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Measurements of saturated densities and critical parameters for the binary mixture of 2,3,3,3-tetrafluoropropene (R-1234yf) + difluoromethane (R-32)

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ABSTRACT

The vapor–liquid coexistence curves near the critical point of the binary mixture of 2,3,3,3-tetrafluoropropene (R-1234yf) + difluoromethane (R-32) were measured by means of the visual observation of meniscus disappearance. Eleven, eighteen, and eleven saturated densities were obtained for mixtures with 50.00 mass%, 80.01 mass%, and 90.00 mass% of R-1234yf, respectively. The critical temperatures, critical densities, and critical molar volumes of the mixtures were determined from the meniscus disappearing level and the intensity of the critical opalescence. The critical pressures of the mixtures were also determined from the analysis of $p\rho Tx$ measurements. The composition dependence of the critical parameters was formulated with simple correlations.

Mesures des masses volumiques saturées et paramètres critiques d'un mélange binaire de 2,3,3,3-tétrafluoropropène (R-1234yf) + difluorométhane (R-32)

Mots clés : masse volumique critique ; état critique ; pression critique ; température critique ; mélange R-1234yf + R-32

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1. Introduction

2,3,3,3-Tetrafluoropropene ($CF_3CF = CH_2$, R-1234yf) is considered as one of the next-generation refrigerants due to its low global warming potential (100-yr GWP is 4). This novel refrigerant was developed for mobile air conditioners as a replacement of R-134a (Spatz and Minor, 2008a,b; Leck, 2009). Recently, also for room air conditioners or beverage coolers, the performance evaluation have been reported, e.g., Endoh et al. (2010); Minor et al. (2010); Okazaki et al. (2010); Barve and Cremaschi (2012). However, Piao et al. (2012) pointed out that a major R & D effort is required for full commercial use of R-1234yf, because it was revealed that R-1234yf has a considerably smaller volumetric cooling capacity than conventional refrigerants.

On the other hand, some refrigeration manufacturers have started to focus on difluoromethane (CH_2F_2, R-32) for residential air conditioners. The main reason for this is that R-32 requires minimum or no system modification from conventional R-410A systems (Piao et al., 2012). In addition, at high ambient temperatures, R-32 shows substantial performance improvement both for cooling capacity and COP, compared to R-410A (Taira et al., 2001). The major shortcomings of R-32 are that it results in high temperature at compressor outlet, and that it has far from negligible GWP (100-yr GWP of R-32 is 675).

Mixing of R-1234yf with R-32 is a good way to overcome the shortcomings of each refrigerant in the case that they are solely used. Therefore, thermodynamic property data for the mixture are strongly desired. This work experimentally measured the saturated densities and critical parameters of the mixture by direct observation of the meniscus disappearance. The information presented here is essential for the establishment of a thermodynamic property model for the R-1234yf + R-32 mixture.

2. Experimental apparatus

Fig. 1 shows the experimental apparatus used in this work. The details of this apparatus have been described in the previous paper (Higashi, 1994). The main portion of the apparatus is composed of three high-pressure vessels. The optical cell with two Pyrex glass windows was used for observation of the meniscus disappearance of the sample. This optical cell is a SUS-304 barrel-type cylindrical vessel and its inner volume is $11.638 \pm 0.008\ cm^3$, which had been calibrated in advance by filling with pure water at room temperature. The expansion vessel and the supplying vessel were used to change the sample density in the optical cell without charge of a new sample. The inner volumes of the expansion vessel and the supplying vessel are $8.949 \pm 0.003\ cm^3$ and $77.575 \pm 0.016\ cm^3$, respectively. The vessels were installed in a thermostatic silicone-oil bath. Temperature fluctuation in the bath was controlled within ±5 mK with 1.5 kW and 300 W heaters, and with the aid of a PID control system. Temperature measurements were conducted with an AC thermometer bridge (ASL: F700) and a 25 Ω standard platinum resistance thermometer (Chino: R800-2) calibrated against ITS-90. The uncertainty of the temperature measurement was estimated to be within ±10 mK. The density of the sample in the optical cell can be calculated from the mass of the sample and the inner volumes of three pressure vessels at each expansion procedure. The mass of the sample was measured with the balance. The accuracy of the mass measurement is less than ±2 mg. The relative uncertainty of the mass measurement is estimated to be within ±0.01%, because actual mass values of the sample in this experiment are between 20 g and 80 g. The uncertainty of the density measurement depends upon the times of expansion. It is estimated to be within $0.2\ kg\ m^{-3}$ to $0.6\ kg\ m^{-3}$. The uncertainty of the composition measurement is estimated to be within ±0.05%.

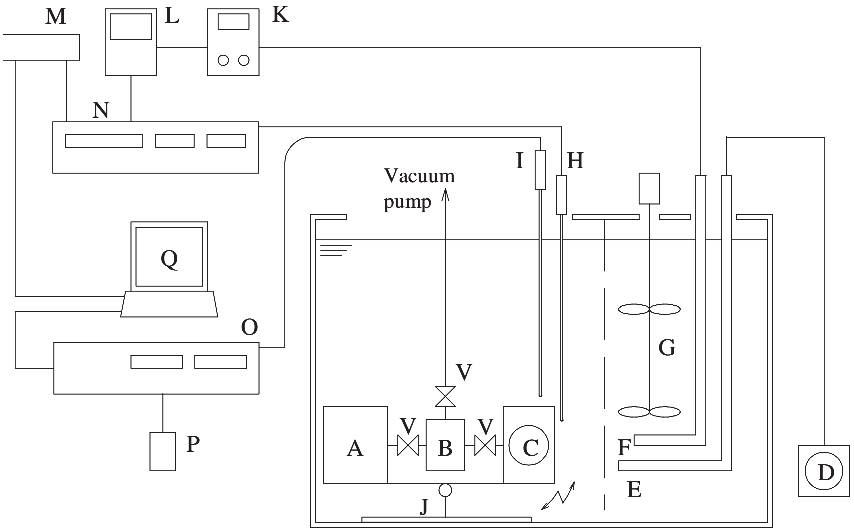

Fig. 1 – Experimental apparatus. (A) Supplying vessel; (B) Expansion vessel; (C) Optical cell; (D) Voltage transformer; (E) Main heater (1.5 kW); (F) Sub heater (300 W); (G) Stirrer; (H, I) 25 Ω standard platinum resistance thermometer; (J) Rocking unit; (K) PID controller; (L) Voltage output setting unit; (M) Digital multimeter; (N, O) AC thermometer bridge; (P) 25 Ω standard resistance; (Q) Computer; (V) High-pressure valves.