Mars Atmospheric ^{40}Ar as a Constraint on Volcanic Outgassing History and Thermal Evolution

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^{40}Ar, a radioactive decay product of ^{40}K, is volcanically outgassed from the interior of Mars. Its atmospheric abundance can be used as a constraint on volcanic history and thermal evolution models of Mars. The abundances of all three argon isotopes in the martian atmosphere have been well-determined by the SAM mass spectrometer on NASA's Curiosity rover. Fractionation of the ^{36}Ar/^{38}Ar ratio from its solar abundance can be used to constrain argon loss due to sputtering from the martian atmosphere.

We have coupled a box model for the evolution of ^{40}Ar in the mantle, crust, and atmosphere of Mars to a parameterized thermal evolution model for the martian interior. The thermal model includes the effects of convective and conductive heat transport and radioactive heating in both the mantle and crust. We calculate the volume of melt production as a function of time and account for the transport of water and radioactive elements from the mantle to the crust using appropriate partition coefficients. Loss of radioactivity from the mantle modifies the thermal evolution. Loss of water from the mantle raises the viscosity and reduces the vigor of convection. Loss of water from the mantle also raises the solidus and reduces the rate of magma production. The calculated magma production provides the transport terms needed in the argon box model. Argon is highly incompatible in common igneous minerals, so ^{40}Ar that is carried volcanically out of the mantle is assumed to escape to the atmosphere.

This coupled model allows us to directly test the effects of key control parameters such as the initial interior temperature, the initial mantle water abundance, and the abundance of radioactive elements on the present-day abundance of atmospheric Ar. Our current best model has 600 ppm K in bulk silicate Mars. This is higher than the canonical Dreibus/Wänke/Taylor Mars composition model (K~310 ppm), but it rules out several competing models with K=920-1040 ppm. Our K value is an upper bound, because it does not yet account for possible degassing to the atmosphere of ^{40}Ar generated from crustal K. We are currently adding a thermal model of the crust to the simulation, which will allow us to calculate crustal degassing and therefore improve our bound on K abundance in the bulk silicate Mars.