Polymers and Auto Racing

Vocabulary

- addition reaction
- catalyst
- condensation reaction
- dimer
- ethylene
- HDPE
- hydroxyl group
- LDPE
- monomer
- NOAX
- NOMEX
- nylon 6,6
- PEEK
- petroleum
- polycarbonate
- polyethylene
- polymer
- polymerization
- polypropylene
- Ziegler-Natta polymerization

Background Information

Without knowing anything at all about polymer chemistry, you can already learn something just from its name. The prefix "poly" means many. The Greek root "meros" means part. The word polymer literally means many parts.

Polymers are very large molecules made of repeating patterns of small molecules, called **monomers**. Many polymers are made by repeating the same small molecule over and over again. Others are made from two monomers linked in a pattern. While most polymers with which you are familiar are man-made, there are some biological polymers – proteins, nucleic acids, and complex carbohydrates – that are fundamental to the way your body functions. These can be made from one monomer or up to twenty different small molecules or monomers coming together to form one large polymer. We are going to focus our attention on synthetic polymers.

Because they contain carbon, polymers are categorized as organic compounds. The most common element found in polymers, besides carbon, is hydrogen. Many polymers are manufactured from feedstock, or raw materials, obtained from **petroleum**. Petroleum is a mixture of hydrocarbon compounds pumped from underground and is the result of extreme time and pressure acting on ancient sea plants and animals. However, the compounds used to make polymers are not necessarily obtained directly from petroleum deposits. Petroleum must first be refined before it can be made into polymers. All polymers must then be manufactured through **polymerization** reactions. The two most common reaction types used to make polymers are **addition reactions** and **condensation reactions**.

In addition reactions, hydrocarbons with double bonds are reacted with each other, breaking the double bond within the smaller monomer and forming a new covalent bond between the two monomers. **Ethylene**, C_2H_4, is commonly used and is combined to make **polyethylene**.

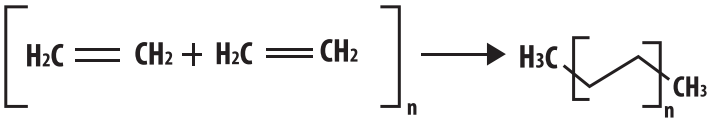


Figure 1 *Addition polymerization of polyethylene*

A **catalyst** changes the rate of reaction. Varying reaction conditions and the type of catalyst used will result in different structures of polyethylene polymers. One method uses high temperature and pressure with a peroxide catalyst and results in low-density polyethylene, **LDPE**. Another method, called **Ziegler-Natta polymerization**, takes place at lower temperature and pressure and produces high-density polyethylene, or **HDPE**. Both are made from the same monomer, ethylene, yet have very different physical properties. LDPE is a polymer with many branches, and less chain-like in structure. HDPE molecules are less branched, packed more closely together, and have stronger intermolecular attraction than LDPE. LDPE is softer and more flexible than HDPE. LDPE is used to make soft items like grocery bags and clear plastic food wrap. HDPE is used more in rigid applications like detergent bottles, toys, and temporary fuel containers.

Another polymer made via addition is **polypropylene**:

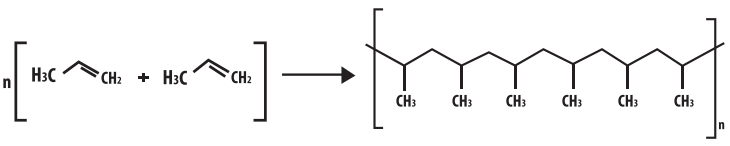


Figure 2 *Addition polymerization of polypropylene*

Condensation reactions occur between molecules that contain oxygen along with hydrogen and carbon. Two hydrogen-containing functional groups must be present on each molecule for the reaction to proceed.

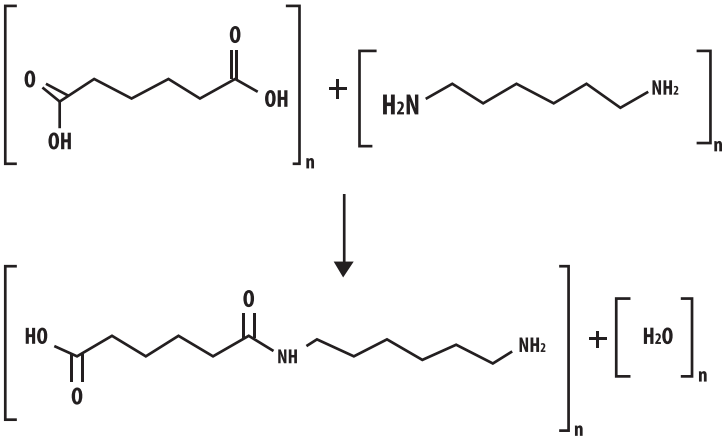


Figure 3 *Condensation polymerization of Nylon 6,6*

Note that in the polymerization of **Nylon 6,6**, a **hydroxyl group** (-OH group) is removed from one molecule and a hydrogen atom is removed from the other. The two molecules may be joined to form a **dimer**, H_2O in this case. Dimers combine to form a polymer, or the polymer may be built monomer by monomer. Either way, a water molecule is formed as a byproduct.

Besides nylon, some common polymers formed via condensation include polyester, a textile fiber; **polycarbonate**, a lightweight, transparent material often used in eyeglasses; and polyurethane, used in many foam, adhesive, insulative, and thus, automotive applications.

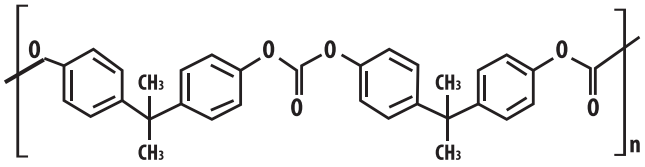


Figure 4 *Polycarbonate structure*

***bracket placement shows where the next bond would form.**

Polymers in Auto Racing

Many polymers are used in the auto racing industry. Some polymers are used in place of metals or metal alloys to reduce weight. Other polymers are used to reduce friction and wear on moving parts. Polymers are also commonly used in the safety features incorporated in the vehicles and equipment worn by the drivers. One exceptionally important piece of safety gear is the fire suit worn by drivers and pit crew members. A polymer called **NOMEX®**, is made from two different monomers. NOMEX® is spun into fibers and woven into fabric that does not burn. In the case of an accident or fuel spill, a fire suit made of NOMEX® or another flame retardant fiber will give the driver or crew member extra time to get away without suffering severe burns to the covered parts of the body.

Not all polymers developed in the auto racing industry are used for safety. Polymer coatings are often applied to the body or moving parts to reduce air resistance and friction between moving parts. Many different companies manufacture these coatings using their own special formula.

Polymers that are highly resistant to thermal degradation are being used to produce engine and exhaust parts. One such polymer is polyetheretherketone, or **PEEK**. This polymer is used to manufacture parts to reduce weight and wear. It does not react or dissolve in most organic or aqueous environments, and it is strong enough to be used in many applications in which cast aluminum is commonly found. Cast aluminum is commonly used in items like wheels on a car, and some engine parts like pistons. Because it is a polymer, a special lubricant and seal are not needed to keep it from grinding away at metal parts it may contact.

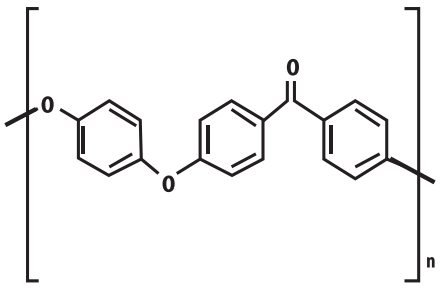
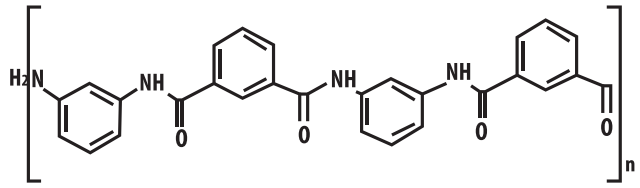
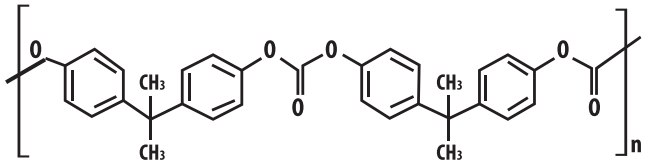
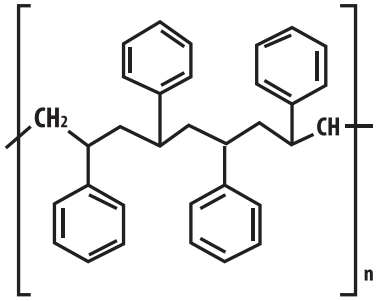
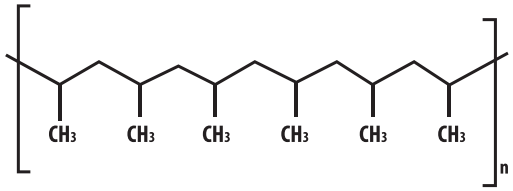


Figure 5 *Structure of polyetheretherketone, or PEEK*

The following table shows some important fibers used to keep race car drivers and their crew members safe:

POLYMER NAME	USE	STRUCTURE
NOMEX® (meta aramid polymer)	Fire retardant fabric	
LEXAN® (polycarbonate)	Windshields and helmet visors	
Polystyrene	Expanded into foam used inside helmets and as part of crash barriers	
Polypropylene	Exanded into foam used inside helmets	

***bracket placement shows where the next bond would form.**

The racing industry has begun using some space-age products and polymers. One example is a substance called **NOAX**, which was first developed following the Columbia accident as an emergency adhesive to be applied while in orbit on the outside of the space shuttle. Also known as "good goo," this material is a flexible polymer that converts to a ceramic at very high temperatures. Formula 1 (F1) engineers are currently investigating this product for use in the exhaust system of F1 cars to protect the car and driver from excess heat from the exhaust. This technology may also be used in manufacturing rust-proof exhaust pipes for passenger vehicles.

All of the polymers listed here, and many more, probably began as hydrocarbons refined from petroleum. Petroleum is most widely used for transportation fuel, but it is also extremely important in manufacturing polymers not only for the auto racing industry but also for use in our everyday lives.

CHEMICAL MANUFACTURING ACTIVITY

Polymers

During fractional distillation crude oil is separated into useful parts. A petrochemical is a product of the fractional distillation process. Usually consisting of long chains, a monomer is a link in the chain. All of the monomer links connected together make a polymer chain.

Chemically bonded monomers form polymers in a process called polymerization. Polymers created from petrochemicals are synthetic or man-made polymers. We use many of these polymers, such as plastics, everyday.

Polymer One

Materials

- Cornstarch
- Water
- Sealable plastic sandwich bags
- Measuring spoons
- Food coloring
- Paper plates

✔ Procedure

1. Put 6 tablespoons of cornstarch in a plastic bag.
2. Add 5 drops of food coloring.
3. Add 4 tablespoons of water.
4. Close the bag and mix together by kneading.
5. If the polymer seems too runny (you cannot pick it up), add a spoonful of cornstarch to thicken. If the polymer seems too thick or crumbly (dry), add a spoonful of water to make it thinner.
6. Open the bag and pour the polymer onto the plate.
7. Use your finger to gently poke the polymer. What happens?
8. Now quickly poke the polymer. What happens?
9. Pick the polymer up. What happens?
10. Roll the polymer in a ball. What happens?

⁂ Conclusion

1. Is this polymer a liquid or a solid? Explain.

CHEMICAL MANUFACTURING ACTIVITY

Polymers

Polymer Two

Materials

- White glue
- Borax
- Water
- Spoon or popsicle stick to stir
- Small plastic cups
- Food coloring
- Graduated cylinder
- Ruler
- Sealable plastic sandwich bags

Preparation

- Make a borax solution: about 6 mL of borax to 235 mL of water.

✔ Procedure

1. Use the ruler to measure and mark 1 cm from the bottom of the small plastic cup.
2. Add white glue to the 1 cm mark.
3. Add a few drops of food coloring and mix.
4. Measure 7 mL of water in the graduated cylinder and add to the glue. Mix well and pour into a plastic bag.
5. Measure 8 mL of the borax solution using the graduated cylinder and add to the glue solution in the plastic bag. Mix well by kneading.
6. If it is too sticky, add borax solution one drop at a time. If it is to stringy, add glue one drop at a time.
7. Once the polymer is formed, you may remove it from the cup and knead it.
8. Pull your polymer apart, string it out, twist it, and roll it into a ball.
9. Write your observations about your polymer.

⁂ Conclusions

1. What happened when you combined the glue solution and the borax solution?

2. Explain how this is a polymer.

CHEMICAL MANUFACTURING ACTIVITY

Slush Powder

Vocabulary

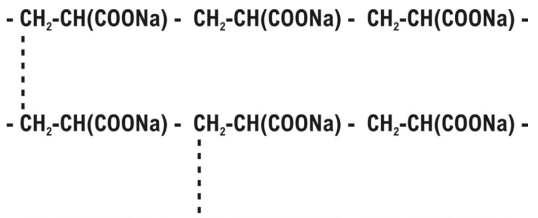
Polymer: a large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern.

Monomer: a molecule that can combine with other molecules to form a polymer.

Dissociate: to split into simpler groups of atoms, single atoms, or ions.

Background

The chemical name for slush powder is sodium polyacrylate. It is a polymer containing many repeating molecules called acrylate monomers connected end-to-end in a large chain. Sodium acrylate is a chain made of carbon, oxygen, hydrogen, and sodium. Cross-links between the sodium acrylate chains (- - - - -) tether the chains together into sodium polyacrylate. These repeating molecules can be thousands to millions of units long.



Sodium polyacrylate, nicknamed the "super slurper," is called a superabsorber because it has the ability to absorb large quantities of water. It can absorb 400-800 times its mass in water, but does not dissolve into a solution because of its three-dimensional network structure. Its liquid-like properties result from the fact that the polymer is composed almost entirely of water. Its solid-like properties are due to the network formed by the cross-links.

Sodium polyacrylate is called a hydrophilic or "water-loving" polymer because of its great affinity for water. So how does this polymer work? In its dry powdered state, the chains of the polymer are coiled and lined with carboxyl groups (–COOH). When water is added, the carboxyl groups dissociate into negatively charged carboxylate ions (COO^{-1}). These ions repel one another along the polymer chain, widening the polymer coils and allowing water to move into contact with more carboxyl groups. As the polymer continues to uncoil, it becomes a gel.

Sodium polyacrylate is used as an absorbent material in disposable diapers and to retain water around plants. It is considered non-toxic, but inhalation of airborne particles of the powder or contact with the eye can cause serious adverse reactions. It is for this reason that using a disposable diaper to obtain the powder is discouraged.

To dispose of the gel, add salt. The presence of salt in the solution greatly decreases the ability of the polyacrylate to absorb and retain water. Once the gel has liquefied, it can be safely poured down a drain.

Materials

- Sodium polyacrylate
- 400 mL Beaker
- 100 mL Beaker
- Water
- Salt (optional)

✔ Procedure

1. Place 1 cc (mL) of sodium polyacrylate in the 400 mL beaker.
2. Add 10 mL of water to the beaker. Observe.
3. Continue adding water 10 mL of water at a time until the sodium polyacrylate absorbs no more water.

Extension

- Experiment with varying strengths of saltwater solution to determine how much a given amount of sodium polyacrylate can absorb. Use a one percent saltwater solution for this experiment, since urine is approximately one percent saline (4.5 mL of salt to 1 liter of water).

Conclusions

1. Describe what happened to the polymer as you added water.
2. Why does the polymer stop absorbing water?
3. Explain how polymers like this one fit into the refining process.

POLYMERS AND AUTO RACING

POLYMERS

ARE MADE UP OF MANY

MONOMERS

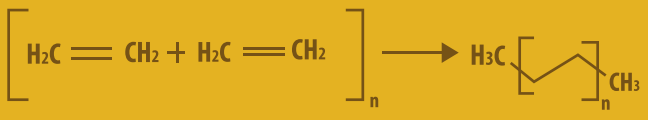
COMMONLY MADE OUT OF

6	1
C	H
12.0107	1.00794
CARBON	HYDROGEN

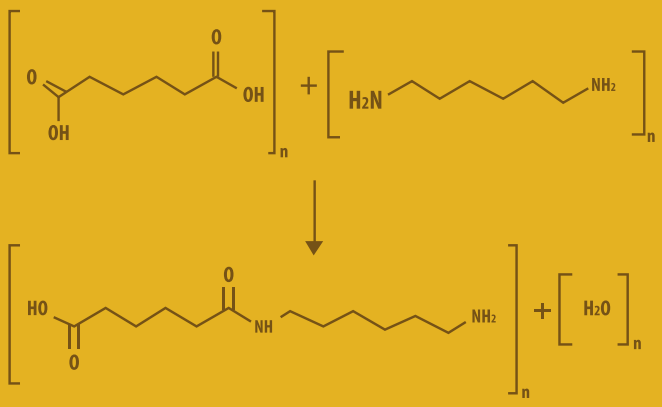
OR

PETROLEUM

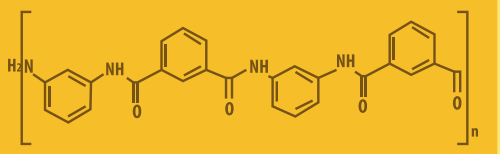
ADDITION REACTION



CONDENSATION REACTION



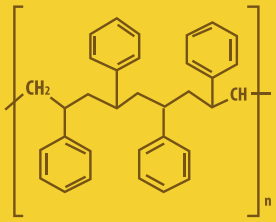
NOMEX® (META ARAMID POLYMER)



IS USED TO MAKE

FLAME RETARDANT FABRIC

POLYSTYRENE

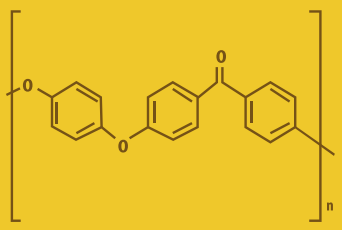


IS USED TO MAKE

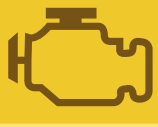
FOAM USED INSIDE HELMETS

PART OF CRASH BARRIERS

PEEK (POLYETHERKETONE)

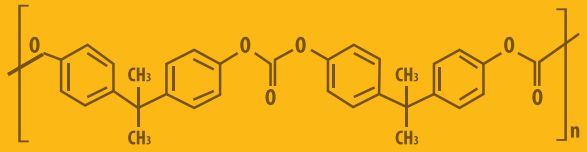


IS USED TO MAKE



ENGINE AND EXHAUST PARTS

LEXAN®(POLYCARBONATE)

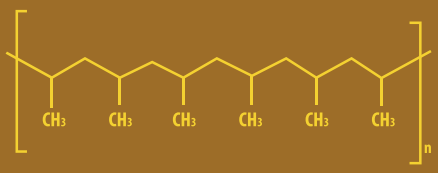


IS USED TO MAKE

WINDSHIELDS

HELMET VISORS

POLYPROPYLENE



IS USED TO MAKE

FOAM USED INSIDE HELMETS