04-CHEM-B8, POLYMER ENGINEERING

December 2015

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Property data required to solve a given problem are provided in the problem statement or are available in the recommended texts. If you are unable to locate the required data, do not let this prevent you from solving the rest of the problem. Even in the absence of property data, you still have the opportunity to provide a solution methodology.
3. The examination is an **open book exam.**
4. Candidates may use any **non-communicating** scientific calculator.
5. Regular graph papers will be provided.
6. Each problem is worth **25 points**. **Four problems** constitute a complete paper.
7. **Only the first four** questions as they appear in the answer book will be marked.
8. State all assumptions clearly.

1. The polyester PET (polyethylene terephthalate), commonly used in the manufacture of synthetic fibers, is prepared through polymerization of bis-hydroxyethyl terephthalate (BHET). During the polymerization, several side reactions occur (which can be ignored) and PET formation can be modeled by step-growth polymerization kinetics. Experiments have shown that the kinetic rate constant of propagation (k_p) at a function of temperature (T, in K) is given by the equation

$$\mathbf{k_p = 4 \times 10^4 \exp(-1.5 \times 10^4/1.98T)} \textbf{ liters per mole per minute}$$

The equilibrium constant (K_P) = k_p/k'_p = 0.5, and independent of temperature. For the initial monomer concentration of 4.58 moles per liter, find the conversion, the average chain length, and polydispersity index after 10 minutes of polymerization at 280 °C. Repeat calculations for 200 °C.

2. The decomposition of benzoyl peroxide is characterized by a half-life of 7.3 hrs at 70 °C and activation energy of 29.7 kcal/mol. What concentration (in moles per liter) of benzoyl peroxide is needed to convert 50% of the original charge of a vinyl monomer to polymer by free-radical polymerization in 6 hours at 60 °C?

DATA: Efficiency of benzoyl peroxide initiator = 0.4
k_p^2/k_t at 60 °C = 1.04×10^{-2} liter per mole per second

3. The following data were obtained for a sample of polymethylmethacrylate (PMMA) in acetone at 30 °C:

η_{rel}	c, in g/100 ml
1.170	0.275
1.215	0.344
1.629	0.896
1.892	1.199

For PMMA in acetone at 30 °C, the intrinsic viscosity ([η], in dl/g) is given the following equation:

$$[\eta] = 5.83 \times 10^{-5} (M_v)^{0.72}$$

where M_v is the viscosity-average molecular weight.

Determine the intrinsic viscosity [η], viscosity-average molecular weight (M_v), and Huggins equation constant (k') for PMMA in acetone at 30 °C.

4. A plastics extruder is known to work best at an optimum melt viscosity of about 20,000 Poises. A vinyl polymer of weight-averaged degree of polymerization of 750 and glass transition temperature of 80 °C had this optimum melt viscosity when it was used in the extruder at a temperature of 150 °C. Now a batch of the same vinyl polymer but with a weight-averaged degree of polymerization of 500 is received. At what temperature should the extruder now be run so that the optimum melt viscosity for processing is achieved?

5. A polymer with viscosity of 250 Pa.s is to be extruded using a screw extruder with details as follows:

Diameter of barrel = 75 mm

Screw speed = 40 rev/min

Screw helix angle = 17.7°

Screw flight width = 7.5 mm

The first metering zone has a length of 250 mm and flight depth of 4 mm. The second metering zone has a length of 500 mm and flight depth of 6 mm. The extruder is to produce film 1 meter wide with a die whose melt channel is 10 mm in length. Find the film die gap required for satisfactory extrusion with the two metering zone just matched.

6. A toughened polypropylene is used in constructing a cylindrical water tank. Creep data for this polypropylene at 23°C is given by the equation

$$\varepsilon = 0.022\,(3.5 + t^{0.16})\,\sigma + \{1.5 \times 10^{-6}\, t^{0.33} \exp(0.9\sigma)\}$$

where ε is the percentage extension after **t** seconds under applied stress σ of MPa. The tank will have a diameter of 3 meters and a height of 2.5 meters. It will be full for 4 months, and then left empty for 8 months before being refilled. Calculate the wall thickness required to ensure that the residual strain in the wall does not exceed 0.05% at the end of the first year. Neglect constraints imposed by the base of the tank.