Effect of composition on adsorption of water on perfect olivine surfaces

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The origin of water in the terrestrial planets is controversial. Both comets and asteroids have isotopic properties inconsistent with Earth's water. We are investigating if adsorption of water onto mineral surfaces in the accretion disk could be a viable source of water in the terrestrial planets. Gases coexist with dust in the accretion disk for long periods. The equilibrium H_2O/H_2 ratio in the accretion disk was $\sim 5 \times 10^{-4}$, which corresponds to a pH_2O of $\sim 10^{-8}$ bar. Note that the equilibrium partial pressure is probably a lower limit. Astronomical observations show that dust clouds consist of Mg-rich olivine, pyroxenes, and other refractory minerals with radii <1 μm. Thus the concomitant presence of water gas and dust with high surface area, points to potential interactions between the two components.

We investigated associative adsorption of a water molecule onto selected olivine surfaces (Stimpfl et al.), namely the {100}, {010} and {110}. Surface energy scans on each surface identified both the loci of adsorption and their associated energy. On each surface we identified several high-energy sorption sites ($E_{ads} > 100$ kJ/mol). In environments with low pH_2O such high-energy sites are most likely the first sites to interact with water molecules. The calculations of (Stimpfl et al.; de Leeuw et al., 2006) using pure forsterite suggest that the inner disk could sustain adsorption of water, both associative and dissociative, onto perfect olivine surfaces (de Leeuw et al., 2000).

To gain a better understanding of the mechanism of adsorption, we are performing minimum energy simulations with olivine with Fa up 14%. We are also conducting molecular dynamic simulations to gain an understanding of the kinetics of desorption. In this talk we will present the results from these latest simulations and quantitatively assess the contribution of this mechanism to the water budgets of the terrestrial planets.

References

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New horizons in U-series dating: Looking beyond the last glacial cycle

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A major impedance to understanding Earth's natural climate cycles is that it has only been possible to obtain accurately dated, high-resolution observations back through the last glacial cycle, spanning the last 130,000 years. Therefore, the last glacial cycle has received a disproportionate amount of attention relative to older climate cycles in Quaternary climate studies. For example, the Last Interglacial, or MIS 5.5, occurring ~125,000 years ago (ka) has been emphasized as an analogue of the present interglacial period, whereas the exceptionally long and warm MIS 11 interglacial, occurring at ~400 ka, may represent a more suitable analogue of the present climate regime for the purpose of speculating on future climate trends.

It is exceedingly difficult to obtain reliable age constraints for older climate episodes because of a progressive loss in the resolution of the chronometers as one goes further back in time, coupled to a lack of well-preserved dateable material. For older time periods, many U-series chronologies do not allow the timing of an interglacial maximum to be resolved from the preceding glacial minimum, nor do they allow abrupt climate episodes to be identified. The primary challenge is thus to devise new analytical protocols offering enhanced precision, to improve the resolution of the U-series chronometer and constrain the timing of climate change at a fine scale for older time periods.

During the last two decades, U-series measurement has advanced with the development of multiple-collector (MC) TIMS and ICP-MS. Despite this, U-series measurement precision has been limited to the one-permil (‰) level due to the large $>10^4$ atomic ratios between ^{238}U and its daughter nuclides, and the requirement for ^{234}U and ^{230}Th to be measured on electron multiplier detector systems that are inherently unstable.

Here, I present the results of recent MC-ICPMS studies that have focussed on dramatically improving measurement precision by up to an order of magnitude by measuring concentrated solutions at high intensity for a short (1–2 min) duration. This enables simultaneous data collection on a stable multiple-Faraday array in place of the usual electron multiplier configuration. These new protocols allow 300 ka samples to be routinely measured with age uncertainties of ± 1 ka (2σ) compared with previous error limits of up to 10 ka, and extend the upper limit of the U-series chronometer further back in time from ~500 to ~800 ka. Multiple-Faraday techniques therefore offer the potential to resolve the finer details of climate change during and beyond the last four glacial-interglacial cycles.

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