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PEBA/PS blend pervaporation membranes: preparation, characterization and performance investigation

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ABSTRACT

In the present study, novel polymeric blend membranes containing polyether block amide (PEBA) and polystyrene (PS) were prepared by solution casting method and used in pervaporative recovery of ethyl acetate (EA) from aqueous solution. The morphology, chemical structure, hydrophobicity, and thermal stability of the prepared membranes were studied by scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, contact angle test, and thermogravimetric analysis (TGA). Furthermore, the effect of polystyrene content on the performance of the prepared membranes in recovery of EA from water was also investigated. The results showed that by increase in PS content the EA permeation flux, total permeation flux, separation factor, and pervaporation separation index (PSI) were noticeably increased. The highest total flux and separation factor of this study obtained using the PEBA/PS blend membrane containing PEBA/PS mass ratio of 70/30 were 465 g/m^{2}h and 147, respectively.

Keywords: Pervaporation; Polyether block amide; Polystyrene; Ethyl acetate

1. Introduction

Wastewater of many factories contain organic compounds [1]. The presence of these compounds in water causes serious environmental problems [2]. Thus, the removal of them from water is very important in environmental protection [3]. These chemicals could be just pollutants or high value products such as aroma compounds [4] which are responsible for odor of different kinds of fruits [5]. Ethyl acetate (EA) as an important chemical material has a fruity smell [6]. Moreover, this organic compound is a valuable raw material widely used in fabrication of perfumes, varnishes, adhesive agents, resins, plasticizers, and medicinal chemicals [1,7]. This chemical is synthesized by esterification process using ethanol and acetic acid [8]. To prevent the inhibition of this reaction due to its reversibility, the produced ester should be separated from the process environment [7]. Therefore, separation of EA from aqueous solution is also required when EA is produced [7].

Several investigations have been done on separation of organic compounds from water [1,9]. Pervaporation (PV) is a remarkable process and a promising membrane technology for separation of solvent mixtures and recovery of aroma compounds [6,10]. PV as a relatively new and economically attractive separation process has many advantages and has been widely used in recovery of organic compounds from dilute solutions in different applications [6,11].

In PV process, the selectivity of the membrane is the main determining factor due to the fact that separation of a component from its solution takes place by its preferential sorption and diffusion from the upside to the downside of the membrane due to the chemical potential gradient [10]. Membrane material as the important item of this process has attracted the most focus of researches [7]. The desirable membrane material should have high permselectivity and permeability as well as good stability [5]. Since the

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organic compounds have hydrophobic characteristics compared to water, hydrophobic polymers like polydimethylsiloxane (PDMS), nitrile-butadiene rubber (NBR), polyurethaneurea (PU), poly(vinyldene fluoride-co-hexafluoropropene) (P(VDF-co-HFP)), poly(ether-block-amide) (PEBA), and ethylene-vinylacetate (EVA) have been used as the membrane material for removal of organic materials from aqueous solution [2,7]. According to the literature, the important membrane materials used for volatile organic compounds(VOCs) extraction are PDMS and PEBA [4].

Many studies have been reported on recovery of EA from the aqueous solution. EA is a hydrophobic organic compound and preferentially absorbed into hydrophobic membranes while water is repelled by these membranes [5]. Song and Lee [6] used a surface modified tube type membrane for PV separation of EA as a volatile organic flavor compound from aqueous solutions. Djebbar et al. [4] applied PEBA membranes with different polyether (PE) contents in PV separation of ethyl esters such as EA from water. They found out that by increasing ether-unit content in the polymer, the ester flux is increased. It should be noted that PEBA is the general name of a class of block copolymers consists of a PE soft segment and a polyamide (PA) hard segment [12]. By changing the ratio of these two segments, the properties of the copolymer could be changed [4].

Usually, simultaneous high permeability and selectivity of membrane could not be obtained using the pure polymeric materials [7]. Thus, achievement of the ideal performance is possible by modification of the membrane as the heart of the separation process. To prepare a modified type of membrane material, polymer blending as a simple and versatile used technique amongst the various modification techniques is one of the considered methods [13]. Several researches have been carried out on the use of blend membranes in membrane processes [14]. In the field of PV, preparation of different blend membranes has been reported [13]. Rao et al. [15] used blend membranes of PEBA/polysulfone (PSf) and PEBA/poly vinyl pyrrolidone (PVP) for separation of acetic acid from aqueous solution via PV process. They found out that PEBA/PSf blend membrane had higher separation factor compared to pure PEBA membrane.

According to the literature, it is known that most of the membranes used for VOC recovery have been prepared by rubbery polymers whereas the membranes prepared by glassy polymers present high selectivity [9]. However, glassy polymers are brittle and hard which come from limited chain mobility of these polymers [9]. For instance, polystyrene (PS) polymer is a low cost polymer widely used in fabrication of plastic products [10]. Unlike the outstanding permeability to aromatic volatile compounds using PS membrane, its weak mechanical properties prevents its application in PV process [16]. However, this polymer was used in several researches using modification methods like blending and copolymerization [16] . For example, Seung et al. [17] prepared PS/poly(2,6-dimethyl-1,4-phenylene oxide) (PPO) blend membrane and studied the permeation characteristics of oxygen and nitrogen. In addition, polymeric blend membrane of polyvinyl chloride (PVC) and PS was used in ultrafiltration process [14]. The blend membranes prepared using the different polymers and PS were also used in PV process. Ray et al. [9] used the unplasticized polyvinylchloride (UPVC)/PS blend membrane for separation of tetrahydrofuran (THF) from aqueous solution. Samanta and Ray [10] carried out PV process via utilization of PVC/PS blend membrane in the recovery of acetone from water.

In PV process, the membrane affinity to the desired component is determinant because separation takes place via sorption of the desired component to the membrane and also the component transport through the membrane. It is also well known that in a binary mixture of two solvents, sorption of one component with the closer solubility parameter to the membrane material solubility parameter is higher than that of the other component [10]. EA and water solubility parameters are about 18.1 $J^{1/2}cm^{-3/2}$ and 47.8 $J^{1/2}cm^{-3/2}$, respectively [2]. Furthermore, according to the literature, it is known that the solubility parameters of PEBA and PS are about 19.51 $J^{1/2}cm^{-3/2}$ and 18.5 $J^{1/2}cm^{-3/2}$ which are close enough to the solubility parameter of EA [12].

In the present work and in order to enhance the affinity of the PEBA membrane to EA, blending the PEBA with PS was considered. Therefore, different amounts of polystyrene polymer were added to PEBA membrane casting solution to increase the membrane affinity to EA and consequently enhancement of the membrane permselectivity. The prepared membranes were used in PV separation of EA from its aqueous solution at room temperature. Membrane characterization tests including scanning electron microscopy (SEM), Fourier-transform infrared (FTIR) spectroscopy, thermogravimetric analysis (TGA), determination of degree of swelling (DS), and assessment of water contact angle were also carried out to investigate the prepared membranes properties. The effects of PS loading on permeation flux and separation factor were also investigated.

2. Experimental

2.1. Materials

PEBAX 2533 SN01 (PEBA) which consists of about 80% PE and 20% PA was obtained from Arkema Co. Ltd., France. PS was purchased from Tabriz petrochemical Co. Ltd., Iran. Dimethyl acetamide (DMAC) and ethyl acetate (EA) were supplied from Merck, Germany.

2.2. Polymer compatibility

Investigation of polymer compatibility has great importance in the field of blend membranes preparation and it extremely affects the fabricated membranes performance [18]. Various experimental methods are available to evaluate the compatibility of polymers [18,19], however, according to the literatures, the compatibility between two polymers can be predicted theoretically using an equation suggested by Schneier [20,21]:

$$\Delta H_m = \left\{ X_1 M_1 \rho_1 \left(\delta_1 - \delta_2\right)^2 \left[\frac{X_2}{\left(1 - X_2\right) M_2 \rho_2 + \left(1 - X_1\right) M_1 \rho_1} \right]^2 \right\}^{1/2} \quad (1)$$

where ΔH_m is the mixing enthalpy, X is the mass fraction, ρ is the density, M is the molecular weight of repeated unit, and δ is the solubility parameter of each polymer. Here, subscripts 1 and 2 denote polymers 1 and 2, respectively. According to the literature, when two polymers are compatible, the value of ΔH_m is less than the critical value of 0.0418 J mol^{-1} [20]. Moreover, based on the literature, the solubility parameters of PEBA and PS are 19.51 and 18.5 J$^{1/2}$ cm$^{-3/2}$, respectively [12]. Using the above equation, the plot of the ΔH_m vs. PEBA mass fraction is illustrated in Fig. 1. According to this figure, for all PEBA mass fractions the ΔH_m curve is below the line of ΔH_m critical value, and consequently, the polymers are completely compatible.

2.3. Membrane preparation

The blend membranes were made by solution casting method in which the required amounts of PEBA and PS polymers with different PEBA/PS values of 100/0, 90/10, 80/20, and 70/30 were accurately weighed and added to DMAC as the common solvent. The solution was stirred for 4 h at 80°C until a homogeneous solution was formed. After debubbling, the solution was cast on a clean glass and kept at room temperature for 1 h. Then it was dried in an oven with 50°C for 1 d. Afterwards, the obtained membrane was peeled off carefully and quickly from the glass using a distilled water bath and then it was dried again in an oven at 50°C for 5 d. The total polymer concentration of the casting solution was 12 wt. % for all the prepared membranes.

2.4. Scanning electron microscopy

To observe the morphologies of both surface and cross section of the membranes, SEM images of the prepared membranes were captured using a LEO1450 VP microscope (Germany). Before imaging the cross section, each membrane was cryogenically fractured under liquid nitrogen to obtain clear cut. All the prepared membranes were coated with thin film of gold using a sputter coater of model SC7620, England.

2.5. Field emission scanning electron microscopy (FESEM)

Microstructure of surface and cross-section of pure PEBA and PEBA/PS blend membranes was also studied using TESCAN MIRA3-FEG field emission scanning electron microscope (Czech Republic). The samples were sputter coated with gold in a Quorum Q150R ES coater (England) and the images were taken in acceleration voltage of 10 kV.

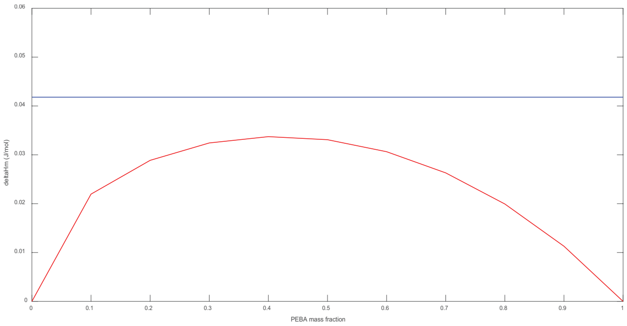


Fig. 1. Mixing enthalpy vs. mass fraction of PEBA polymer in PEBA/PS blends.

2.6. FTIR spectroscopy

The FTIR spectra of all prepared membranes were characterized by a Thermo Nicolet AVATAR 370 FTIR (USA) spectrometer in the wave number range of 500–4000 cm^{-1}.

2.7. Water contact angle measurement

Water contact angle of the prepared membranes was measured at room temperature. Each dried membrane was cut at the size of 1 × 3 cm and fixed on a thick glass. Then using a microscope coupled with a camera, an image of the distilled water droplet on the membrane surface was captured. Average values of contact angle at 5 different locations on the membrane surface were reported.

2.8. Swelling measurement

To investigate the swelling behavior of the prepared membranes, clean and dry membranes with known weights were separately immersed in a solution with the same properties of feed solution at room temperature for 10 d. At regular time intervals, all membranes were wiped out and carefully dried by clean tissue paper and weighted. The degree of swelling (DS) was obtained using the following equation [7]:

$$DS = \frac{m_s - m_d}{m_d} \times 100\% \qquad (2)$$

where m_s and m_d are the weight of swollen and dry membranes, respectively.

2.9. Thermogravimetric analysis

To investigate the thermal stability of the prepared membranes, thermogravimetric analysis (TGA) was carried out using Mettler Toledo TGA/DSC 1 Star System (Switzerland). Each dried membrane with weight of about 10 mg was heated from 25 to 1000°C under nitrogen atmosphere at the heating rate of 10°C/min.

2.10. Pervaporation experiment

PV experiments were carried out using a laboratory scale PV system. The schematic diagram of the PV system is shown in Fig. 2. Feed solution was continuously circulated by a pump from feed tank to the membrane module. For PV process, a circular flat membrane with area of 15.9 cm^2 was used and placed into the sealed stainless steel cell. The feed temperature was kept constant at room temperature. A vacuum pump was used to maintain membrane downstream pressure at 18 mm Hg. The resultant permeate was cooled in a cold trap using liquid nitrogen. The concentration of EA in the permeate side was determined using a digital refractometer (ATAGO, Japan). The average result obtained by analysis of three samples was reported. It should be

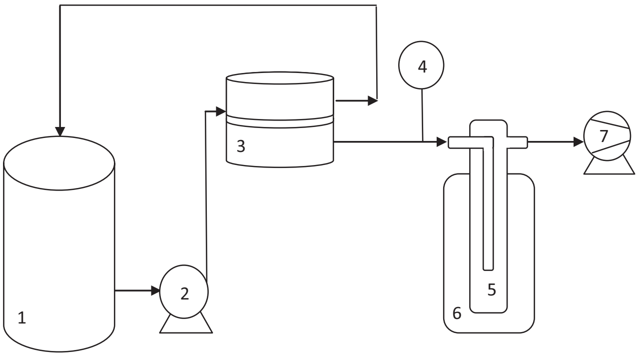


Fig. 2. Schematic diagram of PV system: (1) Feed container, (2) Feed circulation pump, (3) Membrane cell, (4) Vacuum gauge (5) Cold trap, (6) Liquid nitrogen container and (7) Vacuum pump.

noted that the PV product at the permeate side was a liquid solution including water and EA. Since the prepared blend membranes were significantly selective for EA, the concentration of EA in the permeate side was high, but due to the low solubility of EA in water, the PV product at the permeate side was a two phase liquid solution. In order to have a single phase liquid solution for characterization by refractometer, the permeate solution was turned into a single phase liquid solution before analyzing by adding a certain amount of water. To determine the permeation flux (J), separation factor (α) and PV separation index (PSI) of the prepared membranes, the following equations were used [7,22]:

$$J = \frac{Q}{At} \tag{3}$$

$$\alpha = \frac{Y_{EA}/Y_W}{X_{EA}/X_W} \tag{4}$$

$$PSI = J(\alpha - 1) \tag{5}$$

where Q is the mass of permeate, A is the effective membrane area, t is the permeation time and X and Y represent the mass fraction of each component in the feed and permeate, respectively. Furthermore, to evaluate the intrinsic performance of the prepared membranes, the permeability P, and selectivity β, were also calculated according to the following equations [23,24]:

$$P_i = \frac{J_i l}{x_i \gamma_i p_i^{sat} - y_i p^p} \tag{6}$$

$$\beta_{1/2} = \frac{P_1}{P_2} \tag{7}$$

where P_i is the membrane permeability of the component i, J_i is the permeation flux of component i, l is the membrane thickness, γ_i is the activity coefficient of component i, p_i^{sat} is the saturated vapor pressure of component i in the feed temperature, p^p is the permeate pressure, and x_i and y_i are mole fractions of component i in the feed and permeate, respectively. The activity coefficient was estimated using NRTL model.

According to the literature, the concentration range of EA aqueous solution investigated as the contaminated low concentration binary solution is 0–5 wt. % EA in water [11]. To evaluate the applicability of the membranes prepared in this study, the feed concentration of 4 wt. % was considered for PV experiments.

3. Results and discussion

3.1. SEM analysis

Figs. 3 and 4 show the SEM images of surfaces and cross sections of the prepared membranes, respectively. With respect to these figures, no pores can be observed and all of the membranes are completely dense and consequently suitable for PV process. In addition, it is clear that by adding PS polymer to the pure PEBA polymer, membranes morphology remains almost uniform. According to the literature, SEM images of immiscible blend membranes present heterogeneous or distinct phases in the surface images resulted from the weak interfacial adhesion between the two incompatible polymers [16]. Therefore, it is clear that the homogeneous structure of the blend membranes by adding PS polymer to the pure PEBA polymer may be attributed to the suitable compatibility of PEBA and PS polymers.

3.2. FESEM analysis

Surface and cross-sectional FESEM micrographs of all prepared membranes including pure PEBA and PEBA/PS blend membranes are illustrated in Figs. 5 and 6. According to the literatures, uncompatibilized blends show two-phase structure in FESEM images [25]. However, considering the obtained FESEM images from the prepared blend membranes in this study (with 30 and 100 k× magnifications for membranes surfaces and 3, 30, and 100 k× magnifications for membranes cross-sections), all the blend membranes are uniform and no sign of two-phase structure can be seen in these images. Therefore, FESEM results show that PEBA and PS are well compatible at the prepared ratios (PEBA/PS: 90/10, 80/20, and 70/30). It has been also theoretically calculated and presented previously in section 2.2 that PEBA and PS are compatible polymers. Accordingly, the homogeneity of the blend membranes morphology from FESEM images confirms the theoretical compatibility of the polymers.

3.3. FTIR analysis

The FTIR spectra of pure PEBA, pure PS and PEBA/PS blend membranes are shown in Fig. 7. As shown in this figure, for pure PS membrane, the band around 3030 cm^{-1} corresponds to aromatic C-H stretching [26]. Furthermore, peaks at 1604 and 1496 are attributed to aromatic C=C stretchings [26], and peaks around 760 cm^{-1} and 700 cm^{-1} are due to substituted benzene [10]. Moreover, peak around 560 cm^{-1} represents aromatic ring [10] and the absorption between 1700 and 2000 cm^{-1} (e.g. at 1942 and 1802 cm^{-1}) indicates the weak bands of benzene ring [27–29]. The characteristic peaks of

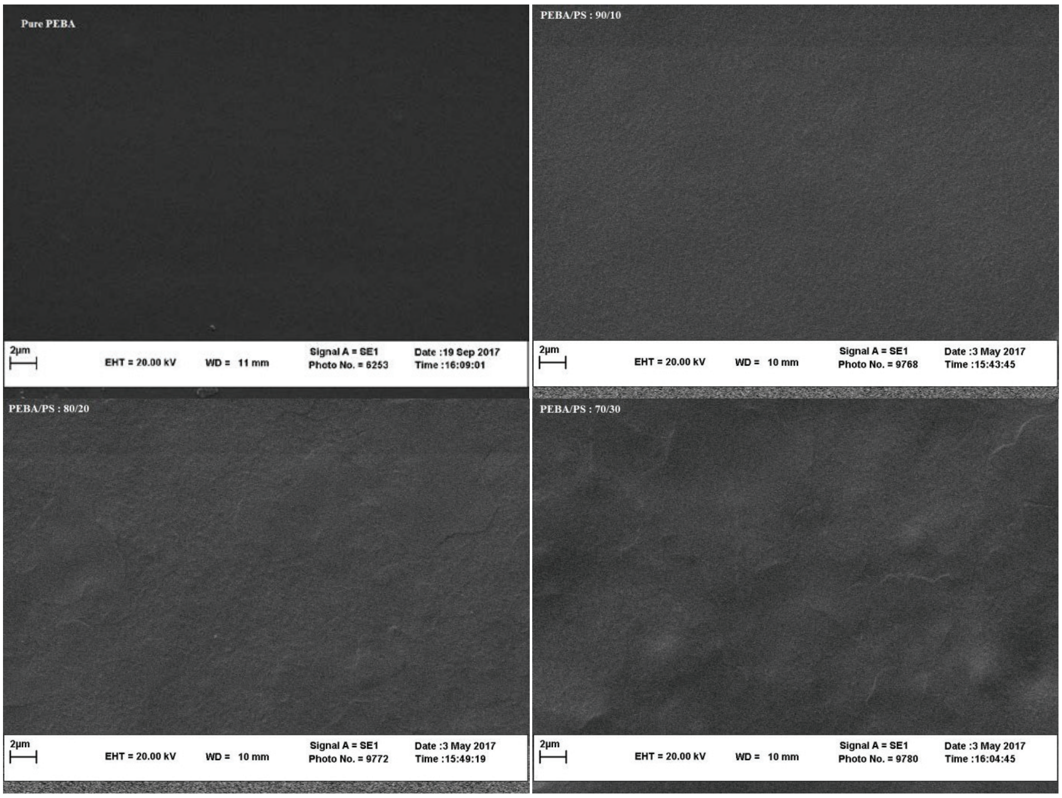


Fig. 3. Surface images of the prepared membranes.

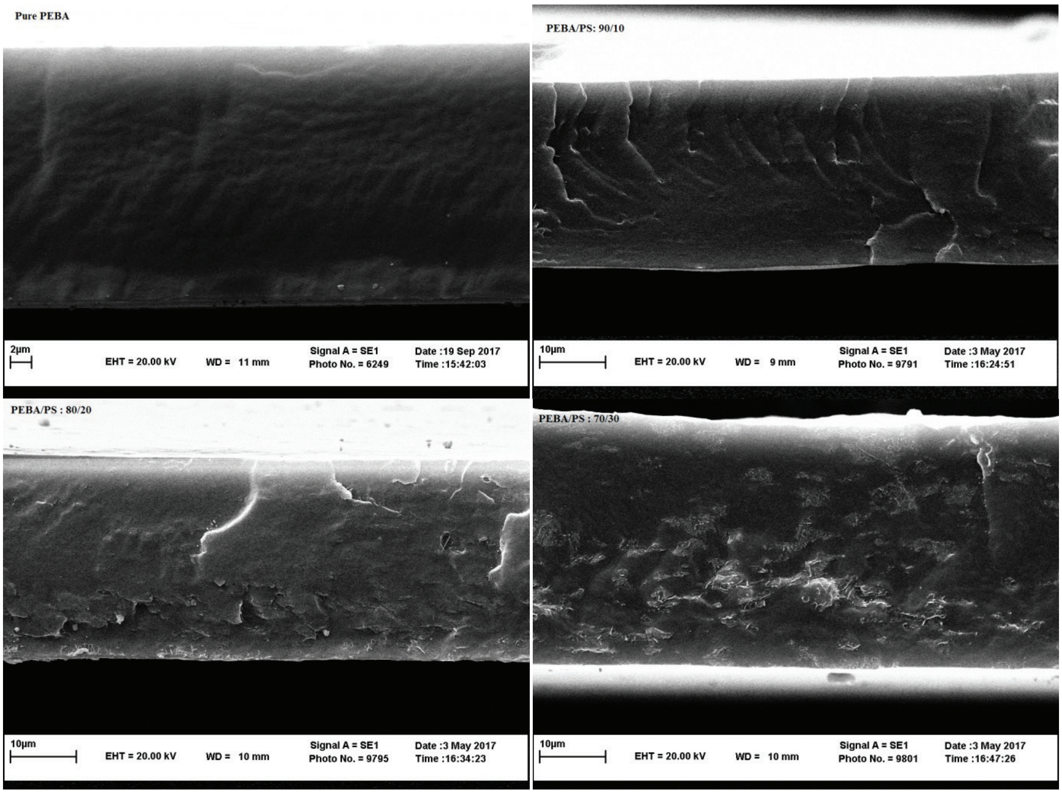


Fig. 4. Cross sectional images of the prepared membranes.

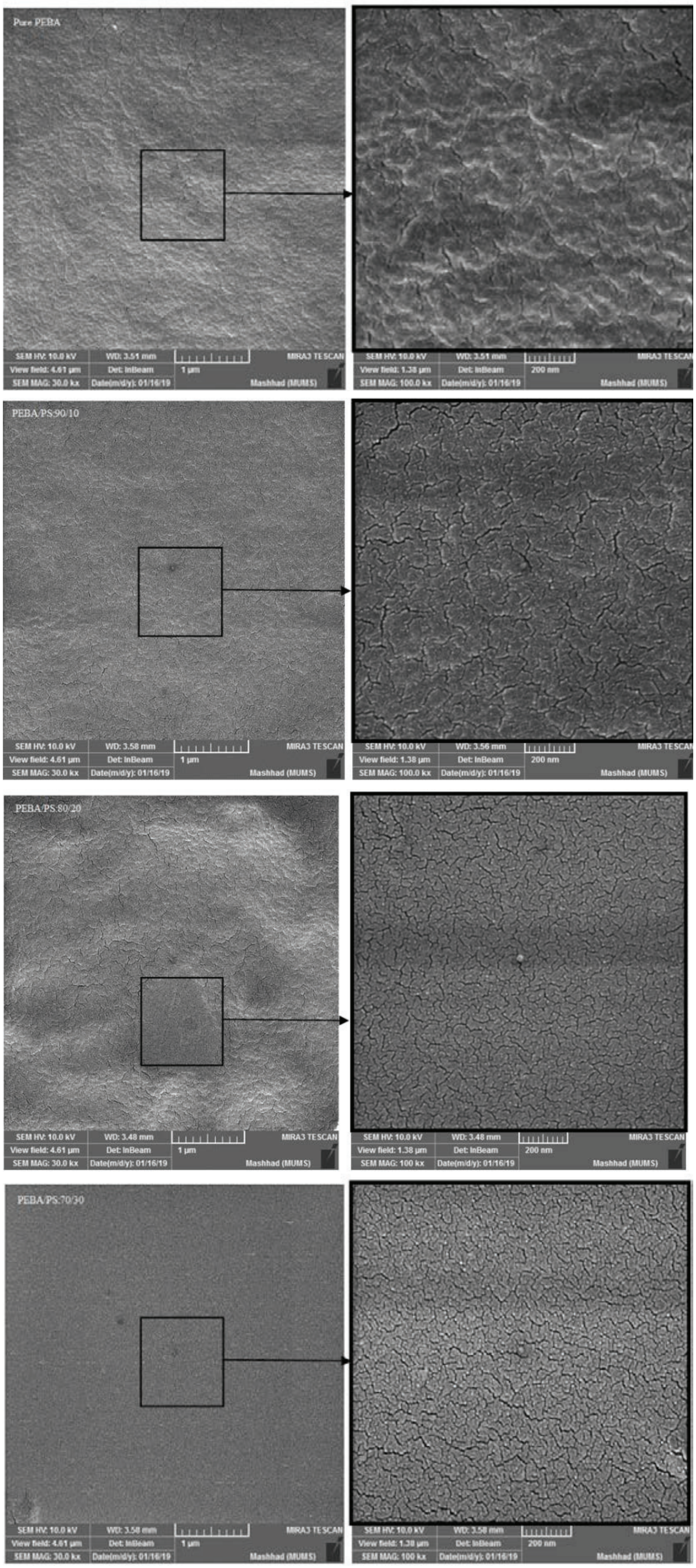


Fig. 5 FESEM images of pure PEBA and PEBA/PS blend membranes surfaces.

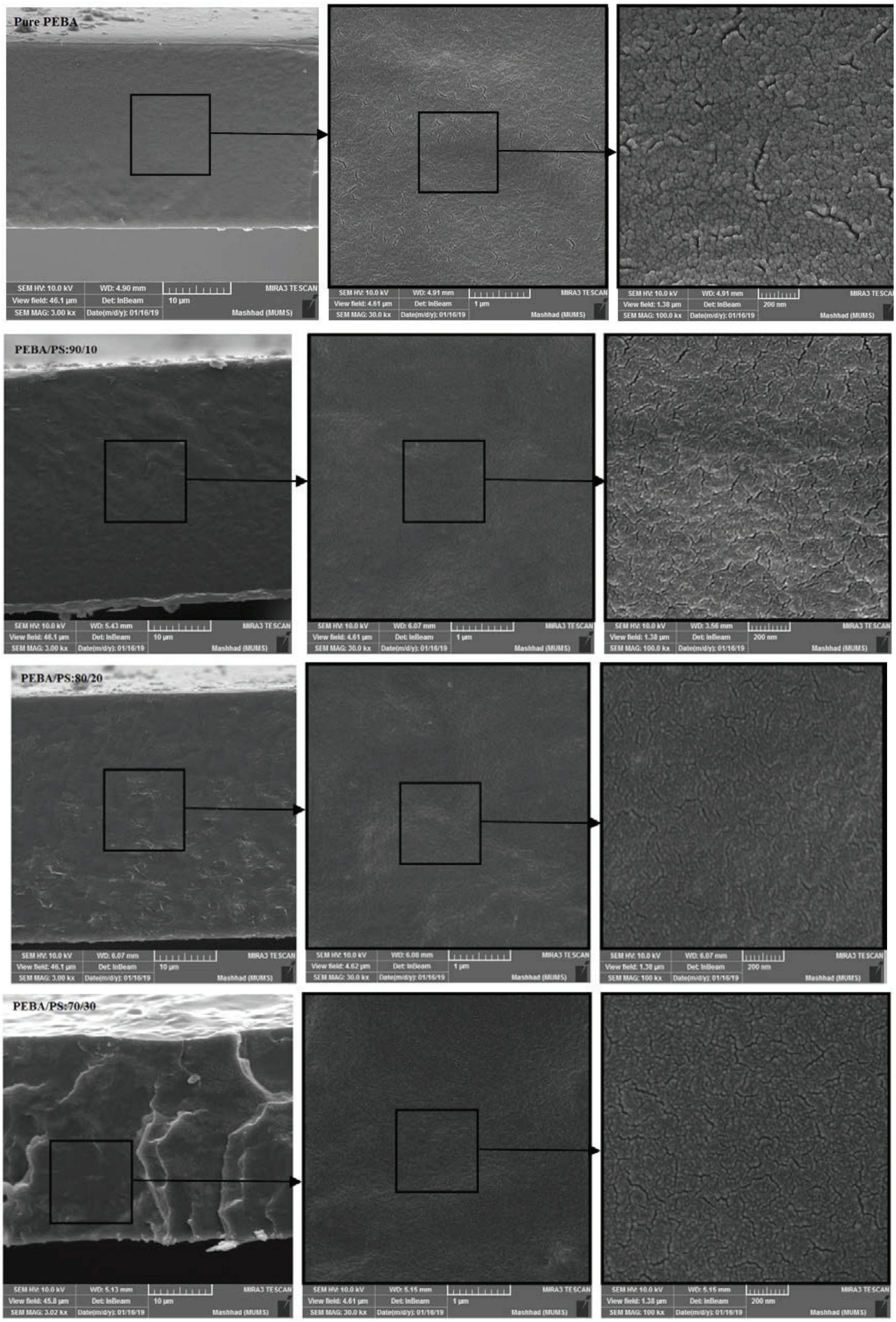


Fig. 6. FESEM images of pure PEBA and PEBA/PS blend membranes cross sections.

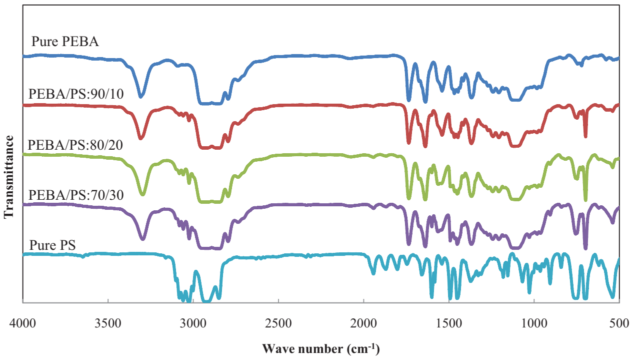


Fig. 7. FTIR spectra of the prepared membranes.

pure PEBA membrane observed around 3315 cm^{-1} and 1646 cm^{-1} are assigned to N-H and H-N-C=O groups [30]. In the case of the blend membranes in comparison with pure PEBA membrane, it is evident that absorption peaks clearly appear at around 700, 760, and 560 cm^{-1} corresponding to peaks of pure PS membrane which indicate the presence of PS in the prepared blend membranes. As shown in this figure, by increasing the PS amount in the blend from 10 to 30 wt. % these absorption bands became slightly sharper. In addition, the peaks among 1700–2000 cm^{-1} in the FTIR spectra of the blend membranes are more visible, indicating the presence of more polystyrene polymer in the blends.

3.4. Water contact angle

The effect of PS loading on water contact angle of the prepared membranes is shown in Fig. 8. As observed, water contact angle of pure PEBA is 73.26° which is in good agreement with the literature [31]. Moreover, the water contact angle of the blend membranes was considerably increased from 73.26° to 94.56° by addition of PS to the casting solution. From the literature, it is known that the polystyrene water contact angle is about 91° [32] which is higher than that of PEBA. Water contact angle parameter depends on both surface porosity and hydrophobicity of a membrane [33,34]. As observed in SEM images, all the prepared membranes show a poreless and dense top layer. Therefore, water contact angle values are only related to the hydrophobicity of the membranes. Considering the above explanation and Fig. 8, increase in water contact angle with the increasing the PS content from 0 to 30 wt. %, can be attributed and interpreted by improved hydrophobicity of the membranes due to presence of PS polymer in the modified membranes.

3.5. Degree of swelling

The results of DS measurement of the prepared membranes using the feed (4 wt. % EA in water) are shown in Fig. 9. As observed, initial addition of PS, i.e. 10 wt.%, to the membrane matrix resulted in increasing the DS value so that this parameter reached to 5.6%. The increase in DS value after addition of PS can be attributed and interpreted by the tendency of PS polymer to EA which can be explained by the very close solubility parameters of EA and PS, 18.1 J$^{1/2}$cm$^{-3/2}$ and 18.5 J$^{1/2}$cm$^{-3/2}$, respectively [2,12].

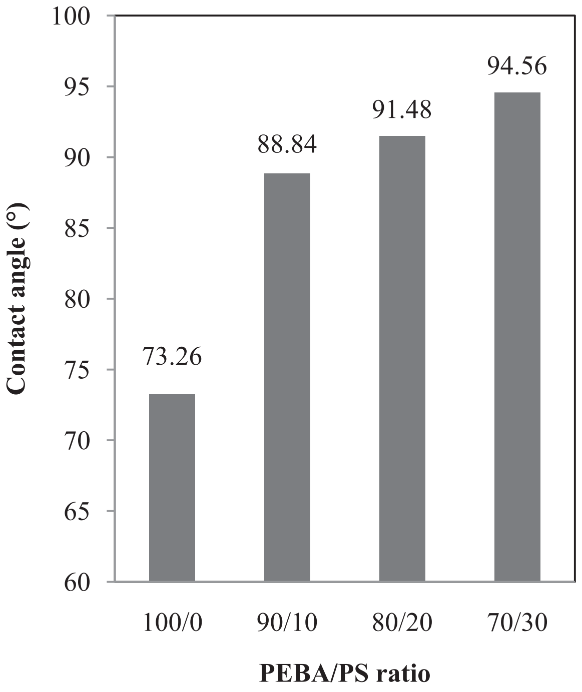


Fig. 8. Contact angle of the prepared membranes at different mass ratios of PEBA/PS.

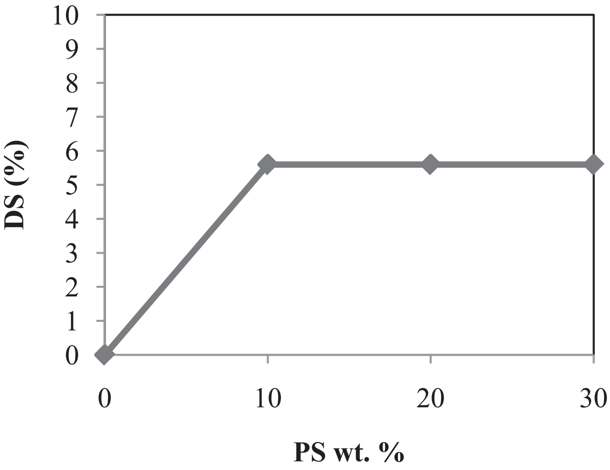


Fig. 9. Swelling degree of the prepared membranes using the feed in terms of different mass percents of PS.

The swelling degree results of the prepared membranes using pure solvents are also illustrated in Fig. 10. As observed, the DS value of all membranes in pure water has no change with increase in PS concentration. However, the DS value of the blend membranes in pure EA increases with increase in PS concentration, indicating the affinity of blend membranes to EA. This result can be interpreted by close solubility parameters of PS and EA. According to Fig. 10 the main increase in DS value is observed after initial increase in PS concentration from 0 to 10 wt. % and variation of swelling degree after further addition of PS polymer to PEBA/PS blend membranes is slight.

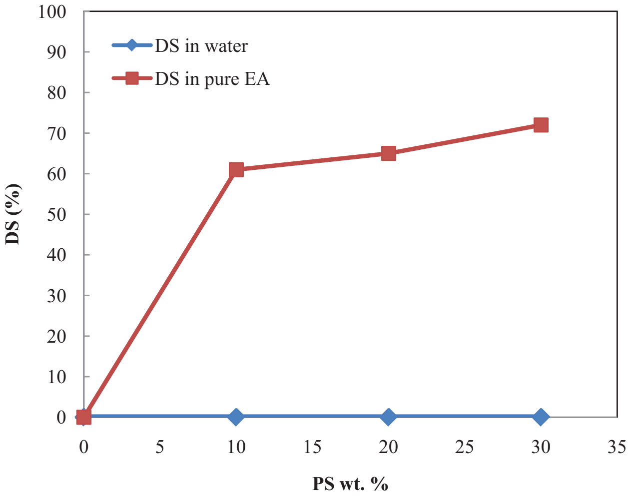


Fig. 10. Swelling degree of the prepared membranes using water and EA in terms of different mass percents of PS.

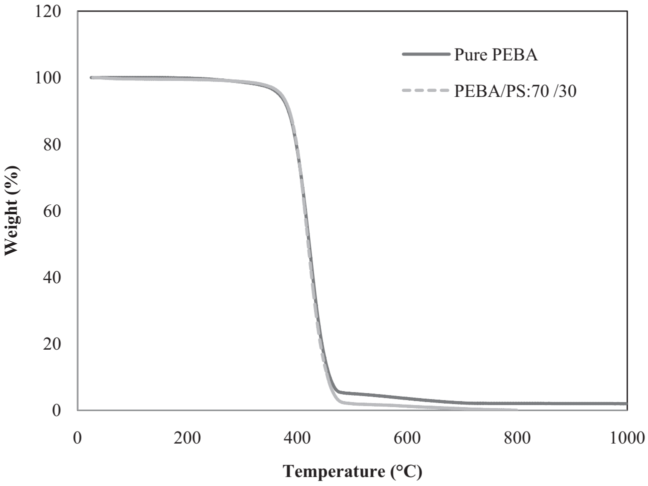


Fig. 11. Thermogravimetric analysis of two membranes of pure PEBA and PEBA/PS with mass ratio 70/30.

3.6. Thermal stability

The thermal decomposition curves of pure PEBA membrane and membrane containing 30 wt.% PS and 70 wt.% PEBA are shown in Fig. 11. As observed, thermal degradation of pure PEBA membrane is between 350 and 480°C which is almost in accordance with the literature [7,31]. Moreover with respect to the literature, thermal degradation of the pure PS membrane occurs in the range of 370–480°C [35]. According to Fig. 11, it can be observed that both curves are very similar and almost overlapped. Furthermore, thermal decomposition of these membranes began about 270°C and the temperature in which 50% weight loss occurs was almost 420°C. Thus, it could be concluded that the thermal stability of both membranes is very similar and the addition of the polystyrene polymer does not change the thermal degradation behavior of the membrane.

3.7. Pervaporation performance

All the prepared membranes were characterized in PV separation of EA dilute aqueous solution. According to SEM images, all the prepared membranes were dense and consequently suitable for the use in PV experiments. The PV performance of the prepared membranes as a function of the PS loading is shown in Figs. 12–14. The results of separation factor are illustrated in Fig. 12. As observed, by adding PS and increasing the PS/PEBA mass ratio in the prepared membranes, the separation factor and in other words, selectivity of membranes to EA in comparison with water was noticeably increased. It is well-known from literature that organic molecules generally permeate through the hydrophobic part of the membrane structure [7]. For the prepared membranes in this study, the PE segment of the PEBA membrane is the hydrophobic part of the membrane. In the PEBA copolymer used in the present study, the polar hard segment of PA is dispersed in the PE matrix. The hydrophobic PE segment mainly provides the permeation path for the organic molecules and permeation of water molecules through the low content and discontinuous segment of PA is very difficult [7]. By adding PS with the strong affinity to EA, the hydrophobicity of the membrane was improved and the probable routes for water molecules were more reduced. For example, for pure PEBA membrane, separation factor was 35 while it was increased to 147 for the membrane prepared by PS/PEBA mass ratio of 30/70. This can be attributed to the similar solubility parameters of EA and PS which evidently facilitates the transmission of EA molecules through the membranes containing higher concentration of PS polymer. Fig. 13, which presents higher EA permeation flux due to the increase in PS concentration, confirms this subject. On the other hand, according to the results of water contact angle measurement presented in the previous sections, increase in PS content of the prepared

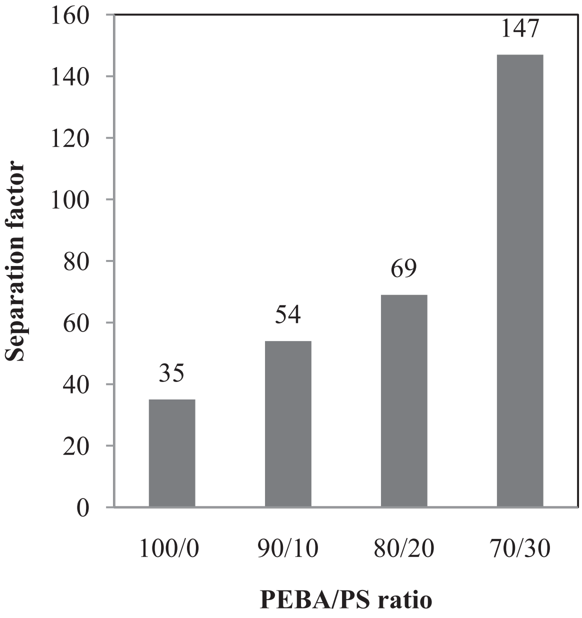


Fig. 12. Separation factor of the prepared membranes at different mass ratios of PEBA/PS.

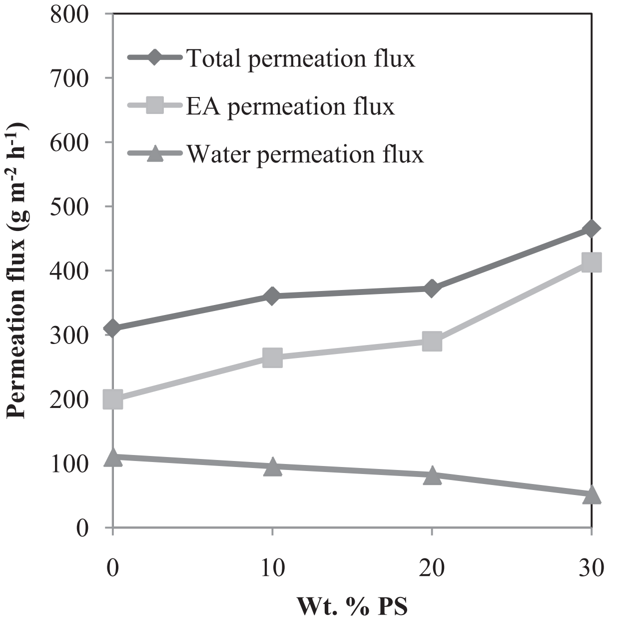


Fig. 13. EA, water and total permeation flux of the prepared membranes in terms of different mass percents of PS at 25°C and 2.3 L/min feed flow rate.

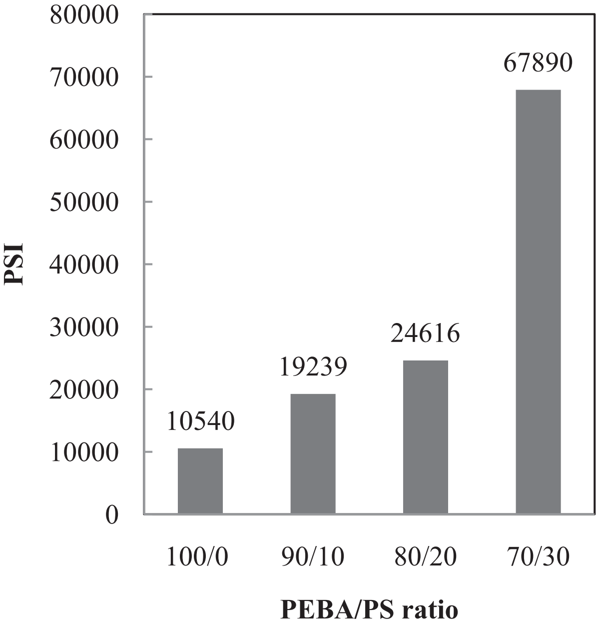


Fig. 14. PV separation index (PSI) of the prepared membranes at different mass ratios of PEBA/PS at 25°C and 2.3 L/min feed flow rate.

membranes results in formation of membranes with higher hydrophobicity which restrict the transmission of water molecules. Lower water permeation flux due to increase in PS concentration, presented in Fig. 13, confirms this subject.

The PV separation index (PSI) values as an indication of the overall PV performance of the prepared membranes are presented in Fig. 14. It is obvious that the behavior of this parameter as a function of PS loading is ascending. The best value of PSI parameter was 67890 related to the membrane prepared with PEBA/PS mass ratio of 70/30 which is significantly more than the value of 10540 related to the pure PEBA membrane. PSI is a function of separation factor and total permeation flux. As observed in Figs. 12 and 13, the membrane prepared with PEBA/PS mass ratio of 70/30 presents the maximum value of separation factor and permeation flux. Thus, it is evident that this membrane shows the maximum value of PSI parameter.

The effects of the PS polymer on the permeability and selectivity of the prepared membranes were also investigated and the results are illustrated in Figs. 15 and 16, respectively. According to Fig. 15, the incorporation of PS polymer into the prepared membranes generally increased the EA permeability and decreased the water permeability. Moreover, significant improvement of membrane selectivity in regard to the blend membranes is also obvious in Fig. 16 which means that affinity of the blend membranes to EA has been improved. According to the permeability results of the pure PEBA membrane (Fig. 15), after normalizing the flux by driving force and membrane thickness, the water permeability became greater than that of EA. In other words, pure PEBA membrane is almost water selective with a water permeability of about twice higher than EA permeability. Indeed, the EA permeability through the blend membranes was improved by increasing the PS content in the blend membranes. In fact, according to the permeability results, in contrast to the pure PEBA membrane, the blend membranes are more permeable to EA than water. These membranes are therefore EA selective. As observed in Fig. 15, by adding 20 wt.% PS polymer to the membrane, the permeability of EA was increased and reached to the water permeability value so that both component permeabilities became almost the same. Afterwards, increasing the PS content of the blend membranes to 30 wt.% was followed by a considerable increase in EA permeability. The EA permeability of the PEBA/PS membrane with 30 wt.% PS polymer was more than 3 times higher than water permeability. Therefore, it is evident that EA passes through the blend membranes better than the pure PEBA membrane.

As observed in Fig. 16, the selectivity was augmented with the increase in PS content. This improved selectivity achieved by adding PS polymer to the membranes is produced by the combination of increasing the permeability of EA and decreasing the permeability of water which was investigated above.

The permeability vs. selectivity is also presented in Fig.17. It is clearly observed from this figure that by increasing the selectivity, the EA permeability was increased while water permeability of the membranes was decreased. This result can be interpreted again considering the fact that by the increase in PS content into the blend membranes; their affinity to EA is enhanced due to the close solubility parameters of PS polymer and EA.

4. Conclusion

The blend membranes containing PEBA and PS were prepared. Performance of the prepared membranes in EA

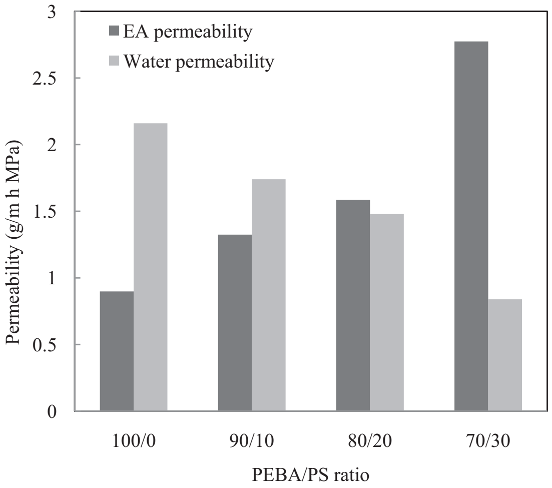
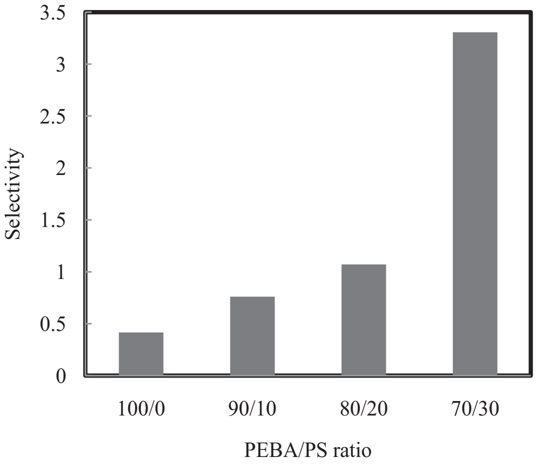


Fig. 15. EA and water permeability of the prepared membranes at different mass ratios of PEBA/PS.



FFig. 16. Selectivity of the prepared membranes at different mass ratios of PEBA/PS.

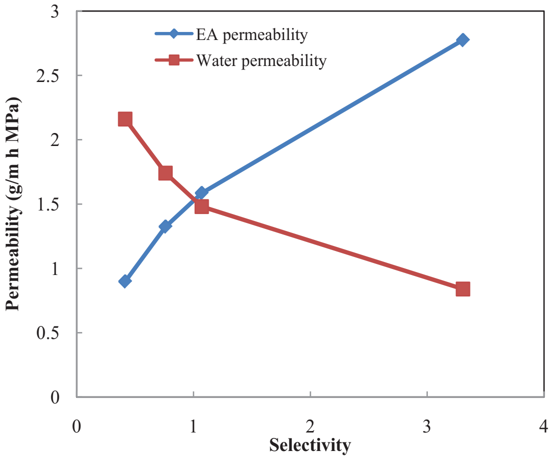


Fig. 17. Permeability vs. selectivity of the prepared membranes.

removal from aqueous solution was noticeable. The results showed that by increase in PS content, the overall PV performance of the prepared membranes including separation factor, permeation flux, and PSI value were considerably improved. In addition, the enhancement of EA permeability as well as the reduction of water permeability and consequently improvement of blend membrane selectivity was also resulted from the PV experiments. This observation can be attributed and interpreted by the noticeable affinity between EA and PS polymer. Moreover, the results showed that the addition of PS to PEBA did not change the thermal stability of the membrane significantly. Higher water contact angle and swelling degree were the other effects of adding PS.

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