

Miscibility Study of Unsaturated Polyester-Polystyrene and Unsaturated Polyester-Polycarbonate Blends

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ABSTRACT: The miscibility studies of unsaturated polyester resin (UPR) blends with two different thermoplastics, polystyrene (PS) and polycarbonate (PC) in common solvent chloroform were carried out by viscosity, ultrasonic velocity, density, and refractive index methods. Two interaction parameters, μ and α were calculated using viscosity data for these blends. The positive interaction parameter values (μ and $\alpha > 0$) obtained for the UPR/PS blend and the negative interaction parameter values (μ and $\alpha < 0$) obtained for the UPR/PC blend indicate that the former is a miscible blend and the latter is an immiscible blend. These results were further confirmed by ultrasonic velocity, density, and refractive index measurements.

Keywords: polymer blends, miscibility, viscosity, ultrasonic velocity

1. INTRODUCTION

Polymer blends are dominating various application areas because of their tailor-made properties. However, there are only a few papers concerned with polymer blends where one component is crystallizable/amorphous and another is highly crosslinked [1-2]. Although unsaturated polyester resins due to their low manufacturing costs and high tensile strength, have been widely used as one class of the most important thermosetting plastics in the industry such as glass fiber reinforced polyesters [3] and molding compounds [4], only a few researchers concentrate on their

blends. Therefore, further investigation of unsaturated polyester polymer blends is of practical significance.

The final properties of a polymer blend will commonly depend on the properties of its polymeric components, its composition and, mainly, on the miscibility of the polymers at a molecular level [5-7]. Relatively few systematic studies have been paid to the miscibility and phase behavior in blends of thermosetting resins with thermoplastics. Because the resulting morphology and extent of phase separation is known to affect the optical and mechanical properties of the cured blends, the need for an understanding of the miscibility and phase separation behavior in

thermosetting polymer blends is of practical importance [8].

Since a number of miscible blends are prepared from solution, the study in the solution state is of fundamental importance. Although the solid-state morphology is lost in solution, the specific interaction responsible for mixing two different polymers in the solid-state will be retained [9]. Also, blending the polymers in solution ensures effective attainment of equilibrium between the different polymer components in solution. Furthermore, viscosity can be measured effectively, which is one of the techniques employed in the present work to study the miscibility of polymer solution blends. For these reasons, the authors have selected the solution blending method to investigate the miscibility of unsaturated polyester resin with different thermoplastics.

Polymer-polymer miscibility is generally considered as the result of specific interactions between polymer segments [10]. There have been various physical techniques of studying the miscibility of the polymer blends [11]. Plots of the intrinsic viscosity, $[\eta]$, against blend composition or plots of reduced viscosity, η_{sp}/C , against solution concentration, C , have been used as a criteria for polymer-polymer compatibility [12,13], Hourston and Hughes [14] and Kuleznev et al. [15] suggested the use of ultrasonic velocity and viscosity measurements for investigating the polymer miscibility. Singh and Singh [16,17] have suggested the use of ultrasonic velocity and viscosity measurements for investigating the polymer miscibility. Paladhi and Singh [18,19] have shown that the variation of ultrasonic velocity and viscosity with blend composition is linear for miscible blends.

In the present study, the miscibility of the polymer blends of unsaturated polyester resin (UPR) with polystyrene (PS) and polycarbonate (PC) have been carried out by viscosity, ultrasonic velocity, density, and refractive index techniques which are inexpensive, simpler and quicker. The

authors selected UPR as it is relatively inexpensive, has good mechanical properties, used in fiber-reinforced plastic structures and also find use as decorative coatings. PS is very widely used in the manufacture of injection-molded articles of household items and packing containers. PC is a transparent plastic and has very high impact strength. Many useful articles such as telephone parts, machinery housings, safety shields etc. can be made from this plastic.

2. EXPERIMENTAL

The blends of UPR ($M_n = 2,500$) with PS ($M_v = 90,000$) and PC ($M_v = 25,000$) of different compositions were prepared by mixing solutions of the polymers in chloroform. The total weight of the two components of a particular blend in solution was maintained at 1g/dL. The reduced viscosity of blend solutions was measured at 30 °C using an Ubbelohde suspended level viscometer. The ultrasonic velocity of the blend solutions was measured by an ultrasonic interferometer. The temperature was maintained at 30 °C by circulating thermostated water from a thermostat with a thermal stability of ± 0.05 °C through the double wall jacket of the ultrasonic experimental cell. The density of the solutions was measured at 30 °C with a specific gravity bottle. The refractive indices of the blend solutions were measured with an Abbe's refractometer with thermostated water circulation system at 30 °C.

3. RESULTS AND DISCUSSION

Fig. 1 shows the Huggins plots for UPR/PS and UPR/PC blends in which the weight fraction of both the components of the blend has been maintained at 0.5.

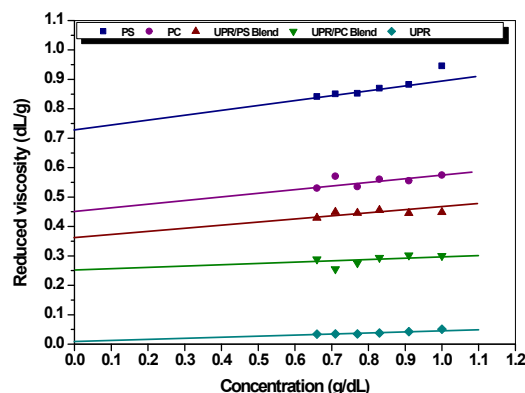


Figure 1: Huggins plots for PS, PC, UPR/PS blend, UPR/PC blend and UPR in chloroform at 30 °C

Chee [20] has given an expression for the interaction parameter when the polymers are mixed in weight fractions of W_1 and W_2 as follows:

$$\Delta B = \frac{b - \bar{b}}{2W_1W_2} \quad (1)$$

where $\bar{b} = W_1b_{11} + W_2b_{22}$.

Here b_{11} and b_{22} are the slopes of the viscosity curves for the components and b is related to Huggins coefficient, K_H as

$$b = K_H[\eta]^2 \quad (2)$$

For ternary system, it is also given by

$$b = W_1^2 b_{11} + W_2^2 b_{22} + 2W_1W_2 b_{12} \quad (3)$$

where b_{12} is slope of the viscosity curve for the blend solution.

Using these values, Chee [20] has developed a novel approach, the μ parameter to determine the polymer-polymer miscibility, which is as follows:

$$\mu = \frac{\Delta B}{\{[\eta]_2 - [\eta]_1\}^2} \quad (4)$$

where $[\eta]_1$ and $[\eta]_2$ are the intrinsic viscosities for the pure component solutions.

The blend is miscible if $\mu \geq 0$ and immiscible when $\mu < 0$ [20]. In the present study, the values of μ for UPR/PS and UPR/PC blends were computed as 0.0049 and -0.1026 indicating that the UPR/PS blend is miscible and the UPR/PC blend is immiscible.

Based on the arguments of Chee, Sun et al. [21] proposed another criterion for polymer-polymer miscibility, the α parameter, which is given as follows:

$$\alpha = K_m - \frac{K_1[\eta]_1^2 W_1^2 + K_2[\eta]_2^2 W_2^2 + 2\sqrt{K_1K_2} [\eta]_1[\eta]_2 W_1W_2}{\{[\eta]_1 W_1 + [\eta]_2 W_2\}^2} \quad (5)$$

where K_1 , K_2 and K_m are the Huggins constants for individual components 1, 2, and the blend respectively. While deriving this equation, the long-range hydrodynamic interactions are taken into account. Sun et al. [21] suggested that a blend is miscible if $\alpha \geq 0$ and immiscible when $\alpha < 0$. In the present study, the α values were found to be 0.4625 for UPR/PS blend and -0.4176 for UPR/PC blend indicating that the former blend is miscible and the latter blend is immiscible.

In order to confirm the miscibility or otherwise of these blends and the validity of equation (5), the variation of the ultrasonic velocity (v), density (ρ), and refractive index (n_D) of the polymer blend solutions with composition were shown in Figs. 2, 3, and 4, respectively. From these figures, it is clearly evident that the variation is linear for UPR/PS blend, indicating a single-phase for the blend. In the case of UPR/PC blend, the variation of ultrasonic velocity, density and refractive index is non-linear, which infers the multi-phase and thus the immiscible nature of the blend (Fig. 2-4).

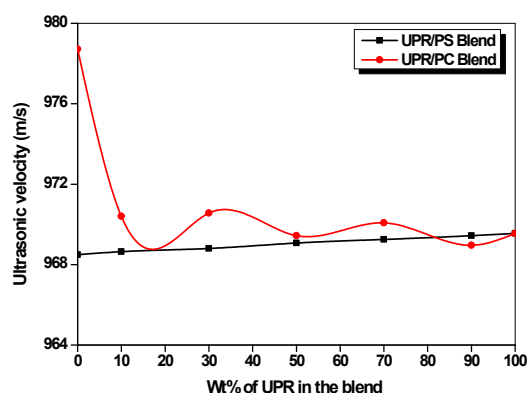


Figure 2: The variation of ultrasonic velocity with the composition of UPR/PS and UPR/PC blends in chloroform at 30 °C

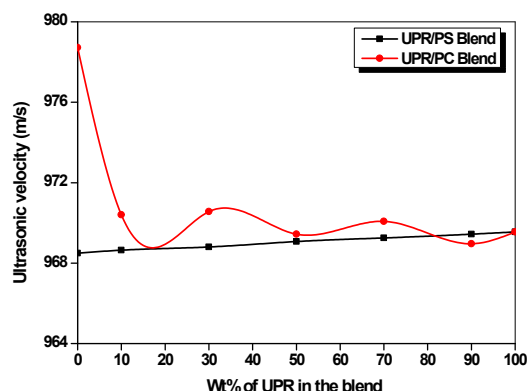


Figure 3: The variation of density with the composition of UPR/PS and UPR/PC blends in chloroform at 30 °C

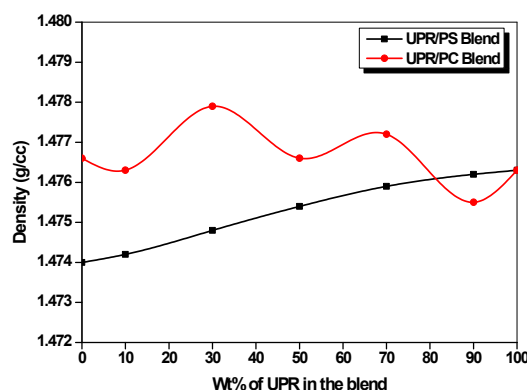


Figure 4: The variation of refractive index with the composition of UPR/PS and UPR/PC blends in chloroform at 30 °C

Singh et al. [16] have pointed out that the variation of v and ρ with blend composition is linear for miscible blends, whereas the curves depicting this variation for immiscible blends are found to have S or inverted S shapes. In the present case, the variation of v , ρ , and n_D with blend composition for UPR/PS and UPR/PC was found to be linear and non-linear, respectively. This observation clearly indicates that the UPR/PS blend is miscible and the UPR/PC blend is immiscible.

The same information is found when equation (5) is employed to compute α value. Thus, this observation confirms the validity of equation (5). These results have further been supported by adiabatic compressibility, β_{ad} , a parameter derived from the following equation:

$$\beta_{ad} = 1/v^2\rho \quad (6)$$

where v is the ultrasonic velocity and ρ is the density of the blend solutions. The variation of adiabatic compressibility with blend composition is presented in Fig. 5. It

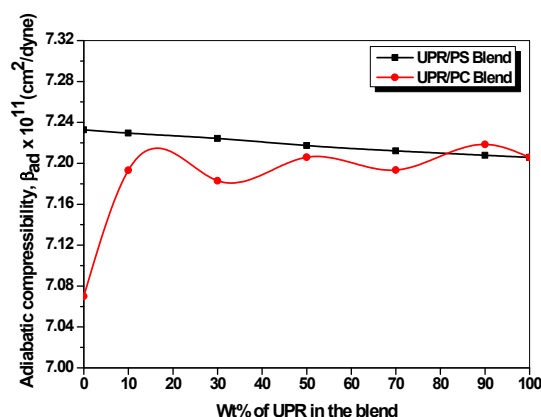


Figure 5: The variation of adiabatic compressibility with the composition of UPR/PS and UPR/PC blends in chloroform at 30 °C

was already established that the variation is linear for miscible blend and non-linear for immiscible blend [17,21]. Fig. 5 shows the

linear and non-linear variation of adiabatic compressibility with composition of UPR/PS and UPR/PC blends, respectively indicating that UPR/PS blend is miscible and UPR/PC blend is immiscible.

4. CONCLUSION

Miscibility of two polymer solution blend systems, unsaturated polyester/polystyrene (UPR/PS) and unsaturated polyester/polycarbonate (UPR/PC) were studied using various simple and inexpensive physical techniques such as, viscosity, ultrasonic velocity, density and refractive index. Interaction parameters, μ and α were experimentally determined by viscosity method for both the blend systems. The UPR/PS blend evidenced positive μ and α values and the UPR/PC blend evidenced negative μ and α values. Based on these values, UPR/PS blend was assigned as miscible and UPR/PC blend was assigned as immiscible. These results were further confirmed by ultrasonic velocity, density and refractive index methods.

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