

Experimental study the temperature dependence of water diffusion in dacite melts

P. G. Bukhtiyarov¹, E. S. Persikov¹, S. Newman²

¹Institute of experimental Mineralogy RAS, Chernogolovka, Russia

²California Institute of Technology, Pasadena, USA

pavel@iem.ac.ru

The temperature dependence of the diffusion of H₂O in haplodacite melts (Ab90Di8Wo2, mole %) has been study at the P(H₂O) = 20MPa in the temperature range of 1000° - 1200°C using a new small gradient methodology. Experimental data obtained is showed that the temperature dependence of water diffusion in haplodacite melts at an average concentration of water C (H₂O) = 0.67 wt. % in them can be described by an exponential Arrhenius- Frenkel's equation, with the activation energy - E = 65 ± 15 kJ / mole.

Key words: diffusion, temperature, pressure, dacite, model, IR-spectroscopy, water, melts

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Knowledge of the temperature dependence of water diffusion in magmatic melts is one of the fundamental problems to understand of a few magmatic processes such as: degassing of magma during volcanic eruptions, the interaction of fluids and magma, the nucleation and growth of crystals and bubbles, and many others. Since the water solubility is much higher than the solubility of other components of the fluid, the diffusion of water is often of the limiting stage of these processes. We have experimentally studied the temperature dependence of the diffusion of H₂O in haplodacite melts (Ab90Di8Wo2, mole %) at the P(H₂O) = 20MPa in the temperature range of 1000° - 1200°C using a new small gradient methodology [Persikov & Bukhtiyarov, 2009; Persikov et. al., 2010] (see fig.1).

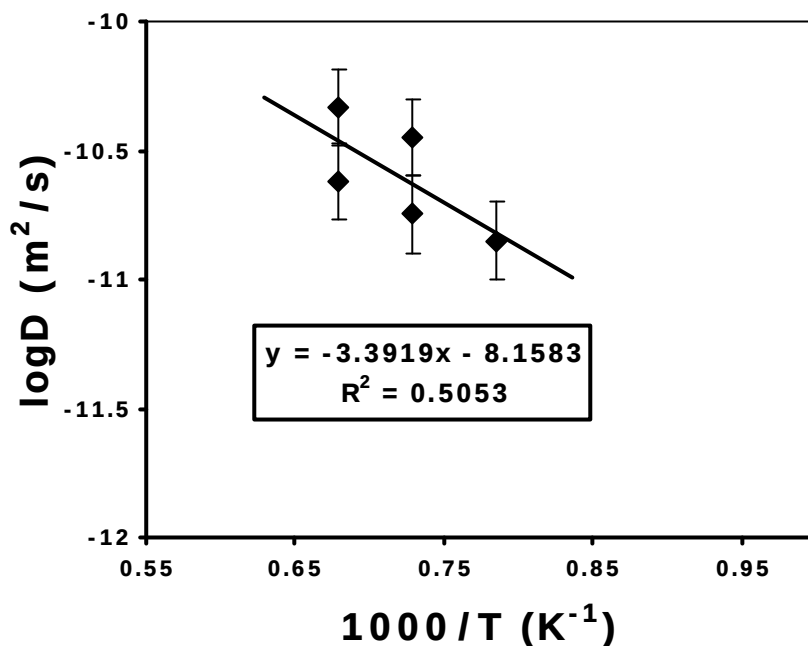


Fig.1. The temperature dependence of water diffusion in haplodacite melts (C(H₂O) = 0.67 wt.%): ♦ – experimental data with the standard deviation ± 30 % rel.

Experiments were performed on a high gas pressure vessel using the original equalizer - separator, that is conduct the experiments in open capsules without of the change of the original geometry of the capsules. Diffusion of water was studied by hydration of anhydrous haplodacite melts, which received by melting of stoichiometric mixtures of the powder of natural mineral (albite + diopside + wollastonite) at the temperature 1500°C for 4 hours in a high temperature furnace at an air atmosphere. Samples pressurized by water in a high gas pressure vessel at the $P(H_2O) = 20\text{MPa}$ is heated initially at 1500 °C / hour to below the required temperature on the 300-500°C, and then very quickly heated to the needed temperature at the rate of 300°C/min. After that melt is kept for the time which is need to form of the diffusion profile in the melt and spent the isobaric quenching at 300 - 500 °C/min. Concentration of water along the diffusion profiles were determined by quantitative FTIR spectroscopy using of the Beer-Lambert's equation. The diffusion of water was determined by analytical [Crank, 1975] and numerical solutions to solve of the second Fick's law of diffusion.

Analysis of experimental data showed that the temperature dependence of water diffusion in haplodacite melts at an average concentration of water $C(H_2O) = 0.67\text{ wt. \%}$ in them can be described by the following exponential Arrhenius- Frenkel's - equation:

$$D = D_0 \cdot \exp(-E/RT) \quad (1),$$

where $R = 8.314\text{ J/mole}\cdot\text{K}$ is the universal gas constant, E is the activation energy of water diffusion for haplodacite melts (J/mole), and T is in K. The activation energy obtained for the activation energy of water diffusion in haplodacite melts ($C(H_2O) = 0.67\text{ wt. \%}$) – $E = 65 \pm 15\text{ kJ / mole}$ is well consist to a previously obtained data for the polymerized haplogranitic melts ($C(H_2O) = 0.5\text{ wt. \%}$) – $E = 64 \pm 10\text{ kJ / mole}$ [Nowak & Behrens, 1997] and for the obsidian melts ($C(H_2O) = 0.5\text{ wt. \%}$) – $E = 67 \pm 21\text{ kJ / mole}$ [Shaw, 1973]. But it is quite different with the values of the activation energy of water diffusion in natural potassic melts ($C(H_2O) = 0.5\text{ wt. \%}$) - $E = 147 \pm 42\text{ kJ / mole}$ [Freda et al. 2003] and in basalt melts ($C(H_2O) = 0.2\text{ wt. \%}$) – $E = 126 \pm 32\text{ kJ / mole}$ [Zhang Y. & Stolper, 1991]. It should be noted that such comparing of activation energy of water diffusion in the melts of different composition is rightfully in strict meaning if the value of D_0 in the equation (1) is a constant.

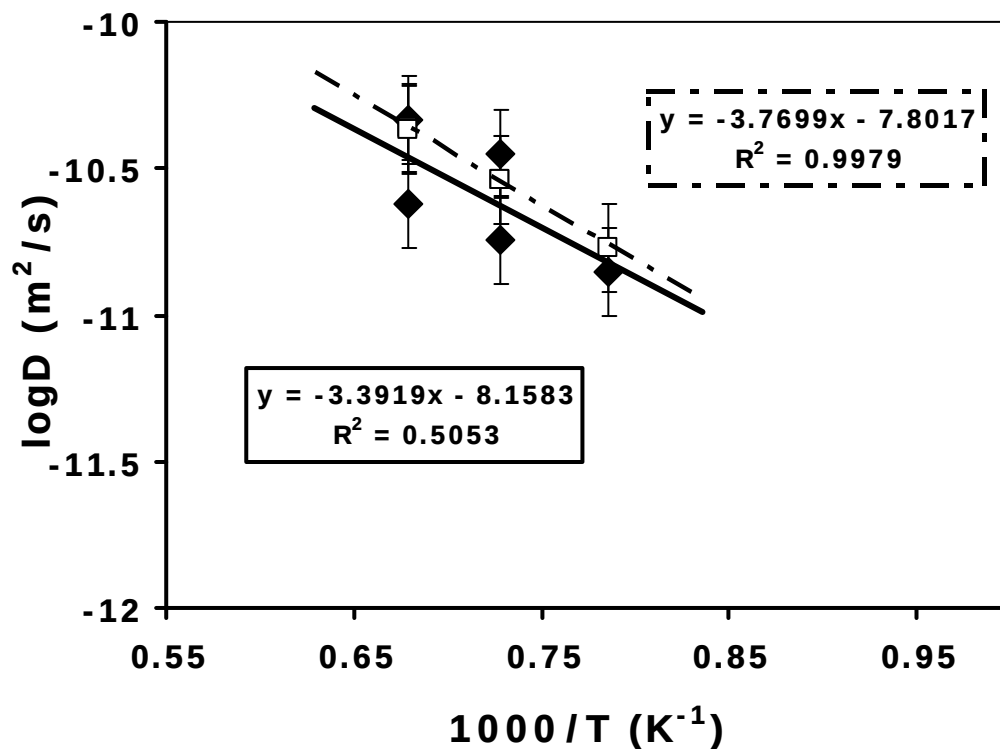


Fig. 2. Temperature dependence of water diffusion in haplodacite melts ($C(H_2O) = 0.67\text{ wt. \%}$) (dark symbols - an experimental data, open symbols - predicting data which were obtained using a new model; [Persikov et al., 2010]).

This problem is solved now for the calculation of activation energy of viscous flow [Persikov, 1991, 1998] but it is not solved for the calculation of activation energy of water diffusion in the melts of different composition. Therefore we are suggested of the next way to solve of this problem. Recently a new model was proposed to calculate the water diffusion in a wide range of composition of magmatic melts, pressures and temperatures [Persikov *et al.*, 2010]. The predicted temperature dependence of water diffusion in haplodacite melts have been obtained using this model (see fig. 2). The data on the fig. 2 shows of a good agreement between experimental and predicted values of the temperature dependence of water diffusion in haplodacite melts with standard deviation which is equal $\pm 0.15 \log$ of $D(H_2O)$. Predicted value obtained for the activation energy of water diffusion in haplodacite melts ($C(H_2O) = 0.67$ wt.%) – $E = 64 \pm 5$ kJ / mole is practically the same to the experimental value.

Conclusions:

1. A new experimental data is indicates that the temperature dependence of water diffusion in haplodacite melts with an average concentration of water in melt $C(H_2O) = 0.67$ wt. % and in the temperature range of $1000^\circ - 1200^\circ C$ is obey the exponential Arrhenius-Frenkel's equation with an activation energy equals $E = 65 \pm 15$ kJ / mole.
2. Model developed to calculate of the water diffusion in silicate melts [Persikov *et al.*, 2010] is allowed to obtain of a well enough data on temperature dependencies of water diffusion in magmatic melts.

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