Surface Tension and density of binary mixtures containing ionic liquid (1-methyl-3-pentyl-imidazolium hexafluorophosphate) and poly(ethylene glycol)

ABSTRACT: Surface tension and density of the binary mixtures containing 1-methyl-3-pentyl-imidazolium hexafluorophosphate [MPI][PF₆] and poly(ethylene glycol) (PEG) [Mw = 400] are measured over the whole composition range. The surface tension deviation values are calculated from the experimental surface tension over the whole concentration range, and they are positive and become less positive with increasing temperature. The surface thermodynamic functions, such as surface entropy, enthalpy, as well as standard molar entropy, and molar enthalpy of vaporization for pure ionic liquid, have been derived from the temperature dependence of the surface tension value.

Keywords: Ionic liquid, density, surface tension, surface thermodynamic property

1. Introduction

It is well-known that Poly(ethylene glycol) (PEG) refers to an oligomer or polymer of ethylene oxide. PEG of various molecular weights have been widely used in processes across many industrial sectors, as a result of being non-toxic, biodegradable, inexpensive, widely available, and with a very low volatility [1]. Low molecular weight PEG (Mw = 400) is liquid at room temperature, making it easy to combine with ionic liquids (ILs), generate solvent systems, and thus use in advanced, environmentally friendly processes. In this work, values of the density and surface tension of the binary mixture [MPI][PF₆] and poly(ethylene glycol) (PEG) [Mw = 400] are measured over the whole concentration range. The surface tension deviations of the binary system {IL + polymer} solution were also investigated.

2. Experimental

2.1. Synthesis of [MPI][PF₆]

[MPI][PF₆] was prepared in our laboratory according to a previously published procedure [2].

2.2. Measurements

To measure the density, IL or binary mixture was placed into the dilatometer, sealed the top of capillary tube, which was on the top of the dilatometer, and placed into a temperature bath for 10 minutes to allow the temperature to equilibrate. From the correction coefficient of deionized water in capillary tube at various temperatures, we can calculate the density of neat IL or binary system by the expanded volume of liquid in capillary tube at various temperatures. Each sample was measured at least three times to determine an average value, and the values of the density are ± 0.0001 g mL⁻¹. The surface tension measurements were made by a Kyowa Interface Science’s automatic tensiometer CBVP-A3 (Japan). The uncertainty of the surface tension measurements is ±0.2 mN m⁻¹.

3. Results and Discussions

3.1. Neat Components

The density of neat IL [MPI][PF₆] and PEG400 were measured from 301 to 359 K, and are presented in Table 1. In general, the density decreases with temperature for both neat substances, the correlation with temperature can be expressed using the following linear equation:

\[ \rho = A + BT \]  

The characteristic parameters A and B were determined from the intercept and slope of the corresponding lines, and the best linear fitting |A| and |B| are listed in Table 2.

The surface tension, \( \gamma \), of PEG400 and [MPI][PF₆] at various temperatures are shown in Fig. 1, the surface tension of PEG400 from 293.15 to 359.15 K at atmospheric pressure. Using the quasi-linear surface tension variation with temperature observed for the pure IL, the surface thermodynamic properties, such as surface entropy, surface enthalpy, the standard molar entropy, and molar enthalpy of vaporization (\( \Delta H_{vap} \)) were estimated. The surface tension deviations \( \Delta \gamma \) of the binary system {IL + polymer} solution were also investigated.

\[ \gamma = H^A - TS_0 \]  

\[ S = \left( \frac{\partial \gamma}{\partial T} \right)_p \]