# Density and Speed of Sound Measurements of Nonane and Toluene with Dissolved $CO_2$ at HTHP Conditions

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Thermophysical properties of binary mixtures of hydrocarbons with carbon dioxide have not been studied extensively in the literature, especially at high-temperature and high-pressure (HTHP) conditions. In this work, we have measured the density and speed of sound of the binary systems [$x CO_2$ + (1 - $x$)$C_9H_{20}$] and [$x CO_2$ + (1 - $x$)$C_7H_8$] under HTHP conditions. The mole fractions of $CO_2$ in the binary mixtures studied were: $x$ = 0, 0.2, 0.4, 0.6 and 0.8. The density measurements were performed at temperatures between (283 and 473) K and at pressures up to 68 MPa. The density measurements were carried out with an Anton Paar vibrating-tube densimeter, calibrated with helium and deionised water over the full ranges of pressures and temperatures investigated. The calculated expanded relative uncertainty of density at 95 % probability was found to vary between (0.09 and 0.12) % upon temperature. The results have been correlated with a modified Tait equation and also compared with the predictions of the GERG-2008 equation of state. The speed of sound was studied in the temperature range (253 to 473) K and pressures up to 400 MPa by means of a double-path pulse-echo apparatus operating at 5 MHz. The ultrasonic cell was calibrated with pure water at $T$ = 298 K and $p$ = 1 MPa against the speed of sound given by the 1995 equation-of-state formulation of the International Association for the Properties of Water and Steam (IAPWS-95) which for that state point, has an uncertainty of 0.005%. Combined with isobaric heat capacity data, density data were extrapolated for pressures up to 400 MPa by integration of speed of sound data. Other observable thermophysical properties such as thermal expansion coefficient and compressibility were derived from the measured sound speed data over the full pressure range.