Effect of temperature on some rheological properties of low-density polyethylene

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Abstract

This paper presents some of rheological properties of low-density polyethylene (LDPE) that Solute into benzene with different concentrations and at a range of temperatures of 20 - 40°C. Density, flow time and viscosity measurements showed that these properties increase with increasing the concentration while all of them decrease with increasing the temperature.

Physical Classification QC 170-179

Introduction

From the application point of view, the physical properties are very important for polymers [1]. These properties affect transparency, strength, flexibility and solubility as well as the physical structure affects the thermal properties of polymer. Therefore, the study of these properties is useful to enhance polymers [2].

Molecular weight (M_W) is one of the most fundamental parameters in characterizing the polymer. Molecular weight can be determined by different techniques. One of these technics is viscosimetry, although this is not an absolute method and requires the determination of constants [3].

The viscosity study of polymers has been of continuing interest, mainly due to its simplicity and its importance in the characterization of the intermolecular interaction between the two different polymers. Viscosity is said to be the measure of the resistance to flow of a material solution [4].

The equation that is generally used to represent the relationship between the intrinsic viscosity [η] and the average molecular weight M, is the Mark-Houwink-Kuhn-Sakurada (MH) equation [5]:

$$[\eta] = KM^{\alpha} \qquad (1)$$

where K and α are constants for a given polymer–solvent–temperature system.

Experimental Part

Low-density polyethylene used in this study; some of its popular properties are listed in the following table:

Table 1: Properties of polyethylene [6].

Density (gm/cm³)	Dielectric constant (Ohm/cm)	Ability to absorption of water	Resistance to thermal changes
0.87 – 0.965	10^{18}	Low	80° - 90°

High purity (99.5%) benzene was used as a solvent; some of its properties are showed in table 2:

Table 2: Properties of benzene [7].

Density (gm/cm³)	Viscosity (CP.)	Boiling point	Molecular weight (gm/mol)

| 0.8786 | 0.652 | 80.1 °C | 78.112 |

Five different concentrations (0.005, 0.01, 0.015, 0.02 and 0.025) gm/ml of polymer solutions were prepared by solving various weights of polyethylene into 100 ml of benzene. Density of all polymeric solutions was measured using density meter of volume of 25 ml. Viscosity was examined using the capillary type viscometer which allows the reading of flow times of the sample taken by using stop watch and the measurement was conducted at (20, 30, 40)°C. The following viscosities were determined using the equations given [8];

Shear viscosity, $\dfrac{\eta_s}{\eta_o} = \dfrac{\rho_s t_s}{\rho_o t_o}$ (2)

Relative viscosity, $\eta_{rel} = \dfrac{\eta_s}{\eta_o}$ (3)

Specific viscosity, $\eta_{sp} = \eta_{rel} - 1$ (4)

Reduced viscosity, $\eta_{red} = \dfrac{\eta_{sp}}{c}$ (5)

Effe. molecules radius, $r^3 = \dfrac{\eta_{red}}{6.3 \times 10^{24} C_m}$ (6)

where $\eta_s, \eta_o, \rho_s, \rho_o, t_s$ and t_o are viscosity of polymer solution, viscosity of solvent, density of polymer solution, density of solvent, flow time of polymer solution and flow time of solvent, respectively. While C_m is the molar concentration of polymer.

Results and discussion

Figure 1 shows the behavior of density as a function of concentration at different temperatures. Density was increased with an increase in concentration; this is due to increasing the mass of solution per volume unit as well as swelling of the polymer molecules because of the solvent molecules interference with the polymer molecules [9]. On the contrary, the density is decreased with increasing the temperature due to expansion the polymer solution with an increase in temperature [10].
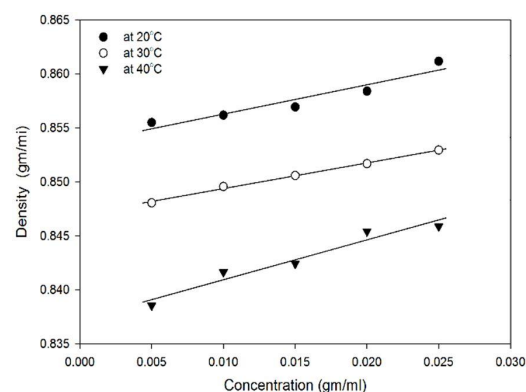

Figure 1: Density as a function of concentration at different temperatures.

From table 3, it can be noted that the value of flow time for the polymer solutions is increased with increasing the concentration due to increasing fraction force between molecules of polymer and the internal side of capillary tube. At the same time, we can observe that the flow time decreased with increasing the temperature for all concentrations because of decreasing the internal fraction.

Table 3: Flow time as a function of concentration at different temperatures.

Concentration (gm/ml)	Flow time (sec)		
	at 20°C	at 30°C	at 40°C
0.005	12.5	11.93	11.22
0.01	19.14	17.89	16.93
0.015	34.8	32.83	28.92
0.02	127.27	122.51	111.49
0.025	722.93	607.09	412.82

Shear viscosity was calculated by using eq.2 and then plotted in Figure 2. It shows that the shear viscosity behavior as a function of concentration. There is an increase in the shear viscosity along with increasing the polymer concentration at constant temperature due to increasing the rotational and transferal motion [11],[12]. At the same time, it is observed that the value of shear viscosity is decreased with increasing the temperature from 20 to 40°C for each concentration due to expansion of the polymer solution with the increase the temperature.
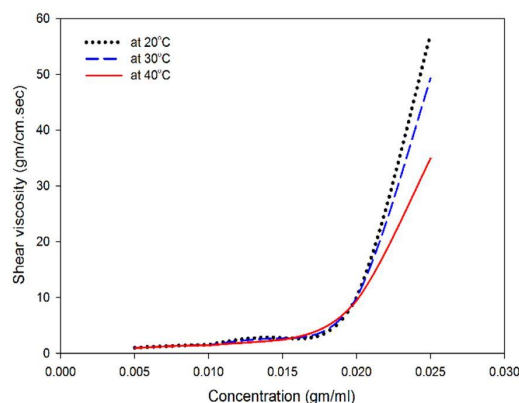
Figure 2: Shear viscosity as a function of concentration at defferent tempertures

The values of relative and specific viscosities were calculated by using eqs. 3 and 4, respectively. Figures 3 and 4 show the behavior of the relative and specific viscosities as a function of concentration at various temperatures.
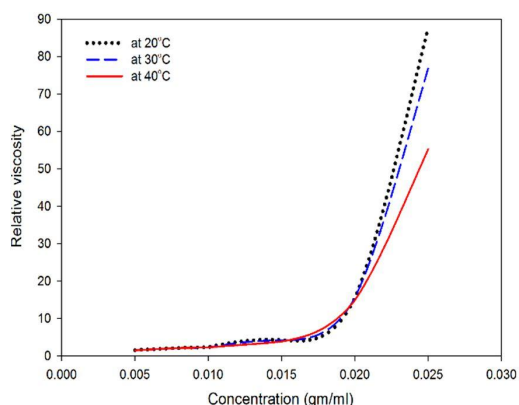

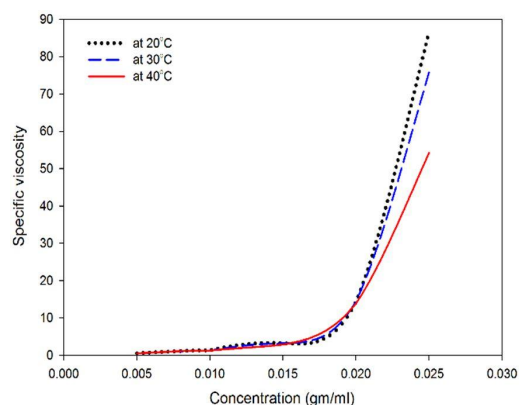Figure 3: Relative viscosity as a function of concentration at different temperatures.

Figure 4: Specific viscosity as a function of concentration at different temperatures.

Relative and specific viscosities have the same behavior of the shear viscosity because of their values depend on the value of the shear viscosity [13].

Depending on eq. 5 the reduced viscosity with unit of dL/gm was plotted against concentration in Figure 5 at various temperatures. The value of intrinsic viscosity was calculated from the y-interception when the concentration reduces to zero, then viscosity average molecular weight deduced from the intrinsic viscosity and eq. 1 to be 26700 where K and α are 5.79×10^{-4} dL/gm and 0.695, respectively [14].
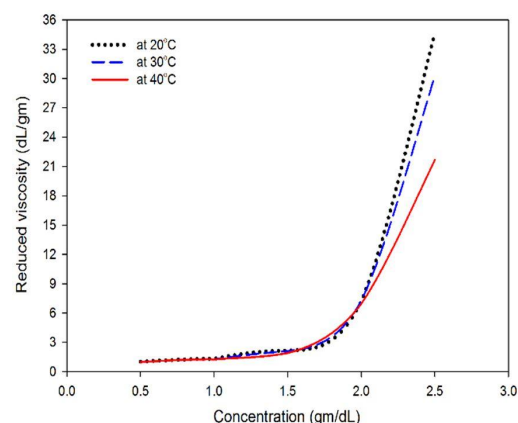

Figure 5: Reduced viscosity as a function of concentration at different temperatures.

The value of effective molecules radius was calculated by using eq. 6, it is equal to 3.98×10^{-10} cm.

Conclusion

We have investigated the rheological properties of low-density polyethylene at various temperatures as a function of concentration. The density and measured viscosities were increased with increasing the concentration of polymer in the solvent. The increasing of temperature leads to decrease the flow time and then to decrease the viscosity of the polymer. Finally, we noted that the solubility of the polymer increased with increasing the temperature.

Acknowledgements

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تأثير درجة الحرارة في بعض الخصائص الانسيابية لبولي إثيلين واطئ الكثافة

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الخلاصة:

يتضمن البحث دراسة بعض الخصائص الفيزيائية لمادة بولي اثلين واطى الكثافة المذاب في البنزين بتركيزات (0.005, 0.01, 0.015, 0.02, 0.025) gm/ml وبمدى من درجات الحرارة (20,30,40)^{o}C وهذه الخصائص هي الكثافة، زمن الانسياب، اللزوجة القصية، اللزوجة النسبية، اللزوجة النوعية، اللزوجة المختزلة واللزوجة الذاتية للبوليمر. بينت الدراسة بأن جميع الخصائص في اعلاه تزداد مع زيادة التركيز وتتناقص مع زيادة درجة الحرارة.

كلمات مفتاحية: بولي اثلين واطى الكثافة، الخصائص الانسيابية، اللزوجة.