Evaporation of Tellurium from silicate melts: Implications for lunar volatiles. C. J. Renggli[1], J. L. Hellmann[2,3], C. Burkhardt[2], S. Klemme[1], J. Berndt[1], P. Pangritz[1], T. Kleine[2]. [1]Institut für Mineralogie, Universität Münster, D-48149. [2]Institut für Planetologie, Universität Münster, D-48149. [3]Now in: Department of Geology, University of Maryland, USA-20742. (renggli@wwu.de)

Introduction: The behavior of Te in high temperature planetary processes remains poorly constrained, although recent measurements of Te concentrations and stable isotopic signatures in planetary materials [1-3] mandate a better understanding of the element's evaporation behavior. For example, despite its low 50% condensation temperature of 665 K (in a solar nebula gas at 10^{-4} bar [4]) the abundance of Te in lunar mafic impact melt breccias is similar to that in pristine lunar mafic target rocks, suggesting no Te evaporation upon high T impact melting [1]. To investigate the mechanisms behind this surprising observation, here we present experimental results on the evaporation of Te from a silicate melt as a function of temperature and oxygen fugacity (fO$_2$).

Methods: We synthesized a CaO-MgO-SiO$_2$-Al$_2$O$_3$-B$_2$O$_3$ glass from chemical grade oxides, carbonate and H$_2$BO$_3$ at 1200 °C for 30 minutes. One wt.% TeO$_2$ was added to the glass powder in a final step and the mixture was molten for 7 minutes at 1200 °C. This approach produced a homogeneous glass with 0.95 ± 0.04 wt.% TeO$_2$, determined by electron microprobe analysis. The glass was then crushed into shards with diameters of 1-2 mm. These shards were suspended on a Pt-wire in a gas-mixing tube furnace for 15-minute evaporation experiments. The samples were then quenched in a cold-water bath. We controlled the fO$_2$ of the experiments by mixing CO-CO$_2$ gas. We conducted the experiments at 900-1550 °C, and at fO$_2$ relative to the Fayalite-Magnetite-Quartz buffer (FMQ) from 6 log-units below FMQ (FMQ-6) to oxidizing conditions in air. We analyzed the experiments by electron microprobe, laser-ablation ICP-MS, and multi-collector ICP-MS. Details on the analytical methods are given in [3].

Experimental results and discussion: The evaporation of Te from silicate melts is dependent on temperature and oxygen fugacity. Up to 1250 °C the rate of evaporation is limited by diffusion in the glass, observed as diffusion profiles measured in cross-sections through the samples. At 900 and 1050 °C we observe very limited Te evaporation (Fig.1). At 1200 °C up to 80% of the initial Te content evaporates, but we observe little dependence on fO$_2$. At T>1250 °C the degree of evaporation becomes strongly dependent on fO$_2$, with increasing volatility towards higher fO$_2$.
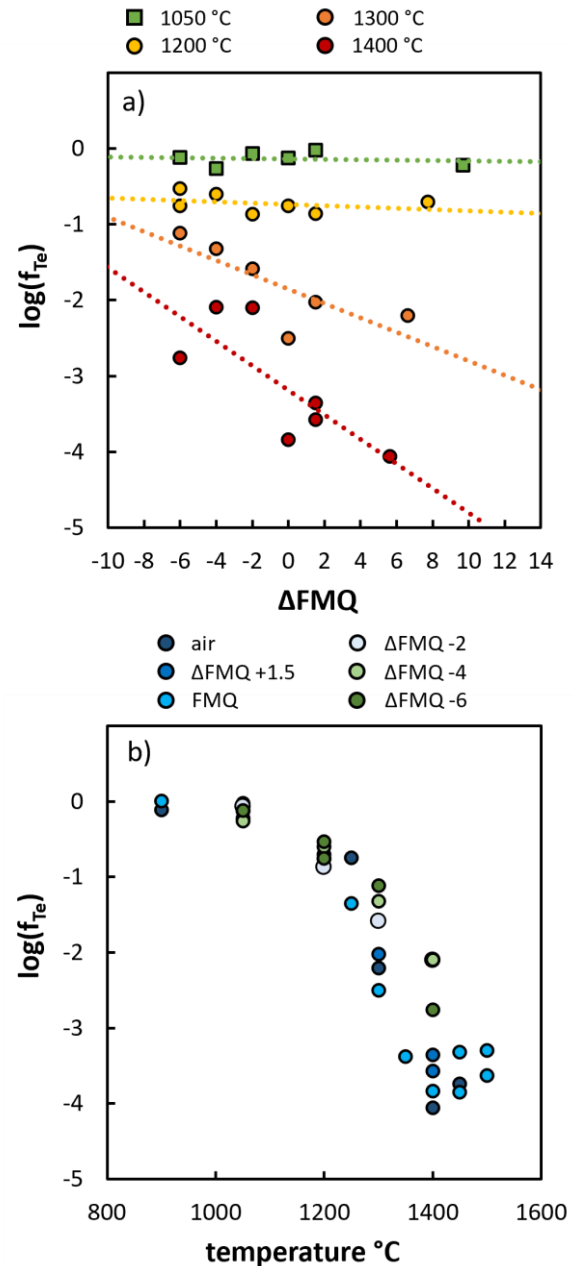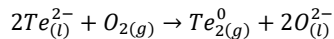

Fig. 1. *Experimental results of Te evaporation experiments. a) logarithm of the fraction of undegassed Te to the starting material after 15 min. (log(f_{Te})), as a function of fO$_2$ shown relative to the FMQ (Fayalite-Magnetite-Quartz) buffer in log-units. b) log(f_{Te}) as a function of temperature, where the colors of the symbols denote fO$_2$ relative to FMQ.*

The residual Te content reaches a minimum of $\log(f\text{Te}) \sim -3.5$ (which is equal to ~2ppm Te in absolute concentrations) at 1400 °C and at FMQ, and does not further decrease at higher temperatures (Fig. 1b). This concentration represents a telluride capacity C_{Te} in our melt compositions, comparable to the dissolution of reduced S^{2-} in silicate melts, also referred to as the sulfide capacity C_S [5].

In air, Te evaporates as $Te^{4+}O_2$. At less oxidizing conditions (FMQ+1.5 and below), Te occurs as Te^{2-} in the melt and evaporates primarily as a Te_2 gas species, in a water free system. Accordingly, the evaporation reaction can be written as:

$$2Te_{(l)}^{2-} + O_{2(g)} \rightarrow Te_{2(g)}^0 + 2O_{(l)}^{2-}$$

where Te^{2-} replaces O^{2-} in the anion sublattice of the aluminosilicate melt. This evaporation reaction is referred to as a pseudo-equilibrium [5]. At equilibrium we would expect the data to show a slope of -1/2 in a Te concentration vs. oxygen fugacity plot (e.g. Fig.1a). However, our evaporation experiments are not intended to reach equilibrium, and the telluride solubility limit is only reached in the strongly degassed high temperature experiments at T>1400 °C. Like S and Se, we expect that the telluride solubility would be higher in an Fe-bearing system [6].

Implications for lunar volatiles: At oxygen fugacities relevant to lunar magmatic rocks (FMQ-3.3 to FMQ-6 [7]) Te has a low volatility. We therefore predict little evaporation of Te_2 from erupting lunar lavas. A significant evaporative loss of Te would require oxidation of the melts. This is in agreement with observations from lunar impact melt breccias, which show little to no volatilization and loss of Te, Se, and S [1]. Chemical processes in large scale lunar impact events remain poorly understood. However, the limited degassing of volatile elements like Te suggests that oxidation of melts and gases is not an important mechanism.

The volatile behavior of Te appears decoupled from S in the "Rusty Rock" 66095, which experienced secondary fumarolic metasomatism at ~580 °C [8-9]. Whereas S is enriched in 66095, Te and Se show no significant enrichment in the "Rusty Rock" and similarly altered samples such as 60016 and 65095 [10]. The absence of Te enrichment in these samples suggest either a depletion of Te relative to S in the source of the fumarolic gas, or degassing may have occurred at an $f\text{O}_2$ where S is relatively more volatile compared to Te.

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