16-CHEM-B8, POLYMER ENGINEERING

May 2017

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. Graph paper is not required to solve any problem.
6. Each problem is worth **20 points**. **Five problems** constitute a complete paper.
7. **Only the first five** questions as they appear in the answer book will be marked.
8. State all assumptions clearly.

1. The volumetric flow rate (Q) of 3% solution of carboxymethylcellulose in water was measured in a long capillary (of radius R) as a function of pressure drop, and the following results were obtained for the wall shear stress (τ_w):

Q/R^3 (in sec^{-1})	τ_w (in N/m^2)
195	220
275	255
395	298
550	341
705	382
980	441
1375	509
1965	584
2750	670
3930	751
5500	825
7070	887
9820	1000
13750	1070
19645	1200

Compute the non-Newtonian viscosity as a function of shear rate.

2. An anionic polymerization is being carried out with an initial monomer concentration of 2 M.

(a) **[12.5 points]** Determine the final number-average and weight-average chain lengths and molecular weights along with the extent of polymerization and polydispersity for initiator concentrations of 0.01 M.

(b) **[12.5 points]** Calculate the radical concentration and polymer concentration as a function of time for chain length (j) = 3, 7 and 10 for the same monomer and initiator concentration.

DATA: Initiation rate coefficient (k_i) = ∞
Propogation rate coefficient (k_p) = 100 dm^3/mol.s

3. A polymer was fractionated into the following six fractions:

Fraction	**Molecular Weight**	**Mole Fraction**
1	10,000	0.1
2	15,000	0.2
3	20,000	0.4
4	25,000	0.15
5	30,000	0.1
6	35,000	0.05

The molecular weight of the monomer is 25 g/mol.

Determine the number-average molecular weight, weight-average molecular weight, number-average variance and polydispersity of the polymer.

4. We would like to manufacture a 2-meter wide, 0.1-mm thick polyvinyl chloride (PVC) film at a rate of 1200 kg/hr with an inverted-L calender. Suggest a design procedure to select roll sizes, gap separations, and operating conditions.

5. A non-Newtonian polymer melt ($m = 2.18 \times 10^4$ $N.s^n/m^2$ and $n = 0.39$) is injected into a molding machine at a constant rate of 1.2×10^{-6} m^3/s. The mold runner is 25.4 cm long and has a radius of 2.54 mm.

(a) [15 points] Calculate the variation of injection pressure and penetration depth of the polymer melt as a function of time.

(b) [5 points] What is the injection pressure required to fill the entire runner?

6. You are in charge of implementing a control system to produce a copolymer of uniform composition in a semi-batch reactor. The reactor is fitted with a jacket to which steam can be fed to heat the reactants to the desired reaction temperature (during which conversion is negligible). Once the reaction has begun, the steam is shut off and replaced by cooling water, which is throttled by a feedback control system to maintain the reactor temperature fairly constant. What information would you need to know, and how would you go about designing a control system to feed the more reactive monomer at the correct rate?