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# UNIVERSITI SAINS MALAYSIA

First Semester Examination  
2015/2016 Academic Session

December 2015 / January 2016

## EBP 202/3 – Polymer Structure [Struktur Polimer]

Duration : 3 hours  
[Masa : 3 jam]

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Please ensure that this examination paper contains NINE printed pages before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

This paper consists of SEVEN questions.

*[Kertas soalan ini mengandungi TUJUH soalan.]*

**Instruction:** Answer FIVE questions. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.

**Arahan:** Jawab LIMA soalan. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]

The answers to all questions must start on a new page.

*[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]*

You may answer a question either in Bahasa Malaysia or in English.

*[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

In the event of any discrepancies in the examination questions, the English version shall be used.

*[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]*

1. [a] Discuss the conformation and configuration of polymer.

*Bincangkan konformasi dan konfigurasi polimer.*

(60 marks/markah)

- [b] Draw the Gauche and Trans-conformation of polyisobutylene by using Newman projections.

*Lukiskan konformasi Gauche dan Trans bagi poliisobutilena dengan menggunakan proyeksi Newman.*

(40 marks/markah)

2. [a] A linear polyethylene has average molecular weight of  $1.12 \times 10^6$  g/mol. Given that the bond length of C-C and bond angle is 0.154 nm and  $109.5^\circ$  respectively. Calculate the following:

- (i) contour length
- (ii) root mean square (RMS) end-to-end distance according to freely jointed chain model
- (iii) root mean square (RMS) end-to-end distance according to valence angle model

*Satu polietilena linear mempunyai berat molekul purata  $1.12 \times 10^6$  g/mol. Diberikan panjang ikatan C-C dan sudut ikatan ialah 0.154 nm dan  $109.5^\circ$  masing-masing. Hitungkan yang berikut:*

- (i) *panjang kontur*
- (ii) *punca purata kuasa jarak hujung-ke-hujung berdasarkan model rantai bersambung bebas*
- (iii) *punca purata kuasa jarak hujung-ke-hujung berdasarkan model sudut valens*

(70 marks/markah)

- [b] Discuss the effects of short-range steric restriction on the polymer chain dimension.

*Bincangkan kesan-kesan penyekatan sterik berjarak pendek terhadap dimensi rantai polimer.*

(30 marks/markah)

3. [a] Discuss the free volume theory.  
*Bincangkan teori isipadu bebas.*

(40 marks/markah)

- [b] A new linear amorphous polymer has a  $T_g$  of  $+10^\circ\text{C}$ . At  $25^\circ\text{C}$  it has a melt viscosity of  $3.2 \times 10^8$  poises. Calculate its melt viscosity at  $50^\circ\text{C}$ .

*Satu polimer amorfus linear mempunyai  $T_g +10^\circ\text{C}$ . Pada suhu  $25^\circ\text{C}$ , polimer tersebut mempunyai kelikatan leburan sebanyak  $3.2 \times 10^8$  poises. Hitungkan kelikatan leburan bagi polimer itu pada suhu  $50^\circ\text{C}$ .*

(60 marks/markah)

4. [a] Figure 1 displays changes of X-ray diffraction patterns for a certain polymer sample. Discuss what could have caused such changes.

Give example of a polymer processing technique that exploits advantages of that phenomenon.

*Rajah 1 mempamerkan perubahan yang berlaku kepada pola pembelauan sinar-X bagi suatu sampel polimer. Bincangkan apakah punca kepada perubahan tersebut.*

*Berikan satu contoh teknik pemprosesan polimer yang mengeksploit kelebihan fenomena tersebut.*

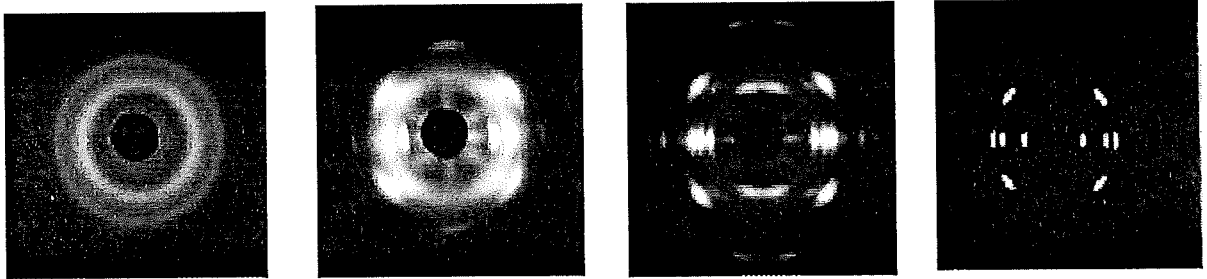


Figure 1: Changes in X-ray diffraction patterns for a polymer sample

*Rajah 1: Perubahan pola pembelauan Sinar-X bagi suatu sampel polimer*

(40 marks/markah)

- [b] One of the important parameters in the degree of crystallinity determination is the density of 100% polymer crystal. The following equation presented a way to calculate volume of a given polymer crystal unit cell.

$$V = abc(1 + 2 \cos \alpha \cdot \cos \beta \cdot \cos \gamma - \cos^2 \alpha - \cos^2 \beta - \cos^2 \gamma)^{1/2}$$

Using the above equation, determine the density of crystals for these polymers;

- (i) Isotactic polystyrene  $[-\text{CH}_2-\text{CHC}_6\text{H}_5-]_n$  has a trigonal unit cell with 18 chemical repeat units in the unit cell. Given that the unit cell has these dimensions;

$$a = 2.19 \text{ nm}, b = 2.19 \text{ nm}, c = 0.665 \text{ nm and } \alpha = \beta = 90^\circ, \gamma = 120^\circ$$

*Salah satu parameter penting dalam penentuan derajat keterhabluran ialah ketumpatan hablur polimer 100%. Persamaan berikut memberikan cara untuk mengira isipadu suatu sel unit hablur polimer.*

$$V = abc(1 + 2 \cos \alpha \cdot \cos \beta \cdot \cos \gamma - \cos^2 \alpha - \cos^2 \beta - \cos^2 \gamma)^{1/2}$$

*Menggunakan persamaan di atas, tentukan ketumpatan hablur-hablur polimer berikut;*

- (i) *Polistirena isotaktik  $[-\text{CH}_2-\text{CHC}_6\text{H}_5-]_n$  mempunyai sel unit trigonal dengan 18 unit ulangan kimia dalam sel unit tersebut. Diberi bahawa sel unit itu mempunyai dimensi-dimensi berikut;*

$$a = 2.19 \text{ nm}, b = 2.19 \text{ nm}, c = 0.665 \text{ nm dan } \alpha = \beta = 90^\circ, \gamma = 120^\circ$$

(30 marks/markah)

- (ii) Poly(vinyl alcohol)  $[-CH_2-CHC_6OH_5-]_n$  has a monoclinic unit cell of dimensions;  $a = 0.551 \text{ nm}$ ,  $b = 0.781 \text{ nm}$ , and  $c = 0.251 \text{ nm}$  with two chemical repeat units per unit cell. The angle  $\beta$  is  $91.7^\circ$  and all the other angles are  $90^\circ$ .

Also given are:

- Relative atomic mass of hydrogen, carbon and oxygen;  
 $H = 1$                        $C = 12$                        $O = 16$
- Avogadro number,  $N_A = 6.023 \times 10^{23} \text{ mol}^{-1}$

*Poli(vinil alkohol)  $[-CH_2-CHC_6OH_5-]_n$  mempunyai sel unit monoklinik dengan dimensi-dimensi;  $a = 0.551 \text{ nm}$ ,  $b = 0.781 \text{ nm}$ , and  $c = 0.251 \text{ nm}$  dengan dua unit ulangan kimia per sel unit. Sudut  $\beta$  adalah  $91.7^\circ$  dan sudut-sudut lain adalah  $90^\circ$ .*

*Juga diberi:*

- *Jisim atom relatif bagi hidrogen, karbon dan oksigen;*  
 $H = 1$                        $C = 12$                        $O = 16$
- *Nombor Avogadro,  $N_A = 6.023 \times 10^{23} \text{ mol}^{-1}$*

(30 marks/markah)

5. [a] Discuss four (4) factors that will affect degree of crystallinity for a polymer.

*Bincangkan empat (4) faktor yang akan mempengaruhi darjah keterhabluran bagi suatu polimer.*

(40 marks/markah)

- [b] Two polypropylene (PP) samples from the same grade were analysed using Differential Scanning Calorimetry (DSC) technique. It was found that 11.300 mg of the PP granule gave a melting enthalpy, ( $\Delta H_m$ ), of 0.7845 Joule. Whereas, another PP sample, which has gone through an extrusion process yielded a melting enthalpy, ( $\Delta H_m$ ) of 0.9835 Joule for 12.700 mg sample. Given that melting enthalpy of a 100% PP crystal, ( $\Delta H_m^\circ$ ) is 207.1 Joule/g, calculate the degree of crystallinity of both PP samples.

Why there is a difference of melting enthalpy between these samples?

*Dua sampel polipropilena (PP) dari gred yang sama menjalani ujian Kalorimetri Imbasan Pembezaan (Differential Scanning Calorimetry – DSC). Didapati 11.300 mg granul PP memberikan entalpi peleburan, ( $\Delta H_m$ ) sebanyak 0.7845 Joule. Manakala, satu lagi sampel PP yang telah mengalami proses pengekstrudan memberikan entalpi peleburan, ( $\Delta H_m$ ) sebanyak 0.9835 Joule bagi 12.700 mg sampel. Berbantuan maklumat entalpi peleburan untuk 100% hablur PP, ( $\Delta H_m^\circ$ ) ialah 207.1 Joule/g, kirakan darjah keterhabluran bagi kedua-dua sampel PP tersebut.*

*Mengapakah terdapat perbezaan entalpi peleburan di antara sampel-sampel PP itu?*

(60 marks/markah)

6. [a] What do you understand about spherulite? State the differences between homogenous and heterogenous crystallization process.

*Apakah yang anda faham mengenai sferulit? Nyatakan perbezaan penukleusan homogenus dan penukleusan heterogenus.*

(30 marks/markah)

- [b] Elaborate the method used in studying polymer crystallization using an optical microscope. Discuss the effect of temperature on the crystallization rate.

*Huraikan kaedah eksperimen yang digunakan dalam mengkaji penghabluran polimer menggunakan suatu mikroskop optik. Bincangkan kesan suhu ke atas kadar penghabluran.*

(50 marks/markah)

- [c] Discuss one (1) type of activity or process that can produce molecular orientation and its importance in polymer studies.

*Bincangkan satu (1) jenis aktiviti atau proses yang mampu menghasilkan orientasi molekul dan kepentingannya dalam kajian polimer.*

(20 marks/markah)



7. [a] Two polymer samples, one is thermoplastic and the other is thermoset, need to be prepared using surface replication technique for Transmission Electron Microscopy (TEM). Describe the difference in sample preparation technique for each sample and state the purpose of conducting such technique.

*Dua sampel polimer, satu adalah termoplastik dan satu lagi termoset, perlu disediakan menggunakan teknik peniruan permukaan bagi Mikroskopi Tranmisi Elektron (TEM). Jelaskan perbezaan dalam teknik penyediaan sampel bagi setiap sampel dan nyatakan tujuan teknik tersebut dijalankan.*

(50 marks/markah)

- [b] Dynamic Mechanical Analyzer (DMA) was used to determine glass transition temperature ( $T_g$ ) of poly(lactic acid). Assume that the  $T_g = 65^\circ\text{C}$  and  $T_m = 160^\circ\text{C}$ . Plot a suitable graph to show how to determine the  $T_g$  of poly(lactic acid).

*Penganalisa mekanikal dinamik telah digunakan untuk menentukan suhu peralihan kaca ( $T_g$ ) bagi poli(asid laktik). Anggapkan  $T_g = 65^\circ\text{C}$  dan  $T_m = 160^\circ\text{C}$ . Lakarkan satu graf yang sesuai untuk menunjukkan bagaimana menentukan  $T_g$  bagi poli(asid laktik).*

(50 marks/markah)