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Miscibility Study Of Polymer Blend By Viscosity, Ultrasonic Velocity, And Refractive Index Measurements

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ABSTRACT

Miscibility studies of unsaturated polyester resin-poly(methyl methacrylate) (UPR-PMMA) blend in chloroform were carried out in different percentages of the blend components. The viscosity, ultrasonic velocity, and refractive index methods were employed for the miscibility studies at 30^{0}C. The interaction parameters have been obtained using the viscosity data to probe the miscibility. These values indicated that the UPR-PMMA blend is miscible. This was confirmed by the ultrasonic velocity and refractive index methods.

KEYWORDS

Polymer blends;
Miscibility;
Viscosity;
Ultrasonic velocity;
Refractive index.

INTRODUCTION

Chemical or physical blending of polymers is the simple means to obtain a variety of physical and chemical properties from the constituent polymers[1]. The gain in new properties depends on the degree of compatibility or miscibility of the polymers at a molecular level. The miscibility results in altogether different morphology of the blends ranging from single-phase systems to two or multiphase systems. Relatively few systematic studies have been paid to the miscibility and phase behaviour in blends of thermosetting resins with thermoplastics. In the present study, we have measured the viscosity, ultrasonic velocity and refractive index of unsaturated polyester resin-poly(methyl methacrylate) (UPR-PMMA) blend solution in chloroform at 30^{0}C to study the miscibility of the blend.

There have been various physical techniques of studying the miscibility of the polymeric blends [2]. Plots of the intrinsic viscosity, [η], against blend composition or plots of specific viscosity divided by solution concentration, η_{sp}/C, against solution concentration, C, have been used as a criteria for polymer-polymer compatibility[3,4]. Hourston and Hughes[5] and Kuleznev et al.[6] suggested the use of ultrasonic velocity and viscosity measurements for investigating the polymer miscibility. Singh and Singh[7,8] have suggested the use of ultrasonic velocity and viscosity measurements for investigating the polymer miscibility. Paladhi and Singh[9,10] have shown that the variation of ultrasonic velocity and viscosity with blend composition is linear for miscible blends. Chee et al.[11] studied the miscibility of polymer blends of poly(3-hydroxy butyrate) (PHB) in combination with poly(ethylene oxide) (PEO) and poly(ε-caprolactone) (PCL). Their viscometric study demonstrated that PEO is miscible with PHB, whereas PCL is immiscible.

EXPERIMENTAL

The various blends of UPR (M/s. Rishabh Polymers Pvt.Ltd., India, M_n=2,500) with PMMA (M/s. GSFC, India, M_v = 98,000) have been made by mixing solutions of the polymers in chloroform in the required compositions. The total weight of the two components in solution was maintained at 1 g/dL.

The reduced viscosities of all polymer solutions have been measured using Ubbelohde suspended level viscometer. The ultrasonic velocity measurements of the solutions were performed by an ultrasonic interferometer (Mittal Enterprises, New Delhi, India). The ultrasonic experimental cell has a double wall jacket with thermostated water circulation system. The experimental frequency was 2 MHz and velocity measurements are accurate to better than ± 0.05%. The refractive index of the blend solutions has been measured with Abbe's refractometer (M/s. Mittal Enterprises, India). All the above parameters were measured at 30^0C.

RESULTS AND DISCUSSION

Figure 1 shows the Huggins plots for UPR-PMMA blend in which the weight fraction of both the components has been maintained at 0.5. Chee [12] 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

$$b = W_1^2b_{11} + W_2^2b_{22} + 2W_1W_2b_{12} \quad (3)$$

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

Using these values, Chee [12] 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 μ≥0 and immiscible when

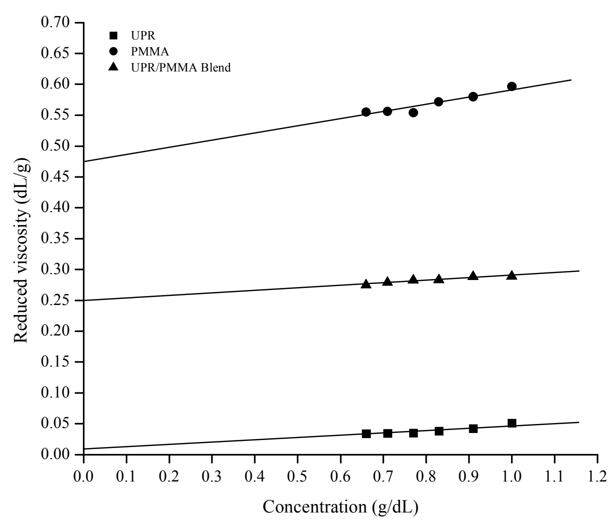

Figure 1: Huggins plots for UPR, PMMA and blend of UPR-PMMA in chloroform at 30^0C

$\mu<0$ [12]. In the present study, the value of μ for UPR-PMMA blend was computed as 0.0298 indicating that the UPR-PMMA blend is miscible.

Also based on the arguments of Chee, Sun et al. [13] proposed another criterion for polymer-polymer miscibility, the α parameter, which is given as follows:

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

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.[13] suggested that a blend is miscible if $\alpha \geq 0$ and immiscible when $\alpha<0$. In the present study, the α value was found to be 0.4582 for UPR-PMMA blend indicating that the UPR-PMMA blend is miscible.

The measured values of ultrasonic velocity and refractive index of UPR-PMMA blend solutions were tabulated in TABLE 1. In order to confirm the miscibility or otherwise of these blends and the validity of equation (5), the variation of the ultrasonic velocity (U), and refractive index (n_D) of the polymer blend solutions with composition have been depicted in figures 2 and 3, respectively. From these figures, it is clearly evident that the variation is linear for UPR-PMMA blend, indicating a single-phase for the blend. Singh et al.[8] have pointed out that the variation of ultrasonic velocity and density with blend composition is linear for miscible blends, whereas the curves depicting this variation for immiscible blends are found to have nonlinear shapes. In the present case, the variation of U and n_D with blend composition for UPR-PMMA blend is found to be linear. This observation clearly indicates that the UPR-PMMA blend is miscible.

TABLE 1: Ultrasonic velocity and refractive index of UPR-PMMA blend solutions in chloroform at 30°C

Wt% of UPR in the Blend	Ultrasonic velocity, m/s	Refractive Index
0	965.36	1.4340
10	965.68	1.4340
30	965.76	1.4340
50	966.24	1.4340
70	966.36	1.4340
90	967.76	1.4340
100	969.55	1.4340

The same information is found when equation (5) is employed to compute value. Thus, this observation confirms the validity of equation (5). It is also observed that the ultrasonic velocity and refractive index of the UPR-PMMA blend did not vary much more than those of the pure components did, which attributed to the miscible nature of the blend. Recently, John et al.[14] studied the solution blends of

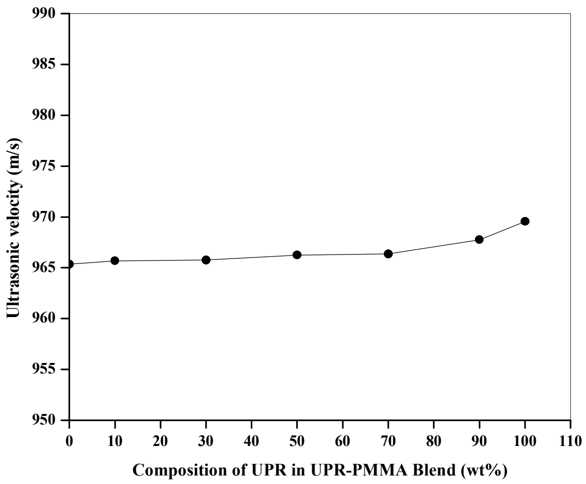

Figure 2: The variation of ultrasonic velocity with composition of UPR-PMMA blend in chloroform at 30^{0}C

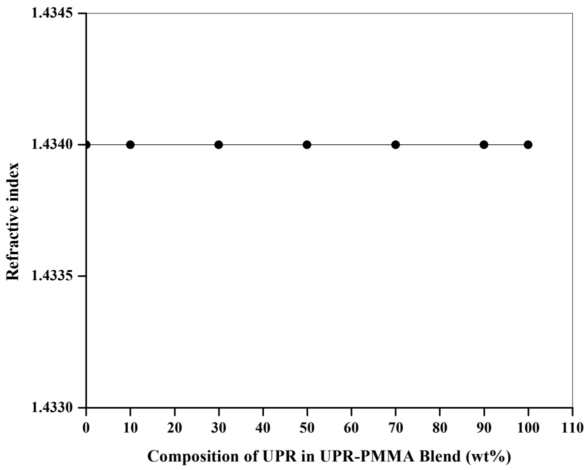

Figure 3: The variation of refractive index with composition of UPR-PMMA blend in chloroform at 30^{0}C

poly(vinyl acetate)(PVAc) with poly(methyl methacrylate) (PMMA) and poly(vinyl chloride)(PVC) using these techniques and reported that both PVAc/PMMA and PVAc/PVC blends were miscible.

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