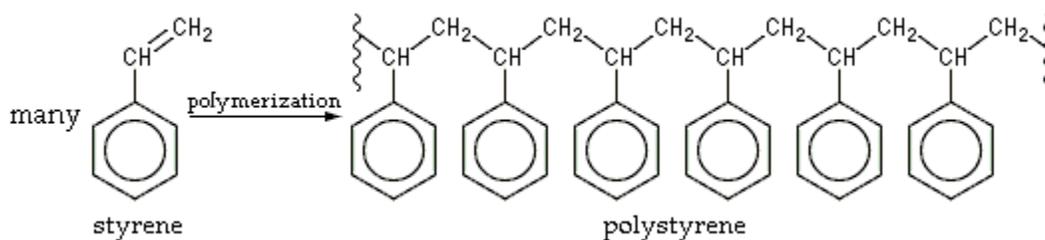


# Polymers

**Polymers** are long chain, giant organic molecules assembled from many smaller molecules called **monomers**. Polymers consist of many repeating monomer units in long chains, sometimes with *branching* or *cross-linking* between the chains. A polymer is analogous to a necklace made from many small beads (monomers). A chemical reaction forming polymers from monomers is called **polymerization**, of which there are many types. A common name for many synthetic polymer materials is plastic, which comes from the Greek word "plastikos", suitable for molding or shaping.

In the following illustrated example, many monomers called styrene are polymerized into a long chain polymer called polystyrene. The squiggly lines indicate that the polymer molecule extends further at both the left and right ends. In fact, polymer molecules are often hundreds or thousands of monomer units long.



## Introduction

Many objects in daily use from packing, wrapping, and building materials include half of all polymers synthesized. Other uses include textiles, many electronic appliance casings, CD's, automobile parts, and many others are made from polymers. A quarter of the solid waste from homes is plastic materials - some of which may be recycled as shown in the table below.

Some products, such as adhesives, are made to include monomers which can be polymerized by the user in their application.

## Polyurethane Foam



C. Ophardt, c. 2003

# Types of Polymers

There are many types of polymers including synthetic and natural polymers.

## Natural biopolymers

- Polypeptides in [proteins](#) - silk, collagen, keratin.
- Polysaccharides ([Carbohydrate chains](#)) - [cellulose](#), [starch](#), [glycogen](#)
- [Nucleic acids](#) - [DNA](#) and RNA

## Synthetic polymers

- Plastics
- Elastomers - solids with rubber-like qualities
- [Rubber](#) (carbon backbone often from hydrocarbon monomers)
- [silicones](#) (backbone of alternating silicon and oxygen atoms).
- Fibers
- Solid materials of intermediate characteristics
- Gels or viscous liquids

# Classification of Polymers

- Homopolymers: These consist of chains with identical bonding linkages to each monomer unit. This usually implies that the polymer is made from all identical monomer molecules. These may be represented as : -[A-A-A-A-A]-  
Homopolymers are commonly named by placing the prefix poly in front of the constituent monomer name. For example, polystyrene is the name for the polymer made from the monomer styrene (vinylbenzene).
- Copolymers: These consist of chains with two or more linkages usually implying two or more different types of monomer units. These may be represented as : -[A-B-A-B-A-B]-

# Polymers classified by mode of polymerization

- [Addition Polymers](#): The monomer molecules bond to each other without the loss of any other atoms. Addition polymers from alkene monomers or substituted alkene monomers are the biggest groups of polymers in this class. Ring opening polymerization can occur without the loss of any small molecules.
- [Condensation Polymers](#): Usually two different monomer combine with the loss of a small molecule, usually water. Most polyesters and polyamides (nylon) are in this class of polymers. Polyurethane Foam in graphic above.

## Polymers classified by Physical Response to Heating

### Thermoplastics

Plastics that soften when heated and become firm again when cooled. This is the more popular type of plastic because the heating and cooling may be repeated and the thermoplastic may be reformed.

### Thermosets

These are plastics that soften when heated and can be molded, but harden permanently. They will decompose when reheated. An example is Bakelite, which is used in toasters, handles for pots and pans, dishes, electrical outlets and billiard balls.

## Recycled Plastics

Recycle Code	Abbreviation and Chemical Name of Plastic	Types of Uses and Examples
1	PET - polyethylene terephthalate	Many types of clear plastic consumer bottles, including clear, 2-liter beverage bottles
2	HDPE - High density polyethylene	Milk jugs, detergent bottles, some water bottles, some grocery plastic bags
3	PVC - Polyvinyl chloride	Plastic drain pipe, shower curtains, some water bottles
4	LDPE - Low density polyethylene	Plastic garbage and other bags, garment bags, snap-on lids such as coffee can lids

5	PP - Polypropylene	Many translucent (or opaque) plastic containers; containers for some products such as yogurt, soft butter, or margarine; aerosol can tops; rigid bottle caps; candy wrappers; bottoms of bottles
6	PS - Polystyrene	Hard clear plastic cups, foam cups, eating utensils, deli food containers, toy model kits, some packing popcorn
7	Other	Polycarbonate is a common type, Biodegradable, Some packing popcorn

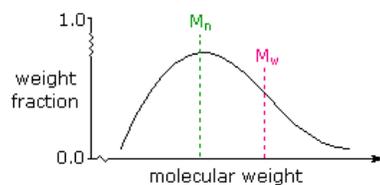
## Molecular Weights of Polymers

Unlike simpler pure compounds, most polymers are not composed of identical molecules. The HDPE molecules, for example, are all long carbon chains, but the lengths may vary by thousands of monomer units. Because of this, polymer molecular weights are usually given as averages. Two experimentally determined values are common:  $M_n$ , the number average molecular weight, is calculated from the mole fraction distribution of different sized molecules in a sample, and  $M_w$ , the weight average molecular weight, is calculated from the weight fraction distribution of different sized molecules. These are defined below. Since larger molecules in a sample weigh more than smaller molecules, the weight average  $M_w$  is necessarily skewed to higher values, and is always greater than  $M_n$ . As the weight dispersion of molecules in a sample narrows,  $M_w$  approaches  $M_n$ , and in the unlikely case that all the polymer molecules have identical weights (a pure mono-disperse sample), the ratio  $M_w/M_n$  becomes unity.

$$M_n = \sum n_i M_i \quad n_i = \text{mole fraction of chains with molecular weight } M_i$$

$$M_w = \sum w_i M_i \quad w_i = \text{weight fraction of chains with molecular weight } M_i$$

note  $w_i = \frac{n_i M_i}{M_n}$



$M_n$  and  $M_w$  in a typical sample of polydispersed macromolecules

Source: [http://chemwiki.ucdavis.edu/Organic\\_Chemistry/Polymers](http://chemwiki.ucdavis.edu/Organic_Chemistry/Polymers)