

Chemistry 1500: Chemistry in Modern Living

Topic 9: The World of Plastics and Polymers

Polymer/Materials Science

Chemistry in Context, 2nd Edition: Chapter 10, Pages 319-350

Chemistry in Context, 3rd Edition: Chapter 9, Pages 337-374

Chemistry in Context, 4th Edition: Chapter xxx, Pages xxx-xxx

The Figure, Table, & Problem numbers in these notes are taken from the 4th edition of the text unless otherwise noted.

Graphics from Text: Figure xxx.0

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9A Carbon Allotropes

- Allotropes are different chemical forms of the same Element
- Carbon is unique, especially in its tendency to form long chains
 - Graphics from Text: Figures 10.2 and 10.3 in 2nd Edition and 9.2a, b, c in 3rd Edition, the allotropes of Carbon

- Diamond
 - All covalent bonds

- Graphite
 - Covalent bonds within layers (i.e., arene like)
 - Van der Waals bonds between layers

- Buckminsterfullerene
 - Covalent bonds within cages (i.e., arene like)
 - 5 and 6 membered rings
 - Van der Waals bonds between cages

9B The Plastic Economy

➤ Scale of Production

➤ Graphics from Text: Figure 10.4 in 2nd Edition and 9.5 in 3rd Edition, Annual US production (in billions of pounds)

➤ Approximately 100,000,000,000 pounds of plastics are produced in year in US

➤ Regularly increasing production

➤ Uses of plastics

➤ To replace other materials

➤ Lower cost and/or better performance

➤ Ask Students: What materials to plastics replace in consumer products

➤ Group Activity

9C Polymers

- Starting Materials for plastic production
 - Fossil Fuel Starting Materials
 - Petroleum
 - Graphics from Text: Figure 10.12 in 2nd Edition and 9.15 in 3rd Edition, the uses of a barrel of oil
 - Natural Gas
 - Coal
 - Biological Starting Materials
 - Plant Materials
 - Bacterial Products
 - Animal Products

➤ Monomers

- The small molecules from which plastics are made
- Must have a very low cost per pound (typically a few tens of cents)
- Relatively low **molecular weights** (typically from 28 to a hundred or so)
- **Constant structures** in pure samples
- **Constant molecular weights** in pure samples

➤ Polymers

- Large molecules composed of many similar or identical Repeating Units
- Must have quite low prices or will be replaced by other materials
- Molecular Weights from thousands to millions
- **Variable structures** even in pure samples
- **Variable molecular weights** even in pure samples

9D Some Natural Polymers

- The bulk of living organisms (other than water) is composed of natural polymers

- Ask Students: What are some of the more common natural polymers?

- Group Activity

9E Polyethylene

- The most common plastic
 - Over 20,000,000 tons are produced each year in US
 - Found in plastic bags, construction materials, aircraft, etc.
- Equation for **synthesis**



Is equivalent to saying



- At high temperatures the reaction can reverse
 - **Depolymerization**
- Occurs because **π -bonds** are stronger than **σ -bonds**

9F Higher Order Polymer Structures

➤ Backbone Structure

- The structure of the **repeating units** that link polymers together

➤ Side Chains

- Occur in variable frequency depending on synthetic methods
- Occur in variable lengths depending on synthetic methods

➤ Cross Links

- Connect adjacent chains

➤ High Density Polyethylene, HDPE

- Long relatively straight chains

➤ Low Density Polyethylene, LDPE

- Highly **branched Structures**

9G The Big Six

- Five have long chains of carbon atoms in their backbones (i.e., they are giant **alkanes**)
- Graphics from Text: Table 10.1 and Figure 10.9 in 2nd Edition and Table 9.1 and Figure 9.11 in 3rd Edition, The Big Six
- **LDPE** prepared from **Ethylene**

- **HDPE** prepared from **Ethylene**

➤ Polyvinyl Chloride, PVC, prepared from Vinyl Chloride

➤ Polystyrene, PS, prepared from Styrene

➤ Polypropylene, PP, prepared from Propylene

➤ Polyethylene Terephthalate, PETE, prepared from Ethylene Glycol and Terephthalic Acid, Polyester

➤ Ask Students: List at least three uses for each of these classes of polymers

➤ Group Activity

9H Addition Polymerization

- Addition Polymerization reactions occur without the loss of mass
- Thus, the weight of **monomer** you start with equals the weight of polymer isolated
- No wastage of mass

- Addition Polymerizations typically occur via a type of reaction called **Chain Growth**
- This involves rapid increases in molecular weight and highly reactive intermediates

- Leads to polymers with very high molecular weights

- Examples include: **LDPE, HDPE, PVC, PS, and PP**

9I Condensation Polymerization

- Condensation Polymerization reactions occur with the loss of mass (most commonly water is lost)
- Thus, the weight of **monomer** you start with is greater than the weight of polymer isolated
- Wastage of mass

- Condensation Polymerizations typically occur via a type of reaction called **Step Growth**
- This involves slow increases in molecular weight and no highly reactive intermediates

- Leads to polymers with lower molecular weights

- Examples include: **PETE**
- Reaction for PETE synthesis

9J Polymer Bonds vs. Discrete Molecule Bonds

- Same types of covalent bonds

- Alkane type C-C single bonds
 - Ethane vs. Polyethylene

- Ether Linkages
 - Diethyl Ether vs. Polyethylene Glycol, PEG

- Ester Linkages
 - Ethyl Acetate vs. PETE

- Amide Linkages
 - Methyl Acetamide vs. Nylon

9K The Story of Kevlar

➤ Polyphenylene Terephthalamide = Kevlar

➤ Reaction for Synthesis

➤ Structure

➤ Purification

➤ Properties

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