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Liquid-liquid interfacial tension of equilibrated mixtures of ionic liquids and hydrocarbons

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Ionic liquids are possible alternative solvents for the separation of aromatic and aliphatic hydrocarbons by liquid-liquid extraction. Interfacial tension is an important property to consider in the design of liquid-liquid extraction processes. In this work, the liquid-liquid interfacial tension and the mutual solubility at 25 °C have been measured for a series of biphasic, equilibrated mixtures of an ionic liquid and a hydrocarbon. In particular, the ionic liquids 1-alkyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide (with the alkyl substituent being ethyl, hexyl or decyl), 1-ethyl-3-methylimidazolium ethylsulfate, and 1-ethyl-3-methylimidazolium methanesulfonate have been selected, as well as the hydrocarbons benzene, hexane, ethylbenzene, and octane. The selected sets of ionic liquids and hydrocarbons allow the analysis of the influence of a series of effects on the interfacial tension. For example, the interfacial tension decreases with an increase in the length of the alkyl substituent chain of the cation or with an increase of the degree of charge delocalisation in the anion of the ionic liquid. Also, the interfacial tension with the aromatic hydrocarbons is markedly lower than that with the aliphatic hydrocarbons. A smaller effect is caused by variation of the size of the hydrocarbon. Some of the observed trends can be explained from the mutual solubility of the hydrocarbon and the ionic liquid.

ionic liquid, aromatic hydrocarbon, aliphatic hydrocarbon, interfacial tension, liquid-liquid equilibrium

1 Introduction

In the last years, research on ionic liquids has experienced a formidable increase. The appealing properties of these salts with low melting temperatures have attracted the attention of both industry and academia. It is difficult to generalise properties common to all substances qualifying as ionic liquids; however, many of them exhibit a practically negligible volatility, the ability to dissolve a broad range of compounds, and a reasonably good thermal stability [1–3]. In addition, there exists the possibility of tailoring the properties of ionic liquids to a significant extent, for a specific application, by judicious choice of the combination of the constitutive ions [3, 4]. All these characteristics resulted in the early suggestion of ionic liquids as promising alternative

solvents for reaction and separation processes. Although many other applications have been suggested beyond their utilisation as simple solvents (for example, in material science or in biological/pharmaceutical areas) [5], this continues to be a major driver for research within the field [2, 6].

One of the main applications proposed for ionic liquids in the separations arena is their use as solvents in liquid-liquid extraction processes [2]. Liquid-liquid equilibrium data, which are critical for the design of this kind of processes, have been determined for different systems comprising ionic liquids and molecular compounds involved in specific industrial separation problems. From these data, key parameters such as selectivity or capacity can be inferred. There are, however, other relevant factors, which can influence the solvent selection and are necessary for a good design of solvent extraction units. One such factor is the interfacial tension between the liquid phases. Ideally, it

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would be desirable that the immiscible mixture had a moderate interfacial tension, thus balancing the ease of dispersion (of non-equilibrated phases) and the promotion of phase separation (once the phases are equilibrated) [7].

Compared to the already significant number of liquid-liquid equilibria studied for systems comprising an ionic liquid, much less attention has been paid to the interfacial tension in these systems. In the literature, interfacial tension values can be found mainly for binary systems composed by an ionic liquid and water [8-12], or by an ionic liquid and a hydrocarbon [9, 12-16], with a few examples of an ionic liquid with another kind of molecular compound [9, 13, 17]. There is one further example, for a ternary system comprising an ionic liquid, heptane and thiophene [18]. It can be seen that hydrocarbons have been some of the preferred compounds for these studies. This is in good connection with the relative relevance of research oriented to two industrial applications that have attracted most interest for the development of solvent extraction processes based on ionic liquid technology: desulfurisation of fuels, and separation of aromatic and aliphatic hydrocarbons [2]. To date, however, most references have reported the liquid-liquid interfacial tension of mixtures of ionic liquid and aliphatic hydrocarbons, with only one work reporting measurements with an aromatic hydrocarbon [9].

In this article, we have investigated the interfacial tension, along with mutual solubility, of biphasic liquid-liquid systems formed by binary mixtures of ionic liquid and aromatic hydrocarbon. The C6 hydrocarbons benzene and hexane, and the C8 hydrocarbons ethylbenzene and octane, have been selected for this study, to analyse the influence of both the aromatic/aliphatic character and the number of carbons of the hydrocarbon. Regarding the ionic liquids, several members of the homologous series of 1-alkyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide ionic liquids (abbreviated as $[C_n mim][NTf_2]$, with *n* being the number of carbons in the substituent alkyl chain) have been selected; namely those with ethyl, hexyl and decyl substituent chains. Thus, this set of ionic liquids allows for the analysis of the influence of the length of the alkyl substituent chain, which is a characteristic tunable feature of imidazolium-based ionic liquids [19]. In order to explore the effect of the anion, two other ionic liquids with a common cation have been 1-ethyl-3-methylimidazolium investigated: ethylsulfate ([C₂mim][EtSO₄]) and 1-ethyl-3-methylimidazolium methanesulfonate ([C₂mim][CH₃SO₃]). These are, in fact, the first non-fluorinated ionic liquids for which the interfacial tension with hydrocarbons is reported in the literature.

2 Materials and methods

2.1 Materials

Benzene (Sigma-Aldrich, > 99.0 %), hexane (Fluka, > 99.0 %), ethylbenzene (Fluka, > 99 %) and octane (Fluka, >

99.0%) were used as received. All ionic liquids were synthesised according to similar procedures to those previously reported [20–22], and briefly summarised in the following paragraphs.

The ionic liquid [C₂mim][NTf₂] was synthesised in two steps. First, 1-methylimidazole (Aldrich, 99%) was directly alkylated with bromoethane (Sigma-Aldrich, 98%), at 40 °C under inert atmosphere, for 48 h, to produce 1-ethyl-3-methylimidazolium bromide. Then, an aqueous solution of the latter was mixed with an aqueous solution of lithium bis(trifluoromethanesulfonyl)imide (3M, 98%), generating the hydrophobic [C₂mim][NTf₂] by metathesis. Dichloromethane (Fluka, 99.9%) was added for a better separation of the organic and aqueous phases; and the organic phase was washed several times with fresh water, until no precipitation was observed upon addition of an aqueous solution of silver nitrate to the residual washing phase. After removal of dichloromethane in a rotary evaporator, the desired ionic liquid was purified under reduced pressure (< 0.1 mbar) at 80 °C for no less than one day.

The ionic liquids $[C_6 mim][NTf_2]$ and $[C_{10}mim][NTf_2]$ were synthesised in an analogous manner to $[C_2 mim][NTf_2]$, carrying out the alkylation step at a suitable temperature with 1-chlorohexane (Fluka, > 99%) or 1-chlorodecane (Fluka, > 97%), respectively, instead of bromoethane.

The ionic liquids $[C_2mim][EtSO_4]$ and $[C_2mim][CH_3SO_3]$ were prepared directly by alkylation of 1-methylimidazole with diethylsulfate (Aldrich, > 98%) or ethylmethanesulfonate (Fluka, 98.0%), respectively. 1-Methylimidazole was placed in a two-neck round-bottomed flask with a reflux condenser attached to the main neck. It was placed in an ice bath, and then the stoichiometric amount of the alkylating agent was added carefully and stepwise, through the secondary neck of the flask. The ice bath and the dropwise addition were necessary in order to neutralise the high exothermicity of the alkylation reactions. After complete addition of the reactants, the temperature was risen to ensure total alkylation. As with the $[NTf_2]$ -based ionic liquids, the resulting ionic liquid was purified under reduced pressure.

The structure and purity of all ionic liquids was confirmed by ¹H and ¹³C NMR spectroscopy. Their chemical structures are shown in Figure 1. Their water content (which is an important impurity that can critically affect the properties and performance of ionic liquids [23]) was found to be lower than 500 ppm for all ionic liquids, as determined by Karl-Fischer titration in a MetrOhm 737 KF coulometer.

2.2 Methods

Binary mixtures of an ionic liquid and a hydrocarbon were prepared, with a global composition lying in the immiscible domain. They were placed inside jacketed glass cells, at a controlled temperature of 25.0 °C (by means of Selecta Ultraterm 6000383 water bath thermostats, precise to within 0.1 °C), and they were vigorously stirred for a minimum of



Figure 1 Chemical structures of the ionic liquids used in this work. (a) $[C_n \text{mim}][\text{NTf}_2]$ (with *n* being 2, 6, or 10); (b) $[C_2 \text{mim}][\text{EtSO}_4]$; (c) $[C_2 \text{mim}][\text{CH}_3\text{SO}_3]$.

1.5 h, followed by a settling period of no less than 4 h to allow complete phase separation. Without disturbance of the liquid-liquid interface, samples were taken from both phases in equilibrium, and stored at 25.0 °C. For compositional analysis, a small aliquot of each equilibrated sample was dissolved in a suitable deuteriated solvent (either CDCl₃ (Aldrich, 99.8%) or CD₃OD (Aldrich, +99.8%)), and placed into an NMR tube which was immediately capped. The rest of the samples' volume was used in determining the interfacial tension.

Compositional analysis was carried out by means of ¹H NMR spectroscopy. The samples were run in a 7.04 T (300 MHz resonance for 1H) Varian Mercury 300 spectrometer, using a relaxation time of 20 s. The mole fractions of hydrocarbon and ionic liquid in each case were calculated from the integrated areas under specific peaks of the spectra. For the ionic liquids, in general, the peaks corresponding to the methylene group (corresponding to 2H) and methyl group (3H) bonded to the nitrogen atoms in the imidazolium ring were selected. In the particular case of $[C_2 mim]$ [EtSO₄], also the peak of the methylene group (2H) bonded to the oxygen atom in the anion was included in the calculations. For benzene, its only peak (6H) was selected. For ethylbenzene, the peak corresponding to the hydrogen atoms of the aromatic ring (5H) and the one for the methylene group (2H) were used. Regarding the linear hydrocarbons, their peak for the terminal methyl groups (6H) was chosen. In the systems with $[C_6mim][NTf_2]$ and $[C_{10}mim][NTf_2]$, the latter peak was overlapped by the peak of the terminal methyl group of the long alkyl substituent chain of the imidazolium ionic liquid, and therefore the corresponding algebraic calculations had to be made to subtract this contribution, in order to get the final mole fractions of the analysed mixture. With these sets of peaks selected, the maximum error of the results obtained may be estimated at 2% in mole fraction for the ionic liquid rich

phase; whereas for the hydrocarbon rich phase an uncertainty of 0.5% in mole fraction can be estimated.

Interfacial tensions were experimentally determined in a Krüss K11 tensiometer, using the method of the Wilhelmy plate. An especially adapted platinum plate with cylindrical shape (Krüss accessory reference PL22, with dimensions 10 mm height \times 20 mm base perimeter \times 0.1 mm width) was used. This adapted plate is suitable for the performance of reliable measurements with lower amounts of sample than the conventional flat plate. The measurements were performed in accordance with the instructions by the manufacturer. Cylindrical open-top glass vessels, with a large enough diameter as to avoid influence of wall effects, were used to place the denser and/or lighter phases along the different steps of the measuring procedure. These vessels were partially immersed in an oil bath at 25.0±0.1 °C, as measured by a built-in thermometer, with the temperature being controlled by means of circulating water from a Julabo F12 cryogenic bath. Each interfacial tension value reported in this work is the average of ten consecutive immersion measurements, after two initial immersions that were systematically discarded. The described method has an estimated uncertainty of ca. 0.3 mN/m.

3 Results and discussion

The liquid-liquid equilibrium and the interfacial tension, at 25.0 °C, of the binary mixtures of each hydrocarbon (benzene, hexane, ethylbenzene, or octane) with each ionic liquid ([C₂mim][NTf₂], [C₆mim][NTf₂], [C₁₀mim][NTf₂], [C₂mim][EtSO₄], or [C₂mim][CH₃SO₃]) were determined. The compositions of each phase in equilibrium, as well as the corresponding interfacial tension between both phases, are reported in Table 1. In all cases the phase rich in ionic liquid was the lower one, whereas the lighter phase was rich in the hydrocarbon.

In general, no ionic liquid was detected in the upper phase, with exception of the mixtures of $[C_{10}mim][NTf_2]$ with the two aromatic hydrocarbons. In these cases, a low mole fraction of the ionic liquid in the hydrocarbon-rich phase could be measured. For these two systems, the miscibility gap is quite narrow and is located in the hydrocarbon-rich region [19], thus yielding two phases in equilibrium in which the upper phase is almost pure hydrocarbon and the "ionic liquid-rich phase" has a hydrocarbon mole fraction of ca. 0.90 or greater. As a result of such similarity in the composition of both equilibrated phases, the interfacial tension of the systems benzene + $[C_{10}mim][NTf_2]$ and ethylbenzene + $[C_{10}mim][NTf_2]$ is very low, and could not be precisely measured.

For all four systems hydrocarbon + $[C_2mim][NTf_2]$ and for the two systems of $[C_{10}mim][NTf_2]$ with the C6 hydrocarbons, the equilibrium composition obtained in this work can be compared to previous results reported in the litera-

Table 1 Mole fraction of ionic liquid (x_{IL}) in the lower and upper phases in equilibrium at 25.0 °C, as well as the corresponding interfacial tension (γ), for binary systems hydrocarbon + ionic liquid

Hydrocarbon	Ionic liquid	x _{IL} , upper phase	<i>x</i> _{IL} , lower phase	$\gamma(mN/m)$
Benzene	[C10mim][NTf2]	0.004	0.047	< 0.1
	[C ₆ mim][NTf ₂]	0.000	0.135	0.5
	[C ₂ mim][NTf ₂]	0.000	0.241	1.2
	[C ₂ mim][EtSO ₄]	0.000	0.553	3.6
	[C ₂ mim][CH ₃ SO ₃]	0.000	0.704	5.2
Hexane	[C10mim][NTf2]	0.000	0.644	0.3
	[C ₆ mim][NTf ₂]	0.000	0.917	4.7
	[C ₂ mim][NTf ₂]	0.000	0.972	11.0
	[C ₂ mim][EtSO ₄]	0.000	0.987	14.2
	[C ₂ mim][CH ₃ SO ₃]	0.000	0.970	18.3
Ethylbenzene	[C10mim][NTf2]	0.003	0.107	< 0.1
	[C ₆ mim][NTf ₂]	0.000	0.260	0.8
	[C ₂ mim][NTf ₂]	0.000	0.502	2.8
	[C ₂ mim][EtSO ₄]	0.000	0.876	6.7
	[C ₂ mim][CH ₃ SO ₃]	0.000	0.950	9.2
Octane	[C10mim][NTf2]	0.000	0.794	0.7
	[C ₆ mim][NTf ₂]	0.000	0.989	5.5
	[C ₂ mim][NTf ₂]	0.000	0.986	11.7
	[C ₂ mim][EtSO ₄]	0.000	0.999	16.0
	[C ₂ mim][CH ₃ SO ₃]	0.000	0.997	19.5

ture [19, 24]. All values agree within the estimated experimental uncertainty, with the only exception of the composition of the lower phase for the system hexane + $[C_{10}mim][NTf_2]$, whose deviation is slightly larger, and probably related to the effect of different impurities (associated with different sources of the components) that may influence the liquid-liquid equilibrium. Comparison with literature data is also possible for some interfacial tension values. In particular, Gardas *et al.* [12] have reported interfacial tensions at 298 K for the systems $[C_2mim][NTf_2]$ + hexane, $[C_2mim][NTf_2]$ + octane, $[C_6mim][NTf_2]$ + hexane, and $[C_6mim][NTf_2]$ + octane. All their values agree with ours within experimental uncertainty.

By focusing on the systems involving the $[C_n mim][NTf_2]$ ionic liquids, the influence of the length of the alkyl substituent chain of the ionic liquid cation on the interfacial tension can be analysed. Figure 2 shows the evolution as a function of the number of carbons in the alkyl substituent chain. A clear decrease is observed in the interfacial tension with an increase in the length of the alkyl substituent, regardless of the type of hydrocarbon present in the system. This is in agreement with the results by Gardas et al. for systems of aliphatic hydrocarbon + $[C_n mim][NTf_2]$ systems [12], as well as with those by Hu and co-workers for systems of aliphatic hydrocarbon + $[C_n mim][PF_6]$ or $[C_n \min][BF_4]$ ionic liquid [15, 16]. This decrease of interfacial tension with increase of the alkyl substituent length is interpreted as a result of the increased van der Waals interaction existing between the alkyl chain of the ionic liquid and the hydrocarbon. For the systems $[C_{10}mim][NTf_2] +$



Figure 2 Interfacial tension γ of systems $[C_n \min][NTf_2] + hydrocarbon, at 25 °C, as a function of the number of carbon atoms in the alkyl substituent chain of the ionic liquid ($ *n* $). Hydrocarbon: •, benzene; •, ethylbenzene; •, hexane; <math>\blacktriangle$, octane. Lines (solid for C6 hydrocarbons; dashed for C8 hydrocarbons) are mere guides to the eye.

aromatic hydrocarbon, the minimum interfacial tension is practically reached, as a result of the similarity in composition of the phases in equilibrium. In fact, the miscibility gap entirely disappears with a slight increase in the length of the alkyl substituent chain, as it has been previously reported for the system $[C_{12}mim][NTf_2]$ + benzene [19].

The effect of variation of the anion can be observed in Figure 3 for the systems involving ionic liquids with the common $[C_2mim]^+$ cation. For each group of these systems with a common hydrocarbon, the interfacial tension decreases according to the following ordered series of anions: $[CH_3SO_3]^- > [EtSO_4]^- > [NTf_2]^-$. No interfacial tensions of other hydrocarbon + $[C_2mim]$ -based ionic liquid could be found in the literature for expansion of this series. In any case, the series follows the same trend than the degree of charge delocalisation of the anions. Thus, the most polar of the anions ($[CH_3SO_3]^-$) is the one leading to the highest interfacial tensions; and conversely, the $[NTf_2]^-$ anion, with a strong delocalisation of its charge, leads to the lowest interfacial tensions.

From Figures 2 and 3 it is also clear that the aromatic hydrocarbons lead to lower interfacial tensions than their aliphatic counterparts. This can be related to the greater solubility of the aromatic hydrocarbon in the ionic liquid phase (see the lower values of x_{IL} in the lower phase in Table 1). Thus, a substantial presence of the hydrocarbon in both phases may cause a reduction of the tension at their interface. One further effect that can be inferred from Figures 2 and 3 is the increase in the interfacial tension with an increase of the molecular weight of the hydrocarbon within the aromatic or the aliphatic category, without exception. That is, the interfacial tension of any of the systems ethylbenzene + ionic liquid is greater than the one for the corresponding systems benzene + ionic liquid; and, analogously, for the systems octane + ionic liquid the interfacial tension is greater than for the corresponding systems hexane + ionic liquid. This effect is less pronounced than that of the



Figure 3 Interfacial tensions of systems $[C_2mim][A] + hydrocarbon, at 25 °C, where <math>[A]^-$ is the anion of the ionic liquid: $[NTf_2]^-$ (black, left bars of each bar group), $[EtSO_4]^-$ (light gray, central bars), or $[CH_3SO_3]^-$ (dark gray, right bars). The specific hydrocarbon is indicated over each group of bars.

aromatic versus aliphatic nature of the hydrocarbon, since, for example, for a given ionic liquid the interfacial tension in the system with ethylbenzene is still notably lower than that for the equivalent system with hexane (as it can be directly observed in Figure 2 for the case of the $[C_n mim][NTf_2]$ ionic liquids). A similar evolution with the degree of unsaturation was previously observed by Zhu *et al.* for mixtures of hydrocarbons with the ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate [9].

In trying to relate the interfacial tension of the systems hydrocarbon + ionic liquid with the surface tensions (i.e., interfacial tension with air) of the pure compounds, a simple expression originally proposed by Girifalco and Good [25] has been recently applied to binary mixtures of an alkane or an alkene with an ionic liquid [13–16]. Generalising for the combination of an ionic liquid with any type of hydrocarbon, the expression is:

$$\gamma_{\rm IL-HC} = \sigma_{\rm IL} + \sigma_{\rm HC} - 2 \cdot \varphi \cdot \sqrt{\sigma_{\rm IL}} \cdot \sigma_{\rm HC} \tag{1}$$

where $\gamma_{\text{IL-HC}}$ is the interfacial tension of the binary mixture; $\sigma_{\rm IL}$ and $\sigma_{\rm HC}$ are the surface tensions (or, in other words, the interfacial tensions with air) of the ionic liquid and the hydrocarbon, respectively; and ϕ is the interaction parameter, or proportionality factor. This parameter is closely related to the contribution from polar interaction to the interfacial tension, and its value is lower than, equal to, or greater than unity for apolar/polar, apolar/apolar, and polar/polar interfaces, respectively [13, 25, 26]. For application of eq. (1), values of the surface tensions of ionic liquids and of hydrocarbons were taken from the literature. For [C₂mim][NTf₂], $[C_2 mim][NTf_2]$ and $[C_2 mim][NTf_2]$, respective values of 36.68, 32.04 and 31.73 mN/m were obtained by interpolation for 25 °C from the work by Carvalho et al. [27]. For $[C_2 mim][EtSO_4]$, the value of 46.96 mN/m reported by Gómez et al. was used [28]. Regarding [C₂mim][CH₃SO₃], a value of 50.16 mN/m was estimated at 25 °C from a method using the value at 20 °C and density measurements at different temperatures, reported by Hasse et al. [29]. It must be noted that the normal melting temperature of this

ionic liquid is slightly over ambient temperature, although it tends to form a subcooled liquid [30]; thus, the indicated surface tension at 25 °C would be the one corresponding to subcooled [C₂mim][CH₃SO₃]. For the hydrocarbons, the following values were used [31]: 28.20 mN/m for benzene, 28.48 mN/m for ethylbenzene, 17.94 mN/m for hexane, and 21.18 mN/m for octane.

The values of ϕ calculated by means of eq. (1) for the systems studied in this work are reported in Table 2. These values are in the range of 0.80-0.90 for the mixtures of the [C₂mim]-based ionic liquids and the aliphatic hydrocarbons, whereas the remaining values are greater than 0.90 and reach or slightly surpass the unity for the systems comprising the ionic liquid $[C_{10}mim][NTf_2]$. As indicated before, values lower than unity would correspond to apolar/polar interfaces, while unity values would correspond to apolar/apolar interfaces. Thus, the indicated evolution of the parameter ϕ can be interpreted as a transformation from an apolar/polar interface to an interface with a greater apolar/apolar character. A first effect responsible for this evolution is the increase of the length of the alkyl side chain in the $[C_n mim][NTf_2]$ ionic liquids, which increases the apolar contribution of the ionic liquid, thus generating a more apolar/apolar interface with the hydrocarbons. A second effect to consider is the high solubility of the aromatic hydrocarbons in any of the ionic liquids tested, which causes the ionic liquid phase to have an important apolar contribution at the interface, even in the case of ionic liquids with short alkyl substituents. Since values very close to unity have been obtained for ϕ in the systems involving the aromatic hydrocarbons, in particular in those with benzene, and in the systems involving the ionic liquids with a long alkyl substituent (in particular in those with $[C_{10}mim][NTf_2]$), it is postulated that reasonably good estimations can be made for the interfacial tension of systems of this kind from knowledge of the surface tension of the two pure compounds involved, without any extra information.

4 Conclusions

Interfacial tensions for a series of binary systems formed by an ionic liquid and a hydrocarbon with mutual immiscibility

Table 2 Interaction parameter ϕ for binary systems hydrocarbon + ionicliquid

	Hydrocarbon			
Ionic liquid	benzene	ethylbenzene	hexane	octane
[C ₁₀ mim][NTf ₂]	1.00	1.00	1.03	1.01
[C ₆ mim][NTf ₂]	0.99	0.99	0.94	0.92
[C ₂ mim][NTf ₂]	0.99	0.96	0.85	0.83
[C ₂ mim][EtSO ₄]	0.98	0.94	0.87	0.83
[C ₂ mim][CH ₃ SO ₃]	0.97	0.92	0.83	0.80

have been determined at 25 °C, along with the corresponding composition of the co-existing liquid phases in equilibrium. The upper phases were practically composed of pure hydrocarbon. The aromatic hydrocarbons were more soluble than the aliphatic hydrocarbons in the ionic liquids, producing ionic liquid-rich phases with higher hydrocarbon content, and giving rise to lower interfacial tensions. These were also found to decrease, for a given hydrocarbon, with the length of the alkyl substituents of the ionic liquid. Also, for a given cation of the ionic liquid, the interfacial tensions decrease with an increase in the degree of charge delocalisation of the anion. In the binary systems involving an aromatic hydrocarbon or an ionic liquid with a long alkyl substituent chain, the interaction parameter ϕ was higher than 0.90, and in some cases even equal to unity; therefore, a reasonably good estimation of the interfacial tension can be obtained from the only knowledge of the surface tensions of the two compounds involved, by means of eq. (1).

Since interfacial tension is a relevant property in the design of liquid-liquid extractors, the present results are potentially useful in helping to select a suitable ionic liquid to carry out the separation of aromatic and aliphatic hydrocarbons by solvent extraction. In addition, the results would be of usefulness in the subsequent design of the extraction unit.

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