UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2011/2012

January 2012

EBP 202/3 – Polymer Structure
[Struktur Polimer]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains TEN printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH 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, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

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PART A / *BAHAGIAN A*

1. [a] For a linear molecule of polyethylene with molecular weight of 2.4×10^5, calculate the following:

(i) Contour length

(ii) RMS end-to-end distance according to freely jointed chain model

(iii) RMS end-to-end distance if the restriction of the bond angle is taken into consideration. Assume that the bonds rotate freely at the given bond angle

Given that:

Length of each bond = 0.154 nm

Bond angle = 109.5^o

Bagi suatu molekul polietilena dengan berat molekul 2.4×10^5, hitungkan:

(i) Panjang kontur

(ii) Punca purata kuasa-dua jarak hujung-ke-hujung berdasarkan model rantai bersambung bebas

(iii) Punca purata kuasa-dua jarak hujung-ke-hujung sekiranya kekangan sudut ikatan diambil kira dalam pertimbangan. Anggapkan bahawa ikatan-ikatan berputar secara bebas pada sudut ikatan yang diberikan.

Diberikan:

Panjang ikatan = 0.154 nm

Sudut ikatan = 109.5^o

(40 marks/*markah*)

[b] Comment values obtained from 1[a], indicating which one is more realistic estimation of polymer chain dimensions.

Berikan komen bagi nilai yang diperolehi dari 1[a], serta tunjukkan nilai yang mana satu nilai dapat memberikan anggaran dimensi rantai polimer yang lebih realistik.

(10 marks/*markah*)

[c] Both spherulite and polymer single crystals are entities that describe the presence of crystallite region in some polymeric materials. State the major difference in their creation and describe the morphology of both entities.

Kedua-dua sferulit dan hablur tunggal polimer merupakan entiti yang menjelaskan kewujudan kawasan berhablur dalam sesetengah polimer. Nyatakan perbezaan utama dalam penghasilan entiti-entiti tersebut dan jelaskan morfologi yang terhasil dari kedua-duanya.

(50 marks/*markah*)

PART B / *BAHAGIAN B*

2. [a] A sample of polystyrene is composed of the following molecular weight distribution.

Satu sampel polistirena mempunyai taburan berat molekul seperti berikut.

Table 1 : Molecular weight distribution for a polystyrene sample

Jadual 1 : Taburan berat molekul bagi satu sampel polistirena

Weight fraction, w_i *Pecahan berat, w_i*	0.06	0.21	0.30	0.24	0.12	0.05
Mean molecular weight, $M_i \times 10^{-3}$ *Berat molekul purata, $M_i \times 10^{-3}$*	6	11	14	20	30	37

Calculate the number-average molar mass, weight-average molar mass and polydispersity index for the polystyrene sample.

Kirakan jisim molar purata-nombor, jisim molar purata-berat dan indeks polidispersiti bagi sampel polistirena tersebut.

(50 marks/*markah*)

[b] Draw the following configuration for poly(vinyl alcohol):

(i) Syndiotactic

(ii) Atactic

Lukiskan konfigurasi bagi poli(vinil alkohol):

(i) Sindiotaktik

(ii) Ataktik

(10 marks/*markah*)

[c] Differentiate between thermoplastic and thermoset polymer.

(i) Give **TWO** examples and their representative chemical structure for thermoplastic

(ii) Give **TWO** examples and their representative chemical structure for thermoset

Bezakan antara polimer termoplastik dan termoset.

*(i) Berikan **DUA** contoh dan perwakilan struktur kimia bagi termoplastik*

*(ii) Berikan **DUA** contoh dan perwakilan struktur kimia bagi termoset*

(40 marks/*markah*)

3. [a] A linear amorphous polymer has a T_g of +20°C. At 30°C, it has a viscosity of 9 x 10^7 Poise. Determine the difference between its viscosity at 60°C and 70°C.

Suatu polimer amorfus linear mempunyai T_g of +20°C. Pada suhu 30°C, polimer tersebut mempunyai kelikatan bernilai 9 x 10^7 Poise. Tentukan perbezaan kelikatan bagi polimer tersebut antara suhu 60°C dan 70°C.

(60 marks/*markah*)

[b] A poly(vinyl chloride) sampel has a glass transition of 70°C. Proposed suitable approaches when;

(i) The T_g need to be increased.

(ii) The T_g need to be decreased.

Satu sampel poli(vinil klorida) mempunyai suhu peralihan kaca bernilai 70°C. Cadangkan pendekatan yang sesuai apabila;

(i) Nilai T_g perlu ditingkatkan.

(ii) Nilai T_g perlu diturunkan.

(40 marks/*markah*)

4. [a] You are given **three** different types of polymers, i.e. polystyrene, polypropylene and crosslinked epoxy resin. Sketch plots of log elastic modulus versus temperature for all these polymers.

Also, with the aid of the constructed plot, explain changes of log elastic modulus with temperature for polystyrene in terms of its viscoelastic behaviour.

*Anda diberikan **tiga** jenis polimer yang berbeza, iaitu polistirena, polipropilena dan resin epoxy tersambung-silang. Lakarkan plot-plot log modulus elastik melawan suhu bagi kesemua polimer-polimer tersebut.*

Juga, dengan bantuan plot yang telah dibina, terangkan perubahan log modulus elastik dengan suhu bagi polistirena dari segi sifat kelikatkenyalannya.

(50 marks/*markah*)

[b] Explain the differences in glass transition temperatures for the following polymers:

(i) poly(ethylene oxide) and poly(vinyl alcohol)

(ii) poly(methyl methacrylate) and poly(ethyl methacrylate)

Terangkan perbezaan suhu-suhu peralihan kaca bagi polimer-polimer berikut:

(i) poli(etilena oksida) dan poli(vinil alkohol)

(ii) poli(metil metakrilat) dan poli(etil metakrilat)

(30 marks/*markah*)

[c] Discuss the Free Volume Theory and its use in explaining glass transition phenomenon for polymers.

Bincangkan Teori Isipadu Bebas dan kegunaannya dalam menerangkan fenomena peralihan kaca bagi polimer.

(20 marks/*markah*)

PART C / *BAHAGIAN C*

5. [a] With the assitance of data given below, determine degree of crystallinty of Low density polyethylene (LDPE), linear low density polyethylene (LLDPE) and high density polyethylene (HDPE).

Given;

Density of polyethylene crystal	= 1000 kg/m^3
Specific volume of amorphous polyethylene	= 1.16 x 10^{-3} m^3/kg
Density of LDPE	= 920 kg/m^3
Density of LLDPE	= 940 kg/m^3
Density of HDPE	= 960 kg/m^3

Berpandukan data yang diberikan di bawah, tentukan nilai darjah keterhabluran bagi polietilena ketumpatan rendah (LDPE), polietilena linear ketumpatan rendah (LLDPE) dan polietilena ketumpatan tinggi (HDPE).

Diberi;

Ketumpatan polietilena berhablur	*= 1000 kg/m^3*
Isipadu spesifik polietilena amorfus	*= 1.16 x 10^{-3} m^3/kg*
Ketumpatan LDPE	*= 920 kg/m^3*
Ketumpatan LLDPE	*= 940 kg/m^3*
Ketumpatan HDPE	*= 960 kg/m^3*

(30 marks/*markah*)

[b] Explain why there are differences in degree of crystallinity for LDPE, LLDPE and HDPE although they came from the same polymer group.

Terangkan mengapa wujud perbezaan darjah keterhabluran bagi LDPE, LLDPE dan HDPE walaupun ketiga-tiga polimer tersebut berasal daripada kumpulan polimer yang sama.

(40 marks/*markah*)

[c] Describe another method that can be used to determine the degree of crystallinity of a polymer.

Terangkan satu kaedah lain yang boleh digunakan untuk menentukan darjah keterhabluran suatu polimer.

(30 marks/*markah*)

6. [a] Discuss how X-ray can be used to determine polymer crystal structure, giving emphasis on the derivation of the Bragg's equation.

Bincangkan bagaimana sinar-X boleh digunakan untuk menentukan struktur hablur polimer, dengan memberikan penekanan kepada penerbitan persamaan Bragg.

(40 marks/*markah*)

[b] Flat film X-ray diffraction patterns obtained using CuKα beam (Ni filter) for an isotropic polyethylene yielded 3 sharp rings with each having radius of 19.7, 22.2 and 36.6 nm respectively. With the assumption that molecular chain arrangement of polyethylene as orthorombic (i.e. $\alpha = \beta = \gamma = 90^o$);

(i) Calculate the spacing of molecule planes distance, d, that produce the diffraction patterns.

(ii) Show that the diffraction rings produced by by these planes; (1 1 0), (2 0 0) and (3 0 0).

(iii) If the polyethylene sample is subjected to extension, what kind of diffraction pattern would you expect?

Given;

- Specimen distance from film = 5.0 cm
- X-ray wavelength = 0.154 nm
- Unit cell dimension and d_{hkl} for polyethylene is:

a = 0.742 nm b = 0.494 nm c = 0.255 nm

$$d_{hkl} = \left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2} \right)^{-\frac{1}{2}}$$

Satu pola pembelauan sinar-X filem rata diperolehi menggunakan alur cahaya CuKα (penapis Ni) bagi suatu polietilena isotropik yang menghasilkan 3 gelang cahaya berkeamatan tinggi dengan jejari masing-masing berukuran 19.7, 22.2 dan 36.6 nm. Dengan anggapan bahawa penyusunan molekul polietilena adalah secara ortorombik (i.e. $\alpha = \beta = \gamma = 90^o$);

(i) *Kirakan jarak pemisahan satah molekul, d, yang menghasilkan pola pembelauan tersebut.*

(ii) *Tunjukkan bahawa gelang pembelauan dihasilkan oleh satah-satah berikut; (1 1 0), (2 0 0) dan (3 0 0).*

(iii) *Sekiranya sampel polietilena tersebut diregangkan, apakah jenis pola pembelauan yang anda jangkakan akan terhasil?*

Diberi,

- *Jarak spesimen dari filem = 5.0 cm*
- *Jarak gelombang sinar-X = 0.154 nm*
- *Dimensi sel unit dan d_{hkl} bagi polietilena ialah:*

a = 0.742 nm *b = 0.494 nm* *c = 0.255 nm*

$$d_{hkl} = \left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2} \right)^{-\frac{1}{2}}$$

(60 marks/*markah*)

7. [a] Discuss procedures that can produce molecular orientation in polymers and its importance in polymer studies.

Bincangkan kaedah-kaedah yang mampu menghasilkan orientasi molekul dalam polimer dan kepentingannya dalam kajian polimer.

(25 marks/*markah*)

[b] State factors that can affect degree of crystallinity and its relationship with molecular orientation.

Nyatakan faktor-faktor yang boleh mempengaruhi darjah keterhabluran dan hubungannya dengan orientasi molekul.

(25 marks/*markah*)

[c] Describe experimental procedure for polymer crystallisation study using polarized optical microscope.

Perihalkan kaedah eksperimen bagi kajian penghabluran polimer menggunakan mikroskop optik terpolar.

(50 marks/*markah*)

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