American Mineralogist, Volume 96, pages 1079–1089, 2011

Incorporation mechanisms of Ta and Nb in zircon and implications for pegmatitic systems

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Abstract

To investigate the processes that control Ta incorporation in zircon, two types of synthesis experiments were performed: (1) crystallization of zircon from an Li-Mo flux at 1 atm, and (2) crystallization of zircon (with or without coexisting tantalite) from a highly fluxed pegmatitic melt at 200 MPa and nearly water-saturated conditions. The first type of experiment is used to identify the influence of various doping elements (Hf, P, Al, and Mn) on Ta incorporation in zircon. These experiments reveal that P hinders the incorporation of Ta, whereas Al enhances Ta incorporation via charge balancing, and that Ta can be incorporated in the absence of any other doping element via the creation of vacancies in the zircon structure. Hafnium does not affect significantly Ta incorporation. Manganese and lithium do not enter the structure of zircon, except in the presence of P. Experiments with Nb show that the concentration of this element in zircon is nearly one order of magnitude lower than Ta (for similar Ta and Nb concentrations in the flux).

The second type of experiments show how Ta is incorporated in zircon in natural granite and pegmatite systems. In those systems, P and Al have elevated concentrations, and P is preferentially incorporated in zircon via Al substitution to maintain charge balance. Below a P/Ta atomic ratio of ~10 in the melt, Ta competes with P for Al, and P is involved in a coupled substitution with Mn for charge balancing. Concentrations up to 3.7 wt% Ta_2O_5 (0.03 apfu calculated to four atoms of oxygen) were measured in these zircon samples. The partition coefficients of Ta between melt and zircon are around 1 at 800–900 °C at conditions close to tantalite saturation. These results show that zircon incorporates significant amounts of Ta from the melt in P-poor peraluminous granites with a P/Ta atomic ratio lower than ~10, which may ultimately affect the precipitation of Ta minerals. Such interactions between cations both in melts and in mineral structures are important to constrain in order to understand rare-metal enrichment in granitic systems.

Keywords: Zircon, tantalum, pegmatitic systems, crystallization experiments