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The effect of composition on chlorine solubility and behavior in silicate melts

Richard W. Thomas[1] and Bernard J. Wood[1,*,†]

[1]Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, U.K.

Abstract

We have performed experiments at 1.5 GPa and 1400 °C on 25 different bulk compositions to determine the effects of major element compositions on the Cl contents of silicate melts at known fugacities of Cl_2 and O_2. The experimental method involved mixing a "sliding" Cl buffer, a mixture of AgCl, AgI, and Ag with the silicate bulk composition and performing the experiment in a graphite capsule together with a source of CO_2 ($AgCO_3$). The graphite capsules were sealed inside welded Pt tubes to maintain a CO_2-CO atmosphere with oxygen fugacity fixed at the C-CO-CO_2 (CCO) buffer. During the experiment, the Cl buffer segregates leaving a Cl-bearing melt, which quenches to a glass. We used the results to define chloride capacity C_{Cl} for each melt at the pressure and temperature of the experiment:

$$C_{\mathrm{Cl}} = \frac{\mathrm{Cl}(\mathrm{wt\%})}{\sqrt{f(\mathrm{Cl}_2)}} \times \sqrt[4]{f_{\mathrm{O}_2}}$$

Chloride capacity was found to correlate positively with optical basicity and NBO/T and negatively with ionic porosity and the Larsen index. We combined our new data with the results of Thomas and Wood (2021) to derive an equation describing the composition, pressure and temperature dependence of the chloride capacity:

$$\log C_{\mathrm{Cl}} = 1.601 + (4470X_{\mathrm{Ca}} - 3430X_{\mathrm{Si}} + 2592X_{\mathrm{Fe}} - 4092X_{\mathrm{K}} - 894\,P)/T.$$

In this equation, X_{Ca}, X_{Si}, and so on refer to the oxide mole fractions on a single-cation basis, P is in GPa and T in K. The equation reproduces 58 data points with an r^2 of 0.96 and a standard error of 0.089. The addition of literature data on hydrous experiments indicates that the effects of <4.3 wt% H_2O are small enough to be ignored. We also performed experiments aimed at determining the conditions of NaCl saturation in melts. When combined with literature data we obtained:

$$\log(\mathrm{Cl}^-) = \log(a_{\mathrm{NaCl}}) + 0.06 - (2431X_{\mathrm{Ca}} + 3430X_{\mathrm{Si}} - 2592X_{\mathrm{Fe}} + 3484X_{\mathrm{Na}} + 4092X_{\mathrm{K}} - 2417)/T$$

where (Cl^-) is the Cl content of the melt in wt% a_{NaCl} is the activity of NaCl (liquid) and the other symbols are the same as before. The results indicate that basalt dissolves ~8 times more Cl than rhyolite at a given NaCl activity i.e., Cl is ~8 times more soluble in basalt than in rhyolite.

Keywords: Basalt, rhyolite, Cl solubility in melts, compositional effects on Cl solubility, Cl degassing, chloride capacity, NaCl saturation in melts; Experimental Halogens in Honor of Jim Webster