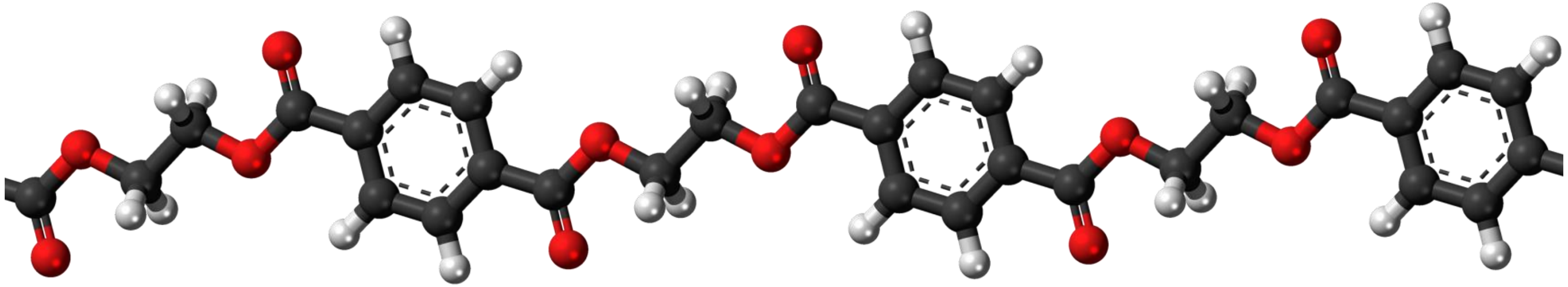
## 2302106 – Basic Organic Chemistry for ISE – Part II

## Lecture 6-4

# Polymers – Properties of Polymers



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**Recommended Textbook:**

Chapter 26 in *Organic Chemistry*, 8th Edition, L. G. Wade, Jr., **2010**, Prentice Hall (Pearson Education)

# Types of Polymer structures

- Linear

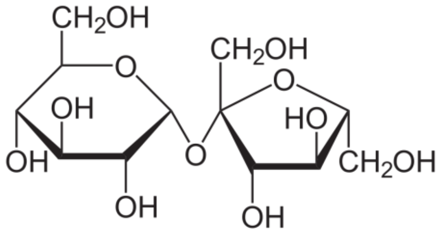
- Branched

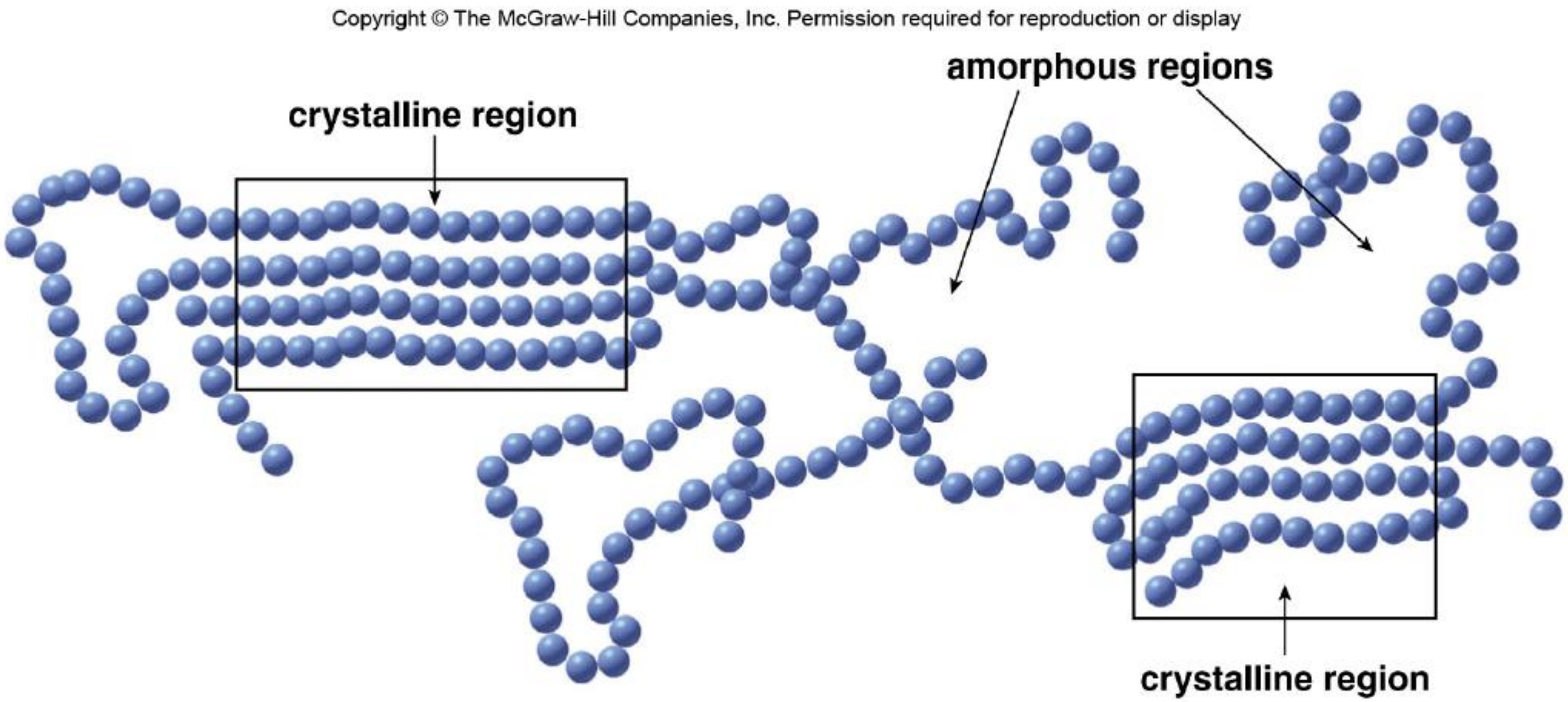
- Cross-linked

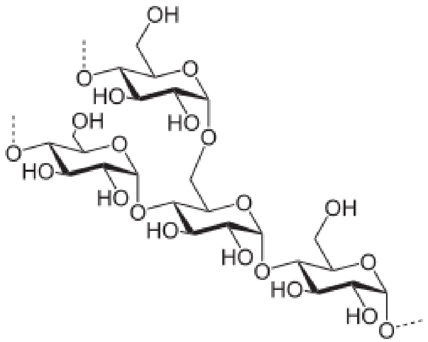
- Networked

# Polymer Crystallinity

- The **large size** of polymer molecules gives them some unique physical properties compared with small organic molecules
- Linear and branched polymers **do not form crystalline solids** because their long chains prevent efficient packing in a crystal lattice
- Most polymers have **crystalline** regions and **amorphous** regions

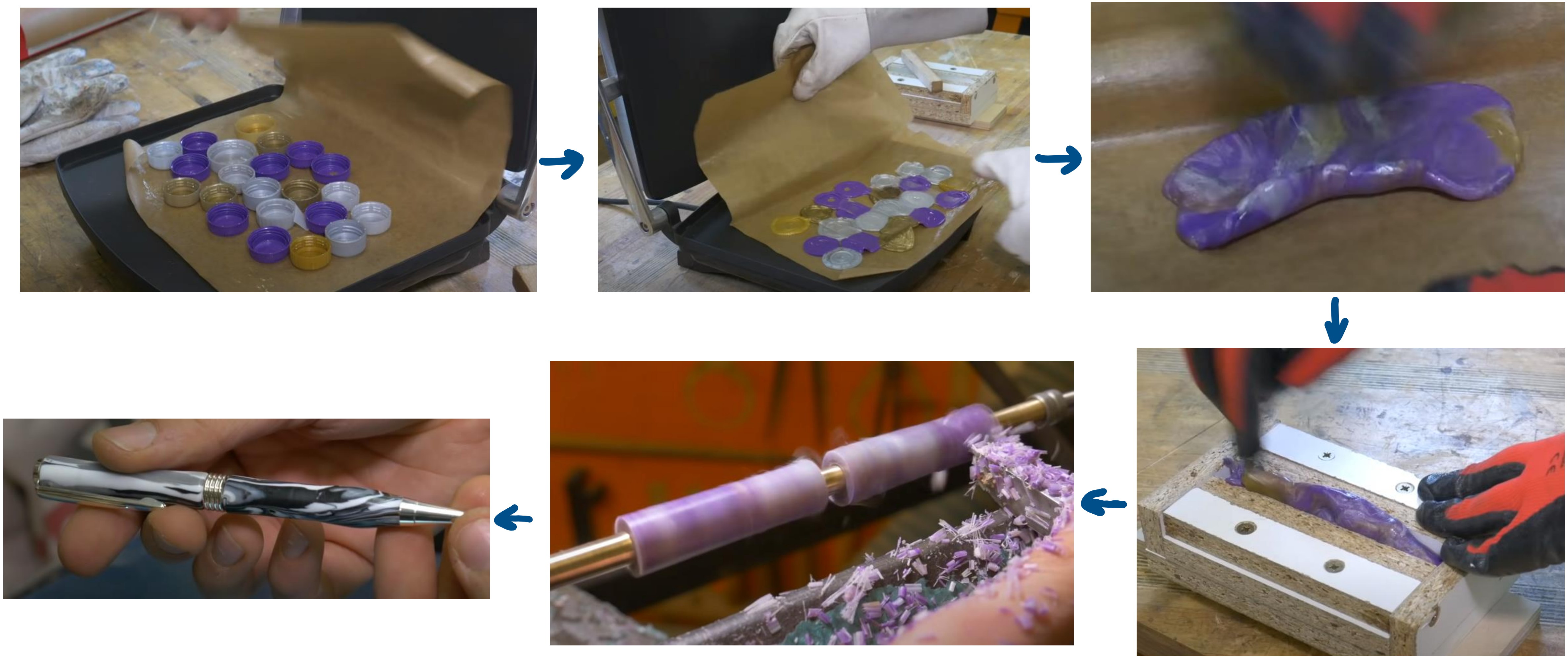


# Thermal Properties

**1) Thermoplastics:** polymers that can be **melted** and then moulded into shapes that are retained when the polymer is cooled.



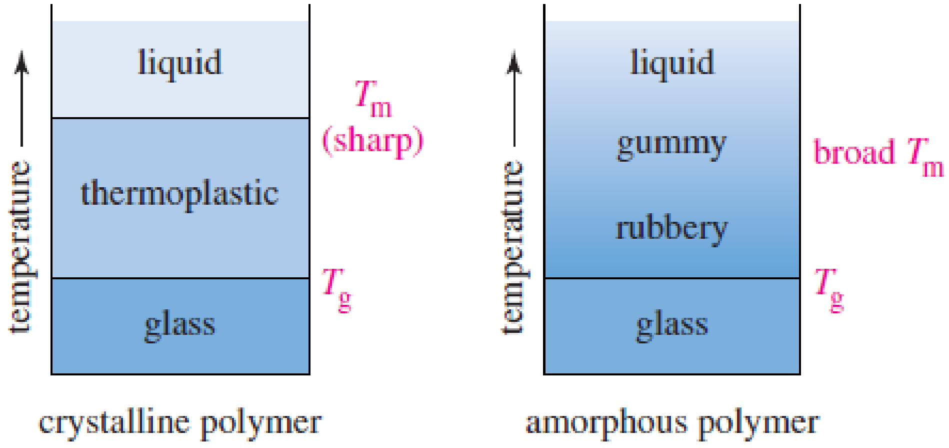
# Thermal Properties

**1) Thermoplastics:** **Three stages:**

I) **At low temperature**: **Glass** – solid and unyielding, and a strong impact causes them to fracture

II) **At temperature above glass transition temperature ($T_g$): Thermoplastic** – flexible and mouldable

II) **At temperature above crystalline melting temperature ($T_m$): Liquid** – crystallites melt and the individual molecules can slide past one another

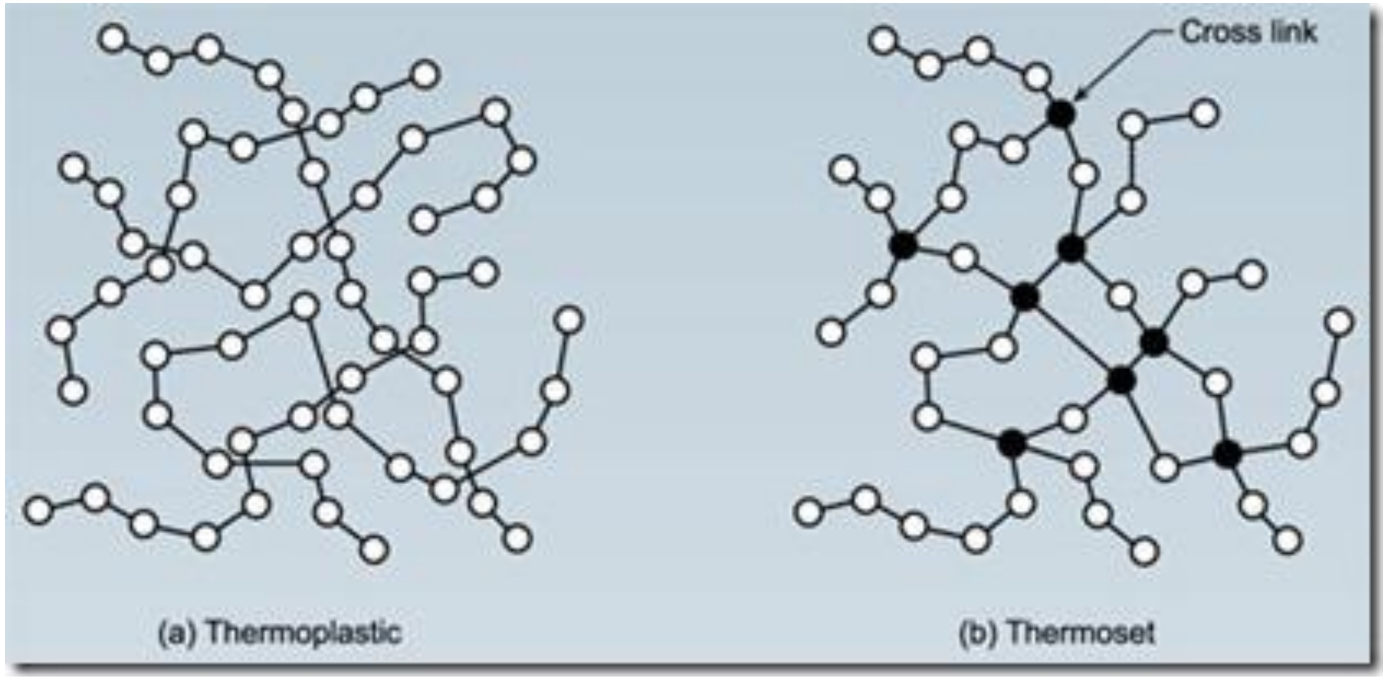



**Long-chain** polymers with low crystallinity (called **amorphous** polymers): no definite $T_m$

# Thermal Properties

**2) Thermosetting Polymers:** complex networks of cross-linked polymers

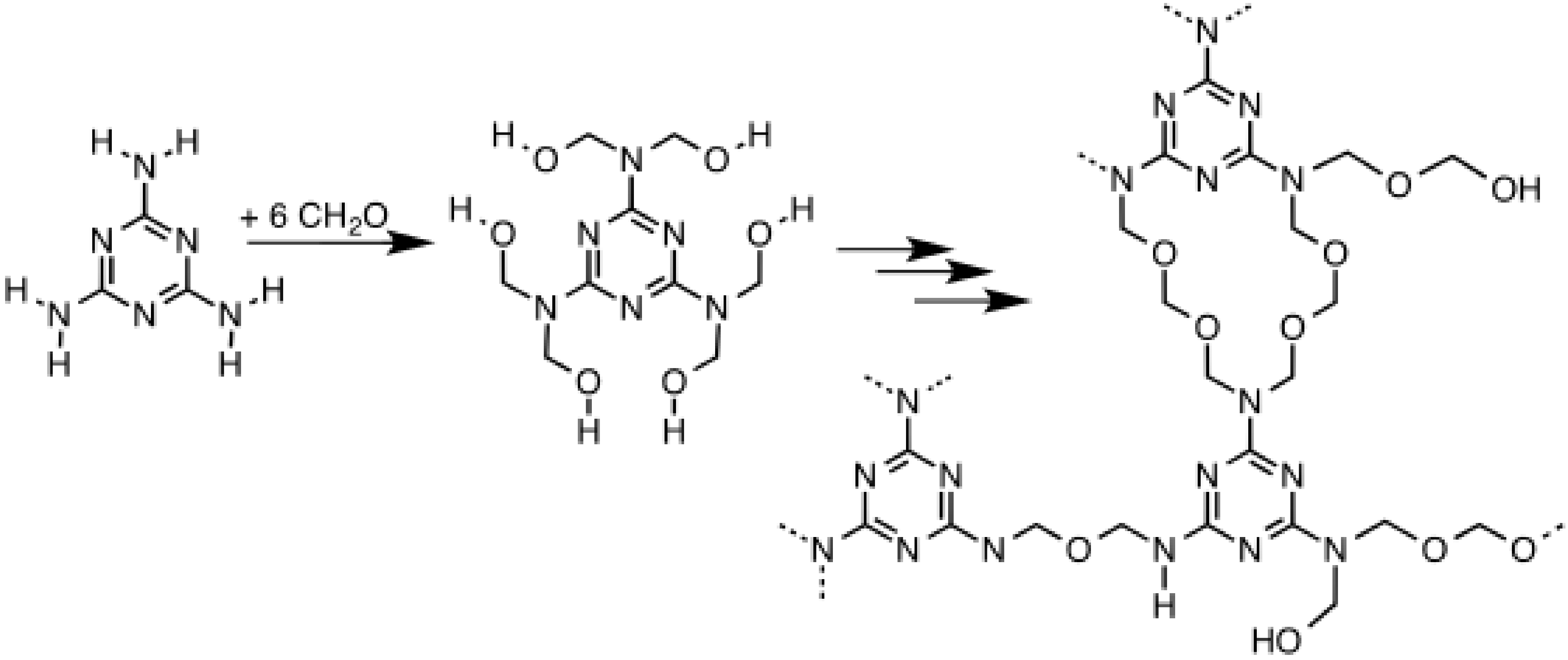
- Formed by **chemical reactions** that occur when monomers are heated together to form a **network of covalent bonds**
- **Cannot be re-melted** to form a liquid phase because these covalent bonds hold the network together



# Thermal Properties

## 2) Thermosetting Polymers:

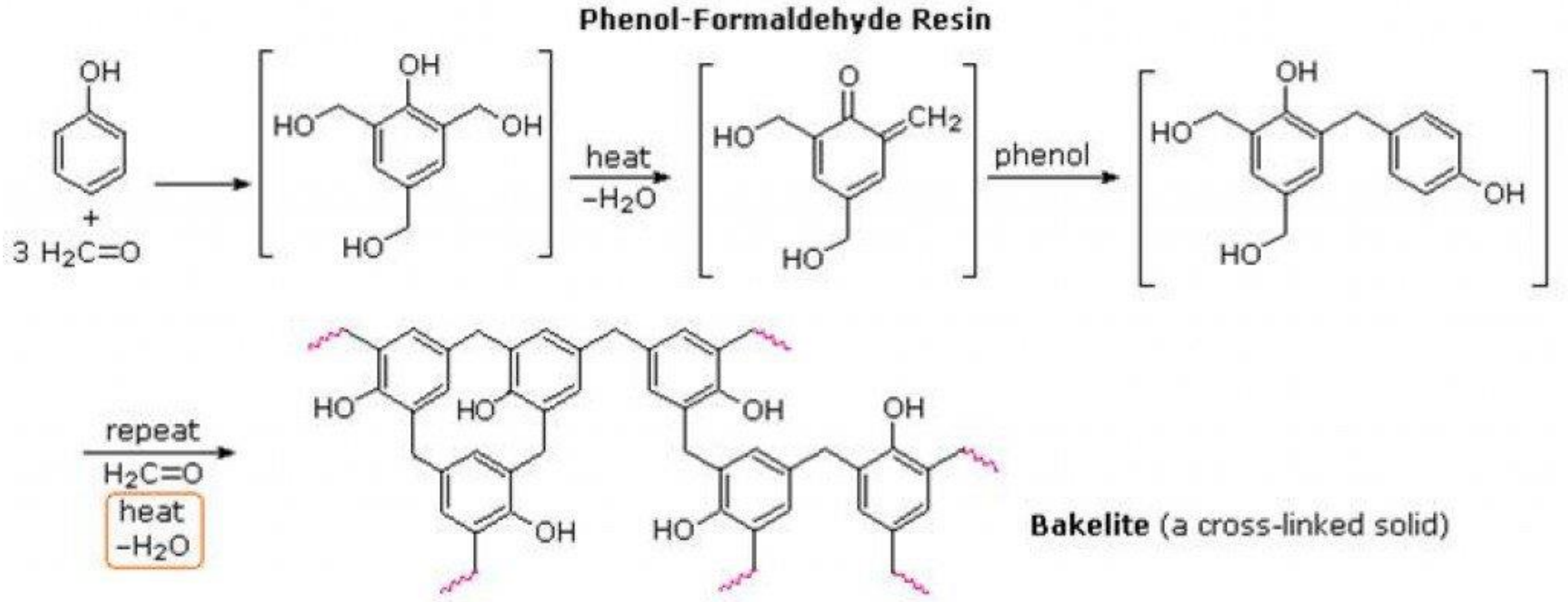
- **Melamine formaldehyde** is a thermosetting polymer, formed from **melamine** and **formaldehyde**



# Thermal Properties

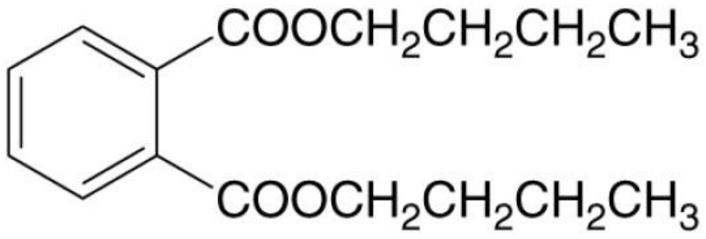
## 2) Thermosetting Polymers:

- **Bakelite** is a thermosetting polymer, formed from **phenol** and **formaldehyde**



# Plasticizers

- If a polymer is too **stiff** and **brittle** to be used in practical applications, **low molecular weight compounds** called **plasticizers** can be added to **soften** the polymer and give it **flexibility**
- The plasticizer interacts with the polymer chains, replacing some of the **intermolecular interactions** between the polymer chains.
- This lowers the crystallinity of the polymer, making it **more amorphous and softer**
- **Dibutyl phthalate** is a plasticizer added to poly(vinyl chloride) used in vinyl upholstery and garden hoses




dibutyl phthalate

It is more **volatile** than the high molecular weight polymers, it slowly **evaporate** eventually making the polymer **brittle** and easily **cracked**

# Environmental Impact of Polymers

- Polymer synthesis and disposal have a tremendous impact on the environment, and have created **two central issues:**

**1) Where do polymers come from?**

What **raw materials** are used for polymer synthesis and what environmental consequences result from their manufacture?

**2) What happens to polymers once they are used?**

How does **polymer disposal** affect the environment, and what can be done to minimize its negative impact?

# Problems with Polymer Disposal

- The same desirable characteristics that make polymers popular materials for consumer products—**durability**, **strength**, and **lack of reactivity**—also contribute to **environmental problems**

- Because polymers do not degrade readily, billions of pounds of them end up in **landfills** every year

- Two solutions to address the waste problem are:

1. **Recycling** existing polymer types to make new materials
2. Using **biodegradable polymers** that will decompose in a finite time span

# Polymer Recycling

- Each polymer is assigned a **recycling code** (1–6) that indicates its ease of recycling; the lower the number, the easier it is to recycle


- Recycling begins with **sorting** plastics by type, **shredding** the plastics into small chips, and **washing** the chips to remove adhesives and labels

- After the chips are dried and any metal caps or rings are removed, the polymer chips are **melted** and **moulded** for reuse

# Polymer Nanoparticles

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ARTICLES

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## Polymer Nanoparticles: Shape-Directed Monomer-to-Particle Synthesis

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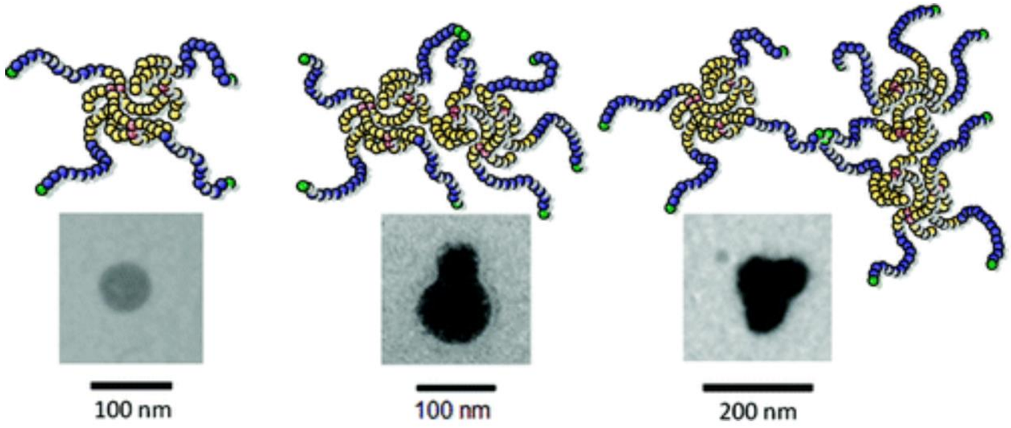
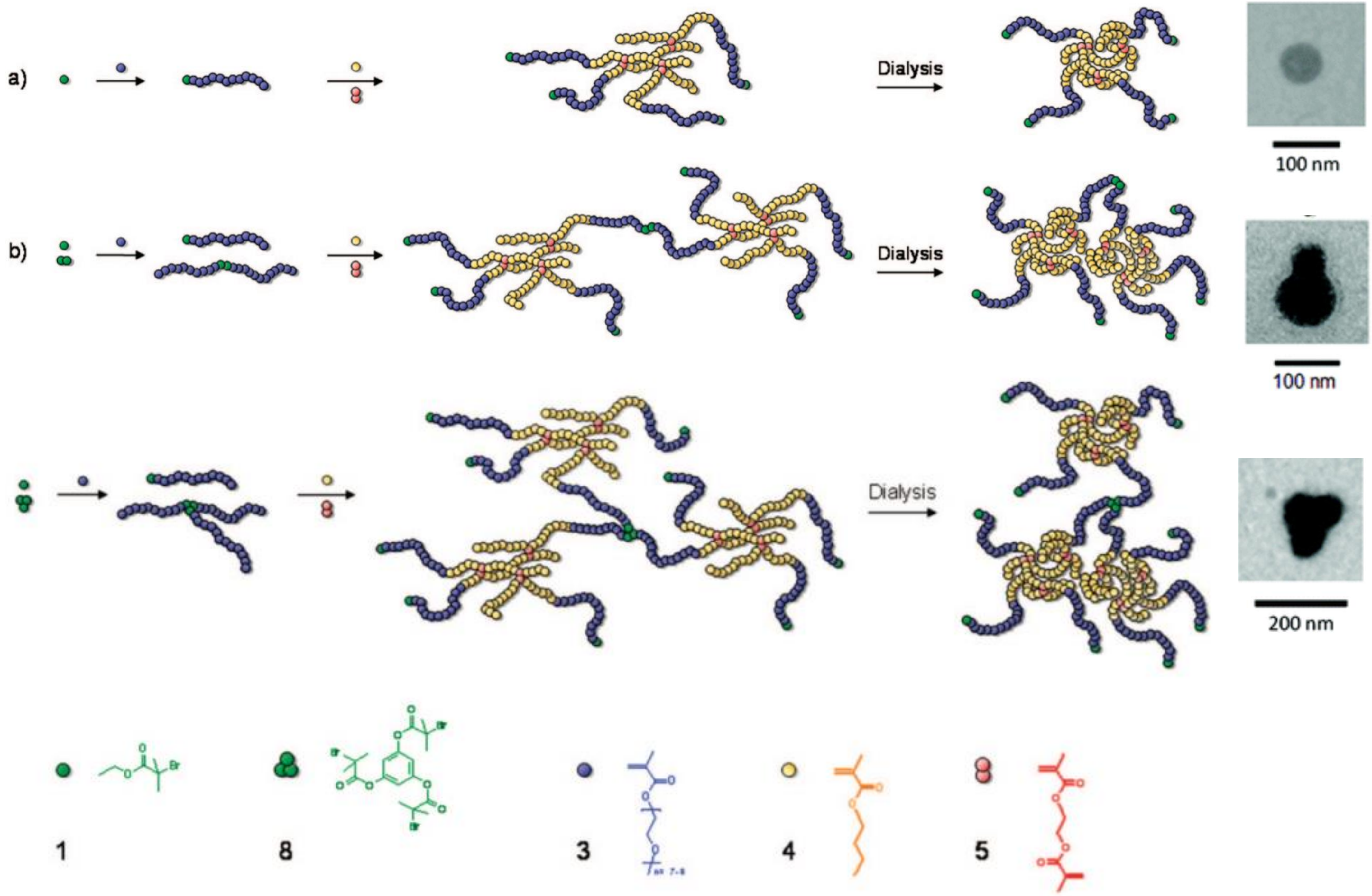
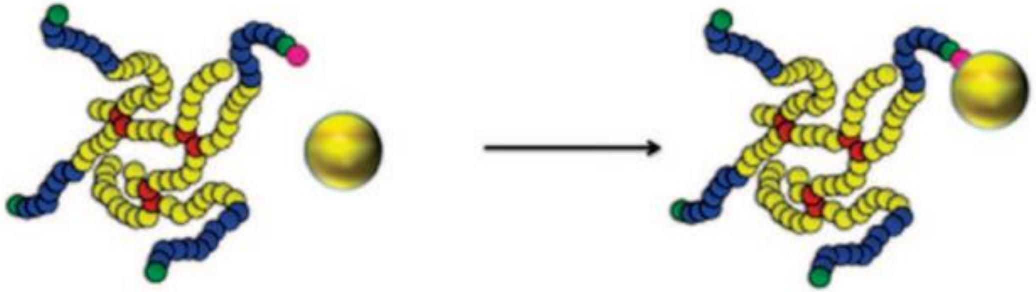
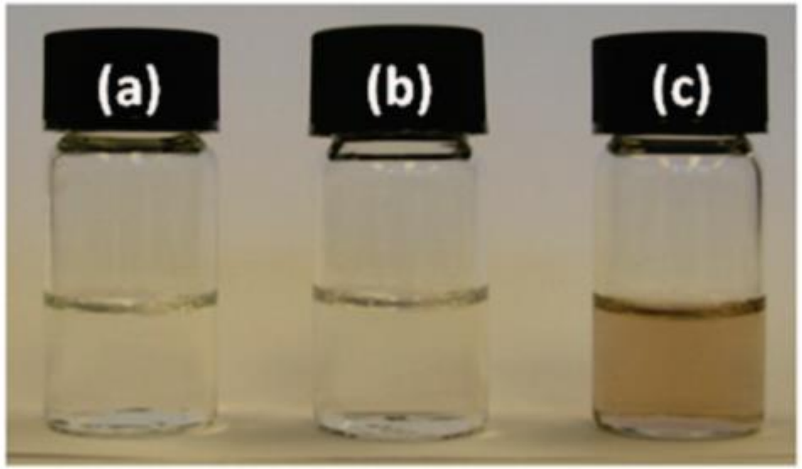



a)
b)
Dialysis
Dialysis
Dialysis
100 nm
100 nm
200 nm
1
8
3
4
5




(a)
(b)
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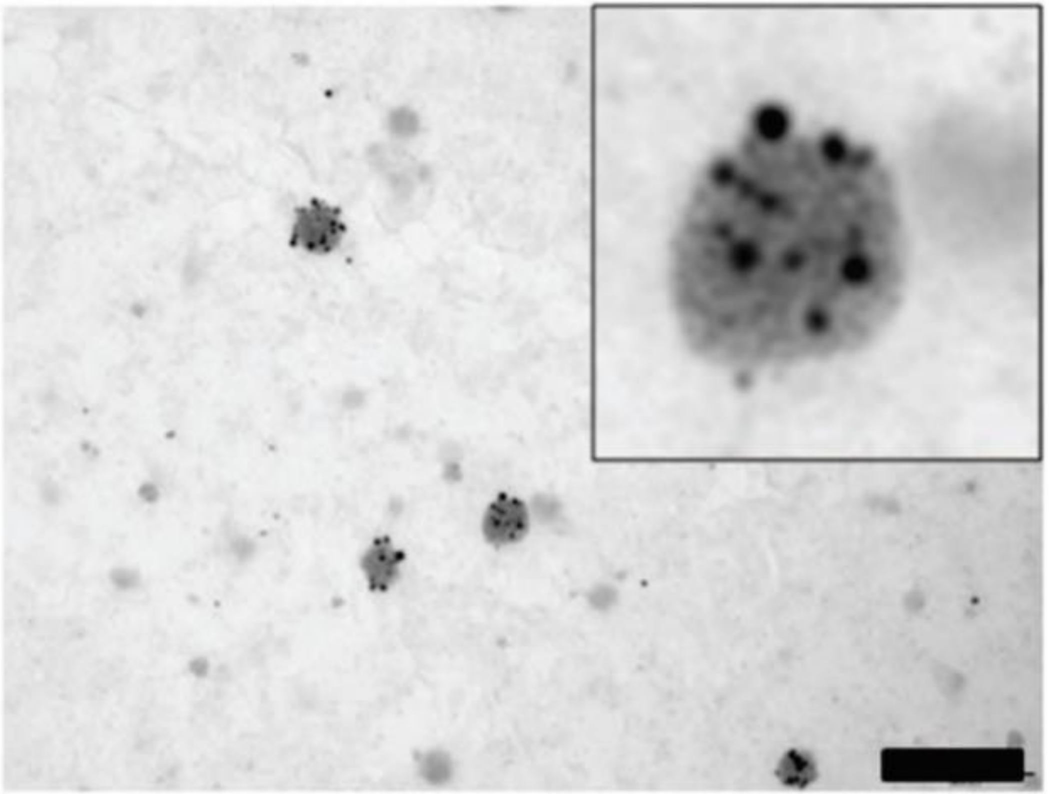
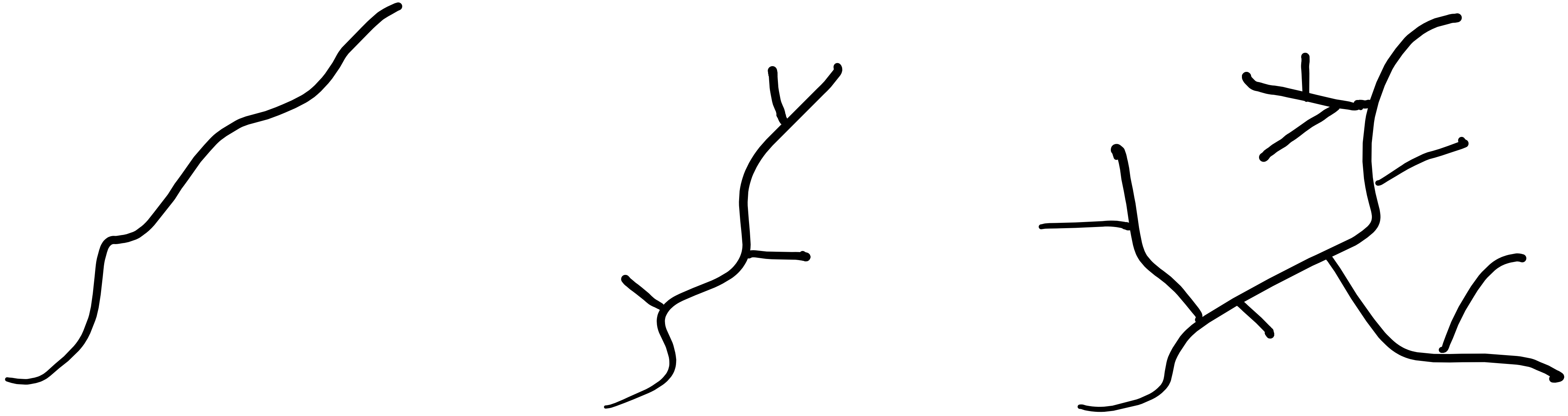


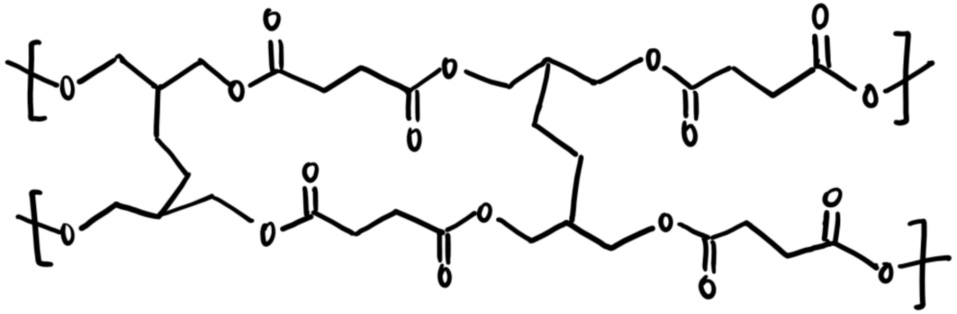
# Example

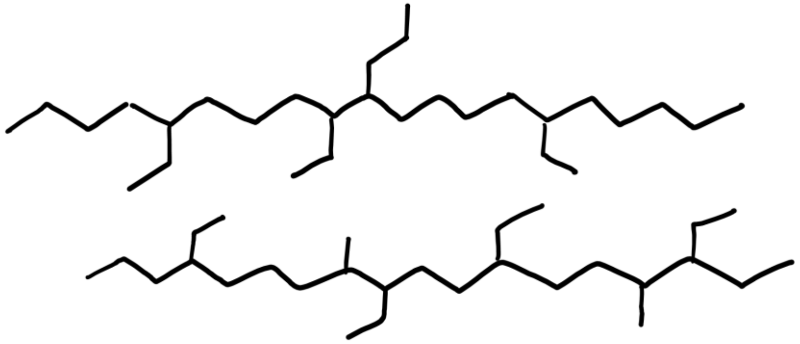
- Rank the density and melting point of these three types of polyethylene

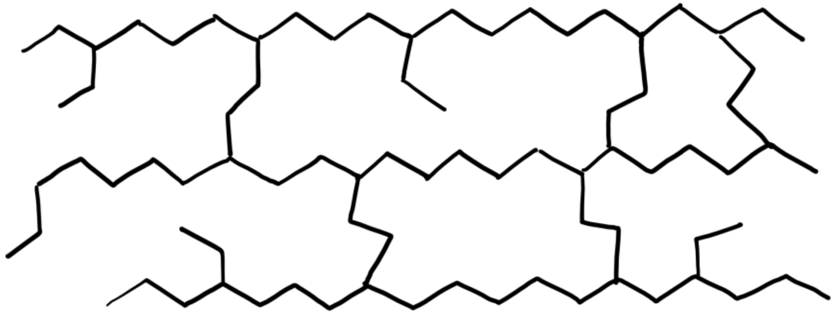


# Example

## Which of the following polymers can be recycled?







# Homework – 1

**i)**

Polyisobutylene is one of the components of butyl rubber used for making inner tubes.

**(a)** Give the structure of polyisobutylene.

**(b)** Is this an addition polymer or a condensation polymer?

**(c)** What conditions (cationic, anionic, free-radical) would be most appropriate for polymerization of isobutylene? Explain your answer.

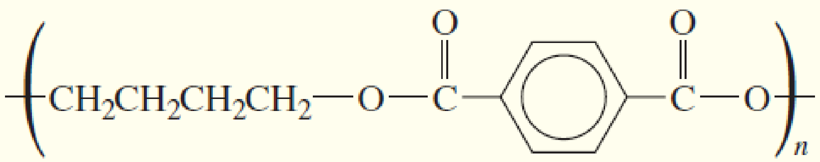
**ii)**

Poly(butylene terephthalate) is a hydrophobic plastic material widely used in automotive ignition systems.

**(a)** What type of polymer is poly(butylene terephthalate)?

**(b)** Is this an addition polymer or a condensation polymer?

**(c)** Suggest what monomers might be used to synthesize this polymer and how the polymerization might be accomplished.



poly(butylene terephthalate)

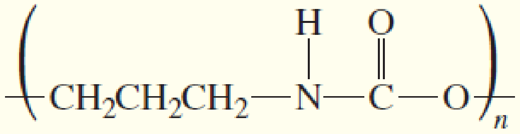
**iii)**

Poly(trimethylene carbamate) is used in high-quality synthetic leather. It has the structure shown.

**(a)** What type of polymer is poly(trimethylene carbamate)?

**(b)** Is this an addition polymer or a condensation polymer?

**(c)** Draw the products that would be formed if the polymer were completely hydrolyzed under acidic or basic conditions.



poly(trimethylene carbamate)

# Homework – 2

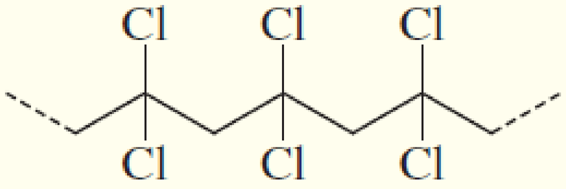
For each polymer shown below,

**(i)** draw the monomer or monomers that were needed to make the polymer.

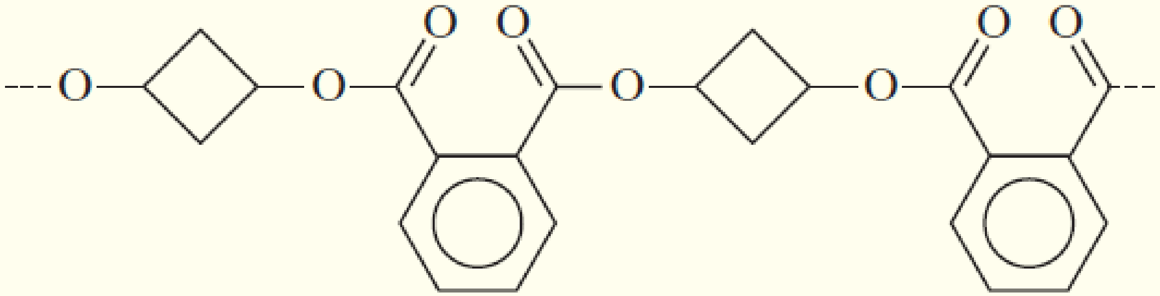
**(ii)** explain whether the polymer is an addition polymer or condensation polymer.

**(iii)** suggest what reagents and conditions one might use to synthesize the polymer.

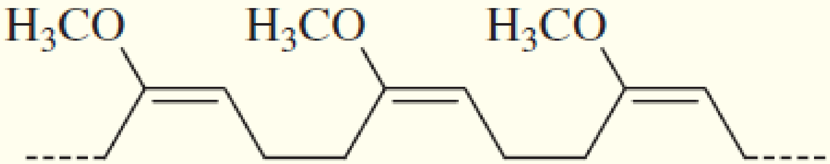
**(a)**



**(b)**



**(c)**



**(d)**