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Vapor–liquid equilibria of the (hexafluoroethane + 1,1,1-trifluoroethane) binary system from 258 to 343 K up to 3.89 MPa

Hakim Madani[a,1], *Alain Valtz*[b], *Christophe Coquelet*[b], *Abdeslam Hassen Meniai*[a], *Dominique Richon*[b,*]

[a]*Laboratoire de l'Ingénierie des Procédés d'Environnement, Université Mentouri Constantine, Algéria*
[b]*MINES, ParisTech, CEP/TEP – Centre Energétique et Procédés, 35 rue Saint Honoré, 77305 Fontainebleau, France*

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ABSTRACT

Development of modern refrigeration systems is critical for the success of new global environmental protection efforts. The binary system of refrigerants: Hexafluoroethane (R116) + 1,1,1-trifluoroethane (R143a), has been studied with the aim of providing PTxy data. Isothermal vapor–liquid equilibrium data have been generated using the "static–analytic" method from 258 to 328 K at pressures from 0.39 to 3.89 MPa. The model composed of the Peng–Robinson equation of state, the Mathias–Copeman alpha function, the Wong–Sandler mixing rules and the NRTL cell theory is applied herein to correlate the data and calculate the critical line.

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Equilibres «liquide-vapeur» du système binaire héxafluoroéthane + 1,1,1-trifluoroéthane de 258 à 343 K jusqu'à 3,89 MPa

Mots-clés : Frigorigène ; Mélange binaire ; R116 ; R143a ; Expérimentation ; Calcul ; Pression ; Vapeur ; Équilibre ; Liquide–vapeur ; Équation

* *Corresponding author*. Tel.: +33 164694965; fax: +33 164694968.
E-mail address: dominique.richon@mines-paristech.fr (D. Richon).
[1] Mr. Hakim Madani is on sabbatical leave from Hadj Lakhdar University, Batna, Algeria.
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1. Introduction

In the wake of the global response for the protection of the environment and sustainable development, the refrigeration industry is forced to find new fluids as acceptable refrigerants. The Montreal Protocol presented in 1987 is one of the landmarks towards the replacement of ozone-destroying refrigerants like chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) with ozone friendly and non-green house fluids. CFCs were prohibited in 1996 in signatory countries of the Montreal Protocol. The deadline for HCFCs which have low ozone depletion potential is 2030. Development of new refrigeration systems is critical for the success of new global environmental protection efforts. In our current research for good refrigerant candidates, we are providing phase equilibrium data (complete phase diagrams) for mixtures of various existing and/or new candidates for refrigeration industry (Madani et al., 2008a,b; Valtz et al., 2002, 2007; Coquelet et al., 2005; Coquelet et al., 2003a,b; Rivollet et al., 2004; Coquelet et al., 2004) The VLE cell used for these purposes relies on the ''static–analytic'' method (Laugier and Richon, 1986) and Rolsi™ sampling (Guilbot et al., 2000).

Hexafluoroethane (R116), CAS no: 76-16-4, is a completely fluorinated haloalkane, which is derived from ethane. It is a non-flammable gas which is negligibly soluble in water and slightly soluble in alcohol. One of its main applications is in the field of refrigeration. Due to the high C–F bond energy, R116 is very inert and unfortunately acts as an extremely stable greenhouse gas, with an atmospheric lifetime of 10,000 years and a global warming potential (GWP) of 9000 (Marks et al., 2003). However its ozone depletion potential (ODP) is 0 (Bozin and Goodyear, 1968).

On the other hand, 1,1,1-trifluoroethane R143a, CAS no: 420-46-2, R143a has an ozone depletion potential ODP = 0 and comparatively high Global Warming Potential (=1000), is non-toxic and fir-safe, and it does not interact with structural and packing materials. Three hydrogen atoms in the R143a molecule contribute to good solubility in mineral oils. Specific heat of vaporization is 19.88 kJ/mole at normal boiling point which is a bit higher than for R125 (18.82 kJ/mole). Discharge temperature is lower than that of R12, R22 and R502. As energy analysis has showed, energy effectiveness of a two-step cycle with R143a is close to the effectiveness of the cycle with R502, lower than that of R22, and higher than that of R125. R143a refrigerant belongs to composition of multicomponent alternative blends suggested for substitution of R12, R22 and R502.

For the development of new refrigeration mixtures with minimal environmental impact (ozone depletion and global warming), one has to rely on reliable thermodynamic properties for a number of refrigerating fluid mixtures. In this work, we present VLE data points for the system (R116 + R143a) at three temperatures below the R116 critical temperature (258.45, 273.30, and 288.25 K) and five above (293.23, 298.17, 308.38, 318.34 and 328.18 K). The experimental results are fitted using the Peng–Robinson (Peng and Robinson, 1976) equation of state, using the Mathias–Copeman (Mathias and Copeman, 1983) alpha function and the Wong–Sandler (Wong and Sandler, 1992) mixing rules involving NRTL (Renon and Prausnitz, 1968) model. For the system R116 + R143a, no data were found previously published in the literature.

Table 1 – Critical parameters (DDB, 97)

Compound	T_c/K	P_c/MPa
R116	293.035	3.042
R143a	346.25	3.759

Table 2 – Mathias–Copeman coefficients

Coefficients	R116[a]	R143a
c_1	0.8128	0.7191
c_2	−1.1603	0.2039
c_3	5.0299	−0.8472

[a] Values from Valtz et al. (2007).

2. Experimental section

2.1. Materials

The R116 was purchased from DEHON (France) with 99.99 vol.% certified purity. R143a was purchased from ARKEMA (France) with 99 vol.% certified purity. Both chemicals were used as delivered.

2.2. Apparatus

The apparatus used in this work is based on the ''static–analytic'' method with liquid and vapor phase sampling. This apparatus is similar to that described by Laugier and Richon (1986).

The equilibrium cell is immersed inside a temperature regulated liquid bath. Temperatures are measured by means of two platinum resistance thermometer probes (Pt100)

Table 3 – Experimental and calculated vapor pressures for R143a. Calculated values are obtained with the PR EoS using the Mathias–Copeman alpha function and parameters of Table 2

T/K	P_{exp}/MPa	P_{cal}/MPa	ΔP/MPa
258.45	0.3884	0.3903	−0.0018
268.15	0.5446	0.5390	0.0056
273.30	0.6325	0.6338	−0.0013
283.06	0.8491	0.8472	0.0019
288.25	0.9767	0.9806	−0.0039
293.30	1.1143	1.1250	−0.0107
298.17	1.2967	1.2788	0.0179
303.24	1.4516	1.4549	−0.0033
308.38	1.6373	1.6512	−0.0139
313.10	1.8530	1.8482	0.0048
318.34	2.0796	2.0868	−0.0072
323.06	2.3304	2.3205	0.0099
328.18	2.5849	2.5952	−0.0103
333.06	2.8978	2.8787	0.0191
338.22	3.2048	3.2028	0.0020

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