Density Measurements of Low Silica $CaO-SiO_2-Al_2O_3$ Slags

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Density measurements of a low-silica $CaO-SiO_2-Al_2O_3$ system were carried out using the Archimedes principle. A Pt 30 pct Rh bob and wire arrangement was used for this purpose. The results obtained were in good agreement with those obtained from the model developed in the current group as well as with other results reported earlier. The density for the $CaO-SiO_2$ and the $CaO-Al_2O_3$ binary slag systems also was estimated from the ternary values. The extrapolation of density values for high-silica systems also showed good agreement with previous works. An estimation for the density value of CaO was made from the current experimental data. The density decrease at high temperatures was interpreted based on the silicate structure. As the mole percent of SiO_2 was below the 33 pct required for the orthosilicate composition, discrete SiO_4^{4-} tetrahedral units in the silicate melt would exist along with O^{2-} ions. The change in melt expansivity may be attributed to the ionic expansions in the order of

$$Al^{3+} - O^{2-} < Ca^{2+} - O^{2-} < Ca^{2+} - O^{-}$$

Structural changes in the ternary slag also could be correlated to a drastic change in the value of enthalpy of mixing.

DOI: 10.1007/s11663-010-9385-1

I. INTRODUCTION

DENSITY is the most fundamental thermophysical property that is directly amenable to the structure correlations of molten slags. Molar volume, which is the reciprocal of density, is a thermochemical property and has direct reflections of Gibbs energies of the slag system. A better understanding of these properties leads researchers to give conclusive evidence in regard to the types and packing of ions present in molten slags. Density is required to estimate other fundamental properties, like surface tension, viscosity, and thermal conductivity from thermal diffusivity so that a relatively complete picture in regard to the behavior of high-temperature molten oxides could be made. It is also a widely used thermodynamic quantity for calculating other critical dimensionless parameters (*viz.* Reynolds, Prandtl, Nusselts, and Grashoffs numbers), which are used in the heat- and mass-transfer calculations.

The Division of Materials Process Science, KTH (Stockholm, Sweden) is involved in extensive research work during the last decade to develop a model that could provide a better approximation for the densities of molten oxide systems.[1] This was only possible by using mutually compatible thermochemical and thermophysical data in the same model and establishing a suitable relation between the two.[2] The key to the model developed was that the cation–anion attraction forces should be reflected both in the relative integral molar enthalpies of mixing and in the molar volume of the silicate melts.[3] A direct relationship could be made between the two as they are correlated directly to the bonding between the nearest and next nearest neighbor ions in the silicate system.

Density measurements of slag systems at high temperatures have been carried out by various methods, some of the most prominent being the Maximum bubble pressure method,[4] Pycnometric method,[5] Levitation method,[6] Sessile drop method,[7,8] and Archimedean method.[9] The $CaO-SiO_2-Al_2O_3$ ternary is the most extensively studied silicate system with several researchers carrying out density measurements at various compositions.[10–13] However, few researchers have made measurements in the low-silica region.[4,14] Some actually have tried to find an explanation for the change in silicate structure with an increase in temperature and have succeeded to some extent.[4]

The aim of the current work is to determine the density of low-silica $CaO-SiO_2-Al_2O_3$ slags and its variation with respect to temperature. A comparison is made between the corresponding values obtained from the density model developed by the division and with the work of Zielinski and Sikora.[14] An attempt is made to find the corresponding densities of the binary systems and to provide an approximate estimation of the density of pure CaO from the experimental values obtained. Furthermore, based on enthalpy and expansivity variations, some approximations to the silicate structure variation with a change in temperature are suggested. Attempts are made in the current laboratory to design suitable experiments to determine the diffusion coefficient

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Manuscript submitted December 17, 2009.
Article published online May 25, 2010.