Laser ICP-MS study of trace element partitioning between olivine, plagioclase and a basaltic melt

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Trace element contents of minerals and co-existing melts can be used to constrain corrections of melt compositions for fractionation and provide estimates of the redox state of magmas. Such application requires high precision, fO_2 controlled measurements at low pressures and variable temperature of mineral-melt trace element partition coefficients. To address this need, 0.1 MPa experiments were performed over a temperature range of 1150-1175°C, at two oxygen fugacities (QFM and Ni-NiO) for ~70h. The starting material (MORB AII96-18-1, Mid-Atlantic Ridge [1]) was doped in 13 trace elements. Both isothermal and rapid cooling experiments were performed. In rapid cooling experiments, the samples were cooled very rapidly (~60 °C/min) from above liquidus (1230°C) to the target temperature. Trace elements in glass, olivine and plagioclase in the run products were analyzed by laser ICP-MS. Fe and Na loss in our experiments is low and unlikely to have significant effects on the liquidus temperature. The average olivine-liquid Fe-Mg K_D is 0.28±0.01, the cpx-liquid Fe-Mg K_D is 0.24±0.01, and the average plagioclase Ca-Na K_D is 0.94±0.03. Rapid cooling has a major effect on phase stability since cpx is absent from rapid cooling experiments at 1165°C whereas isothermal runs contain 4% cpx. The proportions of phases and size of crystals also differ, with bigger and less abundant plagioclase (7% vs 16%) and olivine (4% vs 7%) crystals for rapid cooling. Furthermore mineral/melt partition coefficients are lower for compatible elements for rapid cooling experiments, and the opposite effect is observed for incompatible elements, consistent with boundary layer effects. For example in olivineD′ s are higher for Sc, V and Yb and lower for Ni (19 vs 27) for rapid cooling. These results indicate that partitioning experiments should be performed isothermally.

Comparison of experiments from a non-doped or doped starting material shows good agreement for plagioclase/melt and olivine/melt partitioning. Our results show good negative correlations of the D values for Sr, Al, Ca, Na for plagioclase and Yb for olivine with temperature. Further work will focus on the effect of fO_2 on the partitioning of elements with multiple valences such as Cr and Eu and cpx/melt partitioning using a basaltic andesite as starting material.

[1] Tormey *et al*. (1987) *Contrib. Min. Pet.* **96**, 121–139

Carbonaceous asteroid sample return

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Asteroids are planetesimals that largely orbit between Mars and Jupiter. Many asteroids are primitive, having escaped the high-temperature melting and differentiation that shaped the larger evolved asteroids and the terrestrial planets. The chemical and physical nature, distribution, formation, and evolution of primitive asteroids are fundamental to understanding Solar System evolution and planet formation. They offer a unique record of the complex chemical and physical evolution that occurred in the early solar nebula. Understanding the origin of organic compounds in early Solar System materials is central to astrobiology. Individual asteroids are ‘astrobiological time capsules’ that preserve a record of the evolution of volatiles and organics starting in the interstellar medium, through the birth and early evolution of the Solar System, to present-day space weathering at asteroid surfaces. Study of volatile-rich compounds and organic molecules in extraterrestrial materials are also of inherent interest to the study of Solar System formation.

An asteroid sample-return mission promises enormous scientific payoff. This mission concept has been extensively studied by independent, experienced teams in the U.S., Europe, and Japan and is very mature. All teams conclude that the highest value samples are pristine carbonaceous material from the early Solar System. Given our current technology and launch limitations, sample return from a carbonaceous near-Earth asteroid provides the highest science return with the lowest implementation risk.

An asteroid sample return mission must acquire samples with known geologic context. Finally, thorough contamination control and documentation is essential to achieving the objective of returning a pristine sample. Such a mission should have the following science objectives: 1) Characterize the asteroid physical properties. 2) Globally map the surface texture, spectral properties, and geochemistry of the target. 3) Characterize the regolith at the sampling site *in situ* with emphasis on the textural, mineralogical, and geochemical heterogeneity. 4) Return a sample to Earth in an amount sufficient for molecular, organic, isotopic, and mineralogical analyses and including documentation of all sources of contamination.