UNIVERSITY OF GHANA

BSc. (ENG) MATERIALS SCIENCE AND ENGINEERING

END OF SECOND SEMESTER EXAMINATIONS: 2015/2016

SCHOOL OF ENGINEERING SCIENCES

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 332: PHYSICAL PROPERTIES OF POLYMERS (2 CREDITS)

TIME ALLOWED: TWO (2) HOURS

Answer ALL Questions

Question 1

a) Which of the following provides an absolute measure of the molecular weight of polymers: (i) viscometry, (ii) cryometry, (iii) osmometry, (iv) light-scattering photometry, (v) Gel permeation chromatography?

b) The following table lists molecular weight data for a polypropylene material. Compute

(i) the number-average molecular weight ($\overline{M_n}$),

(ii) the weight-average molecular weight ($\overline{M_w}$), and

(iii) the degree of polymerization.

Table 1

Molecular Weight Range (g/mol)	x_i	w_i
8,000–16,000	0.05	0.02
16,000–24,000	0.16	0.10
24,000–32,000	0.24	0.20
32,000–40,000	0.28	0.30
40,000–48,000	0.20	0.27
48,000–56,000	0.07	0.11

c) Sketch cis and trans structures for

(i) butadiene, and

(ii) chloroprene.

d) If the density of a polymer is 0.85 g/cc and the molar volume is 1,176,470 cc, what is the molecular weight?

Hint: Atomic masses: C=12, H=1

$$\overline{M_n} = \sum x_i M_i \qquad \text{Equation 1}$$

$$\overline{M_w} = \sum w_i M_i \qquad \text{Equation 2}$$

x_i is the fraction of the total number of molecular chains that lie within the size range i

w_i is the weight fraction of molecules that lie within the size range i

M_i is the mean molecular weight within the size range i

25 Marks

Question 2

a) Define the following:
   (i) Relative viscosity of a polymer solution
   (ii) Specific viscosity of a polymer solution
   (iii) Reduced viscosity of a polymer solution
   (iv) Intrinsic viscosity of a polymer solution

b) If the values of K and a in the Mark–Houwink equation are $1\text{x}10^{-2}$ cm^3/g and 0.5, respectively, what is the average molecular weight (M) of a polymer whose solution has an intrinsic viscosity (LVN) of 150 cc/g?

$$LVN = KM^a \qquad \text{Equation 3 (Mark-Houwink equation)}$$

c) Show that, the relative viscosity of a polymer solution can simply be obtained from a ratio of measured flow times for the polymer solution (t) and solvent (t_o).

d) Write chemical structures for polyethylene, polyproplyene, poly(vinylchloride) and polystyrene.

25 Marks

Question 3

a) Draw a log modulus–temperature plot for an amorphous polymer. What are the five regions of viscoelasticity, and where do they fit? To which regions do the following belong at room temperature: chewing gum, rubber bands, Plexiglas®?

b) The density (ρ) and associated percent crystallinity for two polytetrafluoroethylene materials are as follows:

$\rho (g/cm^3)$	Crystallinity (%)
2.144	51.3
2.215	74.2

(i) Compute the densities of totally crystalline (ρ_c) and totally amorphous (ρ_a) polytetrafluoroethylene.

(ii) Determine the percent crystallinity of a specimen having a density (ρ_s) of 2.26 g/cm^3.

c) Sketch typical stress–strain curves to 600% elongation for unvulcanized and vulcanized natural rubber.

d) Define the terms: Young's modulus, tensile strength, chain entanglements, and glass–rubber transition.

Hint:

$$\%\ crystallinity\ (by\ weight) = \frac{\rho_c(\rho_s-\rho_a)}{\rho_s(\rho_c-\rho_a)} \times 100 \qquad \text{equation 4}$$

25 Marks

Question 4

a) Make comparisons of thermoplastic and thermosetting polymers

(i) on the basis of mechanical characteristics upon heating and

(ii) according to possible molecular structures.

b) Show the synthesis of polyamide 610 from the monomers.

c) With the help of a diagram, briefly explain the effect of molecular weight on the following physical properties of polymers: impact strength, tensile strength and melt viscosity.

d) The permeability coefficient of a type of small gas molecule in a polymer is dependent on absolute temperature according to the following equation:

$$P_M = P_{M_0} exp\left(-\frac{Q_p}{RT}\right) \qquad \text{equation 5}$$

where P_{M_0} and Q_p are constants for a given gas-polymer pair.

Consider the diffusion of hydrogen through a poly(dimethyl siloxane) (PDMSO) sheet 20 mm thick. The hydrogen pressures at the two faces are 10 kPa and 1 kPa, which are maintained constant. Compute the diffusion flux [in (cm^3 STP)/cm^2s] at 350 K.

For this diffusion system:

$P_{M_0} = 1.45x10^{-8}(cm^3STP)(cm)/cm^2.s.Pa$

$Q_p = 13.7\ kJ/mol$

Also, assume a condition of steady state diffusion.

Hint:

$$J(Diffusion\ flux) = -P_M\frac{\Delta P}{\Delta x} \qquad \text{equation 6}$$

25 Marks