °C. The corundum phase (Al_2O_3) is stable at all three temperatures. The solubility of Al and Fe in the monoxide phase increases with increasing temperature. The spinel phase field increases in extent with increasing temperature.

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