

Influence of variable fO_2 and TiO_2 on the high pressure phase equilibria of lunar ultramafic glasses

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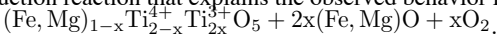
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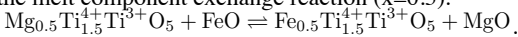
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Pressure-temperature conditions of multiple saturation with olivine and orthopyroxene of intermediate and high titanium Apollo ultramafic glasses strongly depend on fO_2 . Piston cylinder experiments conducted in both graphite capsules (IW+2) and iron capsules (IW-2) bracket the expected range of fO_2 involved in lunar petrogenesis. The pressure of multiple saturation increases by 1 GPa (~200 km) for the Apollo 15 red glass (13.5 wt% TiO_2), and by 0.5 GPa (~100 km) for both the Apollo 17 orange glass (8.8 wt% TiO_2) and the Apollo 14 yellow glass (4.5 wt% TiO_2). The change in multiple saturation (ΔMSP) is not linear with TiO_2 but with $TiFe\# = \text{molar } (Fe+Ti)/(Fe+Ti+Mg)$. We find that the melt activity coefficient ratio of FeO to MgO, or $(Y_{FeO}/Y_{MgO})^{\text{melt}}$, decreases at low fO_2 , suggesting that melt speciation of Fe changes with variable fO_2 .

These two observations limit the nature of melt behavior at low fO_2 . One reaction to describe a melt component oxidation-reduction reaction that explains the observed behavior is:



Armalcolite and ilmenite melt components are in equilibrium at higher fO_2 . At lower fO_2 , some Ti^{4+} reduces to Ti^{3+} . The ilmenite melt component dissociates and donates Ti^{3+} to the modified more-Ti rich armalcolite melt component. To satisfy charge balance, $(Fe, Mg)O$ is ejected into the melt, along with $(Fe, Mg)O$ from the ilmenite melt component. Increasing the available $FeO+MgO$ for the remaining melt components explains the deepening ΔMSP . The reduced armalcolite melt component is most stable at higher $Ti+Fe$ contents, illustrated by the melt component exchange reaction ($x=0.5$):



The reaction proceeds to the right as the $FeTi\#$ increases, explaining both the reduction in $(Y_{FeO}/Y_{MgO})^{\text{melt}}$ and the $\Delta MSP - FeTi\#$ linear relationship.