CHEMICAL DIFFUSION OF OXYGEN IN ANORTHITE$_{20}$-DIOPSIDE$_{80}$ MELTS

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INTRODUCTION

The purpose of this study was firstly to determine chemical diffusion rate of oxygen (diffusion coefficient) in Anorthite$_{20}$-Diopside$_{80}$ melt at different temperatures. Secondly the measured diffusion coefficients were compared to diffusion data collected on other melts along the anorthite-diopside binary, to determine the role temperature and composition play in oxygen diffusion. These data provide a foundation for future studies to determine what oxidation-reduction path magma may take with varied temperature and cooling time. For magma that has already cooled, diffusion data may be used to indicate what environment the magma experienced during cooling.

METHOD

Chemical diffusion of oxygen was determined by monitoring the rates at which 1 (one) weight percent of iron in the sample Anorthite$_{20}$-Diopside$_{80}$ melt is oxidized, at specific temperatures and external oxygen fugacity. The specific temperatures at which this silicate melt was examined were 1375°C, 1425°C, and 1475°C. Iron is used as an indicator of oxygen diffusion because of its distinct characteristic as a multivalent element. Iron changes from ferrous (Fe^{+2}) to ferric (Fe^{+3}) as oxygen diffuses into the sample according to the reaction.

$$4Fe^{+2}{}_{(melt)} + O_2\ (gas/melt) \text{--->} 4Fe^{+3}\ _{(melt)} + 2O^{-2}{}_{(melt)}$$
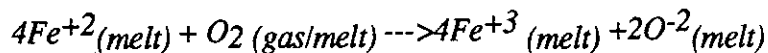
Total ferrous iron was measured for each sample by titration with a cerric solution (Schreiber et al.,1986). Ferric iron was determined by difference. Examining the ratio of ferric to ferrous iron indicated how much oxygen had diffused into the melt over the period of the experiment. Time series and titration experiments provided data that allowed me to plot ferric-ferrous ratios verses time. Fick's second law of diffusion (Shewmon, 1963) was used by Sam Kozak to produce a computer program that calculated ferric-ferrous ratios as a function of time for a model oxygen diffusion coefficient. I tried various estimated diffusion coefficients until the computer output of ferric-ferrous ratios verses time best matched the ratios and times I obtained from my experiments.

Data from diffusion experimentd at 1475°C are shown in Figure 1 along with calculated model profiles. The best fit curve is D=2.8 x10^{-5}cm^2/sec. The other curves were rejected because the did not match with the experimentally derived points. Using the same method for each temperature a diffusion coefficient of 1.35 x10^{-5}cm^2/sec was determine for 1375°C and 1.6 x 10^{-5}cm^2/sec for 1425°C. Chemical oxygen diffusion increases with an increase in temperature. The diffusion coefficients of Anorthite$_{10}$-Diopside$_{90}$ and of Anorthite$_{42}$-Diopside$_{58}$, obtained from previous experiments done by Sam Kozak, were used to examine their trend of diffusion with varying composition. The logarithm of these diffusion coefficients along with those obtained from my experiments were plotted as a function of the inverse of temperature (1/T) and the activation energy for diffusion in this melt was determined.The activation energy was calculated

RESULTS AND DISCUSSION

Time(hr)	1475data	D=9.0e-5	D=1.5e-5	D=2.8e-5
0	0.89	0.76	0.71	0.91
0.27	0.82	0.64	0.58	0.57
0.56	0.39	0.59	0.52	048
0.83	0.45	0.55	0.47	0.44
1.1	0.4	0.52	0.45	0.42
1.67	0.38	0.48	0.41	0.39
2.2	0.37	0.46	0.39	0. 38
24	0.35	0.41	0.36	0.36

Table 1. *This table demonstrates the procedure described in the text above by showing data values of ferric-ferrous ratios and corresponding times at temperature 1475°C, along with model profile for three choices of D.*
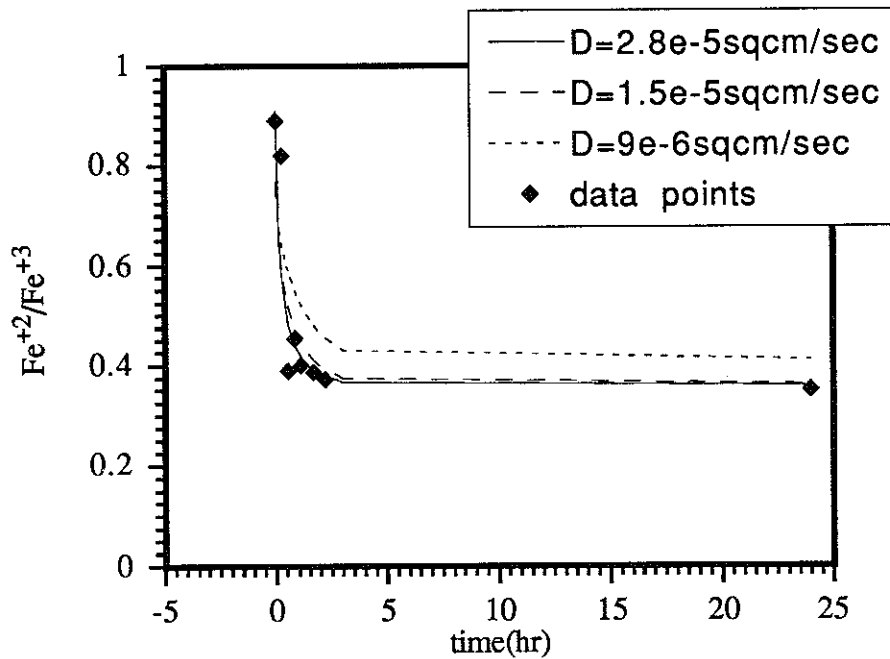

Figure 1. *Ferric-ferrous ratios determined for a series of experiments at 1475°C are shown with calculated profiles for three values of D. The best fit to these data was obtained for a D of 2.8 x 10⁻⁵ cm²/sec.*

using Arrhenius relationship, $\log D = \log D_0 + (E/2.303R)1/T$, where R is the gas constant, T is the temperature, E is the activation energy, D_0 is Arrehenius frequency factor, and D is the diffusion coefficient.
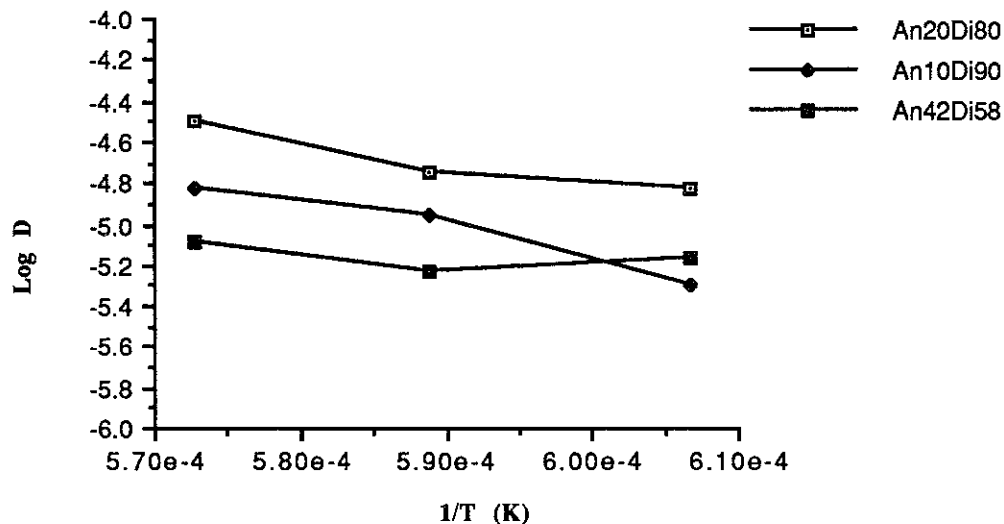

Figure 2. *Activation energies for the various compositions had a range of 40kcal/moles to 60kcal/moles.*

It is evident from Figure 2 that chemical diffusion of oxygen diffusion of oxygen increases with an increase in Diopside content. In studies done by Scarfe (1983) it was found that viscosity increases with a decrease in temperature, and when temperature was held constant there is an increase in viscosity with a decrease in diopside. A relationship between diffusion and viscosity can be determined through their individual relationship with temperature and diopside content, that is, an increase viscosity will result in a decrease in diffusion.

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