Volumes of K-Na mixing for low albite-microcline crystalline solutions at elevated temperature: A test of regular solution thermodynamic models

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ABSTRACT

High-temperature volumes of K-Na mixing have been investigated for a seven-member low albite-microcline ion-exchange series by conducting X-ray powder diffraction measurements from room temperature to approximately 1000 °C using Guinier techniques. Volume expansion is a linear function of temperature for all series members and is due mainly to the lengthening of the a unit-cell axis, although some expansion of b and c occurs for relatively sodic members. The maximum expansion possible for each feldspar is determined both by chemistry and temperature, thus ΔV/ΔT slopes are steepest for the sodic third of the series, then decrease abruptly for increasingly potassic feldspars. Volumes of K-Na mixing for this series are essentially constant with temperature, regardless of the mixing model utilized, and thus are adequately represented by regular solution thermodynamic models.

INTRODUCTION

It is a common practice in geology to apply certain types of thermodynamic data collected at one temperature and pressure, such as internal energies and volumes of mixing (E° and V°, respectively, using the terminology of Thompson 1967), to a wide range of temperatures and pressures. Indeed, standard “regular solution” models assume that these functions are independent of both temperature and pressure (see Thompson 1967, Eqs. 47, 49, and 69).

In recent work, we asked if enthalpies of K-Na mixing for disordered alkali feldspars are a function of temperature (Hovis and Navrotsky 1995). By making high-temperature (704 °C) lead borate solution calorimetric measurements on an analbite-sanidine solid-solution series, then comparing the resulting enthalpies of mixing with those from lower temperature (50 °C) hydrofluoric acid solution calorimetry (Hovis 1988), Hovis and Navrotsky (1995) determined that a regular solution model did indeed represent enthalpies of mixing well over a wide temperature range.

Here we ask the same question about volumes of mixing. We chose to study a low albite-maximum microcline solid-solution series. The volumetric properties of this mineral series at room temperature and pressure are well known from previous investigations (Hovis 1986, 1988; Kroll et al. 1986; Waldbaum and Robie 1971; Waldbaum and Thompson 1968). No phase transformations across the series confuse interpretation of the data, at either low or high temperature, so these minerals make excellent materials for volume analysis.

SAMPLE PREPARATION

A seven-member Na-K ion-exchange series ranging from low albite to microcline was prepared using the procedures described in Table 2 of Hovis (1986). Amelia low albite (sample 7001) was used as the Na end-member. A corresponding microcline (sample 71104) was produced by ion exchange of the albite powder (<325 mesh) in molten KCl at 840 °C for 16.5h. Compositionally intermediate samples were made by combining powders of the low albite and microcline in the desired proportions, mixing and then compressing these powders in cylindrical platinum crucibles, and annealing them for various lengths of time (normally about 10d) at 935 ± 10 °C (for details see Table 1 of Hovis 1986). Each sample was removed from the furnace approximately every 24h, remixed in acetone (to randomize grains of various compositions), then repacked and reloaded for further annealing. The ion-exchange procedures had no detectable effect on the Al-Si distributions of the various samples, owing to the sluggish rates of Al-Si disordering at homogenization and ion-exchange temperatures (see discussion in Hovis 1986, p. 871).

Raw chemical data both for end-member feldspars and for intermediate compositions were obtained by atomic absorption spectroscopy and were reported in Table 3 of Hovis (1986). For convenience the mole fraction of KAlSi3O8 (Nα) for each feldspar is reported again in Table 1 of this paper.

X-RAY EQUIPMENT AND PROCEDURES

X-ray data were collected at room and elevated temperatures for each feldspar sample at the University of Cambridge, England. Measurements were made using a