PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Final Examination : Semester I | Academic Year : 2007

Date : 9 October 2007 | Time : 09.00 – 12.00

Subject : 230 - 463 Polymer Technology | Room : A401

Student Name: ..... ID no. : .....

Number of questions : 4

Time : 3 hours

Total marks : 145

Notes are not allowed.

Calculators are allowed.

Two graph papers are provided.

Writing in pencil is allowed.

Question	Full Marks	Marks Received
1	30	
2	60	
3	25	
4	30	
Total	145	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

Student Name: ..... ID no. : .....

1. a) Describe the process for production of polymethyl methacrylate by suspension polymerization systems. Provide details on characteristics of each component in the reaction mixture.

(5 marks)

b) Plasticizers are added to polymers as additive. Explain their functions and the factors considered in choosing a suitable type of plasticizer. Give the names for one pair of a polymer and a plasticizer.

(5 marks)

c) Give the reasons for the differences in transition temperatures for the following pairs of polymers.

c.1) T_g for polyethylene and polydimethyl siloxane.

c.2) T_m for polypropylene and polyvinyl chloride.

c.3) T_m for polypropylene and polystyrene.

c.4) T_m for nylon 6,6 and nylon 6,10

c.5) T_g for low density polyethylene and high density polyethylene.

(10 marks)

d) Spherulites are formed by crystallization during cooling of polymer melts. Sketch a plot of radial growth rate with temperature for a polymer. Explain the effects of increasing molecular weight on the tendency of a polymer to crystallize.

(5 marks)

e) Explain one method for determination of T_g.

(5 marks)

Student Name: ..... ID no. : .....

2. a) The membrane osmotic pressure data for polyisobutylene in chlorobenzene solvent at 25°C is shown below. Estimate number-average molecular weight, $\overline{M}_n$ of the polymer sample.

Starting concentration, c (g/l)	π , cm.chlorobenzene
5.0	2.50
10.0	10.00
15.0	24.00
20.0	55.00
25.0	105.00
27.5	150.00

Note : at 25°C, density of water = 1.00 g/cc,

density of chlorobenzene = 1.100 g/cc

R = 0.08205 (l.atm)/(mole.K), 1 atm = 1,033 cm.H_2O

$$\left[\frac{\pi}{c}\right] = \frac{RT}{\overline{M}_n} + Bc$$ where B = constant

$$\left[\frac{\pi}{c}\right]_{c=o} = \frac{RT}{\overline{M}_n}$$

$$\left[\frac{\pi}{c}\right]^{\frac{1}{2}} = \left(\frac{RT}{\overline{M}_n}\right)^{\frac{1}{2}}\left(1 + \frac{A_2}{2}\overline{M}_n c\right)$$ where A_2 = constant

$$\left[\frac{\pi}{c}\right]^{\frac{1}{2}}_{c=o} = \left(\frac{RT}{\overline{M}_n}\right)^{\frac{1}{2}}$$

π = osmotic pressure, T = absolute temperature

(15 marks)

Student Name: ..... ID no. : .....63.

b) A sample of a polystyrene analyzed by the gel permeation chromatography method provided the following data:

Mol Wt. Range (g/mol)	wt fraction w_i
5,000-10,000	0.02
10,000-15,000	0.10
15,000-20000	0.18
20,000-25,000	0.29
25,000-30,000	0.26
30,000-35,000	0.13
35,000-40,000	0.02

Calculate the weight-average molecular weight $\overline{M}_w$ and the number-average molecular weight $\overline{M}_n$. Sketch a distribution curve (weight fraction versus molecular weight) . Calculate the polydispersity index.

Note: N_A = Avogadro number

$$N_i = \left\{\frac{w_i}{M_i}\right\} x\, N_A$$

$$N_i M_i = w_i N_A$$

$$\overline{M}_n = \frac{\sum_i N_i M_i}{\sum_i N_i}$$

$$\overline{M}_w = \frac{\sum_i C_i M_i}{\sum_i C_i} = \sum_i w_i M_i = \frac{\sum_i N_i M_i^2}{\sum_i N_i M_i}$$

(15 marks)

Student Name: ..... ID no. : .....

c) In your own words, briefly describe the viscoelastic behaviour of an amorphous polymer.

(5 marks)

d) From the relaxation modulus vs. time at different temperatures for polymethyl methacrylate shown below if it is required to construct a master curve at 115°C, calculate log a_T for shifting from the curve at 112°C at time 1 hour to 115°C by using the WLF equation. Calculate the new time and compare it with the value from the graph. Comment on the limitation of this principle.

Note: $$\log a_T = \frac{-C_1 (T - T_0)}{C_2 + (T - T_0)} = \log \frac{t}{t_o}$$

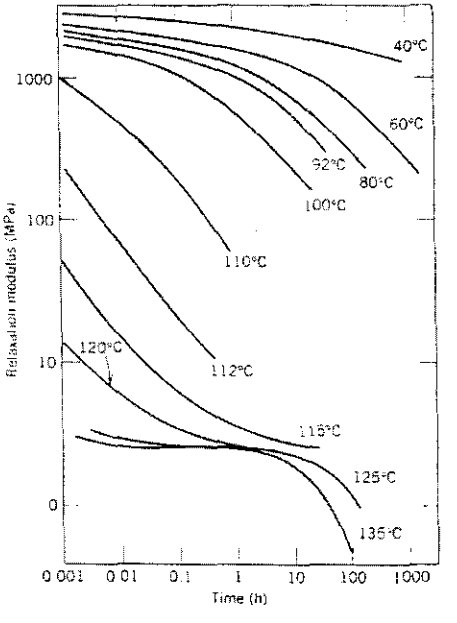
where C_1 = 17.44 (dimensionless) and C_2 = 51.6 K

T and T_o = original and reference temperatures respectively

t and t_o = original and reference times respectively

a_T = shift factor

(10 marks)



Relaxation modulus versus Time for PMMA

Student Name: ..... ID no. : .....

e) Explain one mechanical model that can explain the stress relaxation behaviour of real polymer. Write initial equations for total stress and total strain for such model. Explain the occurrence of stress relaxation in terms of molecular movement.

(10 marks)

f) Sketch storage modulus vs temperature for two same crystalline polymers, one with high degree of crystallinity and another with low degree of crystallinity. Suggest the type of experiment that can be used to obtain this plot.

(5 marks)

Answers to Question 2

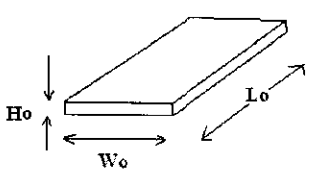
Student Name: ..... ID no. : .....

3. In the extrusion process for polypropylene pipe, the extruder screw geometry is as follows: axial flight land width 2.4 mm, channel depth 4 mm, screw diameter 150 mm, flight helix angle 17° and screw length 3000 mm. The screw speed is 150 rev/min, and the pressure varies linearly over the screw length from the hopper to the die. The leakage flow is negligible.

A rectangular die with dimensions W_0 = 20 mm, L_0 = 25 mm. and H_0 = 2 mm. is fixed to the end of the extruder. The screw metering zone and the annular die temperatures are at 250°C and the melt viscosity and density at this temperature are 1100 Ns/m^2 and 1200 kg/m^3 respectively. Calculate the extruder output and die output in kg/h at pressures 20, 100, 250 and 350 MN/m^2. Plot the characteristic curves for screw and die where Q and P are in kg/h and MN/m^2 respectively. Read the operating point on the graph. (N is Newton, MN is mega Newton or 10^6 N)

For rectangular die, the die output is given by

$$Q_d = \frac{W_0 H_0^3}{12 L_0} \bullet \frac{\Delta P_d}{\eta}$$



Rectangular Die Orifice

Student Name: ..... ID no. : .....

Note:

Output = drag flow + pressure flow + leakage flow

output $Q = Q_D + Q_P + Q_L$

(โดย Q_P และ Q_L มีค่าเป็นลบ มีทิศทางสวนทางกับ Q_D)

drag flow $Q_D = \frac{1}{2}\pi^2 D^2 NH \sin\theta \cos\theta$

pressure flow $Q_P = -\frac{\pi DH^3 \sin^2\theta}{12\eta}\frac{dP}{dl}$

leakage flow $Q_L = -\frac{\pi^2 D^2 c^3}{12\eta e}\tan\theta\frac{dP}{dl}$

N = screw speed, rpm

θ = มุมเกลียว, helix angle

δ หรือ C = ช่องว่างระหว่าง screw กับ barrel ตามแนวรัศมี (radial screw clearance)

e = ความกว้างของ screw land ตามแนวแกน (axial flight land width)

H = ความลึกของฟันเกลียว (flight depth)

D = diameter ภายในของ barrel

η = viscosity ของ polymer melt

s = flight pitch, ระยะฟันเกลียว

(25 marks)

Student Name: ..... ID no. : .....

4. a) Describe the film blowing process for production of LDPE bags.

(5 marks)

b) Give general specifications for an injection moulding machine.

(5 marks)

c) An injection mould has 6 cavities of cups with 2–inch diameter for each cup. The polymer requires moulding pressure of 2 ton force/in^2. Estimate the minimum clamping force of the injection machine.

(5 marks)

d) Ice-cream cups can be made by thermoforming process. Suggest the type of polymer used, processing steps and temperature settings. Assume that the polymer used has T_g and T_m about 100 ^{o}C and 240 ^{o}C, respectively.

(5 marks)

e) Give density values for LDPE and HDPE in g/cm^3. Compare density, clarity and flexibility of the product made from the two polymers.

(2 marks)

f) Give two outstanding properties for polymethyl methacrylate, PMMA. Suggest one type of product made from this polymer.

(2 marks)

g) Polystyrene can be formed into cups by thermoforming process. Comment on the shape and thickness of the product.

(2 marks)

h) Give three forms of polyurethane products and one application for each form of polyurethane.

(2 marks)

i) Melamine can be formed into tableware such as bowls. Comment on safety aspects of this polymer. (2 marks)

_____ End of Question