Cassiterite-saturated minimum melting behavior within Sn-SnO$_2$-SiO$_2$ at 1 atm and 10 kbar

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ABSTRACT

Anhydrous minimum-melting equilibria saturated with Sn$_2$O$_3$ form a pseudo-binary within Sn-SnO$_2$-SiO$_2$, close to the join SnO-SiO$_2$. This relationship, previously observed in various studies at 1 atmosphere and confirmed here, is explored more uniformly across the full compositional range of the system at pressure of ca. 10 kbars using Re capsules. Eutectic points and curves increase significantly in temperature with 10–11.6 kbars of pressure with only modest shifts of eutectic composition from that at ca. 1 bar pressure. No silicate liquid immiscibility was encountered in the minimum-melting regime although it may develop with increasing pressure in SiO$_2$-rich compositions. Possible configurations for the equilibria at temperatures greater than minimum melting suggest wide fields of Sn-SiO$_2$ and Sn$_2$O$_3$-SiO$_2$ liquid immiscibility on either side of the SnO-SiO$_2$ join. The SnO-SiO$_2$ pseudo-binary involves a trough between the two thermo-compositional immiscibility maxima that reflects the thermal stability and volatility of the SnO dimer and its complexes. In general, these data support high solubility of tin in anhydrous silicate melts, at geologically relevant temperatures and somewhat low oxygen fugacities, as the tin contents of the run products ranged from 24–62 and 51–81 wt%, respectively, for ca. 1 bar and 10 kbar experiments.

Keywords: Cassiterite, tin solubility, phase equilibrium experiments

INTRODUCTION

The determination of equilibrium melting phase relations in tin-bearing systems is beset with experimental difficulties. Suitable encapsulation methods, maintenance of bulk composition and oxidation state, difficulties of quenching, and frequent formation of metastable phases present both experimental and interpretational challenges. In a companion paper (Paparoni et al. 2010, this volume), we present new experimental techniques based on the use of evacuated double-silica tubes at low pressure and the use of rhenium capsules at modest pressures to meet these challenges. The latter method is valid because prior work shows minimal tin solubility in rhenium at elevated temperatures (Masalski 1990). The use of prudent electron microprobe analytical techniques is also key to the interpretation of experiments performed with these new encapsulation approaches. In the present paper, we report a re-analysis of SnO$_2$-saturated, pseudo-binary minimum melting relations within Sn-SnO$_2$-SiO$_2$ at two pressure conditions (ca. 1 atm and 10 kbar). Our results for the location of saturation curves at ca. 1 bar differ in detail from those of previous workers, without contradicting the general outline of previous studies. The addition of pressure variation to the newly possible higher precision of liquidus locations affords a more comprehensive description of the phase equilibria involving melt within this petrologically important system.

The Sn-SnO$_2$ system

The silica-free Sn-SnO$_2$ base system is a précis of the ternary system with SiO$_2$. The topology of this system at ca. 1 bar is taken from Paparoni et al. (1997, 1998) and Paparoni (2000), after Kuxmann and Dobner (1980) with the following modifications shown in Figure 1. The melting point of SnO$_2$ has been lowered from ca. 2000 to 1625 °C following the differential thermal analysis (DTA) determinations of Barczak and Insley (1962). Although this temperature may be too low because of interactions of SnO$_2$ with Pt capsules resulting in the production of SnO and a freezing-point depression, we believe it to be more realistic than the ca. 2000 °C estimate because the vapor pressure measurements of Colin et al. (1965) give the 1 bar evaporation temperature of SnO$_2$ as ca. 1830 °C, a value accepted in Figure 1. Rather than postulate an equilibrium involving sublimation of SnO$_2$ at 1 bar, we accept the simpler interpretation of melting before-evaporation that occurs with increasing temperature given in Figure 1.

The stability field of SnO liquid (Fig. 1) has been considerably diminished compared to that of Kuxmann and Dobner (1980). The evaporation temperature of SnO of 1425 °C, rather than ca. 1700 °C, reflects the convergence of the vapor pressure measurements of Colin et al. (1965), Platteeuw and Meyer (1956), and Spandau and Ulrich (1953). The equilibrium vapor pressure over Sn$^+$SnO$_2$, the equilibrium assemblage at the SnO composition, reached 760 mm Hg at ca. 1430 °C for all three studies even though the P-T slopes of the various techniques were quite different and therefore not in full agreement about all aspects of the system.