RAYLEIGH DISTILLATION AND CONDENSATION OF POTASSIUM ISOTOPES. T. M. Esat[1] and I. S. Williams[2], [1]Department of Geology, Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia, [2]Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia.

Introduction: In the laboratory, vacuum vaporization of molten silicate samples can duplicate isotope fractionation effects observed in some meteorite inclusions [1-3]. The shift in isotope ratios with mass loss is expected to follow the Rayleigh process and is logarithmically proportional to inverse square root ratio of the masses. Rayleigh distillation demands a well mixed reservoir and the complete removal of the vaporized material.

The rocky planets, the Moon and some meteorites are depleted in elements that are volatile at temperatures below about 1200 K. Large variations in condensation or vaporization temperatures can be invoked to account for the segregation of volatile from refractory elements. Starting with an initial hot nebula, incomplete condensation and removal of uncondensed volatiles is one alternative; partial vaporization and removal of volatiles by heating of cold nebular material is another possibility. Humayun and Clayton [4], have addressed the causes of volatile depletion in planetary materials by searching for mass dependent isotope fractionation in the moderately volatile element potassium. Samples investigated include chondrites, achondrites, lunar samples and two CAIs. The data show normal isotope compositions. Based on this data, Humayun and Clayton rule out Rayleigh type distillation as the cause of volatile depletion. They extrapolate from this point and exclude the possibility of any mass loss due to vaporization. Furthermore, they declare a distinction between “kinetic,” Rayleigh type distillation and condensation; asserting that condensation only proceeds through an equilibrium process and with minimal isotope effects. On this basis, they attribute volatile depletion to partial condensation from an initially hot solar nebula. However, based on symmetry arguments both condensation and vaporization are expected to produce similar outcomes and therefore cannot be used to exclude one process over the other as the cause of volatile depletion [5].

Vaporization of K: To investigate the behaviour of K isotopes during high temperature vaporization and condensation we have distilled potassium rich glasses in an RF oven in vacuum (<10^{-6} torr); some of the vapour was collected on stainless substrates. An enclosed Mo tube with a retractable plunger at one end was used to completely vaporize K-glass; the plunger was then inserted to condense the vapour. In primitive, undifferentiated solar system materials potassium often occurs as an alteration reaction product coating high temperature phases; in cracks and vugs as nepheline or sodalite and may be largely of secondary origin. In this sense, potassium rich glass is a reasonable proxy for investigating high temperature behaviour of potassium in the early solar nebula.

Isotopic composition of potassium was measured using SHRIMP II, at mass resolution >5000. Mass loss was determined by weighing and potassium loss by electron probe analysis. Ten residues which lost 0 to 51% of K show an enrichment in ^{41}K relative to ^{39}K from 0 to +17.7 ‰ and match the trend expected from Rayleigh fractionation of mono-atomic K [6]. The evolved vapour phase is enriched in the light K isotope by up to –13‰.

Condensates: The metallic gas from completely vaporized K-glass, collected on a cool stainless surface, consisted mainly of K. Seven measurements along the plunger showed significant heavy K isotope enrichment from +1.2 to +11.2‰. This confirms the expectation [5] that isotopes fractionate during partial vaporization as well as condensation by comparable magnitudes. Therefore, the observed absence of potassium isotope fractionation requires a more complicated scenario than vaporization (condensation) from uniformly mixed liquids (gasses) as the cause of the systematic inner to outer solar system volatile element depletion.

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