American Mineralogist, Volume 100, pages 2412–2418, 2015

Crossroads in Earth and Planetary Materials

Quasicrystals at extreme conditions: The role of pressure in stabilizing icosahedral $Al_{63}Cu_{24}Fe_{13}$ at high temperature

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Abstract

Icosahedrite, the first natural quasicrystal with composition $Al_{63}Cu_{24}Fe_{13}$, was discovered in several grains of the Khatyrka meteorite, a CV3 carbonaceous chondrite. The presence of icosahedrite associated with high-pressure phases like ahrensite and stishovite indicates formation at high pressures and temperatures due to an impact-induced shock. Previous experimental studies on the stability of synthetic icosahedral AlCuFe have either been limited to ambient pressure, for which they indicate incongruent melting at ~1123 K, or limited to room-temperature, for which they indicate structural stability up to about 35 GPa. These data are insufficient to experimentally constrain the formation and stability of icosahedrite under the conditions of high pressure and temperature that formed the Khatyrka meteorite. Here we present the results of room-temperature, high-pressure diamond-anvil cells measurements of the compressional behavior of synthetic icosahedrite up to ~50 GPa. High *P-T* experiments were also carried out using both laser-heated diamond-anvil cells combined with in situ synchrotron X-ray diffraction (at ~42 GPa) and multi-anvil apparatus (at 21 GPa) to investigate the structural evolution and crystallization of possible coexisting phases. The results demonstrate that the quasiperiodic order of icosahedrite is retained over the *P-T* range explored. We find that pressure acts to stabilize the icosahedral symmetry at temperatures much higher than previously reported. Direct solidification of AlCuFe quasicrystals from an unusual Al-Cu-rich melt is possible but it is limited to a narrow temperature range. Alternatively, quasicrystals may form after crystallization through solid-solid reactions of Al-rich phases. In either case, our results show that quasicrystals can preserve their structure even after hypervelocity impacts spanning a broad range of pressures and temperatures.

Keywords: Icosahedrite, quasicrystals, CV3 chondrite, redox, Khatyrka meteorite, solar nebula