UNIVERSITY OF GHANA
BSC. (ENG) MATERIALS SCIENCE AND ENGINEERING
SECOND SEMESTER EXAMS: 2016/2017 ACADEMIC YEAR
DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
MTEN 3⁄6: PHYSICAL PROPERTIES OF POLYMERS (2 CREDITS)

INSTRUCTIONS

ANSWER ALL QUESTIONS   **TIME ALLOWED: TWO HOURS**

1. Using examples, sketches, graphs and equations at where appropriate, distinguish between the following as used in polymers.

   (a). semi-crystalline and amorphous polymers
   (b). glassy and rubbery state
   (c). crystalline polymer and spherulite
   (d). glass transition temperature and melting temperature
   (e). viscosity average molecular weight and z (*zentrifuge*) average molecular weight
   (f). shear thickening and shear thinning polymers
   (g). Bingham plastic and Newtonian material
   (h). colligative property and material property

                                                                      (16 marks)

2. By the Raoult's treatment, polymer solutions exhibit large deviations from the ideal law except at extreme dilutions, where ideal behavior is approached as an asymptotic limit. The Flory-Huggins solution theory which builds on the ideal law uses the dissimilarity in molecular sizes to obtain the Gibbs free energy change for mixing of a polymer with a solvent.

   (a). In spite of its simplified assumptions, Flory-Huggins solution theory generates useful results for interpreting experimental results. What are the major limitations of this Flory-Huggins solution theory?

   (b). Explain how the Flory-Krigbaum solution theory addresses the limitations of the Flory-Huggins solution theory that you have stated above.

   (c). The Flory-Krigbaum solution theory gives the partial molar Gibbs free energy of a solution as:
   $$\overline{\Delta G_1} = RT\,(\kappa_1 - \psi_1)\phi_2^2 \qquad (1)$$
   where ϕ_2^2 is the volume fraction of the polymer, and κ_1 and ψ_1 are heat and entropy parameters of the solvent which is also related as given in equation (2).
   $$(\kappa_1 - \psi_1) = \psi_1\left[1 - \frac{\theta}{T}\right] \qquad (2)$$

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where T is the thermodynamic temperature and θ is the Flory temperature. Using equations (1) and (2) as a basis, predict the behaviour of the polymer molecules in solution at the following cases.

(i). when $\kappa_1 = 0$ $(\theta = 0)$
(ii). when $\kappa_1 > 0$ $(T < \theta)$
(iii). when $\kappa_1 = \psi 1$ $(T = \theta)$
(iv). when $\kappa_1 < 0$ $(T > \theta)$

(20 marks)

3. A sample of a soluble natural polymer of mass 0.200 g was dissolved in 25 ml of water and at 30 ^oC the osmotic pressure of the solution was found to be 26.1 $Torr$. What is the molecular weight of the polymer? Is your result apparent molecular weight or average molecular weight? If a series of results give the following molecular weights: 6000 (for 0.25 g), 6200 (0.30 g) , 5900 (for 0.22 g), and 6100 (0.27 g) g/mol, what would be the weight average molecular weight of the polymers. Take R = 0.0821 L atm mol^{-1} K^{-1}. (1 $Torr$ = 133.3 Pa = 1/760 atm)

(10 marks)

4. The value of Mark-Houwink constant for a polystyrene material is 0.60 and the constant of proportionality K is given as 1.6×10^{-5} L/g. Determine the molecular weight of the polystyrene if the limiting viscosity is 0.004 L/g. Explain how does temperature affect the limiting viscosity.

(8 marks)

5. The table below shows the density and enthalpy of vapourization (ΔH_{vap}) of methylethyl ketone and acetone.

solvent	Density (g/cm^3)	ΔH_{vap} (J/g)
methylethyl ketone	0.8	443.504
acetone	0.8	523

Which is better solvent for polystyrene at room temperature? The CED for polystyrene is 313.8 J/cm^3. Assume room temperature to be 25 ^oC.

(8 marks)

6. A 0.5 % solution was made by dissolving 0.25 g of a polymer in 50 ml of solvent. The time for flow between the two appropriate marks for an Oswald viscometer was 60 s and the time of flow for the solution was 80 s. Calculate,

   (a). the relative viscosity
   (b). the specific viscosity
   (c). the reduced viscosity
   (d). inherent viscosity

(8 marks)

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