CO₂ Absorption Studies with Hybrid Solvents of 1-Butyl-3-Methylimidazolium Tetrafluoroborate (BMIM[BF₄]) + N-Methyl-2-Pyrrolidone (NMP) using a New Static-Synthetic Apparatus

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In order to design and optimize separation technologies based on an absorption method, accurate vapor-liquid equilibrium (VLE) data obtained through reliable experimental apparatus are required. To this end, a "staticsynthetic" experimental setup was designed and commissioned. The novel design of the equilibrium cell consists of a sapphire tube compressed between a bottom weld-neck (tapered) flange and a top flat stainless steel flange. The wider base allows for improved agitation of the cell contents; furthermore, the change in height of liquid can be recorded more precisely along the length of the sapphire tube with reduced diameter. An adjustable ruler was designed and attached to the cell to measure the height of liquid. The experimental method was validated by measuring the CO₂ solubility in pure solvents, viz., hexane, NMP, and BMIM[BF₄]. Excellent agreement was obtained between the measured data and that reported in the literature. New solubility data were measured for CO₂ in hybrid solvents with different mass compositions (10 %, 25 % and 50 %) of BMIM[BF4] at temperatures of 298.15, 313.15 and 323.15 K and in the pressure range of 1 to 20 bar. The viscosity, density, and vapor pressure for the NMP + BMIM[BF₄] mixtures were also measured. Depending on the temperature, pressure, and composition of solvents, the solubility of CO₂ in hybrid solvents reveals a decrease of 5 % to 25 % in comparison to the pure solvents. Meanwhile, the addition of NMP to BMIM[BF₄], to make a mixture with 74 % of ionic liquid reduces the viscosity by approximately 70 % which supports the use of BMIM[BF4] for such applications. Furthermore, the loss of solvent and its volatility were decreased when hybrid solvents were used instead of pure NMP. The experimental data were modelled using flash calculations utilizing the Peng-Robinson equation and the Wilson correlation. The average absolute relative deviations (AARD%) obtained were within 4 %.