UNIVERSITY OF GHANA

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BSC. (Eng.) MATERIALS SCIENCE AND ENGINEERING

SECOND SEMESTER EXAMINATIONS: 2016/2017

SCHOOL OF ENGINEERING SCIENCES

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 328: POLYMER PROCESSING TECHNOLOGY I (3 CREDITS)

INSTRUCTIONS: ANSWER ALL QUESTIONS. GRAPH SHEETS WOULD BE PROVIDED. SOME EQUATIONS ARE PROVIDED ON PAGE 6.

TIME ALLOWED: THREE (3) HOURS

1.

a. One district one factory, an initiative by the Government of Ghana has resulted in the establishment of a nylon manufacturing factory in Akyem Kwabeng in the Atiwa district. The factory is making nylon 6,6 from hexamethylenediamine and adipic acid. One batch is made every 8 hour shift. In each batch equimolar reactants are used and conversion is usually 98.0 %. At the end of the run the bulk product is extruded and chopped into pellets.

   I. Calculate the number average molecular weight. ***(5 Marks)***

   II. The afternoon shift operator dumped in too much adipic acid. From his records you calculated that the mole ratio was 2 % excess adipic acid. If the batch went to the usual conversion, what was the number average molecular weight? ***(5 Marks)***

   III. The night shift operator weighed things correctly but fell asleep and let the reaction run too long (~ 99 % conversion). What will be the number average molecular weight? ***(5 Marks)***

IV. How would you mix these batches to obtain $\bar{M}_n$ of the usual product? What will be $\bar{M}_w$? *(5 Marks)*

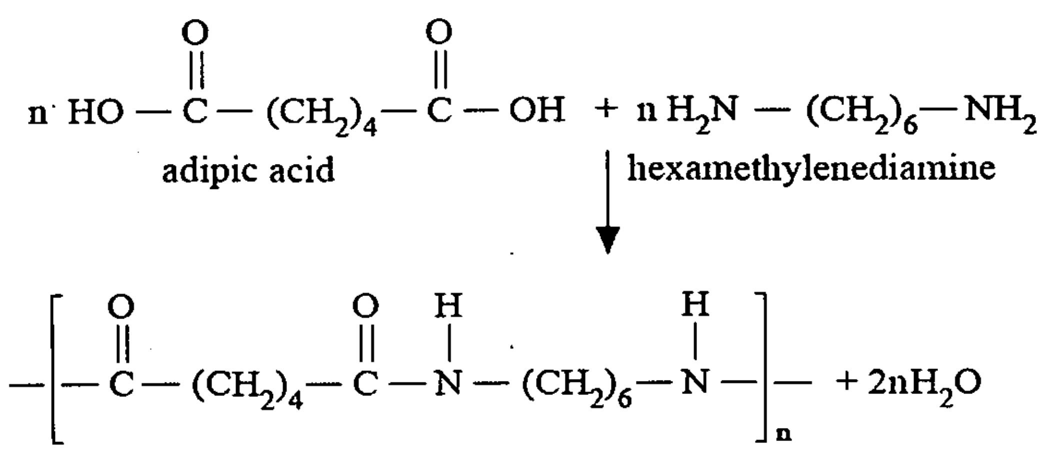
b. Nylon 6,6 is frequently used when high mechanical strength, rigidity and good stability under heat is required. As a result of this, nylon 6,6 is used in the automotive industry for making 3D structures. The nylon 6,6 produced from the factory is transported to Katanka Automobile Company Limited (KACL) to be used in the production of radiator end tanks (Figure 1 on Page 5).

I. Describe the polymer unit operation that will be suitable for the production of radiator end tanks from nylon 6,6. The description should include details of the polymer compounding process. *(10 Marks)*

II. The quality assurance department of KACL sampled some of the radiator end tanks for analysis and noticed inconsistencies in product properties/quality. As an example the glass transition temperatures varied from product to product. What do you think accounted for this inconsistencies? Support your answer with undergraduate polymer processing technology arguments.

(5 Marks)

The polymerization reaction is provided below:



nylon 6,6

[The Atomic Mass of C, O, H and N are 12, 16, 1 and 14, respectively]

2.

a. Equimolar mixture of 1,10-decanediol and adipic acid was polymerized under mild conditions to 82 % conversion of the original carboxyl groups and the resulting product was further polymerized at a higher reaction temperature of 161 °C in the presence of p-toluene sulfonic acid (0.004 mole per mole of polymer) yielding the following conversion data (Table 1) of the end hydroxyl and carboxyl acid groups :

Table 1

Time(min)	0	5	10	15	20	30	40	50	60	75	90	105
% Reaction	0	34.6	54.7	65.5	70.8	77.9	82.9	85.7	87.9	90.1	91.5	92.6

The molar mass of adipic acid and 1,10-decanediol is 146 and 174 g/mol, respectively.

Determine the rate constant for the catalyzed polyesterification reaction. ***(15 Marks)***

b. Polymeric materials with self-healing properties have recently become the area of intense research by scientists. Processes for developing self-healing polymers and polymer composites can be categorized as intrinsic and extrinsic.

   I. Differentiate between extrinsic and intrinsic processes for developing self-healing polymers and polymer composites. ***(4 Marks)***

   II. Describe briefly three (3) techniques that can be used to achieve self-healing in polymers and polymer composites. ***(6 Marks)***

3.

a. PET is a polymeric materials used for the manufacturing of disposable water bottles. A scientist working with PET has made some observations outlined below;

- When PET is cooled rapidly from 300 °C (state 1) to room temperature (state 2), the resulting material is rigid and perfectly transparent.
- The PET becomes translucent after heating the cooled PET to 100 °C and maintaining it at that temperature (state 3).
- When the translucent PET is again cooled down to room temperature it becomes rigid, but it is now translucent rather than transparent (state 4).

For this polymer, the melting and glass transition temperatures are 267 °C and 69 °C, respectively.

I. Describe the molecular mechanisms responsible for the behavior of the polymer in each state. ***(8 Marks)***

II. Sketch a general specific volume vs temperature curve for this polymer indicating the melting and glass transition temperatures and the locations of the states 1-4 describe above. ***(5 Marks)***

b. One application of advanced polymeric materials is their use in developing sustained drug delivery systems. Sodium Salicylate, an anionic drug is a common anti-inflammatory drug used in Ghana. You have been hired as a consultant to help develop a sustained drug delivery system using Sodium Salicylate so that patients using that drug will not be required to take 650 mg Sodium Salicylate every 4 hours but once a week. You have been given a biodegradable polymer (PLGA), Sodium Salicylate, biocompatible cationic surfactant (CTAB), a solvent that dissolves PLGA and deionized water. Describe into details the process that you will use to develop the sustained drug delivery system.

(7 Marks)

4. The crystallinity of isotactic polypropylene (iPP) was studied with DSC. Heating rate for melting the sample was 10 $°C/min$ up till 200 °C temperature. The sample was kept at 200 °C for five minutes after which it was cooled to 121 °C very quickly and kept there for 10 minutes. Melting enthalpies (ΔH_f) were used to obtain the values for relative degree of crystallinity X(t) in Table 2 below. The DSC curve for the melting of iPP is shown in Figure 2. The heat of fusion of fully crystalline polypropylene is 209 J/g.

a. Calculate the degree of crystallinity for isotactic PP ***(4 Marks)***

b. Determine the constants n and k for Avrami equation. ***(12 Marks)***

c. What can be said about geometry of the crystals based on the Avrami constant n? ***(4 Marks)***

Table 2

t(s)	0	20	60	120	180	240	300	420	600
X(t)	0	0.0026	0.0383	0.1947	0.4454	0.6988	0.8753	0.9916	0.9999

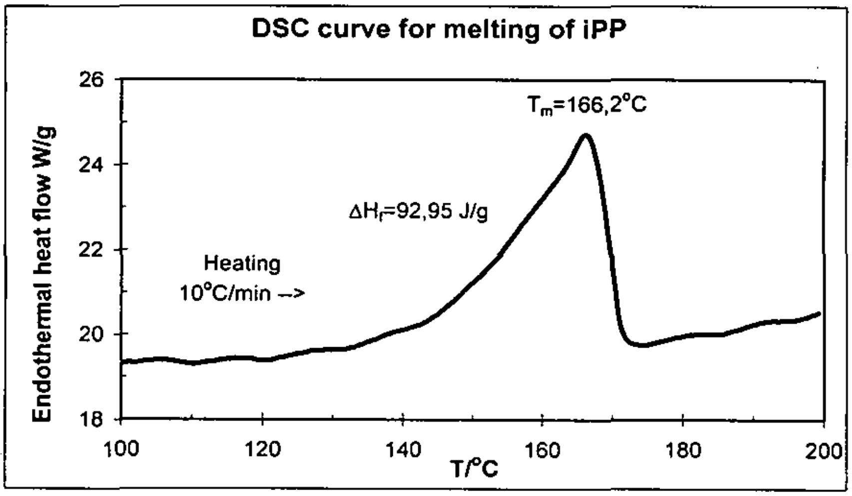


Figure 2: DSC curve of second heating scan after 10 min crystallization at 121 °C.

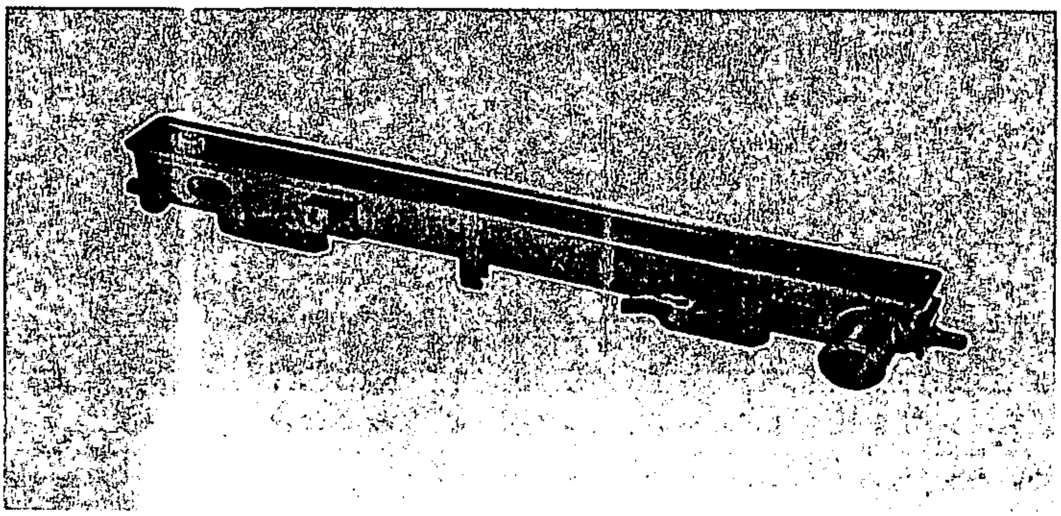


Figure 1: Radiator End Tank

Equations

$$\bar{M}_n = \bar{X}_n M_o$$

$$-\frac{d[COOH]}{dt} = k'[COOH][OH]$$

$$\bar{X}_n = \frac{1+r}{2r(1-P)+1-r}$$

$$\bar{M}_n = \frac{\sum N_i M_i}{\sum N_i}$$

$$\bar{M}_w = \frac{\sum N_i M_i^2}{\sum N_i M_i}$$

$$X(t) = 1 - \exp(-kt^n)$$