American Mineralogist, Volume 98, pages 2172–2182, 2013

Melting and subsolidus phase relations in the system Na_2CO_3-$MgCO_3$±H_2O at 6 GPa and the stability of $Na_2Mg(CO_3)_2$ in the upper mantle

Anton Shatskiy[1,2,*], Pavel N. Gavryushkin[1,2], Igor S. Sharygin[1,2], Konstantin D. Litasov[1,2], Igor N. Kupriyanov[1], Yuji Higo[3], Yuri M. Borzdov[1], Ken-ichi Funakoshi[3], Yuri N. Palyanov[1,2] and Eiji Ohtani[4]

[1]V.S. Sobolev Institute of Geology and Mineralogy, Russian Academy of Science, Siberian Branch, Koptyuga pr. 3, Novosibirsk 630090, Russia
[2]Novosibirsk State University, Novosibirsk 630090, Russia
[3]Japan Synchrotron Radiation Research Institute, SPring-8, Kouto, Hyogo 678-5198, Japan
[4]Department of Earth and Planetary Material Science, Tohoku University, Sendai 980-8578, Japan

Abstract

Phase relations in the Na_2CO_3-$MgCO_3$ system have been studied in high-pressure high-temperature (HPHT) multi-anvil experiments using graphite capsules at 6.0 ± 0.5 GPa pressures and 900–1400 °C temperatures. Sub-solidus assemblages are represented by Na_2CO_3+$Na_2Mg(CO_3)_2$ and $Na_2Mg(CO_3)_2$+$MgCO_3$, with the transition boundary near 50 mol% $MgCO_3$ in the system. The Na_2CO_3-$Na_2Mg(CO_3)_2$ eutectic is established at 1200 °C and 29 mol% $MgCO_3$. Melting of Na_2CO_3 occurs between 1350 and 1400 °C. We propose that $Na_2Mg(CO_3)_2$ disappears between 1200 and 1250 °C via congruent melting. Magnesite remains as a liquidus phase above 1300 °C. Measurable amounts of Mg in Na_2CO_3 suggest an existence of $MgCO_3$ solid-solutions in Na_2CO_3 at given experimental conditions. The maximum $MgCO_3$ solubility in Na-carbonate of about 9 mol% was established at 1100 and 1200 °C.

The Na_2CO_3 and $Na_2Mg(CO_3)_2$ compounds have been studied using in situ X-ray coupled with a DIA-type multi-anvil apparatus. The studies showed that eitelite is a stable polymorph of $Na_2Mg(CO_3)_2$ at least up to 6.6 GPa and 1000 °C. In contrast, natrite, γ-Na_2CO_3, is not stable at high pressure and is replaced by β-Na_2CO_3. The latter was found to be stable at pressures up to 11.7 GPa at 27 °C and up to 15.2 GPa at 1200 °C and temperatures at least up to 800 °C at 2.5 GPa and up to 1000 °C at 6.4 GPa. The X-ray and Raman study of recovered samples showed that, under ambient conditions, β-Na_2CO_3 transforms back to γ-Na_2CO_3.

Eitelite [$Na_2Mg(CO_3)_2$] would be an important mineral controlling insipient melting in subducting slab and upwelling mantle. At 6 GPa, melting of the $Na_2Mg(CO_3)_2$+$MgCO_3$ assemblage can be initiated, either by heating to 1300 °C under "dry" conditions or at 900–1100 °C under hydrous conditions. Thus, the $Na_2Mg(CO_3)_2$ could control the solidus temperature of the carbonated mantle under "dry" conditions and cause formation of the Na- and Mg-rich carbonatite melts similar to those found as inclusions in olivines from kimberlites and the deepest known mantle rock samples—sheared peridotite xenoliths (190–230 km depth).

Keywords: Na_2CO_3-$MgCO_3$, eitelite, natrite, alkaline carbonates, high-pressure experiment, in situ X-ray diffraction, Raman, Earth's mantle