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POLYMERS

Mega molecules Out of Small Ones

Recommended grades level(s) 11-12

Time Duration: - 50 minutes

Objective(s):
The learner will produce a linear and a cross-linked polyester.
The learner will compare properties of the two polyesters.
The learner will prepare a take-home viscosity demonstration.
The learner will prepare a nylon rope and calculate its length.
The learner will distinguish from an equation whether a polymer is mono- or copolymer.

Materials and/or Resources:
2 watch glasses
Aluminum foil
Concentrated sulfuric acid
2 test tubes
Ring stand
Phthalic anhydride
Sodium acetate
Glycerol
Ethylene glycol
Hot plate
Piece of polyester
Disposable test tube
Stoppers
Paper clips
Solution of hexamethylenediamine
Distilled water
Large beaker
Tweezers
Ethanol

Background Information:
Polymers are large molecules produced by the combination of many small molecules called monomers. By changing monomers, different polymers can be produced. Scientists are often able to achieve specific properties in polymers by the right choice of monomers.

Polymerization reactions are of two types. One type is the addition reaction in which a double bond is each molecule is changed to a single bond as the molecules are joined together. Polyethylene is an example of this type of polymerization reaction. The other type is the condensation reaction in which a small molecule such as water (H_2O), ammonia (NH_3), or hydrogen chloride (HCl) is produced along with the polymer bond.

Polymers are also classed as monopolymers, only one type of monomer molecule, or copolymer, more than one type of monomer molecule.

One of the many places that polymers have had a major impact is in synthetic fibers. A large part of the clothes that we wear are synthetic fibers. There are also other uses besides clothing for these polymers. Two well-known synthetic fibers are nylon and polyesters.

Nylon is a polyamide because the bond formed between monomer units is an amide bond. There are several different nylons produced depending on the monomers used. The properties of the nylons also depend on the treatment after production. Nylons may be used in stockings after being made into thread or molded into something like a sebacoyl chloride. The nitrogen in hexamethylenediamine will bond to the carbonyl carbon (C=O) forming an amide bond. Hydrogen is bonded to the nitrogen and the chlorides are lost from their original molecules.

$$H_2N(CH_2)_6NH_2 \qquad + \qquad Cl\overset{\overset{O}{||}}{C}(CH_2)_8\overset{\overset{O}{||}}{C}Cl \longrightarrow \qquad HCl \; +$$

Hexamethylenediamine Sebacoyl Chloride

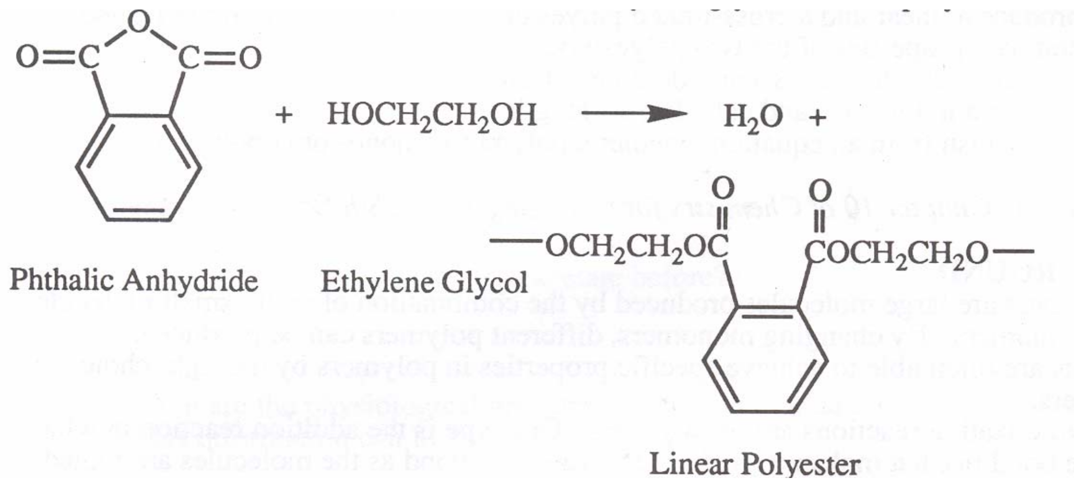
$$-NH(CH_2)_6\;NH\overset{\overset{O}{||}}{C}(CH_2)_8\overset{\overset{O}{||}}{C}NH(CH_2)_6\;NH\overset{\overset{O}{||}}{C}(CH_2)\;\overset{\overset{O}{||}}{C}-$$

Nylon

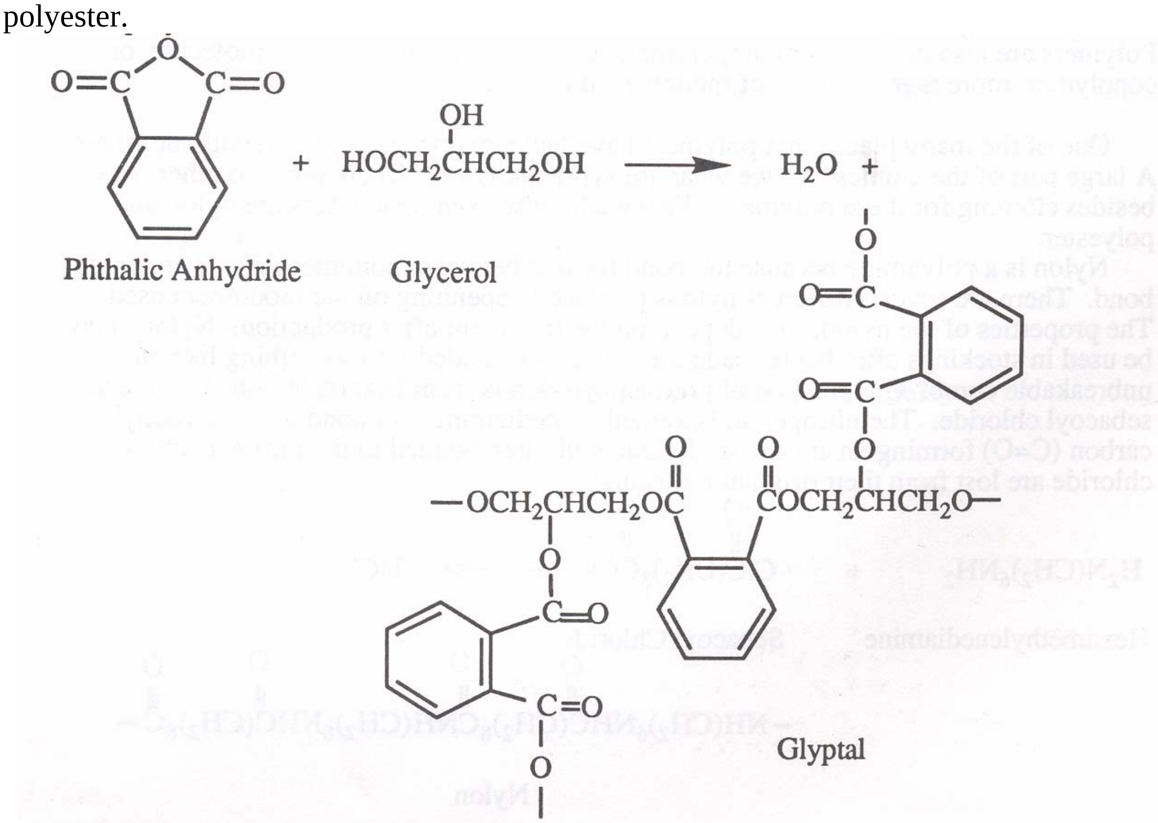
Because there are six carbons in hexamethylenodiamine and ten in sebacoyl chloride, the nylon formed is nylon 6.10. If adipoyl chloride (with six carbons) is used, the product is nylon 6.6.

Different products can be made from the same polymer. Polyester can be a solid or it can be drawn into a thread. Almost everyone has some clothing made of polyester and in this investigation; a hard solid of polyester will be made.

Making two different polyesters shows an example of making a polymer with the properties desired. They are polyesters because of the ester (COC=O) bond between the monomers. In both reactions the COC bond in phthalic anhydride is broken to form two new bonds with alcohol groups (OH). With ethylene glycol linear polyester is formed.



When glycerol with three OH groups is used, a cross-linked, three dimensional polyester called glyptal is formed. Glyptal is a harder, more brittle compound than is the linear polyester.



Procedures:

1. Clamp two test tubes in a slanting position, close together on a ring stand. To each add 2.5 g of phthalic anhydride and 0.1 g of sodium acetate. To one of the test tubes add 1.0 mL of glycerol. To the other tube add 1.0 mL of ethylene glycol. Point the tubes away from everyone and heat the test tubes gently. Heat each tube equally. The apparent boiling of the solutions is due to the escape of

water produced as the condensation reaction occurs. Continue to heat for 5 minutes after the “boiling” starts.

2. While one student heats the reactants, the other student needs to cover the inside of two watch glasses with aluminum foil.

3. When the 5 minutes is up, pour the contents of each test tube onto a covered watch glass. Allow to cool.

4. Test the two products for viscosity, elasticity, and brittleness

5. Put concentrated sulfuric acid in the test tubes to dissolve the polyester in the test tube.

6. Clamp a disposable test tube in a slanting position on a ring stand. Add 2.5 g of phthalic anhydride, 0.1 g of sodium acetate and 1.0 mL of glycerol. Point the tube away from everyone and heat the test tube gently. The apparent boiling of the solution is due to the escape of water produced as the condensation reaction occurs. Continue to heat for 10 minutes after the “boiling” starts. Allow cooling in the test tube.

7. When cool, stopper the test tube. With a paper clip stand this will be a neat take-home display. It will look like it is about to pour out of the test tube but it will take a long time to pour out. A large paper clip slipped into the open end of the test tube will make a stand to prevent the test tube from rolling.

8. During the time the polyesters are cooling, make a nylon rope. Prepare a 0.5 M solution of hexamethylenediamine by adding 0.5 g of NaOH and 1.5 g of hexamethylenediamine in 25 mL distilled water. Place 25 mL of 0.5 M hexamethylenediamine in a 150 mL beaker. Food coloring or phenolthalein can be added to the solution for color.

9. Prepare 0.2 M sebacoyl chloride by dissolving 1 mL sebacoyl chloride in 25 mL hexane. Slowly pour 25 mL of 0.2 M sebacoyl chloride down the side of the beaker, forming a second layer on top of the diamine solution. Disturb the diamine layer as little as possible.

10. Measure around a large beaker, which will be used to wind the rope as it is produced.

11. With tweezers, carefully grasp the interface between the phases and pull it out slowly and carefully. Do not jerk. Catch the end around the larger beaker. As you rotate the large beaker pulling more of the nylon out of the beaker, the two phases will react at the interface until one phase is exhausted. Count the number of turns of the large beaker that it takes to exhaust the reactants.

12. Wash the nylon rope in water or ethanol thoroughly before handling.

13. Calculate the length of the rope and test for viscosity, elasticity, and brittleness.

14. The solid polymers and foil can be thrown into the trash. When all of the polyester has dissolved, the sulfuric acid in the test tubes can be flushed down the drain with lots of water. Hopefully the nylon reactants will be used up.

Development Resources:

Chemical Investigations for Changing Times. C. Alton, Paula Marshall, John W. Hill. 8th edition Prentice Hall Upper Saddle River, NJ