National Exams

98-Chem-B8, Polymer Engineering

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. Candidates may use any nonprogrammable calculator, ex., a Casio FX-991 or Sharp EL-540. **This is an Open Book Exam.**

3. Any **four** questions constitute a complete paper. Only the first four questions as they appear in your answer book will be marked.

4. All questions have equal value.

Question 1
(20 marks)

For each of the following pairs of polymers, decide which is more likely to have the greater tensile strength, and give 1 reason for your choice:

(4 marks) (a) Lightly crosslinked polyethylene; network phenol-formaldehyde.

(4 marks) (b) Lightly crosslinked polyvinyl chloride; branched polyvinyl chloride.

(4 marks) (c) 95% crystalline and linear PTFE having a number-average molecular weight of 650,000 g/mol; 80% crystalline and linear PTFE having a number-average molecular weight of 500,000 g/mol.

(4 marks) (d) Atactic polypropylene having a weight-average molecular weight of 750,000 g/mol; isotactic polypropylene having a weight-average molecular weight of 750,000 g/mol.

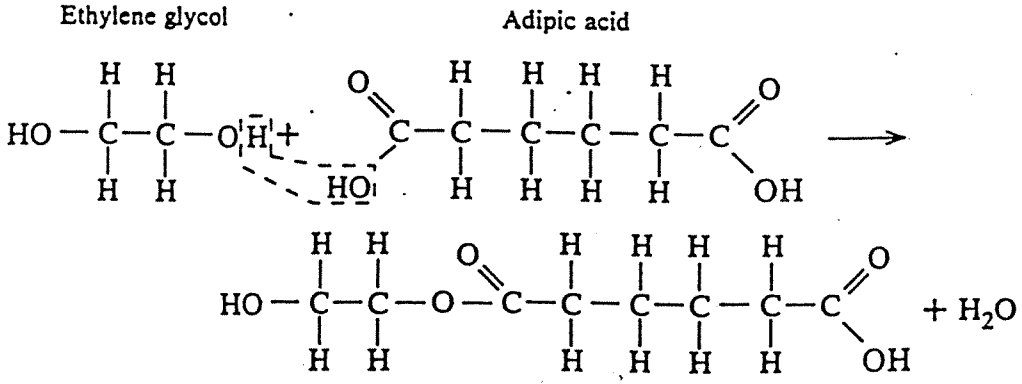
(4 marks) (e) Alternating styrene-butadiene copolymer; graft styrene-butadiene copolymer.

Question 2
(20 marks)

(8 marks) (a) Decide whether the molecular weight of a polymer that is synthesized by addition polymerization is relatively high, medium, or relatively low for the following situations:

(i) Rapid initiation, slow propagation, and rapid termination.
(ii) Slow initiation, rapid propagation, and slow termination.
(iii) Rapid initiation, rapid propagation, and slow termination.
(iv) Slow initiation, slow propagation, and rapid termination.

(12 marks) (b) A polyester is formed according to the following equation:



(i) How much ethylene glycol must be added to 20.0 kg of adipic acid to produce a linear chain of polyester according to the above equation?

(ii) What is the mass of the resulting polymer?

Question 3
(20 marks)

(4 marks) (a) Why does the addition of glass fibers increase the heat-distortion temperature of crystalline polymers, such as polyethylene and polypropylene, but not of glassy ones, such as polycarbonate and polysulfone?

(5 marks) (b) Cite five important characteristics for polymers that are to be used in thin-film applications.

(11 marks) (c) A cubic container with a volume of 1.00 m^3 is to be insulated so that a charge of 100 kg of ice will take at least 20 h to melt completely. What thickness of insulation is required? Urethane foam insulation, $k = 0.050$ W/m·°C; heat of fusion for water is 79.7 cal/g (334 kJ/kg); average outside temperature is 40°C.

Question 4
(20 marks)

(8 marks) (a) Typically, one or more additives can be mixed with a polymer to improve certain properties. Give four types of additives and for each, its usefulness in a plastic.

(12 marks) (b) A polymer used in an injection-molding operation has the following operating data for a given mold (P_B is the nozzle pressure, η_o is the polymer Newtonian viscosity at the temperature immediately prior to the mold, and t_f is the fill time).

P_B, psi	η_o, poise	t_f, s
14,000	62,500	6.7
12,000	12,960	2.7

What would the fill times be for the following P_B and η_o?

P_B, psi	η_o, poise
19 000	38 600
19 000	210 000
16 000	80 500
14 000	14 500
10 000	12 960

Filling times can be estimated by using the following empirical expression based on the flow of the molten polymer in a given geometry:

$$t_f = \beta \, \eta_o \, P_B^{-\alpha}$$

where t_f = fill time

α and β = constants determined for the machine

P_B = nozzle pressure

Question 5
(20 marks)

At room temperature, which of the following polymers would you expect to be elastomers and which would you expect to be thermosets? Justify each choice.

(4 marks) (a) Epoxy having a network structure.

(4 marks) (b) Lightly crosslinked poly(styrene-butadiene) random copolymer that has a glass-transition temperature of -50°C.

(4 marks) (c) Lightly branched and semicrystalline polytetrafluoroethylene that has a glass-transition temperature of -100°C.

(4 marks) (d) Heavily crosslinked poly(ethylene-propylene) random copolymer that has a glass transition temperature of 0°C.

(4 marks) (e) Thermoplastic elastomer that has a glass-transition temperature of 75°C.