Density Measurements on Helium, Neon, and Three Mixtures at Temperatures from (100 to 283.15) K Utilizing a Single-Sinker Densimeter

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Mixed refrigerants composed of noble gases are potential working fluids for various cryogenic processes. In particular, mixtures of helium and neon are considered evaporating refrigerants at very low temperatures, e.g., for efficient precooling stages in large-scale hydrogen liquefaction plants [1] or cooling concepts of particle accelerators [2]. For the development and optimization of such processes, accurate knowledge of the thermophysical properties or the working fluids is essential. In this regard, Tkaczuk et al. [3] recently published a new equation of state for mixtures of helium, neon, and argon. They, however, faced the challenge that only a few experimental data sets are available in the literature. Particularly, the available density data for mixtures of helium and neon is mostly rather old, and at temperatures between (41 and 233) K, no densities are reported at all.

Thus, comprehensive density measurements on helium, neon, and three binary mixtures were carried out using a low-temperature single-sinker densimeter. The new (p ,ρ ,T) data at pressures from (1 to 10) MPa significantly expand the database and allow for the evaluation of the performance of available equations of state. For the pure substances, 64 (p ,ρ ,T) state points were recorded in a temperature range of (100 to 283.15) K. For each of the three gravimetrically prepared mixtures with different molar helium fractions, 36 state points were investigated along six isotherms at temperatures from (100 to 233.15) K (in total 108 state points). The relative expanded combined uncertainty (k = 2) was estimated to be within (0.015 and 0.305) % and (0.024 and 0.157) % for the pure fluids and binary mixtures, respectively. Here, the uncertainty is roughly inversely proportional to the density of the fluid.

Evaluation of the new data demonstrates the reliability of the present single-sinker densimeter even for the determination of gas densities as low as 2.05 kg·m^{-3}. For the pure substances, the relative deviations to densities calculated with the corresponding reference equations are within (−0.03 to 0.01) % for helium and within (−0.12 to 0.01) % for neon. Densities of binary mixtures show deviations of (−2.71 to −0.06) % to values calculated with the model of Tkaczuk et al. [3] and of (−0.68 to 0.78) % to densities predicted with a preliminary equation of state for helium and neon mixtures by Lemmon [4]. These results disclose significant inaccuracies of the available mixture models, caused by the weak database that was available for their development. The data presented in this work can be used to adjust equations of state and to substantially improve the accuracy of calculated densities at the investigated temperatures.

References

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