Solubility and Diffusion of Helium in Amorphous Diopside and Anorthite: Measurements Above and Below the Glass Transition

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Introduction

Noble gases are important tracers of a wide range of geochemical processes, therefore knowledge of solubility and diffusion coefficients are essential for any quantitative interpretation of noble gas abundance in natural materials. We have experimentally determined these parameters in amorphous silicates in the system CaAl2Si2O8 - MgCaSi2O6 (anorthite - diopside), with emphasis placed on the role of variable melt structure, due to i) changes in composition and ii) significant temperature dependent changes such as those associated with the glass transition. Glasses of composition diopside and anorthite were synthesised, then mechanically mixed to produce intermediate compositions. Beads of liquid, approximately 2mm in diameter, were suspended on Pt-wire loops and held for 24 hours at 1600°C at 1 bar under a flow of pure He.

Solubility

The Henry coefficients for solution (K_H) was determined by complete extraction of He from glass chips (typically 10 mg) heated by laser: The results for the two endmember glasses saturated at 1600°C are:

K_H (Di) = 1.88.10^{-4} cc STP/g.atm,
K_H (An) = 3.95.10^{-4} cc STP/g.atm.

Higher He solubility in anorthite is consistent with the lower density (d=2.7 g/cm³), thus higher ionic porosity, of this glass compared to diopside (d=3.3 g/cm³). Solubilities of intermediate compositions are found to be a linear function of composition. Our results are consistent with those reported by Carroll (1991) and underline the important relationship between solubility and silicate melt structure.

Diffusion

Noble gases in glasses were extracted by stepwise heating and analysed by static mass spectrometry in the temperature range 700-1200K. Diffusivity is found to have an Arrhenius temperature dependence, characterised by values of pre-exponential factor (D_0) and activation energies (Ea) of:

[D: D_0 = 16.91 cm/s ; Ea = 39.93 Kcal/mol]
[An : D_0 = 1.113 cm/s ; Ea = 30.31 Kcal/mol]

The diffusion coefficient of anorthite is higher than that of diopside, but values for the two appear to intersect at temperatures close to 1100K. A significant finding of this study is that no discernible change in activation energy is observed across the glass transition, despite significant volume changes (Toplis and Richet, 2000). These results are consistent with the suggestion of Jambon (1982), which reported no change in diffusion across the glass transition.