Experimental data and correlation of surface tension of binary polymer solutions at different temperatures and atmospheric pressure

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Abstract

In this work, the surface tension (σ) of aqueous solutions of various PEGs(poly ethylene glycol) with molecular weights of 200, 300 and 6000 in water and of poly(propylene glycol) (PPG) with a molecular weight of 2000 in ethanol were measured in the (293.2-338.2) K temperature range and atmospheric pressure. The results of measurements were fitted to linear equation relating surface tension of the solution to the mass fraction of polymer and the solution temperature. The coefficients of the equation are determined by linear multiple regression and the model results are compared with experimental data so that the absolute overall average mean relative deviation of the model is less than 0.55% for PEGs and 0.74% for PPG2000.

Keywords: Surface tension, polymer solution, correlation

1. Introduction

Thermophsical properties are required both for engineering and product design. The surface tension of a liquid mixture is an important property which plays an important role in affecting the mass and heat transfer at the interface. In the chemical industries, it determines the quality of the products (i.e. coatings, paints, detergents, costemics and agrochemicals) and affects different production processes such as catalysis, adsorbsion, distillation and extraction.

In recent years, aqueous polymer solutions, especially poly(ethylene glycol) + water systems, have found widespread applications, mostly because of their use in two phase aqueous systems for separation of biomolecular mixtures [1-3]. Despite the success of the aqueous two phase separation technique, data on the properties of phase systems that are necessary for the design of extraction processes and for the

development of models that predict phase partitioning are few. Although reviewed surface tensions of pure liquid polymers and the interface properties of polymer-polymer systems are available [4-11], but experimental data for polymer solutions are extremely scare.

In this work, the surface tension of aqueous solutions of various PEGs(poly ethylene glycol) with molecular weights of 200, 300 and 6000 in water and of poly(propylene glycol) (PPG) with a molecular weight of 2000 in ethanol were measured in the (293.2-338.2) K temperature range and atmospheric pressure. The results of measurements were fitted to linear equation relating surface tension of the solution to the mass fraction of polymer and the solution temperature.

2. Experimental

2.1. Materials

Poly(ethylene glycol) with number-average molecular weights of 200 and 300, manufactured by Merck, and 6000, manufactured by Fluka, and Poly(propylene glycol) with a number-average molecular weight of 2000, manufactured by Riedel-deHaen, and ethanol absolute GR(>99.8%), manufactured by Merck, were used in this study. Double-distilled water was used in making the solutions.

2. 2. Apparatus and procedures

The solutions were prepared by mass, using an analytical balance with ± 0.1 mg accuracy. The surface tension measurements were carried out using a thermostated tensiometer model K9 Kruss, Germany, at temperatures of (298.2, 308.2, 313.2, 318.2, 328.2, and 338.2) K and atmospheric pressure. The tensiometer, which is equipped with a Du Noüy platinum-iridium ring (6 mm circumference), was calibrated with distilled water (σ = 72.8 mN/m).

A constant temperature water bath was used to control t he temperature of the solutions to an accuracy of ± 0.1K. Measurements for each solution were repeated five times. It should be noted that we need to know the density of each mixture to calculate its surface tension. The corresponding densities were measured previously in our laboratory [12].

3. Results and Discussion

The surface tension data are fitted by the following relation:

$$\sigma(mN / m) = a + bw + cT(K) \tag{1}$$

where σ is the surface tension of the solution at the measured temperature, a, b in mN/m and c in mN/m.$^{\circ}$C are the coefficients of the equation, w is the mass fraction of polymer in the solution, and T is the solution temperature. Values of the coefficients a, b and c were obtained by linear multiple regression using Tablecurve software and reported in Table 1.

Figures 1- 4 show the measured surface tension of solutions of PEG 200, PEG 300 and PEG 6000 in water and also PPG 2000 in ethanol at some different concentrations and temperatures. These figures show that there are good agreements between the measured quantities and those calculated by equation 1.

Table 1: Coefficients of equation 1 for solutions of PEG (200, 300, and 6000) and PPG 2000

a	b	c	r	ARD%	AARD%
		PEG200			**PEGs**
-0.1891	-20.8411	68.0506	0.9959	-0.01422	
		PEG300			
68.2448	-29.9762	-0.1944	0.9961	0.003634	0.545753
		PEG6000			
65.8374	-19.5177	-0.2073	0.9968	0.029023	
		PPG2000			**PPG**
23.35925	3.9983	-0.0779	0.9881	0.0792164	0.742002

$$\text{ARD}\% = \frac{100}{n} \sum \frac{\sigma_{model} - \sigma_{exp.}}{\sigma_{exp.}}, \ \text{AARD}\% = \frac{100}{n} \sum \left| \frac{\sigma_{exp.} - \sigma_{mod.}}{\sigma_{exp.}} \right|$$
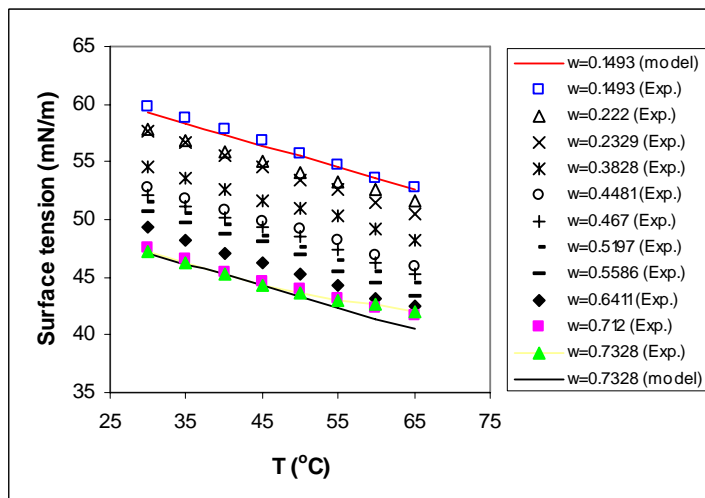

Figure 1: Sureface tension of PEG 200 in water at different temperatures and concentrations.
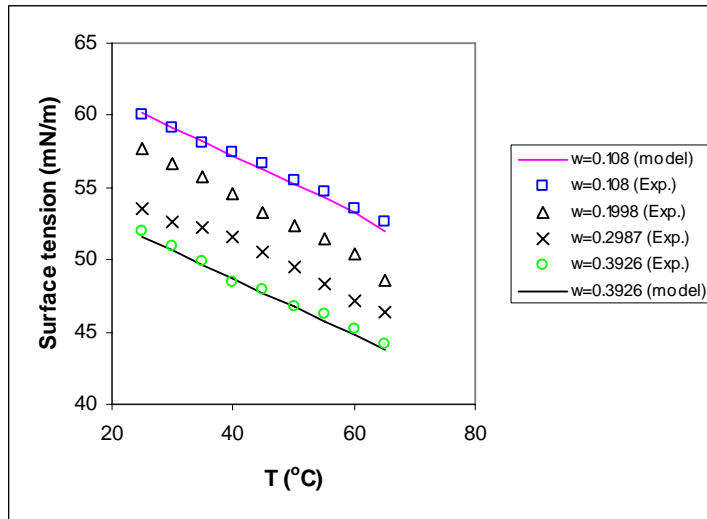
3

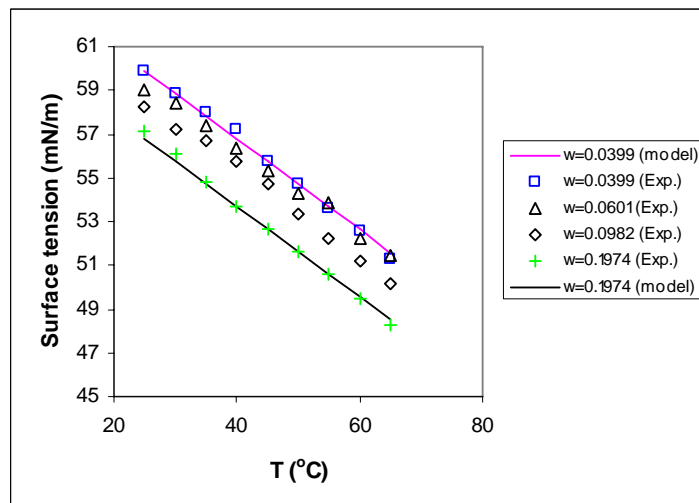**Figure 2: Surface tension of PEG 300 in water at different temperatures and concentrations.**

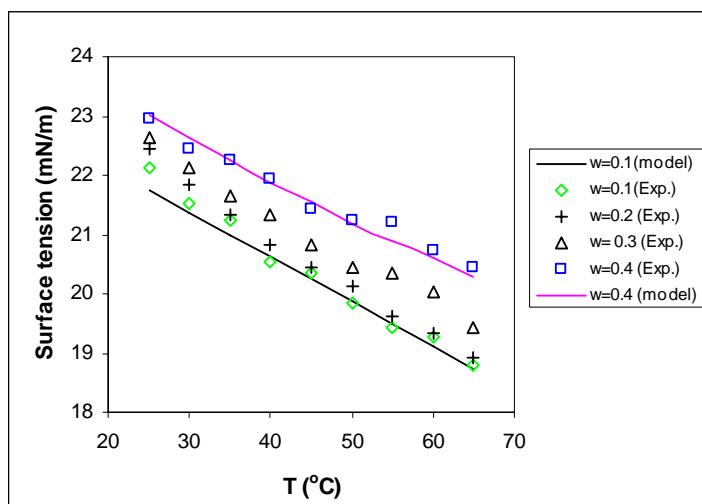**Figure 3: Surface tension of PEG 6000 in water at different temperatures and concentrations.**

Figure 4: Surface tension of PPG 2000 in ethanol at different temperatures and concentrations.

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