Experimental determination of evaporation rates of iron and palladium under nebular conditions and their implications. Y. Xiong¹ and R. Hewins¹, ¹Department of Geological Sciences, Rutgers University, 610 Taylor Road, Piscataway NJ 08854-8066, USA (xiongyl@rci.rutgers.edu; hewins@rci.rutgers.edu).

Introduction: Diverse explanations exist for the formation and zonation of metal grains in chondrites [1–5]. We provide experimental constraints on these models, assuming kinetics were important.

Methodology: Evaporation experiments were conducted using a DELTECH vacuum furnace [6–7]. We used Pd (purity 99.9%) and Fe (purity 99.997%) foils with known surface areas, suspended on Re wire. Isothermal experiments (1210°C, 1483 K) used $P_{H_2} = 1.31 \times 10^{-7}$ atm. With samples at the top of the muffle tube, the furnace was raised to the desired temperature and pumped down to at least $1.31 \times 10^{-8}$ atm. Hydrogen gas was introduced and the sample was lowered to the hot spot. Weight loss was measured (error < 0.1 mg).

Results: Experimental results at 1210°C and $P_{H_2} = 1.31 \times 10^{-7}$ atm (Fig. 1) yield the evaporation rates for Pd and Fe, $2.58 \times 10^{-6}$ g/s cm$^2$ and $1.04 \times 10^{-6}$ g/s cm$^2$, respectively. Our evaporation rate for Fe at 1210°C agrees with [8] at 1220°C ($7.65 \times 10^{-7}$ g/s cm$^2$) considering the partial oxidation of Fe to wustite in their experiments. At this temperature, using [9], the calculated equilibrium pressures for Pd and Fe are $4.14 \times 10^{-8}$ atm and $1.25 \times 10^{-7}$ atm, respectively. Assuming a sticking coefficient of 1, for the above equilibrium pressures, the calculated equilibrium evaporation rates for Pd and Fe are $4.94 \times 10^{-7}$ g/s cm$^2$ and $1.08 \times 10^{-6}$ g/s cm$^2$, respectively.

Implications: The evaporation kinetics of Pd and Fe are drastically different at this temperature though they have almost identical evaporation/condensation temperatures (Pd, 1334 K; Fe, 1336 K [10]). First, under equilibrium conditions, the thermodynamically predicted evaporation rate of Pd is half that of Fe. In contrast, under our experimental conditions, the above trend is reversed, i.e., the evaporation rate of Pd is about two times faster than that for Fe. Second, our measured evaporation rate of Fe is very close to the calculated equilibrium value ($1.08 \times 10^{-6}$ g/s cm$^2$ versus $1.08 \times 10^{-6}$ g/s cm$^2$).

For dynamic evaporation, the rate of evaporation (forward reaction) exceeds the rate of condensation (backward reaction). Since the condensation rate would be smaller than our evaporation rate, we can constrain the minimum time required for growing certain sizes of metal grains by condensation.

The minimum time required for growing metal grains is:

$$W_{Fe} = Akt$$

where $W_{Fe}$ is the mass of Fe condensed as a function of time, $A$ is the surface area of (spherical) metal grains, $k$ is the condensation rate, and $t$ is time. Metal diameters are typically a few hundred microns in CH chondrites [3]. The minimum growth times of metal grains with radii of 555 µm and 100 µm at 1210°C are 38.7 h (1.61 d) and 6.94 h (0.289 d), respectively. This minimum time-scale for the growth of metal grains is not inconsistent with [11].

The drastically different evaporation kinetics for Pd and Fe may have important implications on the chemical fractionation of Pd and Fe if this trend is also observed at other temperatures. This might imply that the current practice of using Fe as a normalization factor for Pd might not be appropriate.