The high temperature, low-pressure phase transitions of crystalline silica

Bendik S. Frantzen[a], Kurt Aasly[b], Bjørn E. Sørensen[c]

[a b c]Department of Geoscience and Petroleum, Norwegian University of Science and Technology, Trondheim, Norway,
[a]bendik.frantzen@ntnu.no, [b]kurt.aasly@ntnu.no, [c]bjorn.sorensen@ntnu.no

Abstract

The transitions of the high temperature, low-pressure phases of silica are based on the work by Fenner (1913). When determining the inversion point between quartz and tridymite at 870°C±10°C Fenner used a flux, sodium tungstate (Na_2WO_4) to accelerate the rate of transformation (Fenner, 1913). The incorporation of sodium tungstate has led to much debate on the validity of tridymite as a pure silica phase. Several scientists have shown the stabilization of tridymite through phase transitions requiring the presence of either impurities or a mineralizer (Flörke 1956, Holmquist 1961, Stevens et al. 1997). Despite this, the phase relations, and the temperatures for the inversions between quartz, tridymite, and cristobalite by Fenner remain the most cited in the literature (Heaney et al. 1994, Stevens et al. 1997).

The understanding of the phase relations of the crystalline high temperature, low-pressure SiO_2 phases and the effects of impurities are of most relevance to industrial processes such as high-purity quartz or silicon production. This research aims to increase the understanding by investigating the effects of impurities and particle size on the high temperature, low-pressure phase transitions of crystalline silica. This has been achieved by heating three different powdered quartz materials with varying purity and PSD in the stability range of tridymite at 900°C to 1500°C with holding times of one, three, and eight hours. The Internal Standard method as explained in Madsen et al. (2011) has been used to assess the role of amorphous silica on the phase transitions. Qualitative phase analysis with X-ray diffraction and Differential Thermal Analysis has shown no stabilization of tridymite in either quartz materials with a purity of 99.3, and 99.9%. The quartz materials transition directly from quartz to cristobalite through an intermediate amorphous phase. The temperature of the transition is found to be 300°C lower for a quartz material with 99.3% purity, compared to the quartz material with 99.9% purity. The finer particle materials display a full conversion to cristobalite at a higher rate than the coarser particle materials.

It is concluded that tridymite cannot form through high temperature phase transformations in crystalline silica according to the silica phase diagram without the presence of a sufficient amount of large cations. Further, the temperature and the rate of the phase transition between quartz and cristobalite are dependent on the purity and the particle size of the silica.

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