Density of $NaAlSi_2O_6$ liquid at high pressure and temperature measured by in-situ X-ray microtomography

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Abstract

Knowledge of the density of silicate liquids at high pressures is crucial in understanding the melt solidification and differentiation processes in the mantle. Low-degree partial melting of mantle peridotite can produce melts that contain high alkali contents. However, the density of alkali-rich melts is not well-studied due to the fact that currently available techniques for density measurements of silicate liquids are not well suited for alkali-rich melts which are usually highly viscous and relatively light. Here we report a new method to determine the density of silicate liquids at high pressures and temperatures by employing synchrotron-based X-ray microtomography technique. The 3D volume of silicate liquid at high pressure and temperature can be successfully reconstructed from a series of radiographs taken on the rotating sample. Using this technique, the density of a jadeite liquid ($NaAlSi_2O_6$) were determined up to ~4.8 GPa and 1955 K with a modified Paris-Edinburgh cell assembly. Our density results are consistent with previous simulations on jadeite liquid, but are significantly higher than those determined by X-ray absorption, indicating that the commonly used X-ray absorption technique may not be suitable for determining the density of silicate liquids with large fraction of lighter components (e.g., Na_2O). By comparing our results with silicate liquids of various compositions from the literature, we examined the compositional dependence of the bulk modulus (K) and its pressure derivative (K') in silicate liquids. The bulk modulus is affected by the alkali ratio (Na_2O+K_2O)/SiO_2 of silicate liquids, with alkali-rich liquids generally having smaller K; the pressure derivative of bulk modulus is affected by the polymerization degree (NBO/T) of the liquids, with polymerized liquids generally having lower K'. Thus, alkali-rich melts, having high alkali ratio and high degree of

polymerization, could be highly compressible in the Earth's mantle. The extrapolated density profile for jadeite liquid suggests that sodium-rich melt generated by low-degree partial melting of mantle peridotite may become denser than surrounding mantle materials and gravitationally stable under upper mantle conditions. In addition, the developed technique in this study may also be readily applied to volatile-rich melts and carbonate melts whose densities may not be easily measured by other techniques, making it a potentially powerful tool to expand the density dataset in the composition-pressure space for melts relevant to the Earth's mantle.