

Effect of Crystallization Kinetics and Volatiles on Oxygen Isotope Fractionation between Anorthite and Basalt Melt: Direct Crystallization and Partial Melting Experiments at 1 atm

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Oxygen isotope fractionation factors between silicate minerals and melts have been determined by means of gas-mediated isotope exchange since the experimental work by Muehlenbachs and Kushiro (1974). However, this method cannot be applied to melt cooled below its liquidus temperature. In order to clarify behavior of oxygen isotope fractionation during magmatic processes, we employed in this study direct crystallization and partial melting methods, and made direct analysis of each pair of crystallized or remaining phenocrysts and residual or produced melt as glass. The crystallization experiments were carried out using synthetic starting materials of $An_{50}Di_{30}Fo_{20}$ for forsterite (liquidus $T = 1350$ degC) and $An_{60}Di_{30}Fo_{10}$ for anorthite (liquidus $T = 1350$ degC) syntheses. These starting materials were held in a Pt-spiral hanging in an infrared image furnace under Ar-stream (forsterite runs) and a Pt-capsule in SiC-resistance furnace (anorthite runs) during 1 to 2 days. The starting materials were once completely fused at 1390 degC, then cooled down to the crystallization temperatures. In this method, crystallized minerals are likely to be isotopically equilibrated with mother melts. The partial melting experiments were performed with two starting mineral assemblages composed of natural olivine, plagioclase, and pyroxenes coexisting in Hachijojima olivine-eucrites which originally have oxygen isotope compositions equilibrated at temperatures of basaltic magma (Matsuhisa, 1979). These phases were sealed into a Pt-capsule with or without CaF_2 (<10 wt%). After the runs, products were separated into minerals and glass, and individually analyzed with a CO_2 laser-fluorination microprobe and an electron microprobe.

Crystallization Experiments

The results of forsterite crystallization experiments give a temperature-dependent fractionation curve approximated by the equation: $10^3 \ln \alpha_{fo-gl} = -26.7 \times 10^6 T^{-2} + 12.3$ in the temperature range of 1100 to 1300 degC ($n = 7$). This roughly agrees with the oxygen isotope fractionation estimated by Kyser et al. (1981) (formulated as $10^3 \ln \alpha_{ol-gm} = -19.9 \times 10^6 T^{-2} + 9.2$). While the experiments for anorthite crystallization give oxygen isotope fractionation (Δ_{pl-gl}) of -0.6 to +0.6 per mil in the temperature range of 1250 to 1310 degC ($n = 5$), showing no clear temperature-dependency, but with a possible negative

correlation with MgO-partitioning against coexisting glass (D -value = MgO_{pl}/MgO_{gl}) when D -values are greater than 0.035. Tsuchiyama (1985) indicated that faster grown anorthite incorporates more MgO as impurity. The fact observed in the present study that Mg-enriched anorthite tends to be depleted in ^{18}O could be ascribed to the effect of crystallization kinetics; MgO and ^{16}O is incorporated into crystals by fast crystal growth.

Partial Melting Experiments

In the partial melting experiments melts produced in the F-free system at 1220 to 1250 degC have basaltic composition with $SiO_2 = 48$ to 49 wt% and Δ_{pl-gl} values of ~ 0.6 per mil. However, melts produced in the F-bearing system have lower SiO_2 contents (40 to 44 wt%) and smaller Δ_{pl-gl} values (0.2 to 0.5 per mil) than those of the F-free system. Similar to the results of the crystallization experiments, the Δ_{pl-gl} values of the F-bearing system are not temperature-dependent, but dependent on F content of melt with the smallest fractionation factor ($\Delta_{pl-gl} = 0.2$ per mil) of the most F-enriched melt (~ 4 wt%). The lowering of silica content of melt and the decrease of liquidus temperature both might favor larger isotope fractionation between crystal and melt, which is opposed to the observation in the present study. Since F behaves as a viscosity-reducer for silicate melt, oxygen isotope fractionation for crystal-melt system could be affected by crystallization and dissolution kinetics. If H_2O has similar role to F for silicate melt, phenocryst minerals grown from hydrous magma can be isotopically different from that of anhydrous magma; the alternate conditions of hydrous and anhydrous are expected in dynamic crystallization processes of active volcanism repeating volatile saturation and degassing.

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