

## CHAPTER 14

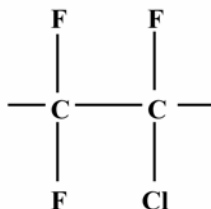
## POLYMER STRUCTURES

## PROBLEM SOLUTIONS

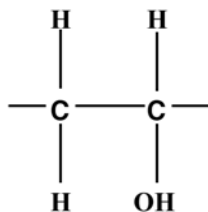
**Hydrocarbon Molecules****Polymer Molecules****The Chemistry of Polymer Molecules**

14.1 The repeat unit structures called for are sketched below.

(a) Polychlorotrifluoroethylene



(b) Poly(vinyl alcohol)



## Molecular Weight

14.2 Repeat unit weights for several polymers are asked for in this problem.

(a) For polytetrafluoroethylene, each repeat unit consists of two carbons and four fluorines (Table 14.3). If  $A_C$  and  $A_F$  represent the atomic weights of carbon and fluorine, respectively, then

$$\begin{aligned} m &= 2(A_C) + 4(A_F) \\ &= (2)(12.01 \text{ g/mol}) + (4)(19.00 \text{ g/mol}) = 100.02 \text{ g/mol} \end{aligned}$$

(b) For poly(methyl methacrylate), from Table 14.3, each repeat unit has five carbons, eight hydrogens, and two oxygens. Thus,

$$\begin{aligned} m &= 5(A_C) + 8(A_H) + 2(A_O) \\ &= (5)(12.01 \text{ g/mol}) + (8)(1.008 \text{ g/mol}) + (2)(16.00 \text{ g/mol}) = 100.11 \text{ g/mol} \end{aligned}$$

(c) For nylon 6,6, from Table 14.3, each repeat unit has twelve carbons, twenty-two hydrogens, two nitrogens, and two oxygens. Thus,

$$\begin{aligned} m &= 12(A_C) + 22(A_H) + 2(A_N) + 2(A_O) \\ &= (12)(12.01 \text{ g/mol}) + (22)(1.008 \text{ g/mol}) + (2)(14.01 \text{ g/mol}) + (2)(16.00 \text{ g/mol}) \\ &= 226.32 \text{ g/mol} \end{aligned}$$

(d) For poly(ethylene terephthalate), from Table 14.3, each repeat unit has ten carbons, eight hydrogens, and four oxygens. Thus,

$$\begin{aligned} m &= 10(A_C) + 8(A_H) + 4(A_O) \\ &= (10)(12.01 \text{ g/mol}) + (8)(1.008 \text{ g/mol}) + (4)(16.00 \text{ g/mol}) = 192.16 \text{ g/mol} \end{aligned}$$

14.3 We are asked to compute the degree of polymerization for polystyrene, given that the number-average molecular weight is 500,000 g/mol. The repeat unit molecular weight of polystyrene is just

$$\begin{aligned}m &= 8(A_{\text{C}}) + 8(A_{\text{H}}) \\ &= (8)(12.01 \text{ g/mol}) + (8)(1.008 \text{ g/mol}) = 104.14 \text{ g/mol}\end{aligned}$$

Now it is possible to compute the degree of polymerization using Equation 14.6 as

$$DP = \frac{\bar{M}_n}{m} = \frac{500,000 \text{ g/mol}}{104.14 \text{ g/mol}} = 4800$$

14.4 (a) The repeat unit molecular weight of polypropylene is called for in this portion of the problem. For polypropylene, from Table 14.3, each repeat unit has three carbons and six hydrogens. Thus,

$$\begin{aligned}m &= 3(A_{\text{C}}) + 6(A_{\text{H}}) \\ &= (3)(12.01 \text{ g/mol}) + (6)(1.008 \text{ g/mol}) = 42.08 \text{ g/mol}\end{aligned}$$

(b) We are now asked to compute the number-average molecular weight. Since the degree of polymerization is 15,000, using Equation 14.6

$$\bar{M}_n = (DP)m = (15,000)(42.08 \text{ g/mol}) = 631,000 \text{ g/mol}$$

14.8 (a) For chlorinated polyethylene, we are asked to determine the weight percent of chlorine added for 8% Cl substitution of all original hydrogen atoms. Consider 50 carbon atoms; there are 100 possible side-bonding sites. Ninety-two are occupied by hydrogen and eight are occupied by Cl. Thus, the mass of these 50 carbon atoms,  $m_C$ , is just

$$m_C = 50(A_C) = (50)(12.01 \text{ g/mol}) = 600.5 \text{ g}$$

Likewise, for hydrogen and chlorine,

$$m_H = 92(A_H) = (92)(1.008 \text{ g/mol}) = 92.74 \text{ g}$$

$$m_{Cl} = 8(A_{Cl}) = (8)(35.45 \text{ g/mol}) = 283.60 \text{ g}$$

Thus, the concentration of chlorine,  $C_{Cl}$ , is determined using a modified form of Equation 4.3 as

$$\begin{aligned} C_{Cl} &= \frac{m_{Cl}}{m_C + m_H + m_{Cl}} \times 100 \\ &= \frac{283.60 \text{ g}}{600.5 \text{ g} + 92.74 \text{ g} + 283.60 \text{ g}} \times 100 = 29.0 \text{ wt\%} \end{aligned}$$

(b) Chlorinated polyethylene differs from poly(vinyl chloride), in that, for PVC, (1) 25% of the side-bonding sites are substituted with Cl, and (2) the substitution is probably much less random.

## Thermoplastic and Thermosetting Polymers

14.13 This question asks for comparisons of thermoplastic and thermosetting polymers.

(a) Thermoplastic polymers soften when heated and harden when cooled, whereas thermosetting polymers, harden upon heating, while further heating will not lead to softening.

(b) Thermoplastic polymers have linear and branched structures, while for thermosetting polymers, the structures will normally be network or crosslinked.

14.14 (a) It is *not possible* to grind up and reuse phenol-formaldehyde because it is a network thermoset polymer and, therefore, is not amenable to remolding.

(b) Yes, it is *possible* to grind up and reuse polypropylene since it is a thermoplastic polymer, will soften when reheated, and, thus, may be remolded.

## Polymer Crystallinity

14.22 The tendency of a polymer to crystallize decreases with increasing molecular weight because as the chains become longer it is more difficult for all regions along adjacent chains to align so as to produce the ordered atomic array.