REVIEW

Cancrinite-group minerals: Crystal-chemical description and properties under non-ambient conditions—A review

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ABSTRACT

This is a review of the thermal and compressional behavior of cancrinite-group minerals with a description of the mechanisms, at the atomic scale, that govern their P-T-induced structure evolution. The open-framework structure of this group of feldspathoids is characterized by the [CAN] topology, which contains large parallel channels (confined by 12-membered rings of tetrahedra), surrounded by columns of cages. At least two structural “subgroups” can be identified according to the nature of the constituents filling the cages, irrespective of the channel population. The minerals of the “cancrinite subgroup” show [NaH₂O]⁺ clusters into the cages and those of the “davyne subgroup” contains [CaCl]⁺ clusters. Beside a similar bulk compressibility and expansivity at room conditions for all the minerals of the group, a different elastic anisotropy, coupled with different deformation mechanisms of the tetrahedral framework, were found to be mainly controlled by the nature of the population filling the cages. The role played by the channel populations appears to be secondary. These experimental findings allow us to provide a model of the structure evolution in response to the different cage content, i.e., NaH₂O⁺ and CaCl⁺.

The high-temperature studies of the hydrous members of the cancrinite subgroup reveal a slow dehydration process, often irreversible at the timescale of the experiments and leading to quasi-anhydrous high-temperature forms that keep their crystallinity even up to 800–900 K (at room P). The experiments at high pressure on the cancrinite-group minerals show a high-P stability, at least up to 7–8 GPa (at room-T), which is quite surprising if we consider their microporous nature. The P-induced stability is the effect of a pronounced structural flexibility, which in turn is based mainly on tilting of rigid tetrahedra around O atoms that behave as hinges. The character and the mechanisms that govern the P-T-induced P6₃/m→P6₃/m phase transition in the compounds of davyne subgroup are also discussed.

Keywords: Feldspathoids, cancrinite, davyne, vishnevite, balliranoite, temperature, pressure, elastic behavior, host-guest interactions, framework deformation, Invited Centennial article, Review article

INTRODUCTION

Feldspathoids are a loosely defined class of minerals with a structure characterized by a three-dimensional framework of linked SiO₄ and AlO₄ (more rarely PO₄ or BeO₄) tetrahedra. This framework contains open cavities (in the form of channels and cages), usually occupied by cations (mainly Na⁺, K⁺, Ca²⁺), anions (mainly CO₃²⁻, SO₄²⁻, Cl⁻), and molecules (mainly H₂O). Compared with feldspars, the aluminosilicate feldspathoids are deficient in SiO₂. They occur in a wide variety of geological environments and conditions, from sedimentary to alkali-rich SiO₂-poor igneous rocks or metamorphic and metasomatic rocks, from crustal to upper mantle conditions. Some feldspathoids have been found in meteorites (e.g., in carbonaceous chondrites, Grossman 1980).

This class of minerals is the major host of C, S, or Cl structurally incorporated in silicates. The structural diversity of feldspathoids is reflected by their complex systematics with at least three different principal families: analcime-leucite (e.g., Gatta et al. 2006, 2008a), nepheline-kalsilite (e.g., Gatta and Angel 2007; Gatta et al. 2010, 2011), and cancrinite-sodalite (e.g., Gatta et al. 2012a; Lotti et al. 2012; Löns and Schulz 1967). Minerals of the melilite family (i.e., melilite sensu stricto, gehlenite, and akermanite) are also considered as feldspathoids (Edgar 1984). A comprehensive overview on the structures of feldspathoids is reported in Merlino (1984).

When compared to other silicates, only a modest number of experiments have been devoted to cancrinite-group minerals at high pressure or high temperature. Some in situ experiments at high temperature on the most important member of the group (i.e., cancrinite sensu stricto) actually provided conflicting results (Hassan 1996a, 1996b; Sirbescu and Jenkins 1999; Hassan et al. 2006; Isupova et al. 2010; Gatta et al. 2014). A full characterization of the phase stability fields of cancrinite-group minerals and of the reactions at the field boundaries is still missing or limited to restricted experimental conditions (e.g., Sirbescu and Jenkins 1999 and references therein). To overcome this deficiency, we...