Delineation of an Augite-pigeonite Solvus at Zero Pressure by Homogenizing Single Clinopyroxene Crystals from Lunar Rock 12021.

by

Malcolm Ross, J. Stephen Huebner, and Eric Dowty,

U.S. Geological Survey, Washington, D. C. 20242

ABSTRACT

An augite-pigeonite solvus has been clearly delineated in terms of temperature and the unit-cell parameter "beta" for pigeonite and an augite from lunar rock 12021. Four "single" crystals of pigeonite containing approximately 25 percent augite exsolved on (001) as submicroscopic lamellae, were heated for about 24 hours in evacuated silica glass tubes at temperatures of 950°, 1064°, 1148°, 1164°, 1176°, 1184°, 1208°, 1243°, and 1258°C. The initial bulk compositions of the pigeonite grains were approximately $Wo_{12}En_{59}Fs_{29}$. The compositions of the host pigeonite and exsolved augite of the unheated crystals was estimated from unit-cell parameters to be $En_{67}Fs_{33}$ (essentially a clinohypersthene composition) and $Wo_{50}(En,Fs)_{50}$, respectively, indicating a nearly complete immiscibility gap between pigeonite (clinohypersthene) and augite at low temperatures. Using X-ray precession techniques, the crystals were photographed after quenching from each annealing temperature. The beta angles of the host and exsolved clinopyroxenes characteristically change with annealing temperature, the pigeonite beta decreasing continuously from 108°50' for the unheated crystals to a minimum of 108°16' after heating at 1176°C. The exsolved augite beta increases from a minimum of 106°0' for unheated crystals to a maximum of 107°0' at 1176°C. During heating from 25° to 1176°C, the intensities of the pigeonite X-ray reflections increase and the intensities of the augite reflections decrease continuously. At 1176°C the augite phase has almost completely dissolved into the host pigeonite. Above 1176°C the pigeonite crystals begin to melt and augite reappears in the X-ray pattern. Continued heating between 1176° and 1258°C causes the beta angle of pigeonite to now increase from the minimum value of 108°16' and the beta of augite to now decrease from the maximum value of 107°0', indicating repartition of the calcium in pigeonite back into augite. At 1258°C the pigeonite with β=108°29' has nearly disappeared leaving augite (β=106°43') and glass. The solubility gap for the two clinopyroxenes is minimized at 1176°C and it is estimated to lie between Wo_{12} and Wo_{30}.

A single crystal of host augite from rock 12021, having the approximate bulk composition $Wo_{25}(En,Fs)_{75}$, was subjected to the same heat treatment. The unheated crystal contained approximately 50 percent pigeonite exsolved on (001). The approximate composition of the host and exsolved phases is $Wo_{50}(En,Fs)_{50}$ and $En_{67}Fs_{33}$, respectively. The beta angles of augite and pigeonite change, respectively, from 106°3' and 108°47' for the unheated crystal to 107°12' and 108°0', respectively, at 1176°C where a minimum in the solubility gap is reached. Above this temperature pigeonite disappears, glass appears, and augite starts to become more calcic with the beta now decreasing from the 107°12' maximum to 106°5' at 1258°C. At this temperature the grain is about 75 percent glass and the augite composition appears to be close to $Wo_{50}(En,Fs)_{50}$.