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Garnet: Current State of Knowledge & Future Research Directions

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Garnet is an important rock-forming mineral whose geological occurrence is widespread. Garnet shows extensive compositional variability and is stable over an enormous range of rock compositions and pressure and temperature conditions. Silicate garnets (E3G2Si3O12) are found in low-pressure metamorphic contact aureoles and they occur as complex solid solutions deep in the Earth's transition zone. There is a broad base of experimental and computer simulation results on their structural, crystal-chemical and thermodynamic properties. Much understanding has been reached but nevertheless important questions and areas of uncertainty remain. What has been learned and what needs to be done?

Extensive research has been done on garnet's structural and crystal-chemical properties using diffraction and spectroscopic as well as computational methods. The level of understanding is, in general, good. Research is now focusing on local crystal-chemical and dynamic properties. Important areas include: i) Atomistic-level dynamic properties and how they affect the macroscopic thermodynamic properties, ii) The nature of E-cation order/disorder in solid solutions, iii) Bonding properties in solid solutions, iv) Behavior under high pressure and iv) Partitioning behavior of trace elements.

In terms of macroscopic physical properties, there has been much work done over the years to determine thermodynamic behavior. Here, however, the level of understanding is less as compared to that of structural properties. What aspects need study? i) Certain thermodynamic functions for some garnet end-member are still not known quantitatively. For example, the third-law entropy of spessartine was recently measured via calorimetry and found to disagree with values in thermodynamic databases, ii) The enthalpies and entropies of mixing for various solid solutions are poorly understood and need investigation and iii) Thermodynamic mixing models, having a sounder crystal-chemical and theoretical basis, need to developed.

In terms of integrating crystal-chemical properties and thermodynamic properties together the intensively studied pyrope-grossular (Py-Gr) binary can be used as a model system (see Geiger 2008). His series can act as a guide as to how investigations on other garnet solid-solution systems should proceed. For example, results indicate that the shorter Ca/Mg-O(2) bond lengths remain roughly constant across the Py-Gr binary. Conversely, the longer Ca/Mg-O(4) bonds lengthen with increasing Gr component in the solid solution and with different degrees. Thus, Ca/Mg-O bond behavior can explain the nature of various micro/nanoscopic crystal-chemical properties as well as thermodynamic behavior. Specifically, the asymmetric nature of the mixing functions ΔHex, ΔSex, and ΔVex can be explained via Ca/Mg-O bond behavior.