

Polymers

Answer key with worked solutions

A. Understanding

1. Definitions.

(a) **Monomer:** a small molecule that joins with many others to form a polymer. (b) **Repeat unit:** the part of the chain that repeats, drawn in brackets with n . (c) **Addition polymerization:** monomers with $C=C$ join as the double bonds open; no other product. (d) **Condensation polymerization:** monomers with two functional groups join, releasing a small molecule (usually water) at every link.

B. Repeat units and monomers

2. Repeat units.

(a) $-[CH_2-CH(CH_3)]-$ (b) $-[CH_2-CHCl]-$ (c) $-[CF_2-CF_2]-$ (d) $-[CH_2-CH(C_6H_5)]-$, each with n after the brackets.

3. Monomers.

(a) **propenenitrile** (acrylonitrile), $CH_2=CHCN$ (b) **propene**, $CH_2=CHCH_3$ (c) **1,1-dichloroethene**, $CH_2=CCl_2$

4. Classification.

Addition: poly(ethene), PVC, PTFE. **Condensation:** nylon-6,6, PET, protein.

5. Nylon-6,6.

(a) An **amide** link, $-CO-NH-$ (a $C=O$ bonded to an $N-H$), formed between $-COOH$ and $-NH_2$. (b) **Water**, H_2O , one molecule per link.

C. Calculations

6. Degree of polymerization.

$$\begin{aligned}\text{(a) } n &= \frac{3.00 \times 10^5 \text{ g/mol}}{100.02 \text{ g/mol}} = \mathbf{3.00 \times 10^3 \text{ repeat units}} \\ \text{(b) } M &= 3.00 \times 10^3 \times 42.08 \text{ g/mol} = \mathbf{1.26 \times 10^5 \text{ g/mol}}\end{aligned}$$

7. Fluorine in PTFE.

$$\text{Repeat unit C}_2\text{F}_4 \text{ has 4 F: } \frac{4 \times 19.00 \text{ g/mol}}{100.02 \text{ g/mol}} \times 100 \% = \mathbf{76.0 \%}$$

8. Water from nylon.

$$\begin{aligned}n(\text{repeat units}) &= \frac{1.00 \times 10^3 \text{ g}}{226.32 \text{ g/mol}} = 4.419 \text{ mol} \\ n(\text{H}_2\text{O}) &= 2 \times 4.419 \text{ mol} = 8.837 \text{ mol} \\ m(\text{H}_2\text{O}) &= 8.837 \text{ mol} \times 18.02 \text{ g/mol} = \mathbf{159 \text{ g}}\end{aligned}$$

D. Challenge

9. Burning poly(ethene).

$$\begin{aligned}\text{(a) } \text{C}_2\text{H}_4 + 3 \text{ O}_2 &\longrightarrow 2 \text{ CO}_2 + 2 \text{ H}_2\text{O} \text{ (per repeat unit)} \\ \text{(b) } n(\text{repeat units}) &= \frac{1.00 \times 10^3 \text{ g}}{28.05 \text{ g/mol}} = 35.65 \text{ mol}; n(\text{CO}_2) = 2 \times 35.65 \text{ mol} = 71.30 \text{ mol} \\ m(\text{CO}_2) &= 71.30 \text{ mol} \times 44.01 \text{ g/mol} = 3.138 \times 10^3 \text{ g} = \mathbf{3.14 \text{ kg}} \\ \text{(c) Advantage: } &\mathbf{\text{energy is recovered}} \text{ and the waste volume is greatly reduced.} \\ \text{Disadvantages:} &\text{ it releases } \mathbf{\text{CO}_2} \text{ (a greenhouse gas: over three times the mass of the} \\ &\text{plastic) and may release } \mathbf{\text{toxic gases}} \text{ (CO from incomplete combustion, HCl from PVC);} \\ &\text{the raw material is } \mathbf{\text{lost}}, \text{ whereas recycling saves crude oil and energy.}\end{aligned}$$