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Diffusion in natural ilmenite

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Diffusion rates in natural ilmenite of composition $Fe^{2+}_{0.84}$ $Fe^{3+}_{0.16}Mn_{0.07}Mg_{0.01}Ti_{0.92}O_3$ from the Vishnevye Mountains (Urals, Russia) have been measured at 1000˚C. Experiments were carried out in a one atmosphere furnace with oxygen fugacity controlled by flow of a CO-CO_2 gas mixture, over a period of four hours. The diffusant source was a synthetic ilmenite ($FeTiO_3$) powder doped with trace amounts of Mg, Co, Ni, Zr, Hf, V, Nb, Ta, Al, Cr, Ga and Y. Since, the natural ilmenite crystal contained Mn it was also possible to study diffusion of Mn from the ilmenite crystal. The experiments were analysed using the electron microprobe and scanning laser ablation ICP-MS. Diffusion profiles were measured for Al, Mg, Mn, Co, Ni, Ga, and Y. Diffusion of Cr, Hf, Zr, V, Nb and Ta was too slow to allow diffusion profiles to be accurately measured for the times and temperatures studied so far. The preliminary results show that diffusion in ilmenite is fast, with the diffusivity determined in this study on the order of 10^{-13} to 10^{-16} m^2s^{-1}. For comparison, Chakraborty (1997) found interdiffusion of Fe and Mg in olivine at 1000˚C on the order of 10^{-17} to $10^{-18}m^2s^{-1}$ and Dieckmann (1998) found diffusivity of Fe, Mg, Co in magnetite at 1200˚C to be on the order of 10^{-13} to 10^{-14} m^2s^{-1}. The order in which the diffusivity of the elements decreases is Mn $>$ Co $>$ Mg $\geq$ Ni $>$ Al $\geq$ Y $\geq$ Ga, that is to say that Mn diffuses the fastest and Ga the slowest. Overall, this study intends to determine diffusion parameters such as frequency factor, activation energy and activation volume as a function of temperature and oxygen fugacity. This research is taking place in the context of a larger study focusing on the use of the garnet-ilmenite system as a geospeedometer. Examination of the consequences of simultaneous diffusion of multiple elements is a necessity if we are to develop an understanding of the crystal-chemical controls on diffusion (cf Spandler & O'Neill, in press).

Chakraborty, S. (1997). Rates and mechanisms of Fe-Mg interdiffusion in olivine at 980˚C -1300˚C. Journal of geophysical research 102 (B6) p.12317-12331.

Dieckmann, R. (1998). Point defects and transport in non-stoichiometric oxides: solved and unsolved problems. Journal of Physics and Chemistry of Solids 59 (4) p. 507-525.

Spandler, C., O'Neill, H. St. C. (in press). Diffusion and partition coefficients of minor and trace elements in San Carlos olivine at 1300˚C with some geochemical implications. Contributions to Mineralogy and Petrology doi: 10.1007/s00410-009-0456-8.