

**Figure 1.** The photo of the Ubbelohde-type capillary viscometer combined with automatic viscometry device.

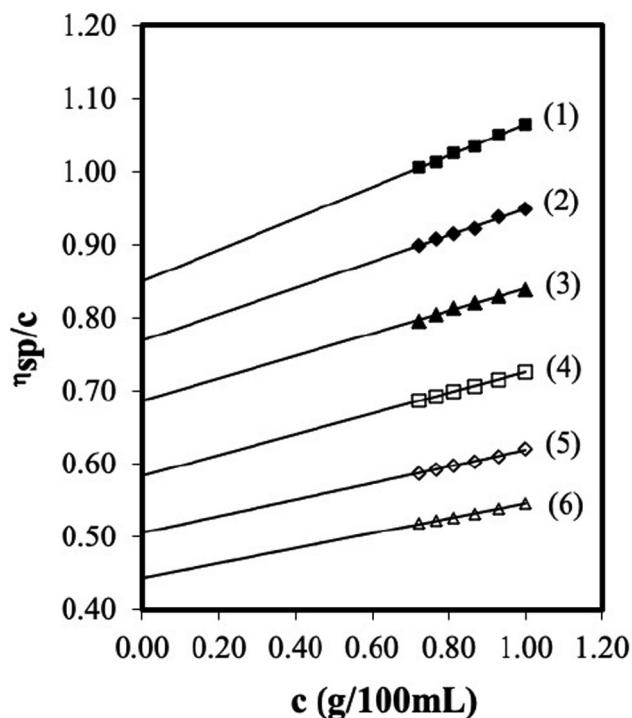
## MATERIALS AND METHODS

PEI and PS were supplied by General Electric Plastics and Scientific Polymer Products, Inc., respectively. Chloroform was purchased from Merck AG Inc., Germany. Polymers were used as dissolved in dilute chloroform solution. FT-IR spectra were collected using a Thermo FT-IR Nicolet IS 10 model spectrometer. DSC measurements were performed using approximately 10 mg samples with a Perkin Elmer DSC 4000. The DSC curves were recorded at a heating rate of 10°C/min between 60 and 230°C. All viscosity measurements were performed at 25°C using a SI Analytics GmbH model Ubbelohde-type capillary viscometer combined with SCHOTT CT-2 model automatic viscometry device (Fig. 1).

Blending in a solvent is the most common and most simple method for preparing polymer blends. Through blending in a solvent, both of polymers must be dissolved in a dilute solvent. Degradation is avoided in this method in comparison with other methods. The stock solutions of PEI/PS blend were prepared to contain 1.0 g polymer in 100 mL dilute chloroform solvent. Initially, about 13 mL of stock solution was put into the Ubbelohde viscometer. After that, a total of five dilutions were made with 1 mL dilutions. Measurements were taken six times in order to obtain more accurate results at each stage.

## RESULTS AND DISCUSSION

Polymer blends were prepared in dilute chloroform solvent by adjusting the ratios of the PEI/PS blends to be 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100 by weight, respectively. Besides, reduced viscosity measurements were performed at 25 °C. Fig. 2 shows the change of reduced viscosity,  $\eta_{sp}/c$ , depending on the change of concentration for polymer blends in different ratios. All of the polymer



**Figure 2.** The linear plot of  $\eta_{sp}/c$  against concentrations of different ratios of PEI/PS blend: 100/0 (6), 80/20 (5), 60/40 (4), 40/60 (3), 20/80 (2), and 0/100 (1) by weight.

**Table 1.** Experimental data obtained from the linear plot of PEI/PS blends in chloroform at 25°C.

PEI/PS in chloroform at 25°C	$\Delta b_b^{exp}$ (cm <sup>3</sup> /g <sup>2</sup> )	$-\Delta[\eta]_b^{exp}$ (cm <sup>3</sup> /g)	r <sup>2</sup>
100/0	0.1019	0.4444	0.9960
80/20	0.1137	0.5057	0.9963
60/40	0.1419	0.5840	0.9985
40/60	0.1540	0.6863	0.9940
20/80	0.1806	0.7687	0.9946
0/100	0.2156	0.8496	0.9980

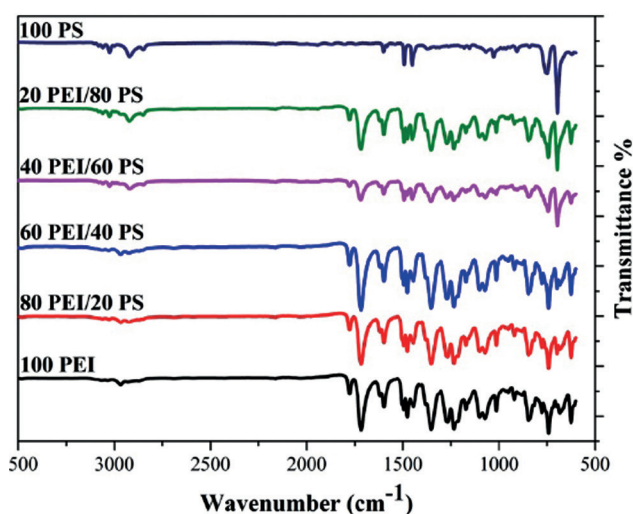
blends prepared in different ratios, including the pure PS and PEI in dilute chloroform solvent, are given linearly in plot.

The values of  $b_b^{exp}$  and  $[\eta]_b^{exp}$  were obtained from the slope and intercept of linear plot (Fig. 2), respectively. The data obtained from the linear plot were given in Table 1.

The miscibility parameters of PEI/PS blends prepared in different ratios can be determined by  $b_b^{exp}$  values obtained experimentally from the linear plot drawn in Fig. 2 and  $b_b^{id}$  values obtained ideally from the methods explained in the theoretical section. Besides, the miscibility parameter

**Table 2.** According to the different methods, the parameters of miscibility for PEI/PS blend in chloroform at 25 °C.

PEI/PS in chloroform at 25°C	$\Delta b_b$ (cm <sup>6</sup> /g <sup>2</sup> )	$\Delta b'_b$ (cm <sup>6</sup> /g <sup>2</sup> )	$-\Delta[\eta]_b$ (cm <sup>3</sup> /g)	Miscibility
80/20	-0.0076	-0.0109	0.0197	Immiscible
60/40	-0.0005	-0.0055	0.0225	Immiscible
40/60	-0.0110	-0.0161	0.0013	Immiscible
20/80	-0.0089	-0.0123	-0.0002	Immiscible



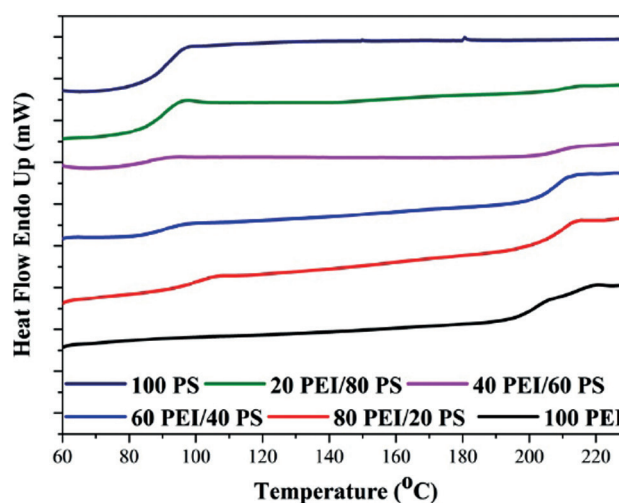
**Figure 3.** FT-IR spectra of pure PEI, PS and PEI/PS blends in compositions of 80/20, 60/40, 40/60, and 20/80 by weight.

can also be determined from the intrinsic viscosity values obtained experimentally from the linear plot drawn in Fig. 2 and ideally obtained when calculated according to Eq. (5).

There are intermolecular interactions between the components of the polymer blends. Considering these interactions, miscibility or immiscibility can be determined according to the numerical difference between experimental and ideal values obtained from different methods.

If the  $\Delta b_b > 0$ ,  $\Delta b'_b > 0$ , and  $\Delta[\eta]_b < 0$ , the polymers are miscible. On the contrary, if the  $\Delta b_b < 0$ ,  $\Delta b'_b < 0$ , and  $\Delta[\eta]_b > 0$ , the polymers are immiscible. Intermolecular repulsion forces between components are more effective when polymers are immiscible. On the other hand, when polymers are miscible, intermolecular attraction forces between components are more effective.

All of the miscibility parameters of PEI/PS blends obtained from different methods were given in Table 2. According to the values of miscibility criteria of PEI/PS



**Figure 4.** DSC thermograms of PEI, PS, and PEI/PS blend compositions at 80/20, 60/40, 40/60, and 20/80 by weight.

**Table 3.** Glass transition temperatures of PEI, PS and their blends in the compositions of 80/20, 60/40, 40/60 and 20/80.

PEI/PS	$T_g$ (°C)	
100/0	206.2	-
80/20	204.8	90.6
60/40	205.1	87.4
40/60	206.7	85.6
20/80	207.2	87.9
0/100	-	88.4

blends  $\Delta b_b < 0$ ,  $\Delta b'_b < 0$ , and  $\Delta[\eta]_b > 0$  shows that PEI/PS blends are immiscible in all prepared compositions.

The miscibility of polymers was also determined using different techniques. Intermolecular interactions between the components were examined using FT-IR. According to FT-IR analysis, the miscibility of polymers can be determined. The FT-IR spectra of the different ratios of PEI/PS blends are showed in Fig. 3. The carbonyl group stretching vibration is specific for PEI and is seen at 1716 cm<sup>-1</sup>. C=O stretching band of PEI/PS blends in compositions at 80/20, 60/40, 40/60, and 20/80 are found as 1716, 1716, 1718, and 1717 cm<sup>-1</sup>, respectively. Similarly, stretching vibrations of the C-O and C=N groups in PEI are seen at 1101 and 1352 cm<sup>-1</sup>, respectively. The stretching vibrations of PEI/PS blends in compositions at 80/20, 60/40, 40/60, and 20/80 were found as 1101 cm<sup>-1</sup> for C-O group and 1352, 1352, 1353, and 1352 cm<sup>-1</sup> for C=N group, respectively. It is known that the miscible systems show small band shifts in the FT-IR spectra. As shown in Fig. 3, the absence of such



- by viscometry. *Eur Polym J* 2006;42:311–315. [\[CrossRef\]](#)
- [15] Cakar F, Ocak H, Bilgin-Eran B, Ozkal S, Cankurtaran O, Karaman F. Miscibility in mixtures of liquid crystal 4-[4-(tetradecyloxy)benzoyloxy] benzoic acid and poly(ether imide). *Mol Cryst Liq Cryst* 2017;656:66–73. [\[CrossRef\]](#)
- [16] Cakar F, Yazici O, Adli E. Miscibility studies on a poly (ether imide) and poly (methyl methacrylate) blends. *J Optoelectron Adv Mater* 2016;10:578–582.
- [17] Khan Z, Baloch MK. Investigating the miscibility of polystyrene/poly (styrene-co-acrylonitrile) blend in tetrahydrofuran by simple physical techniques at various temperature. *Polym Bull* 2013;70:2015–2033. [\[CrossRef\]](#)
- [18] Cakar F, Ocak H, Bilgin-Eran B, Cankurtaran O, Karaman F. Compatibility studies of poly(ether imide) with liquid crystal mixtures. *J Optoelectron Adv Mater* 2013;7:667–671.
- [19] Devasahayam S, Hill, DJT, Pomery PJ, Whittaker AK. The radiation chemistry of ultem at 77 K as revealed by ESR spectroscopy. *Radiat Phys Chem* 2002;64:299–308. [\[CrossRef\]](#)
- [20] Serin M, Cakar F, Cankurtaran O. A study of the electrical properties and secondary transition of poly (ether imide). *J Optoelectron Adv Mater* 2005;7:1517–1522.
- [21] Huggins ML. The viscosity of dilute solution of long-chain molecules. IV. Dependence on concentration. *J Am Chem Soc* 1942;64:2716–2718. [\[CrossRef\]](#)
- [22] Krigbaum WR, Wall FT. Viscosities of binary polymeric mixtures. *J Polym Sci Part A Polym Chem* 1950;5:505–514. [\[CrossRef\]](#)
- [23] Catsiff RHE, Hewett WA. The interaction of two dissimilar polymers in solution. *J Appl Polym Sci* 1962;6:30–32. [\[CrossRef\]](#)
- [24] Garcia R, Melad O, Gomez CM, Figueruelo JE, Campos A. Viscometric study on the compatibility of polymer-polymer mixtures in solution. *Eur Polym J* 1999;35:47–55. [\[CrossRef\]](#)
- [25] Ajitha AR, Thomas S. *Compatibilization of Polymer Blends, Chapter 1-Introduction: Polymer Blends, Thermodynamics, Miscibility, Phase Separation, and Compatibilization*. Amsterdam: Elsevier, 2020:1–29. [\[CrossRef\]](#)