

EXPERIMENTAL SELF-DIFFUSION DATA FOR ORTHOPYROXENE AND ITS SIGNIFICANCE FOR METEORITE COOLING RATES. C. S. Schwandt, Planetary Sciences Branch, NASA-Johnson Space Center, SN4, Houston, Texas 77058-3696.

Orthopyroxene, which can contain compositional zoning of Mg and Fe, is a constituent of many meteorites. Mesosiderite meteorites are breccias consisting of roughly equal proportions of interspersed silicate clasts and Fe-Ni metal. Some clasts are magnesium-rich orthopyroxene ($\text{En}_{83}\text{Fs}_{17}$) surrounded by more iron-rich orthopyroxene ($\text{En}_{63}\text{Fs}_{37}$) overgrowths [1]. The compositions grade transitionally from the clasts into the overgrowths. This information has been used to estimate the high temperature cooling rates of the silicate clast portions of mesosiderites [1, 2, 3, 4]. However, accurate estimation of cooling rates is dependent on the accuracy of the parameters used to calculate them. A critical parameter is the cation diffusion coefficient. Cation diffusion data for orthopyroxene has been lacking, although Ganguly and Tazzoli [3] theoretically estimated the Mg-Fe interdiffusion coefficients from Mg-Fe order-disorder rate data for orthopyroxene. Ganguly et al. [4] used their estimates to show that the cooling rate for the orthopyroxene clast portions of mesosiderites was three to four orders of magnitude slower than estimated by Delaney et al. [1, 2], who considered the diffusion coefficients for orthopyroxene to be similar to the diffusion coefficients for olivine. Recently, Schwandt et al. [5] experimentally determined magnesium self-diffusion coefficients in orthoenstatite ($\text{En}_{90}\text{Fs}_{10}$) for diffusion parallel to each of the crystallographic directions. These experimentally determined diffusion coefficients are slightly smaller than the theoretical values of Ganguly and Tazzoli [3], such that the cooling rate of the orthopyroxene clasts in mesosiderites is about an order of magnitude smaller than estimated by Ganguly et al. [4] and four to five orders of magnitude slower than estimated by Delaney et al. [1, 2].

Schwandt et al. [5] determined ^{25}Mg self-diffusion coefficients for diffusion parallel to each of the crystallographic directions of orthoenstatite for iron-wüstite conditions at temperatures of 750, 800, 850, and 900°C. Self-diffusion coefficients are similar in magnitude to interdiffusion coefficients [6]. The Arrhenius relationships determined from the data indicate that anisotropy of diffusion is minor for that temperature range. The activation energy, E_a , and frequency factor, D_0 , values for diffusion parallel to each crystallographic axis are as follows: *a*-axis $E_a = 360 \pm 52$ kJ/mole and $D_0 = 1.10 \times 10^{-4}$ m²/s, *b*-axis $E_a = 339 \pm 77$ kJ/mole and $D_0 = 6.93 \times 10^{-6}$ m²/s, *c*-axis $E_a = 265 \pm 66$ kJ/mole and $D_0 = 4.34 \times 10^{-9}$ m²/s, where $D = D_0 e^{(-E_a/RT)}$. For the temperature range examined, the uncertainties in the diffusion coefficients, D , are less than an order of magnitude relative to the D 's and nearly overlap with the theoretical D 's of Ganguly et al. [4].

Cooling rates for the orthopyroxene overgrowths of the mesosiderite Lowicz are calculated using the approach of Ganguly et al. [4] based on the Mg-Fe zoning profile of Delaney et al. [1]. Cooling is assumed to have followed an asymptotic relationship where $1/T = 1/T_0 + \eta t$. The time constant, $\eta = 64D(T_0)R/E_a X^2$, has units of K⁻¹t⁻¹. $D(T_0)$ is the diffusion coefficient at the initial temperature determined with the above data, R is the universal gas constant, and X is the length of the diffusion zone [4]. For Lowicz, X is about 1500 μm and T_0 appears to be between 1150°C and 850°C [1, 2, 4]. The resultant cooling rates, $\delta T/\delta t = -\eta T^2$, for this range of temperatures are respectively 11° to 4°/100 y. This is about an order of magnitude smaller than the result of Ganguly et al. [4], but is about four to five orders of magnitude slower than calculated with diffusion

EXPERIMENTAL SELF-DIFFUSION DATA FOR ORTHOPYROXENE...: Schwandt C.S.

coefficients similar to olivine.

To draw conclusions, it is clear that mesosiderites have a complex petrogenesis [7]. Fortunately, the silicate clasts record the high temperature cooling histories and the Fe-Ni metal textures record the low temperature cooling histories of mesosiderites. However, the previous cooling rates for the silicate clasts suggested that they cooled extremely rapidly in a near surface environment of the mesosiderite parent body [2, 4]. In contrast, the metallographic cooling rates are very slow which suggests that the metal portions cooled at greater depth within the mesosiderite parent body [2, 4, 7]. This new orthopyroxene diffusion data now leads to the conclusion that the silicate clast and metal fractions of mesosiderites do not require such extreme differences of environment for their formation, as cooling of the silicate clasts was apparently several orders of magnitude slower than previously thought. As orthopyroxene is a ubiquitous constituent of many other meteorite types, the diffusion data should help define cooling histories for other types of meteorites and is not limited to use with mesosiderites.

[1] Delaney et al. (1980) *L.P.S.C.* XI, 204-206; [2] Delaney et al. (1981) *Proc. Lunar Planet. Sci.*, 12B, 1315-1342; [3] Ganguly and Tazzoli (1994) *Amer. Min.* 79, 930-937; [4] Ganguly et al. (1994) *Geochim. Cosmochim. Acta*, 58, 2711-2723; [5] Schwandt et al. (1995) *Geochim. Cosmochim. Acta*, in review; [6] Freer (1981) *Contrib. Min. Petr.* 76, 440-454; [7] Rubin and Mittlefehldt (1993) *Icarus* 101, 201-212.