Forsterite-willemite: A new pressure standard for solid media experiments

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Accurate and precise determination of sample pressure in piston-cylinder and multi-anvil experiments is essential for the study of pressure-dependent phenomena and crucial to our understanding of deep planetary processes. Where in-situ observation of a pressure standard by X-ray diffraction (XRD) is not possible, high-pressure experimental apparatus is commonly calibrated using electrical transitions at ambient temperature or bracketing univariant phase transitions at high pressure and temperature, but these techniques have their shortcomings. Here we explore the partitioning of Mg and Zn between coexisting $(Mg, Zn)_2SiO_4$ olivine and willemite solid solutions, which is sensitive to pressure but less so to temperature, as a means to calibrate and compare pressures in recovered-sample experiments from 0 to c. 7 GPa at experimentally relevant temperatures.

The binary $(Mg, Zn)_2SiO_4$ shows two orthosilicate phases, Zn-rich willemite and Mg-rich olivine, separated by a miscibility gap, because of the preference of the Zn^{2+} cation for tetrahedral coordination [1]. With increasing pressure, the greater density of the olivine structure tends to counteract the tetrahedral-site preference of Zn^{2+} and the compositions of both solid solutions shift towards their Zn_2SiO_4 end-members. The phase relations are not sensitive to small changes in bulk composition, capsule material, oxygen fugacity, or the small amounts of volatiles (e.g., H_2O) that are almost inevitable in solid-media apparatus. Samples are recoverable to ambient conditions for analysis by XRD and electron microprobe.

We have quantified pressure-temperature-composition relations in this system in the piston-cylinder apparatus, and from this we have developed a pressure standard to 5 GPa. The compositions of both olivine and willemite solutions, expressed as molar Zn/(Zn+Mg), may usually be determined to better than 0.003, compared to variations of ~ 0.5 and ~ 0.3 respectively over the range from 0 to 5 GPa, allowing pressure to be estimated with precision better than 0.05 GPa, at temperatures from c. 1000 ºC up to the melting regime. That the compositions of two solid solutions are determined provides a means of checking for internal consistency.

[1] Sarver and Hummel (1962), *Journal of the American Ceramic Society* 45 (6), 304