
UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014 / January 2015

EBP 202/3 – Polymer Structure [Struktur Polimer]

Duration : 3 hours
[Masa : 3 jam]

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. ONE question in PART A, THREE questions in PART B and THREE questions in PART C.

[Kertas soalan ini mengandungi TUJUH soalan. SATU soalan di BAHAGIAN A, TIGA soalan di BAHAGIAN B dan TIGA soalan di BAHAGIAN C.]

Instruction: Answer FIVE questions. Answer ALL questions from PART A, TWO questions from PART B and TWO questions from PART C. 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. Jawab SEMUA soalan dari BAHAGIAN A, DUA soalan dari BAHAGIAN B dan DUA soalan dari BAHAGIAN C. 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.]

PART A / BAHAGIAN A

1. [a] Discuss the configuration of polymers.

Bincangkan konfigurasi bagi polimer.

(35 marks/markah)

- [b] Draw the following configuration of polystyrene in zig-zag planar.

- (i) isotactic
- (ii) atactic
- (iii) syndiotactic

Lukiskan konfigurasi bagi polistirena dalam satah zig-zag seperti yang berikut:

- (i) isotaktik
- (ii) ataktik
- (iii) sindiotaktik

(15 marks/markah)

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

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

(25 marks/markah)

- [d] State three (3) factors that can affect degree of crystallinity and its relationship with molecular orientation.

Nyatakan tiga (3) faktor yang boleh mempengaruhi darjah kehabluran dan hubungannya dengan orientasi molekul.

(25 marks/markah)

PART B / BAHAGIAN B

2. [a] You are given a task to measure density of a polymer sample using a pycnometer bottle. Explain the basic principle of your measurement and also describe in detail the methodology of your experiment.

Anda diberikan satu tugas untuk mengukur ketumpatan suatu sampel polimer menggunakan botol piknometer. Terangkan prinsip asas kaedah pengukuran anda dan jelaskan secara terperinci kaedah eksperimen anda.

(40 marks/markah)

- [b] Two polyethylene samples were produced using two different processing techniques. One was prepared using compression moulding and the other was moulded using an injection moulding. The following are their respective densities:

$$\text{Compression moulded} \quad \rightarrow \quad \rho_{\text{comp}} = 0.90 \text{ g/cm}^3$$

$$\text{Injection moulded} \quad \rightarrow \quad \rho_{\text{inj}} = 0.96 \text{ g/cm}^3$$

Given;

- Polyethylene form an orthorombic crystal having the following unit cell dimension:

$$a = 0.742 \text{ nm}$$

$$b = 0.494 \text{ nm}$$

$$c = 0.255 \text{ nm}$$

- Specific volume for an amorphous polyethylene, v_a , is $1.18 \times 10^{-3} \text{ m}^3/\text{kg}$
- Relative atomic mass of hydrogen and carbon are: H = 1 C = 12
- No. of repeat unit per unit cell = 2
- Avogadro number, N_A , = $6.023 \times 10^{23} \text{ mol}^{-1}$

Using the above given information, determine the degree of crystallinity for both samples.

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Dua sampel polietilena dihasilkan menggunakan dua teknik pemrosesan yang berbeza. Satu daripada sampel tersebut telah disediakan menggunakan pengacuanan mampatan dan satu lagi diacukan menggunakan pengacuanan suntikan. Berikut adalah ketumpatan bagi setiap sampel:

$$\text{Pengacuanan mampatan} \quad \rightarrow \quad \rho_{\text{comp}} = 0.90 \text{ g/cm}^3$$

$$\text{Pengacuanan suntikan} \quad \rightarrow \quad \rho_{\text{inj}} = 0.96 \text{ g/cm}^3$$

Diberi,

- Polietilena membentuk hablur ortorombik yang mempunyai dimensi sel unit seperti berikut:

$$a = 0.742 \text{ nm}$$

$$b = 0.494 \text{ nm}$$

$$c = 0.255 \text{ nm}$$

- Isipadu spesifik bagi polietilena yang amorfus, v_a , ialah $1.18 \times 10^{-3} \text{ m}^3/\text{kg}$
- Jisim atom relatif bagi hidrogen dan karbon ialah: $H = 1$ $C = 12$
- Bilangan unit ulangan per sel unit = 2
- Nombor Avogadro, N_A , = $6.023 \times 10^{23} \text{ mol}^{-1}$

Menggunakan maklumat yang diberikan di atas, tentukan darjah kehabluran kedua-dua sampel tersebut.

(60 marks/markah)

3. [a] Polymer single crystals are polymer crystals that are derived from solution. What do you called polymer crystals that are derived from polymer melts? Describe the similarity and difference of both polymer crystals.

Hablur tunggal polimer ialah hablur polimer yang diterbitkan daripada larutan. Apakah nama yang anda berikan kepada hablur polimer yang diterbitkan daripada leburan polimer? Jelaskan persamaan dan perbezaan kedua-dua hablur polimer tersebut.

(40 marks/markah)

- [b] In describing mechanisms of organised macromolecules' packing in a small molecular space such found in polymer single crystals, chain folding models have been proposed. Elaborate the features of these models with the assistance of suitable diagrams.

Bagi menerangkan mekanisme penyusunan rapi makromolekul dalam ruangan molekul yang kecil seperti yang ditemui dalam hablur tunggal polimer, model-model Lipatan Rantai telah dicadangkan. Huraikan ciri-ciri model-model tersebut dengan bantuan rajah yang sesuai.

(60 marks/markah)

4. [a] Consider the following statements;

“Degree of crystallinity of a semi-crystalline polymer is dependent of interchain bonding”

“The melting of a semi-crystalline polymer is related to the destruction of crystallite region”

Using polyamide as an example, discuss the relevance of both statements. Support your answer with suitable diagrams.

Pertimbangkan kenyataan-kenyataan berikut;

“Darjah kehabluran suatu polimer separa-hablur adalah bergantung kepada ikatan antara-rantai”

“Peleburan suatu polimer separa-hablur boleh dikaitkan dengan pemusnahan kawasan berhablur”

Dengan menggunakan poliamida sebagai contoh, bincangkan kewajaran kenyataan-kenyataan tersebut. Sokong jawapan anda dengan rajah-rajah bersesuaian.

(50 marks/markah)

- [b] When Differential Scanning Calorimetry (DSC) tests were conducted on two samples of polyethylene terephthalate (PET), these results were obtained. PET virgin sample (pellet) weighing 13.400 mg gave a melting enthalpy, ΔH_m of 0.3385 Joule whereas another PET sample (weighing 12.400 mg), which has gone through an injection moulding process recorded a melting enthalpy, ΔH_m of 0.3895 Joule.

With the knowledge of melting enthalpy of a 100% PET crystal, ΔH_m° is 106 Joule/g, calculate the degree of crystallinity of both PET samples. Why there is a difference of melting enthalpy between these samples?

Apabila suatu ujian Kalorimetri Penskanan Pembezaan dijalankan ke atas dua sampel polietilena tereftalat (PET), keputusan berikut diperolehi. Sampel asal (pelet) PET seberat 13.400 mg memberikan entalpi peleburan, $\Delta H_m = 0.3385$ Joule manakala sampel PET yang telah mengalami proses pengacuanan suntikan (seberat 12.400 mg) merekodkan entalpi peleburan $\Delta H_m = 0.3895$ Joule.

Berbantuan maklumat entalpi peleburan untuk 100% hablur PET, ($\Delta H_m^\circ = 106$ Joule/g), kirakan darjah kehabluran bagi kedua-dua sampel PET tersebut. Mengapakah terdapat perbezaan entalpi peleburan di antara dua sampel PET itu?

(50 marks/markah)

PART C / BAHAGIAN C

5. [a] A linear amorphous polymer has a T_g of $+15^\circ\text{C}$. At 25°C , it has a melt viscosity of 3×10^8 poise. What is the difference between its melt viscosity at 60°C and 80°C ?

Satu polimer amorfus linear mempunyai T_g bernilai $+15^\circ\text{C}$. Pada suhu 25°C , polimer tersebut mempunyai kelikatan leburan sebanyak 3×10^8 poise. Apakah perbezaan kelikatan leburan bagi polimer itu pada suhu 60°C dan 80°C ?

(70 marks/markah)

- [b] Discuss on free volume theory.

Bincangkan teori isipadu bebas.

(30 marks/markah)

6. [a] A linear polyethylene has average molecular weight of 9×10^5 g/mol. Given that the bond length of C-C and bond angle is 0.154 nm and 109.5° respectively. Calculate the following:
- (i) contour length
 - (ii) root mean square (RMS) end-to-end distance according to valence angle model
 - (iii) root mean square (RMS) end-to-end distance according to freely jointed chain model

Satu polietilena linear mempunyai berat molekul purata 9×10^5 g/mol. Diberikan panjang ikatan C-C dan sudut ikatan masing-masing ialah 0.154 nm dan 109.5° . Hitungkan yang berikut:

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

(70 marks/markah)

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- [b] Discuss the effects of long-range steric interactions on the polymer chain dimensions.

Bincangkan kesan interaksi sterik berjarak jauh terhadap dimensi rantai polimer.

(30 marks/markah)

7. [a] Discuss the five regions of viscoelastic behavior of polystyrene based on a log storage modulus (E')-temperature (T) plot.

Bincangkan lima kawasan kelakuan kelikatkenyalan bagi polistirena berdasarkan satu plot log modulus simpanan (E')-suhu (T).

(60 marks/markah)

- [b] Differential scanning calorimetry (DSC) test was performed on a polymer sample. The experiments are carried out in the temperature range 30-150°C.

- (i) Show how to determine glass transition temperature (T_g) and melting temperature (T_m) from the DSC curve. Assume that $T_g = 45^\circ\text{C}$ and $T_m = 100^\circ\text{C}$.
- (ii) Suggest another technique to measure T_g of the polymer sample.

Ujian kalorimeter penskanan pembezaan (DSC) telah dilakukan ke atas satu sampel polimer. Eksperimen tersebut dijalankan dalam julat suhu 30-150°C.

- (i) *Tunjukkan bagaimana penentuan suhu peralihan kaca dan suhu peleburan berdasarkan graf DSC. Anggapkan $T_g = 45^\circ\text{C}$ dan $T_m = 100^\circ\text{C}$.*
- (ii) *Cadangkan suatu teknik lain yang dapat mengukur T_g bagi sampel polimer itu.*

(40 marks/markah)