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Investigation of accuracy of molecular mechanics force field of dimethyl sulfoxide (DMSO): A molecular simulation study

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Dimethyl sulfoxide (DMSO) is a polar organic liquid widely used as a solvent in many chemical reactions. Because of its ability to penetrate through biological membrane easily, DMSO is used as a vehicle for typical application of pharmaceuticals. In many industrial and laboratory applications DMSO – water binary mixtures were used; however, these binary mixtures show distinct properties that are not seen in pure solvents. Molecular dynamics (MD) simulation would give atomic/molecular level description of the properties of DMSO and its binary mixtures. Accuracy of MD results depends on the force field used. Usually, force fields are developed considering few physical and/or chemical properties. MD simulation combined with Kirkwood-Buff (KB) theory for solvent mixtures would give a theoretical approach for comparing many properties with experimental data at different concentrations of DMSO.

Two popular molecular mechanics force fields of DMSO, namely, GROMOS and VLL (by Vishnyakov, Lyubartsev and Laaksonen) were selected for this work. Initial configurations of pure DMSO and aqueous solutions of several DMSO concentrations were simulated in isothermal-isobaric ensemble for 3.0 ns each. Electrostatic energy was calculated using Particle-Mesh-Ewald method.

KB integrals (G_{ij}) of a binary system of components of 1 and 2; can be obtained from MD simulation data via $G_{ij} = 4\pi\int_o^R \left[g_{ij}^{NPT}(r) - 1\right] r^2 dr$ and then it is possible to calculate experimental data such as derivative of activity coefficients (f_{cc}), compressibility (k_T) and partial molar volumes $\overline{V}_1$ and $\overline{V}_2$ with the help of following relationships.

$$\overline{V}_1 = \frac{1 + \rho_2(G_{22} - G_{12})}{\eta};\ \overline{V}_2 = \frac{1 + \rho_1(G_{11} - G_{12})}{\eta};\quad \kappa_T = \frac{\zeta}{\eta kT};\quad f_{11} = \frac{1}{1 + \rho_1(G_{11} - G_{12})};$$

$$\eta = \rho_1 + \rho_2 + \rho_1\rho_2(G_{11} + G_{22} - 2G_{12}) \text{ and } \zeta = 1 + \rho_1 G_{11} + \rho_2 G_{22} + \rho_1\rho_2(G_{11}G_{22} - G_{12}^2)$$

For the parameterization of GROMOS-DMSO force field, only the hydration and solvation free energy have been used while for VLL-DMSO force field, only the liquid structure, density and energy of pure DMSO have considered. Either of these forced fields are lack of reproducing all the experimental parameters [G_{ij}'s, f_{cc}, k_T, $\overline{V}_1$ and $\overline{V}_2$, diffusion coefficients of DMSO (D_D), densities (ρ), dielectric constants (ε)] accurately. It is possible to fine tune potential parameters to show better agreement with the experimental data and this line of work is already underway.

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