

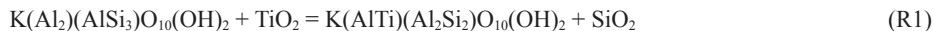
## Titanium in muscovite, biotite, and hornblende: Modeling, thermometry, and rutile activities of metapelites and amphibolites

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### ABSTRACT

Reactions involving the  ${}^{\text{VI}}\text{Ti}^{\text{IV}}\text{Al}-{}^{\text{VI}}\text{Al}^{\text{IV}}\text{Si}$  exchange in muscovite, biotite, and hornblende were calibrated thermodynamically using a set of experimental and natural data in rutile- plus quartz/ coesite-bearing assemblages. The specific respective reactions are



Ideal mixing on octahedral or octahedral plus tetrahedral sites and a non-ideal van Laar solution model yield the best regression results for thermodynamic fit parameters, with  $R^2$  values of 0.98–1.00. Isoleths of the equilibrium constant ( $K_{\text{eq}}$ ) show minimal pressure dependencies of  $<1$  °C/kbar, implying that the equilibria are poor barometers. Model reproducibility of the ideal portion of the equilibrium constant ( $K_{\text{id}}$ ) is excellent (ca.  $\pm 0.1$  to 0.3,  $2\sigma$ ), but the absolute value of the combined term  $\Delta S + K_{\text{id}}$  is quite small (absolute values from 0 to 4), so calibration residuals propagate to temperature errors  $>\pm 50$ –100 °C,  $1\sigma$ . Whereas the consistency of a mica or hornblende composition with a known  $T$  can be evaluated precisely, Ti chemistry in these reactions is sensitive to composition and does not resolve  $T$  (or  $P$ ) well. The activity of  $\text{TiO}_2$  in rutile [ $a(\text{rt})$ ] was also evaluated using both the garnet-rutile-ilmenite-plagioclase-quartz (GRIPS) equilibrium and our new calibrations in rutile-absent, ilmenite-bearing rocks whose peak  $P$ - $T$  conditions are otherwise known. Metapelites have average  $a(\text{rt})$  of 0.9 (GRIPS) and 0.8 (R1), whereas amphibolites have  $a(\text{rt})$  of 0.95 (GRIPS and R3). A value for  $a(\text{rt})$  of  $0.80 \pm 0.20$  (metapelites) and  $0.95 +0.05/-0.25$  (amphibolites) is recommended for trace-element thermobarometers in ilmenite-bearing, rutile-absent rocks. The dependence of Ti contents of minerals on  $a(\text{rt})$  and the reequilibration of Ti during metamorphic reactions both deserve further exploration, and may affect application of trace-element thermobarometers.

**Keywords:** Titanium, rutile, muscovite, biotite, hornblende