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Article

# Volumetric Properties of 9 Binary Liquid Mixtures Ethyl Propanoate + Naphthenes (From Cyclohexane to Decylcyclohexane): Experimental Study from 288.15 K to 328.15 K

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## Abstract

In this work, the volumetric properties of nine binary systems composed of ethyl propanoate and *n*-alkylcyclohexanes (from cyclohexane to decylcyclohexane) were investigated. Densities were measured at atmospheric pressure (101 kPa) over the entire composition range and at temperatures from 288.15 K to 328.15 K. A total of 525 density data points were obtained. Excess molar volumes were derived from the experimental densities and correlated using a Redlich–Kister equation, while mixture densities were modeled with the Jouyban–Acree model. All systems exhibit positive excess molar volumes over the studied temperature and composition ranges, indicating volume expansion upon mixing due to dominant repulsive interactions. The magnitude of the excess molar volume increases with increasing alkyl chain length of the branched naphthenic compound: for an equimolar mixture,  $V^E$  is about  $0.65 \text{ cm}^3 \cdot \text{mol}^{-1}$  for the methylcyclohexane + ethyl propanoate mixture and reaches  $0.83 \text{ cm}^3 \cdot \text{mol}^{-1}$  for the heptylcyclohexane + ethyl propanoate binary system, although a plateau tendency is observed for longer alkyl chains. Excess molar volumes increase linearly with temperature, with a more pronounced temperature effect for shorter-chain alkylcyclohexanes. The Jouyban–Acree model provides an excellent correlation of the density data, yielding average relative deviations between 0.02% and 0.04%, and allows reliable predictions within the investigated temperature range.

**Keywords:** density; excess molar volume; binary system; ethyl propanoate; alkylcyclohexane; naphthene; Jouyban–Acree model



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## 1. Introduction

Mixtures of esters and hydrocarbons are very interesting since they are typical of systems constituted by a polar and a non-polar compound, presenting a highly non-ideal behavior. Consequently, the thermophysical properties of binary liquid mixtures esters + alkanes have been extensively studied [1–10]. Among these properties, density has received the most attention.

All these binary systems, characterized by significant repulsion forces, present pronounced and positive excess molar volumes ( $V^E$ ). Mixtures of esters + linear alkanes have been particularly studied. For these systems, it was found that the excess properties slightly depend on temperature, whereas, for a given ester mixed with different *n*-alkanes, the *n*-alkane chain length has a significant effect: the excess molar volume increases with increasing chain length. For example, at 298.15 K, the binary system ethyl acetate + *n*-pentane

presents a maximum  $V^E$  of roughly  $0.8 \text{ cm}^3 \cdot \text{mol}^{-1}$  whereas for ethyl acetate + *n*-decane,  $V^E$  exceeds  $1.3 \text{ cm}^3 \cdot \text{mol}^{-1}$  [2].

On the contrary, binary systems consisting of ester + naphthenic compounds have received less attention [11–17]. Available studies regarding the density of such mixtures mainly involve cyclohexane or methylcyclohexane. To our knowledge, no systematic study has addressed the volumetric behavior of binary mixtures of ester + branched cyclohexane (*n*-alkylcyclohexanes).

The properties of such mixtures are of interest since these compounds are used in the formulation of solvents, lubricants and industrial oils. Furthermore, due to their high oxygen content and low toxicity, short-chain esters have been envisaged as potential additives for certain fuels in the context developing alternative fuels whereas alkylcycloalkanes serve as key components of bio-based fuels.

The aim of this work is therefore to determine the influence of the branched naphthenic compound alkyl chain length on the volumetric properties of the binary mixtures of ethyl propanoate + *n*-alkylcyclohexanes.

The density of nine binary systems was measured under atmospheric pressure ( $101 \text{ kPa} \pm 2 \text{ kPa}$ ) and at five temperatures ranging from  $288.15 \text{ K}$  to  $328.15 \text{ K}$ : ethyl propanoate + cyclohexane, methylcyclohexane, ethylcyclohexane, propylcyclohexane, butylcyclohexane, pentylcyclohexane, heptylcyclohexane, octylcyclohexane and decylcyclohexane. More than 500 experimental density data points were measured, covering the whole composition range of the studied mixtures. Excess molar volumes were derived from these density measurements to understand the impact of the alkyl chain length on the mixture's behavior.

To our knowledge, among the investigated systems, ethyl propanoate + cyclohexane has been previously studied at  $298.15 \text{ K}$  [16,17] and  $308.15 \text{ K}$  [17] whereas the other systems are investigated for the first time in this work.

## 2. Materials and Methods

### 2.1. Materials

The compounds used in this study were purchased with the highest available purity and were used without further purification. A Karl-Fischer apparatus (Mettler Toledo V30 KF titrator) was used to determine the water content of the components. No water was detected in the naphthenic compounds whereas a water content not exceeding  $0.0004 \text{ g} \cdot \text{g}^{-1}$  was found in the ethyl propanoate sample. Table 1 summarizes the purities and suppliers of the chemicals used in this work. They were degassed under vacuum before use.

**Table 1.** Description of the pure components employed in this work.

Compound	Abbreviation	CAS Number	Supplier	Mass Fraction Purity <sup>a</sup>
ethyl propanoate	EP	105-37-3	ThermoFisher	0.999
cyclohexane	C6	110-82-7	ThermoFisher	0.999
methylcyclohexane	methylC6	108-87-2	ThermoFisher	0.999
ethylcyclohexane	ethylC6	1678-91-7	TCI <sup>b</sup>	0.999
propylcyclohexane	propylC6	1678-92-8	TCI	0.999
butylcyclohexane	butylC6	1678-93-9	TCI	0.990
pentylcyclohexane	pentylC6	4292-92-6	TCI	0.991
heptylcyclohexane	heptylC6	5617-41-4	TCI	0.995
octylcyclohexane	octylC6	1795-15-9	TCI	0.988
decylcyclohexane	decylC6	1795-16-0	TCI	0.997

<sup>a</sup> Information provided by the manufacturers. <sup>b</sup> Tokyo Chemical Industry.

### 2.2. Methods and Uncertainties

A vibrating tube densimeter DMA 4500M (Anton Paar) was used for pure components and mixtures density measurements under atmospheric pressure ( $P = 101 \pm 2 \text{ kPa}$ ). This

equipment, along with a similar procedure, has been fully described in our previous studies [5,10,13].

An analytical balance (Mettler Toledo ML204) with a weighing uncertainty of  $\pm 0.0002$  g, was used to prepare binary solutions of known compositions. The mixtures were quickly prepared in 10 mL glass vials with great caution to prevent evaporation. The following expression was used to calculate the standard uncertainty in molar fraction:

$$u(x_1) = x_1(1 - x_1) \left[ \left( \frac{u(m_1)}{m_1} \right)^2 + \left( \frac{u(m_{EP})}{m_{EP}} \right)^2 \right]^{1/2}, \quad (1)$$

where  $x_1$  represents the mole fraction of the naphthenic compound, and  $m_1$  and  $m_{EP}$  are the masses of the pure components used to prepare the binary mixture. The combined expanded uncertainty  $U(x_1) = 0.0001$  was obtained by multiplying the standard uncertainty by a factor 2 ( $\approx 95\%$  level of confidence).

The densimeter was calibrated using ultrapure water, dry air and regularly checked during measurement campaign by measuring the density of high-purity reference chemicals (2,2,4-trimethylpentane, *n*-hexane and toluene). The temperature sensor of the device was calibrated annually against a calibration Pt-100 probe (model MKT 50—Anton Paar). The temperature expanded uncertainty is  $U(T) = 0.02$  K while the standard uncertainty in density measurements is  $0.0003 \text{ g}\cdot\text{cm}^{-3}$ .

In this work, the temperature program of the densimeter was used to measure the density of the same sample at different temperatures. Prior to this study, new density measurements were carried out for the binary system ethyl propanoate (1) + *n*-heptane (2), which has been studied previously, in order to validate our measurement procedure, including the apparatus's temperature program. The experimental results obtained for the ethyl propanoate + heptane binary system are provided in the Supplementary Materials along with comparisons to the literature data (Figure S1). It is worth noting that the literature studies used for comparison did not employ a temperature program. In these previous works, different mixtures were prepared for each studied temperature. Figure S1 shows that, for each temperature, the excess molar volumes obtained by the two methods are almost identical across the entire composition range. Therefore, the use of the temperature scanning mode of the densimeter does not appear to alter the quality of the experimental results.

Impurities of the chemicals used shall be taken into account to properly evaluate the uncertainty of the measured densities [18]. The following expression was used to calculate the density uncertainty for a single component *i* having a mass fraction purity  $w_i$ :

$$u(\rho_i) = \left[ \left( \frac{u(\rho)}{\sqrt{3}} \right)^2 + (\xi \rho_i (1 - w_i))^2 \right]^{1/2}, \quad (2)$$

A 10% difference was assumed between the density of the component *i* and the impurity [18], that is  $\xi = 0.1$ .

For the pure compounds, the combined relative standard uncertainties thus ranged from  $u_r(\rho_i) = 0.0003$  (for high-purity chemicals with  $w_i = 0.999$ ) to  $u_r(\rho_i) = 0.0012$  (for octylcyclohexane with a 0.988 mass fraction purity).

The combined density uncertainty for the binary mixtures (containing a naphthenic compound *i* + EP) was finally evaluated according to

$$u(\rho_m) = \left[ u(\rho_i)^2 + u(\rho_{EP})^2 + u(x_1)^2 \right]^{1/2}, \quad (3)$$

The combined relative standard uncertainties obtained for the studied mixtures ranged from  $u_r(\rho_m) = 0.0004$  for a high-purity naphthenic compound + EP mixture to

$u_r(\rho_m) = 0.0013$  for the octylcyclohexane + EP binary system, due to the lower purity of the octylcyclohexane sample employed.

### 2.3. Pure Component Densities and Comparison with Literature Values

Pure components densities were measured from 288.15 K to 328.15 K to ascertain the accuracy of the densimeter, confirm the purity of the purchased chemicals and enable comparison with the available literature density data. Table 2 summarizes the pure compounds densities measured in this work along with high-quality experimental values previously reported in the literature for comparison.

**Table 2.** Pure compounds density ( $\rho$ ) measured in this work at temperatures  $T$  and pressure  $P = 101$  kPa \* with literature data for comparison.

Compound	T/K	This Work	Literature
ethyl propanoate	288.15	0.89567	0.89558 [1]; 0.89570 [5]; 0.895707 [19]
	293.15	0.89001	0.89013 [20]
	298.15	0.88430	0.88415 [1]; 0.88435 [5]; 0.88430 [21]
	303.15	0.87856	0.87855 [20]; 0.87850 [21,22]
	308.15	0.87279	0.87262 [1]; 0.87285 [5]; 0.87270 [21]
	313.15	0.86701	0.867094 [19]; 0.86702 [20]; 0.86680 [21]
	318.15	0.86121	0.86108 [1]; 0.86125 [5]; 0.86090 [21]
	323.15	0.85536	0.855456 [19]; 0.85490 [21]; 0.85499 [22]
	328.15	0.84946	0.84941 [1]; 0.84920 [21]
cyclohexane	288.15	0.78326	0.78330 [14]; 0.78322 [23]
	293.15	0.77859	0.77854 [23,24]; 0.77855 [25]
	298.15	0.77390	0.77393 [14]; 0.77386 [17]; 0.77384 [23]
	303.15	0.76917	0.77911 [23,25]; 0.76913 [24]
	308.15	0.76441	0.76444 [14]; 0.76446 [17]; 0.76435 [25]
	313.15	0.75963	0.75960 [24,25]; 0.75954 [26]
	318.15	0.75482	0.75484 [14]; 0.75474 [25]
	323.15	0.74997	0.74994 [24]; 0.74989 [25]
	328.15	0.74510	0.74506 [26]
methylcyclohexane	288.15	0.77359	0.77363 [27]
	293.15	0.76931	0.76931 [27]; 0.7693 [28]; 0.76933 [29]
	298.15	0.76498	0.76499 [27]; 0.76500 [29]; 0.76505 [30]
	303.15	0.76065	0.76065 [27]; 0.7607 [28]; 0.76067 [29]
	308.15	0.75630	0.75632 [29]; 0.75637 [30]
	313.15	0.75193	0.75194 [27]; 0.7519 [28]; 0.75195 [29]
	318.15	0.74755	0.74756 [29]; 0.74758 [30]
	323.15	0.74315	0.74315 [27]; 0.7431 [28]; 0.74315 [29]
	328.15	0.73873	0.73873 [29]
ethylcyclohexane	288.15	0.79195	0.79196 [23]; 0.79184 [31]
	293.15	0.78796	0.78794 [23]; 0.78798 [30]; 0.7880 [32]
	298.15	0.78394	0.78391 [23]; 0.78397 [30]; 0.78382 [31]
	303.15	0.77990	0.77987 [23]; 0.77993 [30]; 0.7799 [32]
	308.15	0.77585	0.77588 [30]; 0.77573 [31]; 0.7758 [32]
	313.15	0.77178	0.77175 [23]; 0.77182 [30]; 0.7718 [32]
	318.15	0.76771	0.76769 [30]; 0.76757 [31]; 0.7677 [32]
	323.15	0.76361	0.7636 [32]
	328.15	0.75950	

Table 2. Cont.

Compound	T/K	This Work	Literature
propylcyclohexane	288.15	0.79745	0.79751 [23]; 0.79742 [33]
	293.15	0.79359	0.79362 [23]; 0.7937 [28]; 0.79353 [33]
	298.15	0.78969	0.78972 [23]; 0.78963 [33]
	303.15	0.78579	0.78582 [23]; 0.7859 [28]; 0.78572 [33]
	308.15	0.78188	
	313.15	0.77797	0.77799 [23]; 0.7781 [28]; 0.77788 [33]
	318.15	0.77404	
	323.15	0.77010	0.77012 [23]; 0.7702 [28]; 0.77000 [33]
	328.15	0.76616	
butylcyclohexane	288.15	0.80314	0.80306 [23]
	293.15	0.79941	0.79931 [23]; 0.79937 [30]; 0.79920 [34]
	298.15	0.79566	0.79556 [23]; 0.79563 [30]
	303.15	0.79189	0.79180 [23]; 0.79188 [30]; 0.79188 [34]
	308.15	0.78814	0.78812 [30]
	313.15	0.78437	0.78426 [23]; 0.78435 [30]; 0.78428 [34]
	318.15	0.78059	0.78049 [30]
	323.15	0.77681	0.77670 [23]; 0.77670 [30]; 0.77680 [34]
	328.15	0.77302	
pentylcyclohexane	288.15	0.80764	0.80765 [23]; 0.80776 [31]; 0.80778 [33]
	293.15	0.80402	0.80400 [23]; 0.80413 [33]
	298.15	0.80036	0.80035 [23]; 0.80052 [31]; 0.80048 [33]
	303.15	0.79671	0.79668 [23]; 0.79682 [33]
	308.15	0.79305	0.79327 [31]
	313.15	0.78939	0.78934 [23]; 0.78949 [33]
	318.15	0.78572	0.78604 [31]
	323.15	0.78205	0.78199 [23]; 0.78214 [33]
	328.15	0.77837	
heptylcyclohexane	288.15	0.81451	0.81450 [27]; 0.81451 [33]
	293.15	0.81102	0.81099 [27]; 0.81100 [33]; 0.81106 [35]
	298.15	0.80752	0.80748 [27]; 0.80749 [33]
	303.15	0.80401	0.80397 [27]; 0.80398 [33]; 0.8036 [35]
	308.15	0.80050	
	313.15	0.79699	0.79695 [27]; 0.79695 [33]; 0.7965 [35]
	318.15	0.79347	
	323.15	0.78995	0.78990 [27]; 0.78991 [33]; 0.7894 [35]
	328.15	0.78643	
octylcyclohexane	288.15	0.81796	0.81760 [23]; 0.81758 [33]; 0.81811 [36]
	293.15	0.81452	0.81414 [23]; 0.81413 [33]; 0.81465 [36]
	298.15	0.81107	0.81068 [23]; 0.81067 [33]; 0.81119 [36]
	303.15	0.80761	0.80722 [23]; 0.80720 [33]; 0.80773 [36]
	308.15	0.80415	
	313.15	0.80069	0.80030 [23]; 0.80028 [33]; 0.80080 [36]
	318.15	0.79723	
	323.15	0.79376	0.79337 [23]; 0.79335 [33]; 0.79386 [36]
	328.15	0.79030	

Table 2. Cont.

Compound	T/K	This Work	Literature
decylcyclohexane	288.15	0.82206	0.82193 [33]
	293.15	0.81872	0.81854 [33]; 0.81858 [37]
	298.15	0.81534	0.81516 [33]; 0.81517 [37]
	303.15	0.81196	0.81178 [33]; 0.81183 [37]
	308.15	0.80858	
	313.15	0.80520	0.80502 [33]
	318.15	0.80183	
	323.15	0.79846	0.79826 [33]
	328.15	0.79508	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa. Relative standard uncertainty:  $u_r(\rho) = 0.0003$  for ethyl propanoate, cyclohexane, methylcyclohexane, ethylcyclohexane, propylcyclohexane,  $u_r(\rho) = 0.001$  for butylcyclohexane,  $u_r(\rho) = 0.0009$  for pentylcyclohexane,  $u_r(\rho) = 0.0006$  for heptylcyclohexane,  $u_r(\rho) = 0.0012$  for octylcyclohexane and  $u_r(\rho) = 0.0004$  for decylcyclohexane.

Excellent agreement was observed between the present measurements and previously reported values (see Table 2), confirming both the reliability of the experimental procedure and the high purity of the chemicals used.

#### 2.4. Modeling

The Jouyban–Acree model [38,39] was employed to correlate the densities of the studied binary liquid mixtures. This model is a powerful tool for representing various liquid mixtures properties, including their temperature dependence. When applied to binary mixture (1 + 2) density, the Jouyban–Acree model may be expressed as

$$\ln \rho_m(T) = x_1 \ln \rho_1(T) + x_2 \ln \rho_2(T) + \frac{x_1 x_2}{T} \left[ J_0 + J_1(x_1 - x_2) + J_2(x_1 - x_2)^2 + J_3(x_1 - x_2)^3 \right], \quad (4)$$

where  $\rho_m$ ,  $\rho_1$ ,  $\rho_2$  are the densities of the mixture, pure component 1, and component 2, respectively, at the studied temperatures  $T$ .  $x_1$  and  $x_2$  are the mole fractions in the mixture, whereas  $J_i$  are the model parameters regressed against experimental data. In this work, model parameters were obtained by nonlinear least-square regressions. Statistically non-significant parameters ( $p > 0.05$ ) were excluded from the model.

A Redlich–Kister type expression was used to correlate excess molar volumes ( $V^E$ )

$$\frac{V^E}{x_1(1 - x_1)} = a_0 + a_1(2x_1 - 1) + a_2(2x_1 - 1)^2, \quad (5)$$

$a_0$ ,  $a_1$  and  $a_2$  are parameters regressed against the excess molar volumes calculated from the measured mixture densities. In addition, excess molar volumes were also predicted using the Jouyban–Acree model.

### 3. Experimental Results

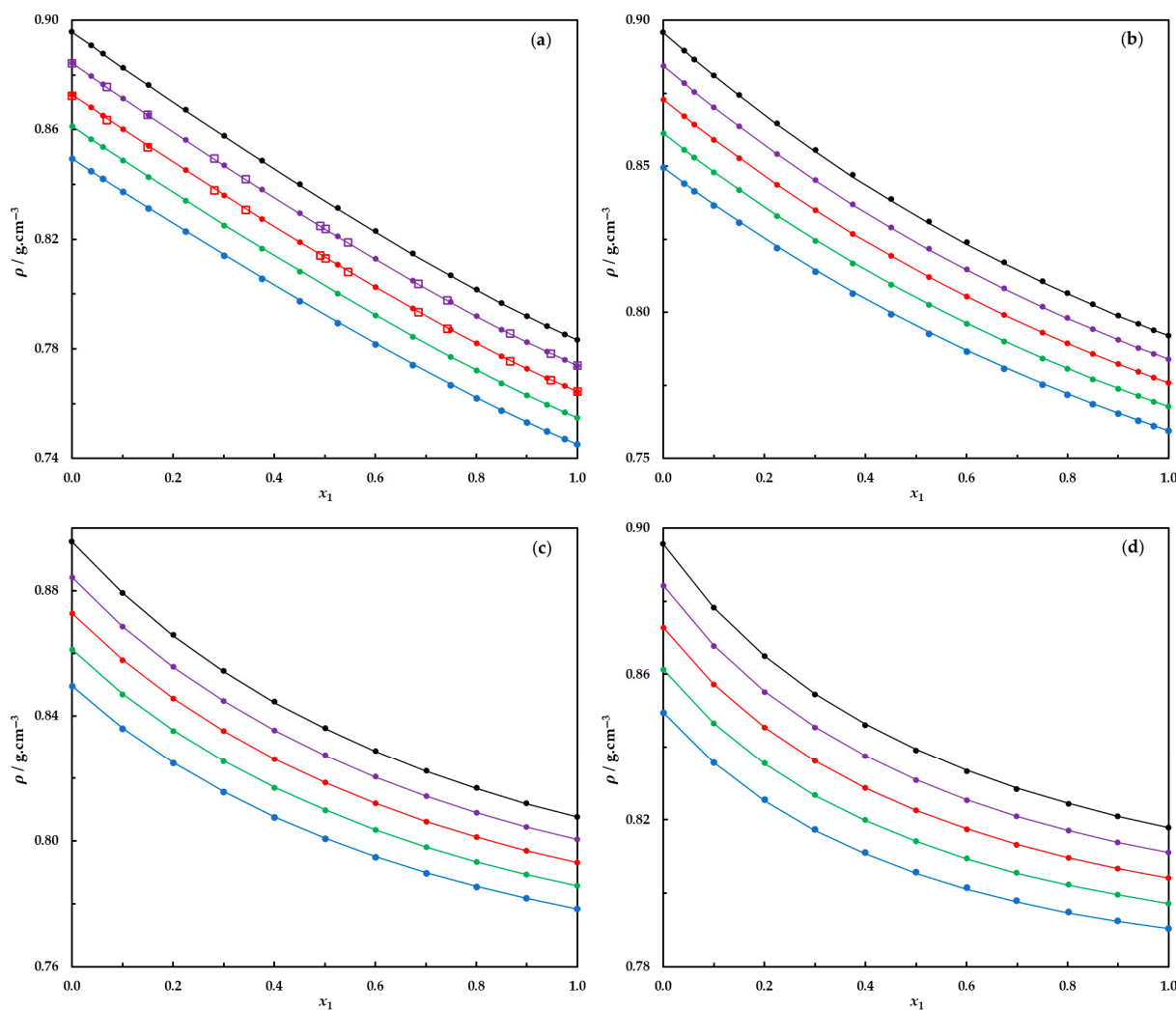
#### 3.1. Densities of the Studied Binary Liquid Mixtures

Tables A1–A9 report the experimental density of the nine binary systems studied at five temperatures, from 288.15 K to 328.15 K. A total of 525 mixtures density measurements were performed. For each binary system, the corresponding combined density uncertainty is specified as it varies from one binary to another due to differences in pure components purities.

An overview of the experimental density data is given in Figure 1 for four binary systems studied in this work.

For the binary system C6 + EP, Figure 1 shows a good agreement between mixtures densities measured in this work and those reported in the literature [17].

The studied liquid mixtures present an important common behavior:  $\rho_m(x_1)$  curves (as plotted in Figure 1) are convex functions across all temperatures investigated. For such systems, the mixing process thus led to a volume expansion originating from the repulsive forces between EP and naphthenic molecules. As a consequence, all the binary systems present positive excess molar volumes, as discussed in the next section.



**Figure 1.** Experimental and calculated densities for four binary systems: (a) C6 (1) + EP (2), (b) ethylC6 (1) + EP (2), (c) pentylC6 (1) + EP (2), (d) octylC6 (1) + EP (2). ●: experimental data from this work at 288.15 K, 298.15 K, 308.15 K, 318.15 K, 328.15 K. □: literature data from [17]. Solid curves: calculated densities using the Jouyban–Acree model with parameters reported in Table 3.

**Table 3.** Jouyban–Acree model parameters for the density prediction,  $\rho_m$  (in  $\text{g}\cdot\text{cm}^{-3}$ ), of 9 binary systems from 288.15 K to 328.15 K \*.

Binary System	$J_0$	$J_1$	$J_2$	$J_3$	ARD/% **
C6 + EP	−5.0945	−2.4512	−1.2886		0.02
methylC6 + EP	−8.2918				0.03
ethylC6 + EP	−12.6314	1.0395			0.03
propylC6 + EP	−15.9696	2.6376			0.03
butylC6 + EP	−18.1420	4.1737	−1.5038		0.02
pentylC6 + EP	−19.9091	5.6871	−2.0186		0.01
heptylC6 + EP	−22.0258	7.8416	−3.6118	1.6193	0.01

Table 3. Cont.

Binary System	J <sub>0</sub>	J <sub>1</sub>	J <sub>2</sub>	J <sub>3</sub>	ARD/% **
octylC6 + EP	−22.4848	8.7799	−4.3675	2.2786	0.02
decylC6 + EP	−23.7602	10.5289	−5.9323	3.4544	0.04

\* Parameters to be used in Equation (4) with T in K,  $\rho$  in  $\text{g}\cdot\text{cm}^{-3}$ , and  $x_1$  in mole fractions. \*\*  $\text{ARD} = \frac{100}{N} \sum \frac{|\rho_{\text{exp}} - \rho_{\text{calc}}|}{\rho_{\text{exp}}}$ .

The volumetric behavior of the mixtures is well-described by the Jouyban–Acree model. The pertinent parameters are provided in Table 3 for each binary system. The low average relative deviations confirm the excellent agreement between experimental and calculated values. These parameters can confidently be used to predict the density of the studied binaries at any temperature between 288.15 and 328.15 K, over the entire composition range.

### 3.2. Excess Molar Volumes Derived from the Mixture's Density Measurements

The mixture density data were used to calculate excess molar volumes,  $V^E$ , using Equation (6)

$$V^E = \frac{x_1 M_1 + x_2 M_2}{\rho_m} - \left( \frac{x_1 M_1}{\rho_1} + \frac{x_2 M_2}{\rho_2} \right), \quad (6)$$

in which  $M_1$ ,  $M_2$  and  $\rho_1$ ,  $\rho_2$  are the pure compounds molar masses and densities, respectively, while  $\rho_m$  is the mixture density and  $x_1$  and  $x_2$  are the mole fractions of components 1 and 2.

To identify potential experimental errors and to ascertain the quality of the primary data,  $V^E/x_1 x_2$  was systematically plotted against  $x_1$  as this function is well-suited to detect outliers [40,41]. If outliers were detected, generally at the dilute ends, a new mixture of comparable composition was prepared and measured to eliminate doubtful data.

The excess molar volumes obtained from the density measurements are reported in Appendix A, Tables A1–A9, for all the studied binary systems and are plotted for 4 binary systems in Figure 2. For clarity, only three isotherms (288.15 K, 308.15 K and 328.15 K) are represented for each binary system in this figure.

As expected, all the investigated systems exhibit positive excess molar volumes, as a result of the repulsive forces prevailing within these mixtures. Among the nine binary systems investigated, the C6 + EP system shows the highest excess molar volumes. The presence of a branching on the naphthenic ring therefore appears to mitigate the expansive effects of the mixtures.

The effects of temperature and alkyl chain length on the behavior of the mixtures is discussed in the following section.

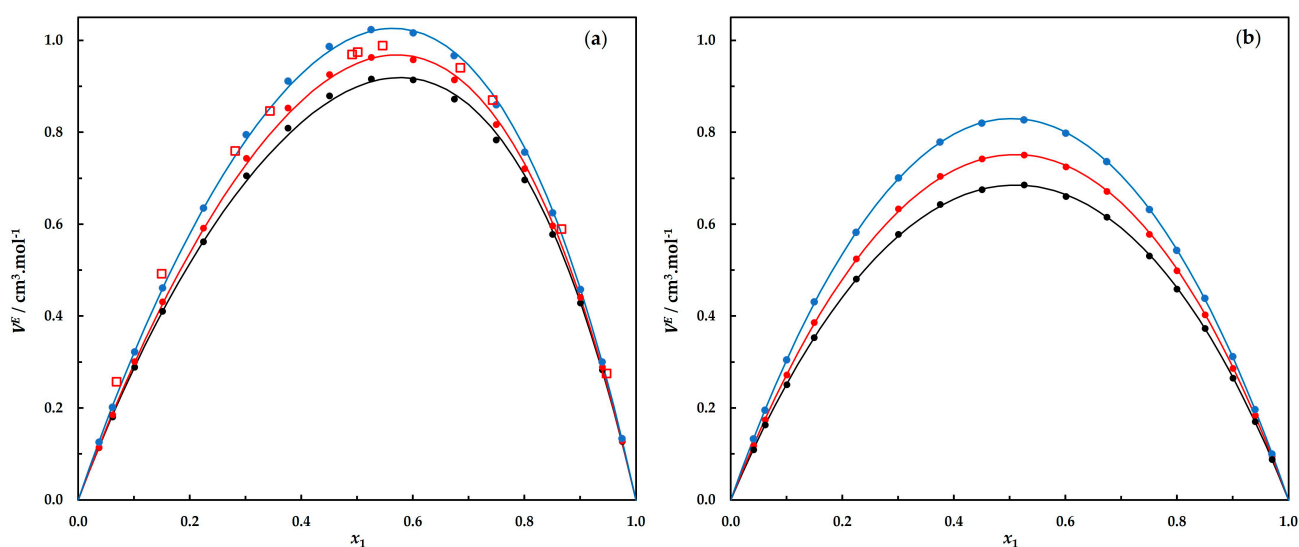
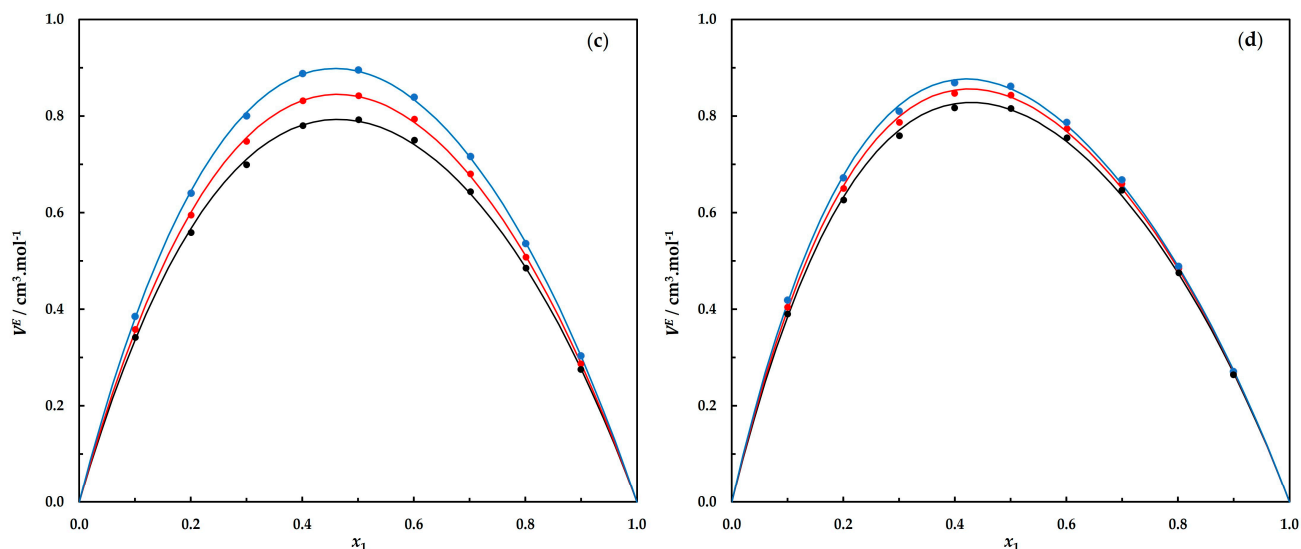


Figure 2. Cont.



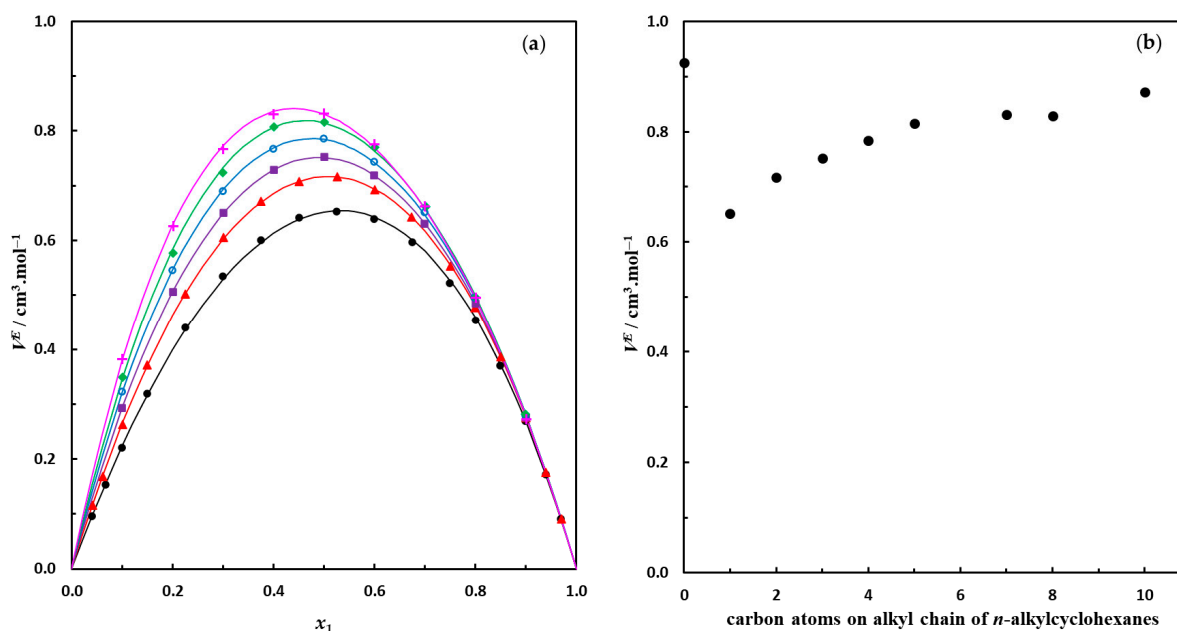
**Figure 2.** Excess molar volumes for four binary systems: (a) C6 (1) + EP (2), (b) ethylC6 (1) + EP (2), (c) pentylC6 (1) + EP (2), (d) octylC6 (1) + EP (2). ●: this work at 288.15 K, 308.15 K, 328.15 K. □: literature data from [17]. Solid curves: Redlich–Kister correlation with parameters reported in Table A10.

In all cases, the Redlich–Kister correlation led to precise correlations of the experimental excess molar volumes. The pertinent coefficients, regressed against experimental data, are listed in Table A10.

## 4. Discussion

### 4.1. Influence of Alkyl Chain Length on the Excess Molar Volumes

As illustrated in Figure 3, the volumetric behavior of the mixtures is notably impacted by the length of the alkyl chain on the cyclohexane ring.

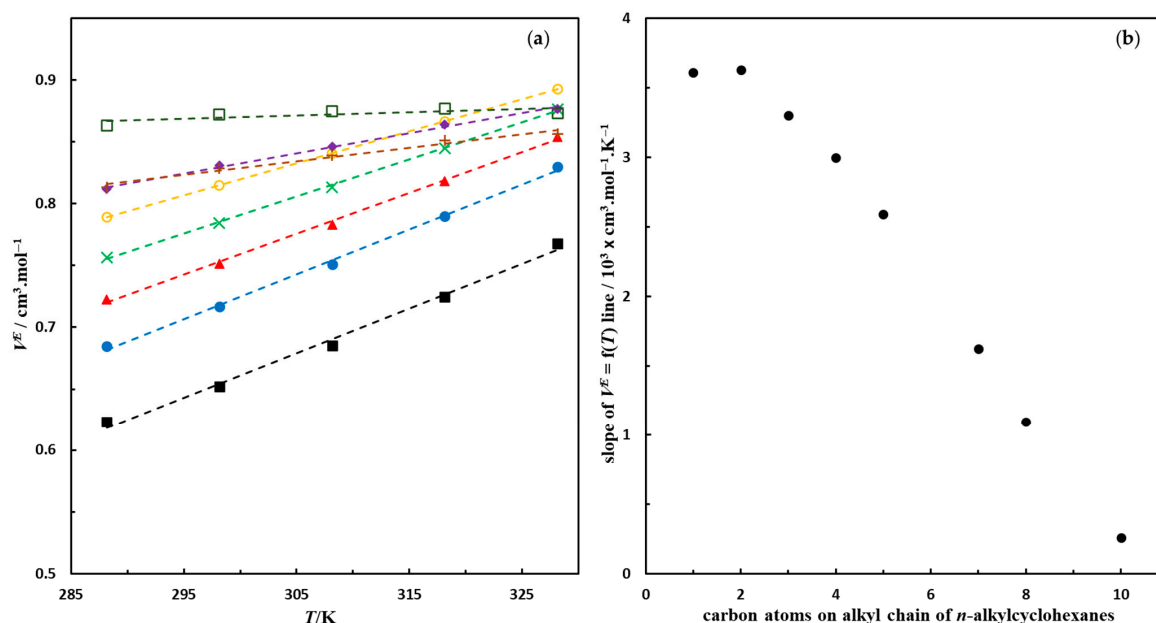


**Figure 3.** (a) Excess molar volumes at 298.15 K for 6 binary systems studied in this work. ●: methylC6 + EP, ▲: ethylC6 + EP, ■: propylC6 + EP, ○: butylC6 + EP, ◆: pentylC6 + EP, +: heptylC6 + EP. (b) Comparison of excess molar volumes at 298.15 K of equimolar mixtures of alkylcyclohexane + ethyl propanoate.

Excess molar volumes increase as the alkyl chain increases. A similar trend has previously been observed for short-chain esters + linear alkanes binary mixtures [1–4]. In this study,  $V^E$  is about  $0.65 \text{ cm}^3 \cdot \text{mol}^{-1}$  for methylC6 + EP (for an equimolar mixture, at 298.15 K) but reaches roughly  $0.83 \text{ cm}^3 \cdot \text{mol}^{-1}$  for heptylC6 + EP. Increasing the alkyl chain length appears to reduce the packing efficiency of the mixture. However, this phenomenon seems to reach a plateau for alkylcyclohexanes longer than pentylC6.

#### 4.2. Influence of Temperature on the Excess Molar Volumes

Figure 4 shows the temperature dependance of  $V^E$ . A linear dependance was found and the excess molar volumes increase as the temperature increases but the influence of temperature becomes less and less pronounced as the alkyl chain length increases.



**Figure 4.** (a) Excess molar volumes for equimolar mixtures alkylcyclohexane + EP as a function of temperature. ■: methylC6 + EP, ●: ethylC6 + EP, ▲: propylC6 + EP, ×: butylC6 + EP, ○: pentylC6 + EP, ◆: heptylC6 + EP, +: octylC6 + EP, □: decylC6 + EP. Dashed lines: linear fits. (b) Variation in the slopes of the linear functions between equimolar excess molar volumes and temperatures.

For the methylC6 + EP mixture, the equimolar excess molar volume increases by more than 20% from 288 K to 328 K whereas it remains nearly constant in the investigated temperature range for the system decylC6 + EP. This behavior suggests that the increase in kinetic energy of the molecules significantly affects interstitial accommodation for mixtures with shorter-chain alkylcyclohexanes, while this effect is mitigated as the alkyl chain length increases.

There are several possible reasons for the experimental observations reported in this study. The volumetric behavior of a mixture arises from multiple interrelated phenomena, so these results should be interpreted carefully. The assumptions made in this study could be refined using advanced solution theories, but this was not the focus of the study.

#### 4.3. Performance Analysis of Models

A Redlich–Kister approach and the Jouyban–Acree model were used to correlate the excess molar volumes determined in this work. The Redlich–Kister approach provides the best description of the excess molar volumes (see Table A10) with a standard deviation of 0.005 between experimental and calculated excess molar volumes (average value across all datasets). This is expected since the Redlich–Kister parameters were directly regressed against the experimental excess molar volumes.

The results obtained using the Jouyban–Acree model (average standard deviation of 0.016) are quite satisfactory given that this model uses a single set of parameters per binary system. Even if the temperature dependence of the excess molar volumes is not very well-described, the Jouyban–Acree model accurately reflects the order of magnitude of the excess molar volumes for all the studied mixtures.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/liquids6020015/s1>, Figure S1: Comparison between excess molar volumes ( $V^E$ ) and  $V^E/x_1x_2$  plots obtained from this work and literature values [1,42] for the binary system ethyl propanoate (1) + n-heptane (2), from 288.15 K to 318.15 K. Black points: this work. Red triangles: data from [1]. Red squares: data from [42]. Curves simply join the points to guide eye.; Table S1: Description of the pure components employed in this work; Table S2: Experimental densities ( $\rho$ ) and Excess molar volumes ( $V^E$ ) of ethyl propanoate (1) + n-heptane (2) system at mole fraction  $x_1$  in ethyl propanoate at temperature  $T$  and  $P = 101$  kPa.

**Author Contributions:** Conceptualization, S.V.; methodology, V.C. and S.V.; software, K.A.A.; investigation, V.C. and K.A.A.; resources, S.V.; data curation, S.V.; writing—original draft preparation, S.V., V.C. and K.A.A.; writing—review and editing, S.V., V.C. and K.A.A.; supervision, S.V. All authors have read and agreed to the published version of the manuscript.

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**Data Availability Statement:** Data provided within the article.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

**Table A1.** Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of cyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in cyclohexane at temperature  $T$  and  $P = 101$  kPa\*.

$x_1$ /mol·mol <sup>-1</sup>	$T = 288.15$ K		$T = 298.15$ K		$T = 308.15$ K		$T = 318.15$ K		$T = 328.15$ K	
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>
0.0000	0.89567	0.00	0.88430	0.00	0.87279	0.00	0.86121	0.00	0.84946	0.00
0.0373	0.89082	0.11	0.87954	0.11	0.86813	0.11	0.85660	0.12	0.84491	0.13
0.0613	0.88774	0.18	0.87650	0.18	0.86514	0.19	0.85364	0.20	0.84201	0.20
0.1010	0.88266	0.29	0.87149	0.30	0.86020	0.30	0.84878	0.31	0.83724	0.32
0.1509	0.87636	0.41	0.86529	0.42	0.85409	0.43	0.84277	0.45	0.83131	0.46
0.2245	0.86725	0.56	0.85631	0.58	0.84526	0.59	0.83408	0.61	0.82274	0.64
0.3013	0.85779	0.71	0.84701	0.72	0.83610	0.74	0.82507	0.77	0.81389	0.79
0.3760	0.84880	0.81	0.83817	0.83	0.82741	0.85	0.81652	0.88	0.80549	0.91
0.4503	0.84005	0.88	0.82957	0.90	0.81896	0.93	0.80823	0.96	0.79735	0.99
0.5252	0.83141	0.92	0.82109	0.94	0.81063	0.96	0.80005	0.99	0.78934	1.02
0.6003	0.82297	0.91	0.81281	0.94	0.80251	0.96	0.79208	0.99	0.78153	1.02
0.6740	0.81490	0.87	0.80488	0.89	0.79474	0.91	0.78448	0.94	0.77408	0.97
0.7494	0.80691	0.78	0.79706	0.80	0.78708	0.82	0.77698	0.84	0.76675	0.86
0.8003	0.80166	0.70	0.79194	0.71	0.78207	0.72	0.77208	0.74	0.76196	0.76
0.8503	0.79671	0.58	0.78708	0.59	0.77732	0.60	0.76743	0.61	0.75742	0.62
0.9003	0.79194	0.43	0.78242	0.43	0.77275	0.44	0.76297	0.45	0.75307	0.46
0.9396	0.78837	0.28	0.77892	0.29	0.76933	0.29	0.75962	0.30	0.74980	0.30
0.9750	0.78531	0.13	0.77592	0.13	0.76639	0.13	0.75675	0.13	0.74699	0.13
1.0000	0.78326	0.00	0.77390	0.00	0.76441	0.00	0.75482	0.00	0.74510	0.00

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ). Relative standard uncertainty:  $u_r(\rho_m) = 0.0004$ .

**Table A2.** Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of methylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in methylcyclohexane at temperature  $T$  and  $P = 101$  kPa\*.

$x_1$ /mol·mol <sup>-1</sup>	$T = 288.15$ K		$T = 298.15$ K		$T = 308.15$ K		$T = 318.15$ K		$T = 328.15$ K	
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>
0.0000	0.89567	0.00	0.88430	0.00	0.87279	0.00	0.86121	0.00	0.84946	0.00
0.0402	0.88951	0.09	0.87827	0.10	0.86690	0.10	0.85542	0.10	0.84380	0.11
0.0666	0.88555	0.15	0.87438	0.15	0.86307	0.16	0.85167	0.17	0.84013	0.18
0.1000	0.88061	0.21	0.86954	0.22	0.85834	0.23	0.84702	0.25	0.83557	0.26
0.1497	0.87338	0.30	0.86243	0.32	0.85138	0.33	0.84021	0.35	0.82889	0.37
0.2252	0.86273	0.42	0.85200	0.44	0.84116	0.46	0.83019	0.49	0.81910	0.52

Table A2. Cont.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.2994	0.85263	0.51		0.84211	0.53		0.83147	0.56		0.82072	0.59		0.80983	0.63	
0.3752	0.84269	0.57		0.83239	0.60		0.82196	0.63		0.81143	0.67		0.80076	0.71	
0.4502	0.83319	0.61		0.82310	0.64		0.81288	0.67		0.80256	0.71		0.79210	0.76	
0.5254	0.82403	0.62		0.81413	0.65		0.80412	0.69		0.79401	0.73		0.78378	0.77	
0.5999	0.81524	0.61		0.80555	0.64		0.79575	0.67		0.78585	0.71		0.77585	0.75	
0.6755	0.80663	0.57		0.79716	0.60		0.78757	0.63		0.77789	0.66		0.76811	0.70	
0.7497	0.79852	0.50		0.78925	0.52		0.77987	0.55		0.77041	0.58		0.76084	0.61	
0.8003	0.79316	0.44		0.78403	0.45		0.77479	0.48		0.76547	0.50		0.75606	0.53	
0.8499	0.78804	0.36		0.77906	0.37		0.76996	0.39		0.76079	0.41		0.75152	0.43	
0.8998	0.78308	0.26		0.77421	0.27		0.76525	0.28		0.75622	0.29		0.74710	0.31	
0.9402	0.77917	0.16		0.77040	0.17		0.76156	0.18		0.75264	0.19		0.74364	0.20	
0.9697	0.77639	0.09		0.76770	0.09		0.75893	0.10		0.75010	0.10		0.74119	0.10	
1.0000	0.77359	0.00		0.76498	0.00		0.75630	0.00		0.74755	0.00		0.73873	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0004$ .

Table A3. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of ethylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in ethylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.0407	0.88963	0.11		0.87841	0.12		0.86709	0.12		0.85564	0.13		0.84408	0.13	
0.0615	0.88661	0.16		0.87550	0.17		0.86426	0.17		0.85290	0.19		0.84141	0.20	
0.1001	0.88118	0.25		0.87021	0.26		0.85912	0.27		0.84791	0.29		0.83657	0.30	
0.1495	0.87446	0.35		0.86367	0.37		0.85277	0.39		0.84175	0.41		0.83060	0.43	
0.2248	0.86474	0.48		0.85424	0.50		0.84362	0.52		0.83289	0.55		0.82204	0.58	
0.3004	0.85554	0.58		0.84531	0.61		0.83496	0.63		0.82451	0.67		0.81395	0.70	
0.3751	0.84698	0.64		0.83702	0.67		0.82693	0.70		0.81675	0.74		0.80646	0.78	
0.4502	0.83888	0.68		0.82916	0.71		0.81933	0.74		0.80942	0.78		0.79940	0.82	
0.5257	0.83115	0.69		0.82169	0.72		0.81212	0.75		0.80247	0.79		0.79272	0.83	
0.6006	0.82394	0.66		0.81471	0.69		0.80539	0.73		0.79599	0.76		0.78650	0.80	
0.6742	0.81720	0.62		0.80822	0.64		0.79914	0.67		0.78998	0.71		0.78075	0.74	
0.7505	0.81065	0.53		0.80191	0.55		0.79307	0.58		0.78417	0.60		0.77518	0.63	
0.7995	0.80665	0.46		0.79806	0.48		0.78937	0.50		0.78062	0.52		0.77180	0.54	
0.8500	0.80267	0.37		0.79424	0.39		0.78571	0.40		0.77711	0.42		0.76845	0.44	
0.9002	0.79892	0.27		0.79063	0.28		0.78225	0.29		0.77381	0.30		0.76530	0.31	
0.9401	0.79604	0.17		0.78787	0.18		0.77960	0.18		0.77129	0.19		0.76291	0.20	
0.9704	0.79394	0.09		0.78585	0.09		0.77767	0.10		0.76945	0.10		0.76116	0.10	
1.0000	0.79195	0.00		0.78394	0.00		0.77585	0.00		0.76771	0.00		0.75950	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0004$ .

Table A4. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of propylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in propylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.0998	0.88048	0.28		0.86959	0.29		0.85859	0.30		0.84748	0.32		0.83623	0.33	
0.2006	0.86686	0.49		0.85643	0.51		0.84588	0.53		0.83522	0.55		0.82445	0.58	
0.3003	0.85481	0.62		0.84478	0.65		0.83465	0.68		0.82442	0.71		0.81409	0.74	
0.4006	0.84391	0.70		0.83427	0.73		0.82453	0.76		0.81471	0.80		0.80479	0.83	
0.5004	0.83412	0.72		0.82483	0.75		0.81546	0.78		0.80602	0.82		0.79649	0.86	
0.5996	0.82528	0.69		0.81635	0.72		0.80732	0.75		0.79824	0.78		0.78908	0.81	
0.6995	0.81723	0.61		0.80862	0.63		0.79993	0.65		0.79118	0.68		0.78236	0.71	
0.8008	0.80983	0.47		0.80153	0.48		0.79315	0.50		0.78473	0.52		0.77626	0.54	
0.9007	0.80328	0.27		0.79526	0.28		0.78718	0.28		0.77905	0.30		0.77088	0.31	
1.0000	0.79745	0.00		0.78969	0.00		0.78188	0.00		0.77404	0.00		0.76616	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0004$ .

Table A5. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of butylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in butylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.1002	0.87990	0.31		0.86912	0.32		0.85821	0.33		0.84720	0.35		0.83607	0.36	
0.2003	0.86640	0.53		0.85613	0.54		0.84574	0.57		0.83526	0.59		0.82467	0.61	

Table A5. Cont.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.3000	0.85471	0.66		0.84489	0.69		0.83498	0.71		0.82497	0.75		0.81488	0.78	
0.4006	0.84436	0.74		0.83496	0.77		0.82548	0.79		0.81592	0.83		0.80628	0.86	
0.5004	0.83526	0.76		0.82626	0.79		0.81717	0.82		0.80803	0.85		0.79881	0.88	
0.5994	0.82729	0.72		0.81865	0.74		0.80992	0.77		0.80115	0.80		0.79231	0.83	
0.6998	0.82007	0.63		0.81176	0.65		0.80338	0.67		0.79495	0.70		0.78647	0.72	
0.7991	0.81377	0.48		0.80576	0.50		0.79769	0.51		0.78958	0.53		0.78142	0.54	
0.9001	0.80808	0.27		0.80036	0.28		0.79258	0.29		0.78476	0.29		0.77691	0.30	
1.0000	0.80314	0.00		0.79566	0.00		0.78814	0.00		0.78059	0.00		0.77302	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0011$ .

Table A6. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of pentylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in pentylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.1002	0.87936	0.34		0.86868	0.35		0.85787	0.36		0.84695	0.37		0.83592	0.38	
0.2005	0.86589	0.56		0.85576	0.58		0.84553	0.60		0.83521	0.62		0.82478	0.64	
0.2999	0.85453	0.70		0.84489	0.72		0.83517	0.75		0.82537	0.78		0.81549	0.80	
0.4006	0.84462	0.78		0.83543	0.81		0.82618	0.83		0.81686	0.86		0.80746	0.89	
0.5006	0.83615	0.79		0.82738	0.82		0.81853	0.84		0.80964	0.87		0.80067	0.90	
0.6008	0.82876	0.75		0.82036	0.77		0.81188	0.79		0.80337	0.82		0.79480	0.84	
0.7015	0.82232	0.64		0.81424	0.66		0.80610	0.68		0.79794	0.70		0.78972	0.72	
0.8007	0.81677	0.49		0.80899	0.50		0.80116	0.51		0.79329	0.52		0.78539	0.54	
0.8992	0.81194	0.28		0.80442	0.28		0.79686	0.29		0.78927	0.30		0.78165	0.30	
1.0000	0.80764	0.00		0.80036	0.00		0.79305	0.00		0.78572	0.00		0.77837	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0010$ .

Table A7. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of heptylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in heptylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.1000	0.87852	0.37		0.86798	0.38		0.85733	0.39		0.84659	0.40		0.83574	0.41	
0.2009	0.86498	0.61		0.85511	0.63		0.84516	0.64		0.83513	0.66		0.82500	0.67	
0.3005	0.85420	0.75		0.84489	0.77		0.83552	0.78		0.82607	0.80		0.81656	0.82	
0.4000	0.84532	0.81		0.83650	0.83		0.82761	0.85		0.81867	0.87		0.80968	0.88	
0.4997	0.83789	0.81		0.82948	0.83		0.82101	0.85		0.81251	0.87		0.80396	0.88	
0.5996	0.83159	0.76		0.82355	0.78		0.81546	0.79		0.80733	0.80		0.79917	0.81	
0.7004	0.82622	0.65		0.81849	0.66		0.81073	0.67		0.80294	0.68		0.79511	0.69	
0.8014	0.82163	0.49		0.81418	0.50		0.80670	0.50		0.79920	0.51		0.79168	0.51	
0.9014	0.81776	0.27		0.81056	0.27		0.80332	0.28		0.79608	0.28		0.78881	0.28	
1.0000	0.81451	0.00		0.80752	0.00		0.80050	0.00		0.79347	0.00		0.78643	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0006$ .

Table A8. Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of octylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in octylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	T = 288.15 K			T = 298.15 K			T = 308.15 K			T = 318.15 K			T = 328.15 K		
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>		$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	
0.0000	0.89567	0.00		0.88430	0.00		0.87279	0.00		0.86121	0.00		0.84946	0.00	
0.1000	0.87823	0.39		0.86777	0.40		0.85720	0.40		0.84655	0.41		0.83578	0.42	
0.2003	0.86495	0.63		0.85520	0.64		0.84537	0.65		0.83547	0.66		0.82548	0.67	
0.3003	0.85451	0.76		0.84535	0.78		0.83612	0.79		0.82683	0.80		0.81748	0.81	
0.3993	0.84614	0.82		0.83746	0.83		0.82872	0.85		0.81994	0.86		0.81111	0.87	
0.5001	0.83911	0.82		0.83085	0.83		0.82254	0.84		0.81420	0.86		0.80582	0.86	
0.6007	0.83329	0.76		0.82540	0.77		0.81746	0.77		0.80950	0.78		0.80150	0.79	
0.6993	0.82849	0.65		0.82090	0.65		0.81327	0.66		0.80562	0.67		0.79795	0.67	
0.8012	0.82433	0.48		0.81701	0.48		0.80965	0.49		0.80229	0.49		0.79490	0.49	
0.8993	0.82093	0.26		0.81384	0.27		0.80671	0.27		0.79958	0.27		0.79243	0.27	
1.0000	0.81796	0.00		0.81107	0.00		0.80415	0.00		0.79723	0.00		0.79030	0.00	

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0013$ .

**Table A9.** Experimental densities ( $\rho$ ) and excess molar volumes ( $V^E$ ) of decylcyclohexane (1) + ethyl propanoate (2) system at mole fraction  $x_1$  in decylcyclohexane at temperature  $T$  and  $P = 101$  kPa \*.

$x_1$ /mol·mol <sup>-1</sup>	$T = 288.15$ K		$T = 298.15$ K		$T = 308.15$ K		$T = 318.15$ K		$T = 328.15$ K	
	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>	$\rho$ /g·cm <sup>-3</sup>	$V^E$ /cm <sup>3</sup> ·mol <sup>-1</sup>
0.0000	0.89567	0.00	0.88430	0.00	0.87279	0.00	0.86121	0.00	0.84946	0.00
0.1001	0.87729	0.43	0.86698	0.44	0.85657	0.44	0.84608	0.44	0.83548	0.44
0.2002	0.86407	0.68	0.85456	0.69	0.84495	0.69	0.83529	0.70	0.82555	0.70
0.2998	0.85412	0.81	0.84520	0.83	0.83623	0.83	0.82721	0.84	0.81813	0.84
0.4001	0.84625	0.87	0.83785	0.88	0.82939	0.89	0.82090	0.89	0.81237	0.89
0.5039	0.83977	0.86	0.83179	0.87	0.82377	0.88	0.81572	0.88	0.80765	0.87
0.6010	0.83486	0.80	0.82722	0.80	0.81953	0.81	0.81183	0.81	0.80411	0.80
0.6984	0.83077	0.69	0.82341	0.69	0.81601	0.69	0.80861	0.69	0.80119	0.68
0.7989	0.82735	0.50	0.82023	0.50	0.81308	0.50	0.80593	0.50	0.79876	0.50
0.8925	0.82465	0.29	0.81773	0.29	0.81077	0.29	0.80382	0.29	0.79687	0.29
1.0000	0.82206	0.00	0.81534	0.00	0.80858	0.00	0.80183	0.00	0.79508	0.00

\* Expanded uncertainties:  $U(T) = 0.02$  K,  $U(P) = 2$  kPa,  $U(x_1) = 0.0001$  mol·mol<sup>-1</sup> ( $k = 2$ , level of confidence  $\approx 0.95$ ).  
Relative standard uncertainty:  $u_r(\rho_m) = 0.0005$ .

**Table A10.** Redlich–Kister coefficients \* (Equation (5)) for the correlation of the excess molar volumes for nine binary systems studied in this work and Jouyban–Acree model's performance in excess molar volumes prediction.

$T/K$	$a_0$	Redlich–Kister $a_1$ $a_2$		$\sigma_{V^E}/\text{cm}^3 \cdot \text{mol}^{-1} **$	Jouyban–Acree $\sigma_{V^E}/\text{cm}^3 \cdot \text{mol}^{-1} **$
<b>cyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.5965	1.0039	0.6133	0.008	0.021
298.15	3.6983	0.9934	0.5387	0.007	0.011
308.15	3.8004	1.0150	0.4653	0.008	0.005
318.15	3.9161	0.9940	0.4994	0.008	0.012
328.15	4.0400	0.9784	0.4633	0.007	0.022
<b>methylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	2.4934	0.2987	0.2093	0.003	0.033
298.15	2.6086	0.3080	0.1913	0.003	0.020
308.15	2.7411	0.3412	0.1676	0.004	0.011
318.15	2.8980	0.3256	0.1701	0.003	0.016
328.15	3.0703	0.3497	0.1422	0.004	0.032
<b>ethylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	2.7391	0.1077	0.2249	0.002	0.037
298.15	2.8673	0.0904	0.2102	0.001	0.021
308.15	3.0041	0.1146	0.1804	0.003	0.006
318.15	3.1588	0.0629	0.2062	0.002	0.013
328.15	3.3191	0.0461	0.1526	0.002	0.029
<b>propylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	2.8907	-0.0836	0.2664	0.001	0.037
298.15	3.0062	-0.1074	0.2541	0.001	0.024
308.15	3.1324	-0.1133	0.2239	0.001	0.012
318.15	3.2739	-0.1461	0.2551	0.001	0.005
328.15	3.4170	-0.1754	0.2568	0.001	0.012
<b>butylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.0271	-0.2416	0.3497	0.003	0.019
298.15	3.1383	-0.2766	0.3046	0.003	0.008
308.15	3.2536	-0.3006	0.2821	0.003	0.006
318.15	3.3793	-0.3515	0.3023	0.002	0.013
328.15	3.5062	-0.3775	0.2954	0.002	0.019
<b>pentylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.1571	-0.4144	0.3757	0.007	0.016
298.15	3.2591	-0.4429	0.3361	0.005	0.008
308.15	3.3621	-0.4642	0.3074	0.005	0.008
318.15	3.4662	-0.5183	0.3502	0.005	0.011
328.15	3.5713	-0.5473	0.3498	0.004	0.013
<b>heptylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.2471	-0.6483	0.5141	0.005	0.009
298.15	3.3237	-0.6893	0.5114	0.005	0.006
308.15	3.3841	-0.7198	0.5169	0.004	0.004
318.15	3.4558	-0.7911	0.5170	0.005	0.006
328.15	3.5061	-0.8269	0.5315	0.004	0.016
<b>octylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.2533	-0.8154	0.5746	0.008	0.015
298.15	3.3133	-0.8601	0.5636	0.008	0.011

Table A10. Cont.

T/K	a <sub>0</sub>	Redlich–Kister		$\sigma_{V^E}/\text{cm}^3 \cdot \text{mol}^{-1} **$	Jouyban–Acree $\sigma_{V^E}/\text{cm}^3 \cdot \text{mol}^{-1} **$
		a <sub>1</sub>	a <sub>2</sub>		
308.15	3.3568	−0.8889	0.5683	0.007	0.005
318.15	3.4039	−0.9461	0.5806	0.007	0.011
328.15	3.4266	−0.9794	0.6048	0.007	0.027
<b>decylcyclohexane (1) + ethyl propanoate (2)</b>					
288.15	3.4529	−0.9878	0.6763	0.012	0.031
298.15	3.4888	−1.0156	0.6874	0.011	0.020
308.15	3.4986	−1.0422	0.6945	0.010	0.007
318.15	3.5088	−1.0928	0.7121	0.010	0.023
328.15	3.4941	−1.1250	0.7139	0.010	0.050

\* Parameters to be used in Equation (5) with  $V^E$  in  $\text{cm}^3 \cdot \text{mol}^{-1}$  and  $x_1$  in mole fractions, \*\* Standard deviation between experimental and calculated excess molar volumes.

## References

- Rios, R.; Ortega, J.; Fernandez, L.; de Nuez, I.; Wisniak, J. Improvements in the experimentation and the representation of thermodynamic properties (iso-p VLE and  $y^E$ ) of alkyl propanoate + alkane binaries. *J. Chem. Eng. Data* **2014**, *59*, 125–142. [CrossRef]
- Fernández, L.; Pérez, E.; Ortega, J.; Canosa, J.; Wisniak, J. Measurements of the Excess Properties and Vapor-Liquid Equilibria at 101.32 kPa for mixtures of Ethyl Ethanoate + Alkanes (from C<sub>5</sub> et C<sub>10</sub>). *J. Chem. Eng. Data* **2010**, *55*, 5519–5533. [CrossRef]
- Fernández, L.; Ortega, J.; Pérez, E.; Toledo, F.; Canosa, J. Multiproperty Correlation of Experimental Data of the Binaries Propyl Ethanoate + Alkanes (Pentane to Decane). New Experimental Information for Vapor-Liquid Equilibrium and Mixing Properties. *J. Chem. Eng. Data* **2013**, *58*, 686–706. [CrossRef]
- Pérez, E.; Ortega, J.; Fernández, L.; Wisniak, J.; Canosa, J. Contributions to the modeling and behavior of solutions containing ethanoates and hydrocarbons. New experimental data for binaries of butyl ester with alkanes (C<sub>5</sub>–C<sub>10</sub>). *Fluid Phase Equilib.* **2016**, *412*, 79–93. [CrossRef]
- Vitu, S.; Berkalou, K.; Havet, J.L.; Caqueret, V. The 2,2,4-trimethylpentane + ethyl propanoate binary system: Density, Bancroft point and vapor-liquid equilibrium at 30, 60 and 101.3 kPa. *J. Chem. Thermodyn.* **2025**, *207*, 107486. [CrossRef]
- Ortega, J.; Fernández, L.; Sosa, A.; Lorenzo, B.; Rios, R.; Wisniak, J. New Advances in the Modeling and Verification of Experimental Information for Ester-Alkane Solutions: Application to a Batch-Distillation Case. *Ind. Eng. Chem. Res.* **2020**, *59*, 8346–8360. [CrossRef]
- Rios, R.; Ortega, J.; Sosa, A.; Fernández, L. Strategy for the Management of Thermodynamic Data with Application to Practical Cases of Systems Formed by Esters and Alkanes through Experimental Information, Checking-Modeling, and Simulation. *Ind. Eng. Chem. Res.* **2018**, *57*, 3410–3429. [CrossRef]
- Susial Badajoz, P.; García-Vera, D.; Marrero-Pérez, A.; Padrón-Guerra, N.; Mujica-González, T. Measurement of VLE Data by Using an Experimental Installation with Automatic Control: Modeling of Binary Systems of Methyl Acetate or Ethyl Acetate with n-Heptane or 2,2,4-Trimethylpentane at Both 0.1 and 1.5 MPa. *J. Chem. Eng. Data* **2019**, *64*, 5591–5608. [CrossRef]
- Ortega, J.; Toledo-Marante, F.J. Thermodynamic properties of (an ethyl ester + a branched alkane). XV.  $H^E_m$  and  $V^E_m$  values for (an ester + an alkane). *J. Chem. Thermodyn.* **2002**, *34*, 1439–1459. [CrossRef]
- Caqueret, V.; Berkalou, K.; Havet, J.-L.; Debacq, M.; Vitu, S. Density, Excess Molar Volume and Vapor–Liquid Equilibrium Measurements at 101.3 kPa for Binary Mixtures Containing Ethyl Acetate and a Branched Alkane: Experimental Data and Modeling. *Liquids* **2023**, *3*, 187–202. [CrossRef]
- Linek, J. Excess Volumes of Binary Liquid Mixtures Containing Ethers, Alcohols, Esters, or Alkanes. *ELDATA Int. Electron. J. Phys.-Chem. Data* **1995**, *1*, 43–52.
- Rajasekhar, P.; Reddy, K.S. Excess Volumes of Methylcyclohexane with Ketones and Esters at 303.15 K. *Phys. Chem. Liq.* **1987**, *17*, 195–200. [CrossRef]
- Berkalou, K.; Caqueret, V.; Zanghelini, G.; Vitu, S. Thermodynamic Behavior of the (Methylcyclopentane + Ethyl Acetate) Binary Liquid Mixture: Density at Several Temperatures and Vapor–Liquid Equilibrium at 25, 50, and 101.3 kPa. *J. Chem. Eng. Data* **2024**, *69*, 1655–1667. [CrossRef]
- Krasniqi, R.; Aliaj, F.; Syla, N.; Musliu, A.; Zeqiraj, A. Thermophysical Properties of Binary and Ternary Mixtures Comprising Methyl Acetate, n-Hexane, and Cyclohexane: Experimental and Modeling Approach. *Int. J. Thermophys.* **2025**, *46*, 100. [CrossRef]
- Qin, A.; Hoffman, D.E.; Munk, P. Excess volumes of mixtures of alkanes with carbonyl compounds. *J. Chem. Eng. Data* **1992**, *37*, 55–61. [CrossRef]
- Jimenez, E.; Romani, L.; Andrade, M.I.P.; Roux-Desgranges, G.; Grolier, J.P. Molar excess heat capacities and volumes for mixtures of alkanolates with cyclohexane at 25 °C. *J. Solut. Chem.* **1986**, *15*, 879–890. [CrossRef]

17. Sastry, N.V.; Patel, S.R.; Soni, S.S. Excess molar volumes, excess isentropic compressibilities, excess viscosities, relative permittivity and molar polarization deviations for methyl acetate+, ethyl acetate+, butyl acetate+, isoamyl acetate+, methyl propionate+, ethyl propionate+, ethyl butyrate+, methyl methacrylate+, ethyl methacrylate+, and butyl methacrylate + cyclohexane at T = 298.15 and 303.15 K. *J. Mol. Liq.* **2013**, *183*, 102–112. [[CrossRef](#)]
18. Elliott, J.R.; Diky, V.; Knotts, T., IV; Wilding, W.V. *The Properties of Gases and Liquids*, 6th ed.; McGraw Hill: New York, NY, USA, 2023; pp. 11–33.
19. Malhotra, R.; Woolf, L.A. PVT Property Measurements for the Liquids Ethyl Propionate and Ethyl Butyrate from (278 to 338) K and (0.1 to 380) MPa. *J. Chem. Eng. Data* **1996**, *41*, 1371–1374. [[CrossRef](#)]
20. Liu, C.Y.; Ku, H.C.; Tu, C.H. Densities and Viscosities of Five Alkyl Esters with Nitroethane Systems at (293.15, 303.15, and 313.15) K. *J. Chem. Eng. Data* **1999**, *44*, 360–364. [[CrossRef](#)]
21. Costa, H.F.; Gardas, R.L.; Johnson, I.; Fonseca, I.M.A.; Ferreira, A.G.M. PVT Property Measurements for Ethyl Propionate, Ethyl Butyrate, and Ethyl Pentanoate Esters from (298 to 393) K and up to 35 MPa. *J. Chem. Eng. Data* **2009**, *54*, 256–262. [[CrossRef](#)]
22. Panduranga Rao, J.; Narendra, K.; Visalakshamma, V.; Krishna, T.S.; Srinivasa Rao, G. Acoustic and volumetric study of binary mixtures containing Ethyl propionate with amides at various temperatures. *J. Chem. Thermodyn.* **2024**, *190*, 107222. [[CrossRef](#)]
23. Luning Prak, D.J. Binary Mixtures of Benzene and Cyclohexane with n-Alkyl Functional Groups up to 12 Carbons Long: Densities, Viscosities, and Speeds of Sound within the Temperature Range (288.15–333.15) K. *J. Chem. Eng. Data* **2022**, *67*, 1378–1396. [[CrossRef](#)]
24. Kolska, Z.; Dvorakova, D.; Mika, J.; Boublik, T. Volumetric behavior of the binary systems benzene–cyclohexane and benzene–2,2,4-trimethyl-pentane at temperatures 293.15–323.15 K. *Fluid Phase Equilib.* **2011**, *303*, 157–161. [[CrossRef](#)]
25. Malek, N.I.; Ijardar, S.P.; Oswal, S.B. Volumetric and acoustic properties of binary mixtures of cyclohexane + benzene and + benzaldehyde at (293.15–323.15) K. *Thermochim. Acta* **2012**, *539*, 71–83. [[CrossRef](#)]
26. Hiroyuki, O. Excess volumes of (1-pentanol + cyclohexane or benzene) at temperatures between 283.15 K and 328.15 K. *J. Chem. Thermodyn.* **2002**, *34*, 849–859. [[CrossRef](#)]
27. Luning Prak, D.J. Binary Mixtures of n-Tridecane with n-Alkylcyclohexanes: Density, Viscosity, and Speed of Sound within the Temperature Range (288.15 to 333.15) K. *J. Chem. Eng. Data* **2023**, *68*, 1053–1066. [[CrossRef](#)]
28. Laesecke, A.; Outcalt, S.L.; Brumback, K.J. Binary Mixtures of n-Tridecane with n-Alkylcyclohexanes: Density and Speed of Sound Measurements of Methyl- and Propylcyclohexane. *Energy Fuels* **2008**, *22*, 2629–2636. [[CrossRef](#)]
29. Zhao, J.; Wu, J.; Dai, Y.; Cheng, X.; Sun, H.; Guo, Y.; Fang, W. Density, Viscosity, and Freezing Point for Four Binary Systems of n-Dodecane or Methylcyclohexane Mixed with 1-Heptanol or Cyclohexylmethanol. *J. Chem. Eng. Data* **2017**, *62*, 643–652. [[CrossRef](#)]
30. Zhang, C.; Li, G.; Yue, L.; Guo, Y.; Fang, W. Densities, Viscosities, Refractive Indices, and Surface Tensions of Binary Mixtures of 2,2,4-Trimethylpentane with Several Alkylated Cyclohexanes from (293.15 to 343.15) K. *J. Chem. Eng. Data* **2015**, *60*, 2541–2548. [[CrossRef](#)]
31. Van Hecke, G.R.; Baldwin, O.W.M.; Wada, B.C. Density, Viscosity, Refractive Index, Isobaric Specific Heat Capacity, Ultrasonic Velocity, Molar Volume, Isentropic Compressibility, Isothermal Compressibility, and Heat Capacity Ratio for Binary Mixtures of the Organic Liquids Ethylbenzene, Ethylcyclohexane, Pentylbenzene, and Pentylcyclohexane at 298.15 K and 0.1 MPa. *J. Chem. Eng. Data* **2022**, *67*, 1037–1053. [[CrossRef](#)]
32. Li, D.; Zheng, Y.; Wang, J.; Pang, Y.; Liu, M. Volumetric properties and viscosity for the ternary system of (1-pentanol+ethylcyclohexane+methylmyristate) and corresponding binary systems at T=293.15-323.15K. *J. Chem. Thermodyn.* **2022**, *165*, 106660. [[CrossRef](#)]
33. Luning Prak, D.J.; Morrow, B.H.; Cowart, J.S.; Trulove, P.C.; Harrison, J.A. Thermophysical Properties of Binary Mixtures of n-Dodecane with n-Alkylcyclohexanes: Experimental Measurements and Molecular Dynamics Simulations. *J. Chem. Eng. Data* **2019**, *64*, 1550–1568. [[CrossRef](#)]
34. Daridon, J.L.; Plantier, F.; Lagourette, B. Speed of Sound and Some Thermodynamic Properties of Liquid Methylcyclopentane and Butylcyclohexane in a Wide Range of Pressure. *Int. J. Thermophys.* **2003**, *24*, 639–649. [[CrossRef](#)]
35. Baylaucq, A.; Zéberg-Mikkelsen, C.K.; Daugé, P.; Boned, C. Dynamic Viscosity and Density of Heptylbenzene and Heptylcyclohexane up to 100 MPa. *J. Chem. Eng. Data* **2002**, *47*, 997–1002. [[CrossRef](#)]
36. Luning Prak, D.J. Binary Mixtures of Nonane and n-Alkylcyclohexanes: Densities and Speeds of Sound within the Temperature Range (288.15–333.15) K and Viscosities at 288.15, 293.15, and 298.15 K and 0.1 MPa. *J. Chem. Eng. Data* **2024**, *69*, 973–986. [[CrossRef](#)]
37. Camin, D.L.; Forziati, A.F.; Rossini, F.D. Physical Properties of n-Hexadecane, n-Decylcyclopentane, n-Decylcyclohexane, 1-Hexadecene and n-Decylbenzene. *J. Phys. Chem.* **1954**, *58*, 440–442. [[CrossRef](#)]
38. Jouyban, A.; Acree, W.E., Jr. A single model to represent physico-chemical properties of liquid mixtures at various temperatures. *J. Mol. Liq.* **2021**, *323*, 115054. [[CrossRef](#)]
39. Muñoz, M.M.; Tinjacá, D.A.; Jouyban, A.; Martínez, F.; Acree, W.E., Jr. Volumetric properties of {PEG 200 (or 300) (1) + water (2)} mixtures at several temperatures and correlation with the Jouyban–Acree model. *Phys. Chem. Liq.* **2018**, *56*, 100–109. [[CrossRef](#)]

40. Peralta, R.D.; Infante, R.; Cortez, G.; Ramirez, R.R.; Wisniak, J. Densities and excess volumes of binary mixtures of 1,4-dioxane with either ethyl acrylate, or butyl acrylate, or methyl methacrylate, or styrene at  $T = 298.15$  K. *J. Chem. Thermodyn.* **2003**, *35*, 239–250. [[CrossRef](#)]
41. Wisniak, J.; Peralta, R.D.; Infante, R.; Cortez, G. Volumetric Properties of the Ternary System 1,4-Dioxane + Butyl Acrylate + Ethyl Acrylate and Its Binary Butyl Acrylate + Ethyl Acrylate at 298.15 K. *J. Solut. Chem.* **2005**, *34*, 171–183. [[CrossRef](#)]
42. Ortega, J.; Espiau, F.; Toledo, F.J.; Dieppa, R. Thermodynamic properties of (an ester + an alkane). XVII. Experimental Hem and Vem values for (an alkyl propanoate + an alkane) at 318.15 K. *J. Chem. Thermodyn.* **2005**, *37*, 967–983. [[CrossRef](#)]

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