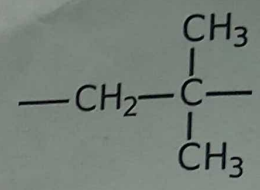
Indian Institute of Technology Guwahati
End-Semester Examination
CL 623: Polymer Science and Technology
Date: 28.11.2022 Total Marks: 100 Time: 3 hours

1. Calculate the combinatorial entropy change of mixing (ΔS^{comb}) and the Gibbs free energy change of mixing associated with dissolving 10^{-5} mol of poly(methyl methacrylate) (PMMA) of average molar mass $\bar{M}_n = 10^5$ g/mol and $\rho_2 = 1.20$ g/cm^3 in 150 g of chloroform, $CHCl_3$ ($\rho_1 = 1.49$ g/cm^3) at 25 °C. The value of the Flory-Huggins polymer-solvent interaction parameter is 0.377. Assume no volume change of mixing. The standard atomic weight of chlorine (Cl) is 35.45. Atomic weights of C and H are 12 and 1 respectively. Take $R = 8.314$ J/(mol.K). **(8 marks)**

2. State two limitations of the Flory-Huggins theory of polymer solutions. **(4 marks)**

3. **(a)** The group molar attraction constants for the groups $-CH_3$, $-CH_2$, $-CH$ and $>C<$ are 147.3 (cal.cm^3)$^{1/2}$mol^{-1}, 131.5 (cal.cm^3)$^{1/2}$mol^{-1}, 85.99 (cal.cm^3)$^{1/2}$mol^{-1} and 32.03 (cal.cm^3)$^{1/2}$mol^{-1} respectively. The structure of the repeat unit of polyisobutylene is shown on the right. If the density of polyisobutylene is 0.92 g/cm^3 at 310 K, what is the Hildebrand solubility parameter of polyisobutylene? Take the atomic weights of C and H to be 12 and 1 respectively.



(b) Consider two solvents: pyridine and n-heptane. Calculate their Hildebrand solubility parameters at 310 K. The molar enthalpy of vapourization of pyridine and n-heptane are 40.2 kJ/mol and 36.1 kJ/mol respectively at 310 K. The molar masses of pyridine and n-heptane are 79.1 g/mol and 100.2 g/mol respectively. The densities of pyridine and n-heptane at 310 K can be taken as 0.98 g/cm^3 and 0.665 g/cm^3 respectively. Which among the two will be a better solvent for polyisobutylene at the given temperature? Provide justification for your answer. The value of the universal gas constant R is 8.314 J/(mol.K). **(4+4=8 marks)**

4. The Flory-Huggins parameter for a polymer-solvent system is given by:

$$\chi = a - \frac{b}{T}$$

where T is the temperature (in K) and a and b are constants independent of T. If $b < 0$, discuss how the miscibility of the polymer in the solvent will be affected by change (increase or decrease) in temperature. If $a = 0.15$ and $b = -120$ K, determine the theta-temperature of this polymer–solvent system. **(4 marks)**

5. Explain the melt spinning process. Write down the advantages and disadvantages of melt spinning process over solution spinning process. What is the effect of spinning speed on crystal size in melt spinning method. **(8 marks)**

6. A piece of copper originally 305 mm long is pulled in tension with a stress of 276 MPa. If deformation is entirely elastic, what will be the elongation. Given, Young Modulus = 110 GPa. **(6 marks)**

7. Write down applications & two examples for each of the given additives. **(16 marks)**

i.	Plasticizer	**v.**	Flame retardant
ii.	Lubricants	**vi.**	Heat stabilizer
iii.	Filler	**vii.**	Antioxidant
iv.	Impact modifier	**viii.**	Antistatic agent

8. Briefly explain the mechanism of free radical polymerization. Prove that reaction rate is proportional to first power of concentration and square root of initial concentration in free radical polymerization. **(8 marks)**

9. Select the most appropriate answer with proper reasoning for the following statements: **(8 marks)**
   a. The viscosity of 1% solution of LDPE will be (same, lower, higher) than the viscosity of 1% solution of HDPE having same Mn.
   b. [η] is (independent or dependent) on the concentration of a polymer solution.
   c. In good solvent the polymer chain molecules remain as (highly entangled, loosely coiled, fully extended chains).
   d. Amorphous polymers have (sharp T_g, sharp melting point, broad crystalline transition, none of these)

10. Explain the extrusion process with the details of each stages and its temperature and pressure profile. Discuss the different type of screws used in the extrusion process. Explain the difference between injection molding & extrusion processing. **(8 marks)**

11. Tabulate various properties of polymers which are essential to know before its melt processing. **(4 marks)**

12. What is polymer clay nanocomposites and how it is superior over pristine polymer processing. Describe the widely used clays in the polymer processing to attain different morphologies. **(6 marks)**

13. Explain different types of tacticity by considering the example of polypropylene polymer. **(6 marks)**

14. What is polymer chain relaxation? Draw the stress relaxation curve for Maxwell model of viscoelastic materials. How do you determine the relaxation time for a transition from non-equilibrium state to equilibrium state? **(6 marks)**