PARTITIONING OF POTASSIUM AND URANIUM BETWEEN Fe-FeS AND SILICATE LIQUIDS, M.T. Murrell,
W.R. Neuser, and D.S. Burnett, Div. of Geological and Planetary Sciences, California Institute of
Technology, Pasadena, CA 91125.

INTRODUCTION. Measurements of K and U partitioning between an Fe-FeS liquid and silicate liquid
(SiO2-K2O-P2O5 eutectic) (a) test the possibility that actinides, as well as K, are potential radio-
active heat sources for planetary cores (b) provide a reasonable simulation of radioactive element
partitioning during low pressure separation of an Fe-FeS melt during the early stages of planetary
differentiation and (c) provide some constraints on high pressure partitioning at the terrestrial core-
mantle boundary. There have been several previous studies of K partitioning into Fe-FeS liquics (1-4).
Experiments in nominally oxygen-free systems, in the presence of K metal and/or other water-soluble
K phases, were used by Ganguly and Kennedy (4) to estimate K "solubilities" of 160-380 ppm in Fe-FeS
liquids. Using different experimental conditions, Crockett (1, 2) reported K concentrations in Fe-FeS
liquids which are similar to or higher than the solubilities of Ganguly and Kennedy. The reported K
distribution coefficients (Dk) (sulfide/silicate) span the range from 2 \times 10^{-2} to 3 \times 10^{-2}. The inter-
pretation of these data has generated considerable controversy (3, 5). It has been found that, for the
reducing conditions accompanying the formation of anatase meteorites, U deviated from lithophile
character and concentrated in Ca whereas K remained lithophile (6, 7). This suggests that in addition
to K, the actinides should also be considered in discussions of radioactive heating of planetary cores.

EXPERIMENTAL PROCEDURE. The silicate starting material was prepared from natural soda-
crystal K-field glass and SiO2 glass at a composition close to the eutectic and was spiked with 20 ppm U and
50 ppm Th. The Fe-FeS starting material was prepared by mixing reagent-grade Fe and FeS to give a
composition just slightly to the Fe side of the Fe-FeS eutectic. About 5-10 mg each of the two compo-
nents were loaded into a machined "soft" iron capsule. Great difficulty was encountered in keeping
the Fe-FeS liquid inside the crucible. This problem was solved, in some cases, by placing a Pt wire
"gasket" between a press-fit cap and the capsule. The capsule was then heated in an N2 atmosphere
overnight at about 950°C (below the eutectic temperatures of either component) to allow the Fe and Pt
to alloy, providing a seal. The temperature was then raised to either 1150 or 1200°C with runs lasting
for 60 to 90 minutes. To quench, the bottom plug of the furnace was removed and the sample dropped,
quenching in each air water. Visible radiation from the capsule ceases in air in about 25 sec-
onds. At present, data are only available for samples quenched in air. Sample capsules were saved
open, mounted in epoxy and polished. U analyses were made by fission track radiography using micro-
track detectors and a thermal neutron fluence of about 1.5 \times 10^{11} cm^{-2}. K analyses were made by elec-
tron microprobe using a LIF crystal spectrometer with long counting times (series of 5 min. counts),
high beam currents (0.15 microamps), and great care taken to determine the bremsstrahlung background
under the K peak. Using beam spot sizes of 5-10 microns, no pitting of the samples or K loss due to
vaporization was observed. Measurements of Si and Al were made on the other crystal spectrometers
at the same time as the K. The silicate glass was analyzed using lower beam currents (typically 0.05
micromamps), larger beam spots (20-30 microns), and shorter counting times (1 min). Analyses of the
glass were also made using conventional analysis routines for all major elements giving about 77%
SiO2, 11% Al2O3, 7.4% K2O, and 4.3% FeO. With the observed amount of FeO, the oxygen fugacity is
buffered at 1-2 orders of magnitude below Fe-FeS.

RESULTS. Three samples (numbers 26, 27, and 28) have been analyzed in detail. Samples 26 and 27
were held for 60 minutes at 1150°C and sample 28 was held at 1200°C for 90 minutes. The samples were
polished parallel to the long axis of the Fe capsule. The bottom, sides, and top of the capsule are
lined with a meniscus-shaped layer of the quenched Fe-FeS liquid. In addition, the silicate glass,
which coats the interior surface of the Fe-FeS layer, contains suspended globes of Fe-FeS, up to about
200 microns in size. Some of these appear to be the vapor phase which could be sulfur species, H2, CO2, or N2. On a microscopic scale the Fe-FeS liquid displays a quench texture of Fe and FeS crystals, with typical FeS crystal sizes of 5-15 microns.
Metal occurs as submicron to micron-sized globes randomly distributed in the FeS, as dendritic growth
patterns, and as individual spheres up to roughly 50 microns in size. In addition, samples 26 and 27
and 28 contain some interstitial material which showed a higher Fe/S ratio than the bulk
FeS and may represent an Fe-S-O liquid.

The first microprobe analyses of the 26 and 27 sections, made after fine polishing with 0.3 micron
Al2O3, showed definite K, Si, and Al peaks for both FeS and FeS grains. After repolishing with a
mixture of diamond powder and commercial petroleum jelly, the Al peaks disappeared, the K peaks were
significantly reduced, substantially and the Si peaks were unaffected. At this stage, Dk values for individual
points were suspiciously variable (20% average deviation) but corresponded to an average value of
1 \times 10^{-3}, which looked reasonable compared to literature results. Given the good resolution of the
crystal spectrometer (66 V, FWHM), all possible elemental interferences with the K (and Si) line could
be ruled out. McKay (8) has reported serious microprobe interferences interpreted as due to matrix
X-rays from glass surrounding crystals less than about 100 microns in size. Such an effect could be a
source of interference in our samples. There is also the possibility that a layer of silicate surface
concentration was smeared over the sulfide during polishing. To check these possibilities, sample 28
was sawed and broken up so that it was possible to make polished sections of the Fe-FeS quenched liquid
alone. Twelve K, Al, and Si analyses were made on the Fe-FeS regions. At the 2% level only one spot
showed a significant K peak. Significant Al was never found, but Si was always present. Since the
distribution of K and background counts at each wavelength for the 12 points can be accounted for by
counting statistics, the data have been averaged. In the averaged spectrum, there is a slight sugge-
PARTITIONING OF POTASSIUM AND URANUM

Marrelli, M.T. et al.

...tion of a K peak at the 1σ level, but we cannot rule out that this is due to general laboratory contamination. This peak corresponds to 8 ± 6 ppm in the Fe-FeS quenched liquid or a 1σ upper limit to D_K of less than 2 x 10^-3, which is about an order of magnitude less than previously found (1-4). Si was consistently observed in both sulfide (300 ppm, D_{Si} = 9 x 10^-3) and metal (250 ppm, D_{Si} = 7 x 10^-4). Goettel (2) reports about 400 ppm Si in Fe-FeS equilibrated with crystalline K-feldspar. Given the high sensitivity of our electron microprobe techniques, we analyzed for contamination silicate (e.g., no trapped glass particles can be found. Within the center of the capsule, the metal-sulfide...