

AN EXPERIMENTAL STUDY OF MINOR ELEMENT PARTITIONING IN OLIVINE IN TYPE 1A CHONDRULES; Gary Lofgren and John DeHart, SN-2 NASA Johnson Space Center, Houston, TX 77058.

INTRODUCTION: Minor element partitioning in olivine having a composition typical of those in type 1a chondrules is not well documented (1) nor understood (2,3). Olivine compositions are widely used to infer the low temperature and/or metamorphic history of chondrules. Many assumptions have been made about the origin of particular compositional features of olivine such as the CaO content. High CaO contents are assumed to be an artifact of crystal growth. Recent dynamic crystallization experiments on chondrule compositions have shown these assumptions are not necessarily valid (2,3). In particular, the CaO content does not appear to be related to the growth rate of the olivine in chondrule melts having small amounts of CaO (< 6 Wt. %).

EXPERIMENTS: Dynamic crystallization experiments were conducted on a Type 1a chondrule composition at a range of cooling rates from 10 to 1000°C/hr beginning at slightly subliquidus temperatures (5 and 15°C below the liquidus). The olivine crystals present at the initiation of cooling are equant and have settled to the bottom of the charge. Those that grew during the experiment vary in shape with increasing cooling rate from equant and slightly skeletal to elongate skeletal to acicular and skeletal. The experiments were quenched at temperatures in the range 900 to 1300°C at 100°C intervals. All the charges contain only olivine and liquid except for a few experiments quenched at 1000 and 900°C which contain pyroxene. All the experiments were conducted at an oxygen fugacity one log unit below the IW buffer.

In the charges cooled at 100 or 1000°C/hr, the olivine is normally zoned in Fe/Mg (Fo 99.5-98) and only slightly normally zoned in Cr, Mn, and Ca; Al is at the detection limit in nearly all the experiments. The CaO level is 0.19-0.21 wt. % throughout most of the cores of the olivine crystals and is zoned up to a maximum of 0.28, but more commonly to as little as 0.22 to 0.24 wt. %. In the 10°C/hr cooling experiments, the zoning is absent from charges quenched above 1000°C, but is usually present in the charges quenched at 1000 and 900°C.

The distribution coefficient for Fe and Mg between olivine and liquid at the crystal-melt boundary was calculated to determine whether major element equilibrium was maintained during cooling. The K_d Fe/Mg does appear to be affected by cooling rate. At 10°C/hr the K_d is not measurably different from the equilibrium value of 0.3, but at 100 and 1000°C/hr it is somewhat lower, 0.26.

The partition coefficient for CaO was calculated two ways: 1) the core composition of the olivine was compared with the initial bulk liquid CaO content (K_d') and 2) the olivine and glass compositions were determined close to the crystal edge, but outside the range affected by secondary fluorescence (K_{di}). Both the value of K_d' , 0.028, and K_{di} , 0.015, are independent of cooling rate. The K_{di} is plotted against the mole % forsterite on in Fig. 1 (Figure from Jurewicz and Watson, 1). The Ca K_d can be corrected for variations in Fe content of the olivine (1). A plot of the corrected K_{d90} against CaO in the melt is shown in Fig. 2 and the K_{d90} for this study plots amongst the data of (1).

DISCUSSION: The decrease in the Fe/Mg K_d with increasing cooling rate is similar to that reported by (4) for more Fe rich olivines grown at similar cooling rates. No satisfactory explanation for this disequilibrium behavior has come to light.

The Ca K_{di} shown in Fig. 1 is on a linear extension of the data of Jurewicz and Watson (1) and appears to be the equilibrium value. The perplexing problem is that K_d' is not the same as K_{di} . K_d' is too Ca-rich to be the initial equilibrium value, and the run was too short to equilibrate the olivine core. Therefore, there ought to be more zoning than is observed. The observed K_d' is the value appropriate for an olivine of Fo 80 (1) or pure forsterite (5) (Fig. 1). In effect, the composition of the olivine remains relatively constant while the CaO content of the liquid is doubled. One interpretation is that the initial level of CaO is disequilibrium because it is incorporated at higher than an equilibrium K_d . In addition it doesn't equilibrate because with progressive crystallization, equilibrium is subsequently

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attained with the changing melt composition. As a result there is no chemical potential driving force to even out the initially high Ca content. This high initial Ca content could occur if the initial growth of the olivine in the experimental charges is more rapid at first then slows with continued cooling allowing equilibrium to be attained.

CONCLUSIONS: The distribution of Fe/Mg between olivine and liquid is the equilibrium value at 10°C/hr cooling, but not at higher rates. Conversely the partitioning of Ca is the equilibrium value at all later stages of cooling. Only the initial CaO content of the olivine is kinetically controlled at a higher than the initial equilibrium value. At lower temperature, the equilibrium CaO content rises, so that equilibrium of the core of the olivine with the fractionating melt is eventually attained. The result is little zoning in CaO.

REFERENCES: (1) Jurewicz A.J.G. and Watson E.B. (1988) *Contr. Mineral. Petrol.* 99, 176-185. (2) Connolly H.C. Jr. and Hewins R. H. (1990) *LPS XXI*, 222-223. (3) Lofgren G.E. (1989) *GCA* 53, 461-470. (4) Cirlin E. et al. (1985) *LPS XVI*, 133-134. (5) Watson E.B. (1979) *Amer. Mineral.* 64, 824-829. (5) Jurewicz A.J.G. (1986) Ph.D. Thesis, Rensselaer Polytech. Inst., 216pp.

Figure 1. Plot of Ca Kd in olivine as a function mole % forsterite. The data point from this study is noted (after, 6).

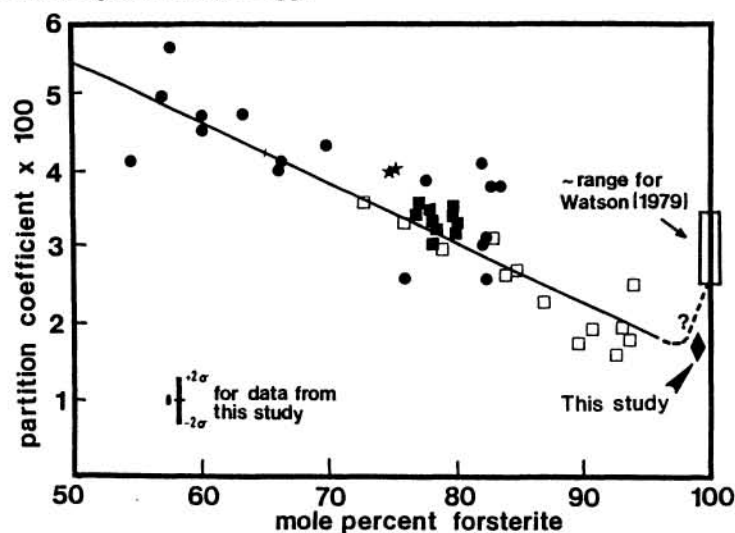


Figure 2. Plot of K_{90} as a function of the CaO content of the melt. The data point from this study is noted (after, 6).

