

Polymer Science 2024/25

Mock Exam

In the real exam, you should write your answers on A4 sheets distributed by us. You are not allowed to use any other document (course material, books, etc.). Calculators, computers, mobile telephones, and other electronic media are not permitted.

You should answer all the multiple-choice questions (in the real exam probably 12 questions in total) and 4 out of the 4 - 6 offered longer questions.

Multiple-choice questions

1. Which of the following reactions is a polycondensation?

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 - a) Reaction of an epoxy resin with a diamine in a closed mold.
 - b) Reaction of a diisocyanate with a diol in the presence of water to form a foamed polyurethane.
 - c) Ring opening polymerization of caprolactam to form polyamide 6.
 - d) Radical polymerization of ethylene to form polyethylene.

2. For an amorphous polymer of high molar mass, $C_\infty = 9$ and the maximum deformability of the entanglement network, $\lambda_{\max} = 4$. What is the average number of bonds between two entanglement points?

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 - a) 20
 - b) 36
 - c) 81
 - d) 144

3. Which statement is false?

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 - a) Provided that all functional groups of monomers have reacted, the dispersity of an ideal polycondensate tends towards 2.
 - b) In a classical radical polymerization, M_w , and the dispersity, may reach very high values compared with those for a polycondensate.

- c) During a living anionic polymerization, a very slow initiation reaction compared with the propagation rate leads to a dispersity close to 1. ☐
- d) The glass transition temperature is sensitive to molar mass, especially when this latter is low. ☐
4. After many years of research, the Polymer Laboratory has succeeded in synthesizing a polymer made up of 3 chains with a molar mass of 100, 100, and 400 kg/mol, respectively. What is the dispersity of this polymer?
- a) 1.5 ☐
- b) 2.0 ☐
- c) 3.0 ☐
- d) 4.5 ☐

Longer questions

1. The melting temperature of a crystalline lamella formed by a polymer is given by

$$T_m = T_{m0} \left(1 - \frac{2\sigma_e}{l\Delta H} \right)$$

- a) Explain the meaning of the different terms in this equation with reference to a schematic representation of a lamella, and thus explain its physical origin.
- b) In a semi-crystalline polymer, the lamellae are organized in the form of spherulites. What is a spherulite and what are the mechanisms that lead to the formation of spherulites from lamellar nuclei within a molten polymer when $T_g < T < T_{m0}$?
- c) During injection molding, a highly stretched molten polymer comes into contact with the walls of a cold mold. What are the consequences for its morphology? (Assuming that the polymer is able to crystallize.)
2. a) What is the glass transition and how can it be measured? For a given polymer, do different measurement techniques give the same value for T_g ?
- b) Show schematically the shear modulus, G , as a function of T for an amorphous polymer. Indicate the orders of magnitude of G as well as the influence of M and the measurement speed. Show the behavior of a semi-crystalline polymer and an elastomer on the same graph.
- c) Briefly explain the principle of free volume theory. How does this theory account for the dependence of T_g on M for linear chains? What is the effect of chain branching on T_g ?

3. a) Explain qualitatively the concept of entanglement, the entanglement network model and the tube model.
- b) Show schematically the evolution of the stress as a function of $\log(t)$ during a relaxation test on a non-crosslinked amorphous polymer, indicating the rubbery plateau, the disentanglement time, τ_d , and the viscous regime. Interpret this behavior with the help of the tube model.
- c) According to Fick's law, the diffusion length is given by $(Dt)^{1/2}$, where D is the diffusion coefficient, which, in case of an entangled polymer chain diffusing inside the tube representing its interactions with its neighbors, will be proportional to M^{-1} . We can assume that the length of this tube, L , is also proportional to M . Show that τ_d varies as M^3 and that the self-diffusion coefficient of an entangled polymer (which describes the rate of diffusion of the center of mass of the chain) is proportional to M^{-2} .