

Sulfur-Iodine Cycle: Phase Equilibrium Data for the Ternary Iodine-Water-HI and the Binary Iodine-Water Systems

Sarah Mena^S, Eduardo Cervo, David Bruce and Mark Thies^C
Chemical and Biomolecular Engineering, Clemson University, Clemson, SC, U.S.A.

One of the primary targets of international interest for the centralized production of hydrogen from nuclear power is the Sulfur-Iodine cycle, which involves highly non-ideal phase behavior between iodine, water, and hydroiodic acid (HI) at elevated temperatures and pressures. Previous studies have revealed the need for experimental data in order to construct more reliable physical property models for Section III of the cycle, which involves the decomposition of HI into molecular hydrogen and iodine. To this end, a continuous-flow apparatus (CFA) was constructed to measure the phase equilibrium for the binary iodine-water and the ternary water-iodine-HI systems. The highly corrosive nature of the system requires special attention. Several versions of the apparatus incorporating different materials, including polymers such as Teflon and PEEK and alloys such as Hastelloy C and tantalum-tungsten Ta-W, were made. Of these, only Ta-W was found to successfully withstand the highly corrosive environment at the temperatures and pressures of interest; in addition PEEK was found to be suitable for ambient-temperature application. Ta-W components, such as valves, fittings, and the equilibrium view cell, were fabricated at Clemson University.

The CFA consists of an arrangement of two separate streams, one of compressed, hot, molten iodine and one of a homogeneous solution of water and HI, that flow to an isothermal bath, where they are combined and brought to equilibrium in an impingement mixer/settler before entering the view cell. Here the phases split gravimetrically into a water-rich phase (light phase) and an iodine-rich phase (heavy phase) and exit through ports located at the top and bottom of the cell. Because the iodine and water-rich phases are essentially opaque to the naked eye, an infrared lens is used to locate the fluid-fluid interface in the view cell, either vapor-liquid (V-L), liquid-liquid (L-L), or even liquid-liquid-vapor. The flow rate of the exiting streams and system pressure are controlled using micrometering valves, with the exiting streams being collected in order to determine phase compositions.

The CFA allows us to obtain LLE, VLE, and LLVE for the Sulfur-Iodine cycle over a wide range of temperatures and pressures. For instance, LLE for the binary iodine-water has been observed at temperatures from 150 to 300 °C. These results are the first known observations of LLE for this system at temperatures above 225 °C. LLE for the ternary iodine-water-HI was also observed, and the boundary of the two-phase envelope for the water-rich phase has been mapped out for temperatures of 160 and 200 °C, with higher temperature measurements up to 300 °C being planned. Measurement of equilibrium tie lines for the water-rich and iodine-rich phases is also underway and will be reported.