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Density, Speed of Sound and Refractive Index of Polyvinylpyrrolidone-K60 + N, N-Dimethylformamide/ Dimethylacetamide Binary Mixtures at Different Temperatures †

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Abstract: Densities, speeds of sound, and refractive indices for the binary mixtures of Polyvinylpyrrolidone-K60 in N, N-Dimethylformamide, and in Dimethylacetamide solvents have been measured as a function of the different concentrations of the polymer at (298.15, 308.15, and 318.15) K temperatures. The thermo physical parameters such as the acoustic impedance, adiabatic compressibility, specific refraction, space-filling factor, and relaxation strength have been evaluated over the entire composition range the concentrations and temperatures based on the experimental data. The results are discussed and interpreted by comparison between the both studied systems.

Keywords: Polyvinylpyrrolidone-K60; polymer; N, N-Dimethylformamide; dimethylacetamide; binary mixtures; densities; speeds of sound; refractive indices; thermo physical parameters

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1. Introduction

Study on thermodynamic and acoustic properties of polymers and solvents contribute to understanding of physicochemical behavior in binary and multi-component liquid mixtures [1,2].

This thermo physical behavior is useful to understand the formation of hydrates in different systems of both scientific and industrial interest [1,3].

In the present investigations, as a continuation of our research on mixtures of solutions [4–7], the experimental data of density, ultrasound speed and refractive index of the polyvinylpyrrolidone-K60 (PVP-K60) polymer in binary mixtures of N,N-dimethylformamide (DMF) and dimethylacetamide (DMA) solvents, for which experimental data are not available, were measured. From the experimental results, the thermo physical parameters such as the acoustic impedance (Z), adiabatic compressibility (β), specific refraction (r_D), space-filling factor (S), and relaxation strength (r) have been evaluated over the entire polymer composition range at three temperatures for PVP-K60 + DMF/and DMA binary systems.

The behavior of the thermo physical parameters on the composition of the polymer was analyzed to understand their nature and effect by comparison in the studied two polar solvents.

2. Materials and Methods

The chemical compounds used in study as PVP-K60 was supplied by Sigma Aldrich, and the DMF and DMA solvents were purchased from Merck. The mixtures were prepared by mixing known compositions of stock and pure DMF and DMA solutions in narrow-mouth, glasses. All precautions have been taken to minimise losses due to evaporation. A volume of 100 cm^3 stock solution of polymer (solute) were prepared by directly weighing the materials using an A&D GH-252 (Japan) electronic balance with a precision of ± 0.0001 g. From stock solution, were prepared the work samples with different fractions of the specific concentration (C) in ranged from (0 to 100) $kg \cdot m^{-3}$.

The density and speed of sound of binary mixtures were measured with an Anton Paar DSA 5000 digital (Austria) analyzer with a precision of ±0.000001 $g \cdot cm^{-3}$. The internal calibration of the instrument was confirmed by measuring the density and speed of sound through atmospheric air and doubly distilled deionized water, according to the recommendations of the manufacturer. Similar to the results described in the literature, the density of water was measured as 0.99704 $g \cdot cm^3$ at 298.15 K. The refractive indices were measured using an Anton Paar GmbH Abbe automatic refractometer with a precision of ± 0.000001, and the temperature of the samples was controlled within ± 0.01 K. The refract meter was calibrated by measuring the refractive index of doubly distilled water. The refractive index of water was measured as 1.33249 at 298.15 K, which is similar to the data presented in the literature.

3. Results and Discussion

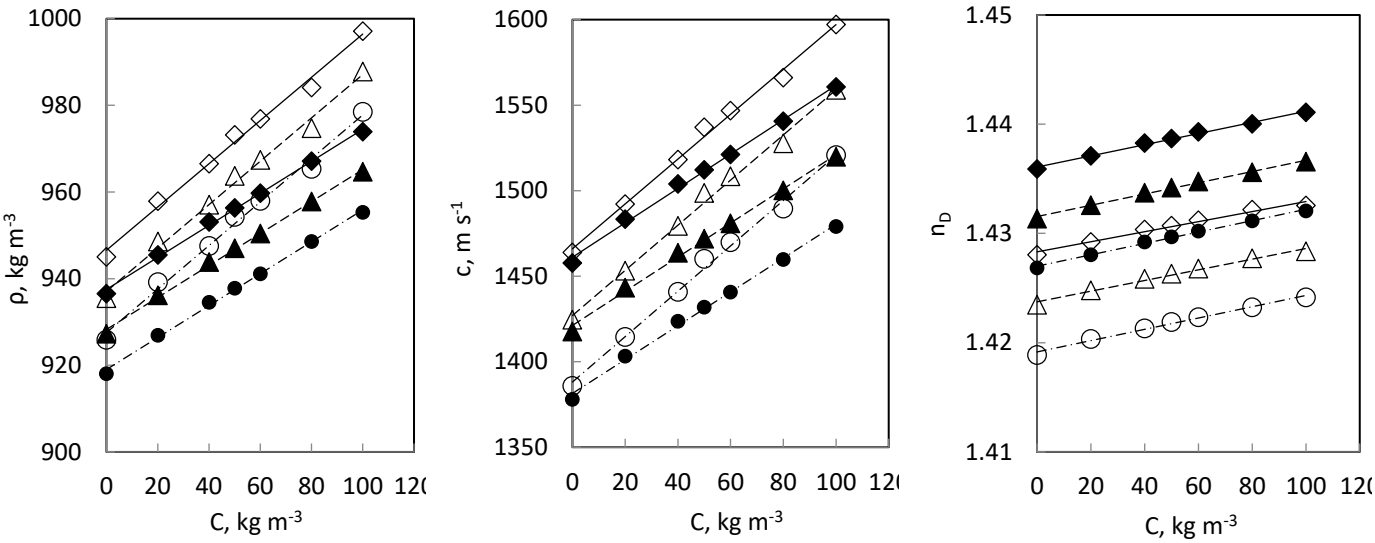
3.1. Results

The thermophysical properties of pure DMF and DMA products were verified by measuring the density (ρ), ultrasound speed (c) and refractive index (n_D). The experimental data of densities, speed of sound, and refractive indices as a function of specific concentration of (PVP-K60) polymer in N,N-dimethylformamide and dimethylacetamide mixtures at various temperatures between (298.15 to 318.15) K are measured.

From the experimental data of PVP-K60 + DMF and DMA binary systems, the thermo physical parameters as the acoustic impedance, adiabatic compressibility, specific refraction, space-filling factor, and relaxation strength have been calculated over the entire polymer composition domain at 298.15, 308.15, and 318.15 K temperatures.

3.2. Figures and Tables

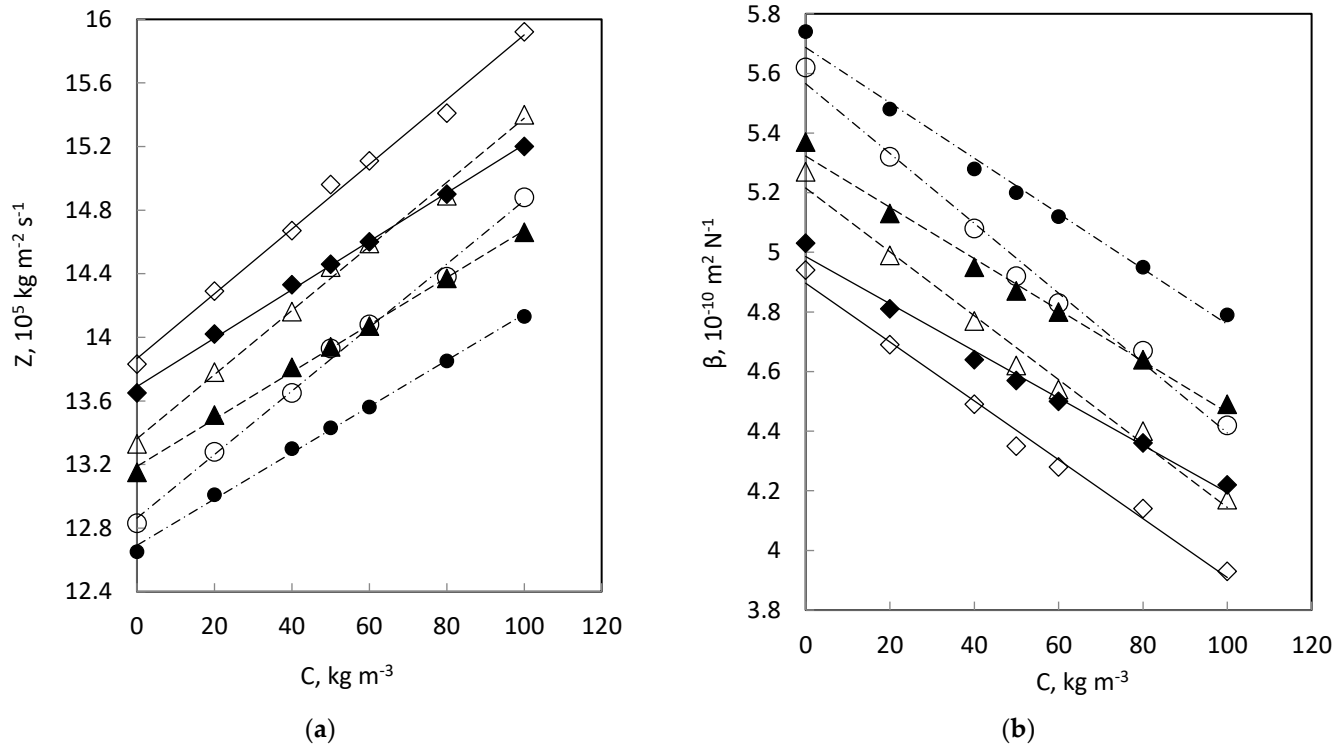
The experimental data of densities, speed of sound, and refractive indices as a function of specific concentration of (PVP-K60) polymer in N,N-dimethylformamide and dimethylacetamide mixtures at various temperatures between (298.15 to 318.15) K are shown in the Figure 1a–c.



(**a**) (**b**) (**c**)

Figure 1. Comparative representation of the Density (**a**), Speed of sound (**b**) and Refractive index (**c**) of binary PVP-K60 + DMF/DMA systems versus concentration of polymer at various temperatures, *T*/*K*: ◊, 298.15; Δ, 308.15; ◯, 318.15 for DMF solvent; ◆, 298.15; ▲, 308.15; ●, 318.15 for DMA solvent; —, — —, —-, polynomial correlated values.

The thermodynamics and optic parameters as the acoustic impedance, adiabatic compressibility, specific refraction, space-filling factor, and relaxation strength were represented in the Figure 2a–d.at the whole compositions and temperatures studied ranges.



(**a**) (**b**)

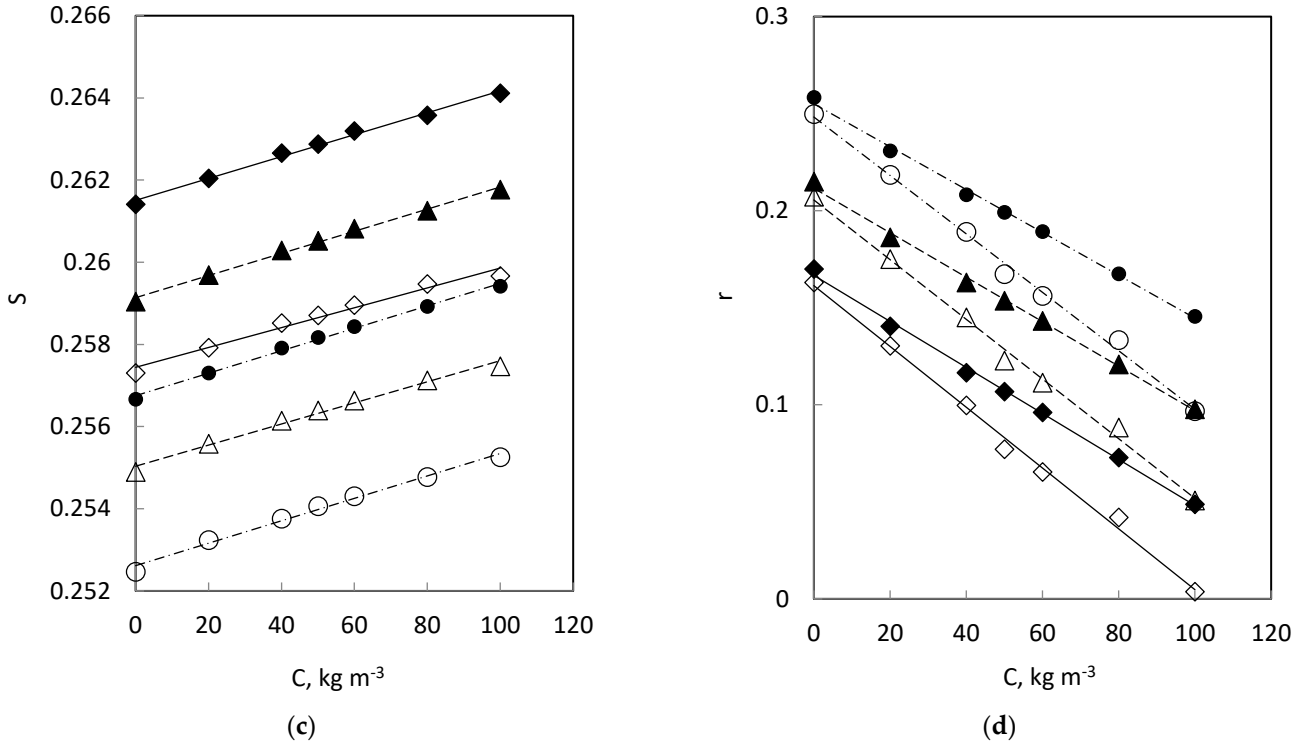


Figure 2. Comparative representation of the acoustic impedance (**a**), adiabatic compressibility (**b**), space-filling factor (**c**), and relaxation strength (**d**) of binary PVP-K60 + DMF/DMA systems versus concentration of polymer at various temperatures, *T/K*: ♢, 298.15; Δ, 308.15; ◯, 318.15 for DMF solvent; ◆, 298.15; ▲, 308.15; ●, 318.15 for DMA solvent; —, ——, —-, polynomial correlated values.

Table 1 presents the correlation coefficient (R^2) obtained from linear polynomial fitting for density ρ, speed of sound *c*, isentropic compressibility β and relaxation strength *r* for binary (PVP-K60) in DMF and DMA mixtures.

Table 1. Correlation coefficient (R^2) obtained from linear polynomial fitting for density ρ, speed of sound *c*, refractive index n_D, acoustic impedance *Z*, isentropic compressibility *β*, space-filling factor *S*, and relaxation strength *r* for binary (PVP-K60) in DMF/DMA mixtures.

T/K	*C/kg·m⁻³*	ρ	*c*	n_D	*Z*	*β*	*S*	*r*
			R^2 for DMF solvent					
298.15	0–100	0.9926	0.9947	0.9796	0.9947	0.9898	0.9796	0.9954
308.15	0–100	0.9923	0.9947	0.9880	0.9950	0.9872	0.9879	0.9954
318.15	0–100	0.9921	0.9948	0.9908	0.9952	0.9893	0.9907	0.9955
			R^2 for DMA solvent					
298.15	0–100	0.9976	0.9964	0.9936	0.9978	0.9902	0.9934	0.9974
308.15	0–100	0.9976	0.9962	0.9951	0.9979	0.9908	0.9948	0.9972
318.15	0–100	0.9976	0.9961	0.9961	0.9976	0.9899	0.9958	0.9972

3.3. Formatting of Mathematical Components

The acoustic impedance (*Z*) was calculated using the following relation:

$$Z = \rho c \quad (1)$$

The isentropic (adiabatic) compressibility coefficient k_S for the pure solvent and liquid mixtures was calculated from the density ρ and the velocity of ultrasound *c* using the Laplace equation:

$$k_S = \frac{1}{\rho\ c^2} \tag{2}$$

The space-filling factor (S) was computed from refractive index (sodium D line) data using the following relation:

$$S = \frac{n_D^2 - 1}{n_D^2 + 2} \tag{3}$$

The specific refraction (r_D) was calculated from the density (ρ) and space-filling factor (S) using the Lorentz and Lorenz equation:

$$r_D = \frac{n_D^2 - 1}{n_D^2 + 2}\frac{1}{\rho} \tag{4}$$

The relaxation strength (r) was calculated using the following equation:

$$r = 1 - \frac{c^2}{c_{ct}^2},\ c_{ct} = 1600\ \text{m}\cdot\text{s}^{-1} \tag{5}$$

4. Conclusions

In the present study, the density, refractive index and speed of sound in binary mixtures of PVP-K60 + DMF/DMA over the composition domain from (0 to 100) kg·m^{-3} at temperatures between (298.15 and 318.15) K were measured.

The results indicated that the obtained parameters depend on the temperature and on the composition of the mixture, which is indicative of the presence of molecular interactions.

A comparison between the two studied systems PVP-K60 + DMF and PVP-K60 + DMA show that the values of the correlation coefficients are comparable for the calculated thermodynamic properties.

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