Distribution of chloride between aqueous fluids and felsic melts at 2 kbar and 800°C

IRINA F. KRAVCHUK* and HANS KEPPLER
Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany

Abstract: The distribution of chloride between an aqueous fluid and a hydrous silicate melt was measured at 2 kbar and 800°C in five model systems: albite-quartz-HCl-H₂O, albite-quartz-NaCl-H₂O, orthoclase-quartz-HCl-H₂O, orthoclase-quartz-KCl-H₂O, albite-orthoclase-quartz-NaCl-KCl-H₂O. Chloride always strongly partitions into the fluid. At the same chloride concentration in the fluid, less Cl is dissolved in the melt in the potassium-bearing systems than in the sodium-bearing systems. While the partition coefficient is constant in the two HCl-containing systems, \( K_{D_{melt/fluid}} \) strongly decreases with chlorine concentration in the other three systems. This effect can entirely be attributed to variations in the activity coefficients of NaCl and KCl in the fluid. Activity coefficients \( (f_{X\text{Cl}})_{c} \) of NaCl or KCl (X = Na or K) in the fluid at a concentration c can be obtained from the equation \( (f_{X\text{Cl}})_{c} = (K_{D_{melt/fluid}})_{c}/(K_{D_{melt/fluid}})_{0} \), where \( (K_{D_{melt/fluid}})_{c} \) = partition coefficient at concentration c, and \( (K_{D_{melt/fluid}})_{0} \) = extrapolated partition coefficient at infinite dilution. Extrapolation of measured partition coefficients to infinite dilution is possible using the relationship \( \ln(K_{D_{melt/fluid}}) = a + b \cdot c^{0.5} \), which yields a good fit of measured partition coefficients at low concentration. Measurements of the chloride partition coefficient between fluids and silicate melts therefore provide a simple means for obtaining activity coefficients in fluids at supercritical conditions.

Since chloride always strongly partitions into the fluid, any exsolution of water vapour from the melt will tend to strip a magma of virtually its entire chlorine content. Therefore, only magmas that remain water-undersaturated until shortly before eruption are expected to contribute large amounts of chlorine to the atmosphere. The ratio of water to chlorine in the melt also controls the enrichment of trace elements in an evolving fluid. If the water/chlorine ratio is low, chlorine can be highly enriched in residual melts. When water saturation is finally attained in such a case, the fluid phase in equilibrium with a melt containing 0.1-0.3 wt.% Cl can contain about 50 wt.% of dissolved alkali chloride. Such highly saline solutions are extremely efficient in extracting trace elements out of magmas.

Key-words: chloride, partitioning, silicate melt, fluid, activity coefficient.

Introduction

Together with H₂O, CO₂ and sulphur compounds, HCl and alkali chlorides are major constituents of volcanic gases (e.g. Symonds et al., 1988). Chlorine compounds therefore must have been important components of the earth’s primary atmosphere that was derived from volcanic emanations. During earth history, large volcanic eruptions had a severe impact on climate (e.g. Devine et al., 1984). The decline in average temperature observed after major eruptions is

* Permanent address: Vernadsky Institute of Geochemistry, Kosygin Street 19, 117 975 Moscow, Russia.

DOI:10.1127/ejm/6/6/0913

0935-1221/94/0006-0913 $ 2.75 © 1994 E. Schweizerbart’sche Verlagshandlung, D-70176 Stuttgart