Solid–Liquid Equilibria for the CO2 + R143a and N2O + R143a Systems

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Abstract A recently built experimental setup for determination of solid–liquid equilibria was slightly modified. The action taken on the existing system focused on correcting the drawbacks of the cooling system. In this version of the setup, a direct liquid nitrogen supply was preferred. By means of the modified apparatus, solid–liquid equilibria of the CO2 + R143a and N2O + R143a binary systems were studied. The triple point of R143a was measured to check the reliability of the modified apparatus, revealing good consistency with the literature. The system’s behavior was measured down to temperatures of 148 K. The results obtained for the mixtures were interpreted by means of the Schröder equation.

Keywords Carbon dioxide · Cascade units · Eutectic · Nitrous oxide · Refrigerants · Solid–liquid equilibria

1 Introduction

As already discussed in previous papers [1–3], solid–liquid equilibria (SLE) play an important role in refrigeration, for the estimation of the lowest temperature at which a blend can be used as a refrigerant fluid. This information is particularly useful for very low-temperature applications, i.e., cascade refrigeration units, where temperatures down to 150 K are commonly reached. In addition, SLE provide theoretical
information on the real behavior of studied systems at low temperatures in terms of the eutectic composition and activity coefficients.

Most SLE measurements enable visual observation of the disappearance of the last amount of solid phase and relatively easy temperature control [4]. The experimental temperature ranges usually spans from 200 K to 400 K. Since the systems under study could be expected to have temperature ranges from 200 K down to about 155 K, we decided that it would be technically more feasible to use a method with no visual observation of phase behavior.

The setup specifically built for this purpose showed some limitations in terms of drainage of condensation, system cut-out problems, sensitivity of the system to atmospheric conditions, high wastage of nitrogen, system inertia, and velocity adjustment problems. Given all these drawbacks, action was taken mainly on the cooling system, for which a direct nitrogen supply was preferred.

In previous studies [1–3], using the first version of the experimental setup, together with the properties of the CO₂+N₂O binary system [2], SLE of CO₂+ and N₂O + four different HFCs (R125, R32, R134a, and R152a) were explored. The main motivation for these binaries lies in the possibility to combine the advantages of natural fluids in terms of low environmental impact (i.e., GWP = 1 for CO₂ and GWP = 310 for N₂O, which can be considered low if compared with HFCs) together with those of HFCs in terms of performance and of the possibility to extend the temperature application limit.

In this article, using the modified experimental setup, SLE of the CO₂ + R143a and N₂O + R143a binary systems were studied. No information on the SLE of these binary systems was available in the literature.

2 Description of the Apparatus

2.1 Measurement Cell

The experimental setup is shown in Fig. 1. The measuring cell (1), with a volume of approximately 47 cm³, was made out of a stainless steel cylinder with a cover welded to the body. Before welding, a stirrer (2) consisting of a stainless steel rod having a rounded end with two steel blades welded onto it was placed in the cell. The stirrer was kept in a perfectly vertical position by means of conical seats created on the raised bottom of the cell and on the underside of the cover so as to contain the rounded ends of the rod. Two holes were drilled in the cover, and a stainless steel tube with a diameter of 4 mm was inserted through and welded to the hole on the left for charging the cell with gas, while the hole on the right, which was 6.25 mm in diameter, was used to house the thermometer (3), the end of which was inserted down to approximately 2.7 cm from the bottom of the cell. The purpose of the stirrer was to prevent any premature stratification of the fluids comprising the various mixtures, while also assuring greater homogeneity during the liquefaction and crystallization of the mixture. The stirrer inside the cell was turned by a magnet, which drives the plate welded onto the lower end of the rod. The magnet was housed in a seat made of brass, which was connected to the shaft of an electric engine driving the rotation of the magnet and thus also of