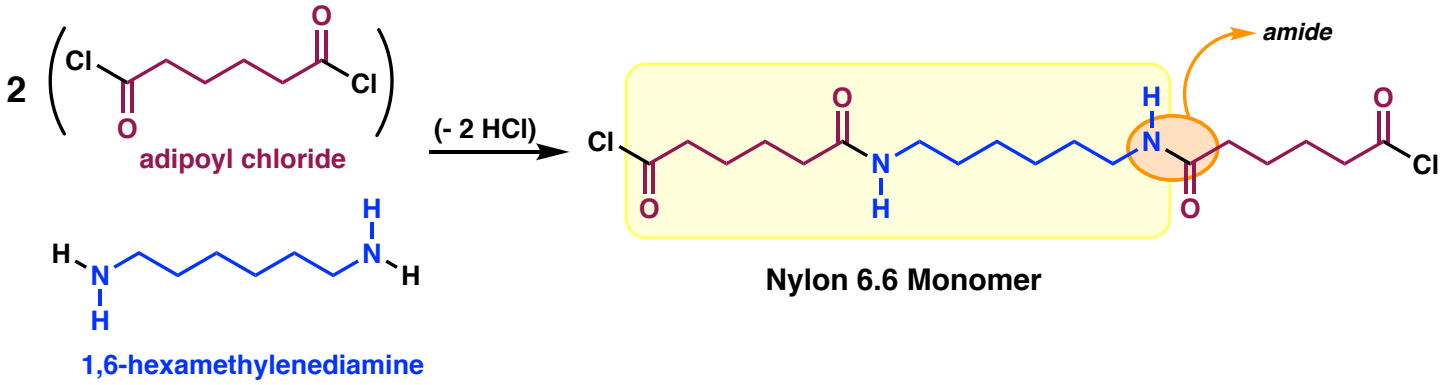
The Synthesis of Nylon

"An Introduction to Condensation Polymerization in Organic Chemistry"

Polymers are large, chain-like molecules made of hundreds or thousands of smaller, repeating molecular units called **monomers.** The monomers are typically connected by covalent chemical bonds. Many polymers occur naturally in plants and animals such as cellulose, which is a natural plant polymer made of glucose monomers. Wool and hair are also polymers that come from animals and are made of protein monomers. Since the early 1900s, synthetic polymers (also known as plastics) have been produced for a variety of industrial and household uses.

One common way of joining molecular units together to produce synthetic polymers is called **condensation polymerization**. During this chemical reaction, a small molecule such as H_2O (water) or HCl (hydrochloric acid) is eliminated as the larger polymer molecule is formed. The polymer commonly known as **Nylon** is formed using this technique. *The reaction of 1,6-hexamethylenediamine and adipoyl chloride to form Nylon 6,6 which is used in the production of fibers for clothing, rope, and carpets proceeds through condensation polymerization.*

When making nylon, hexamethylenediamine, which contains two primary amines ($-NH_2$) and six alkane groups ($-CH_2-$), is combined with adipoyl chloride, which contains two acid chlorides (-COCl) and six alkane groups ($-CH_2-$), to form a nylon monomer in a nucleophilic acyl substitution with hydrochloric acid as the byproduct (see below).



The new polyamide dimer can continue to react with other acid chlorides and amines to produce longer and longer chains of amide linked molecules until either the hexamethylenediamine or the adipoyl chloride is used up.

Your goal in this experiment is to synthesize Nylon 6.6 using a premade solution of hexamethylenediamine in water and a premade solution of adipoyl chloride in hexanes. You will also be adding a solution of sodium hydroxide in water to the solution of hexamethylenediamine to both deprotonate the diamine and neutralize the hydrochloric acid that is produced.

Procedure

Safety precautions: Wear protective gloves, safety glasses, and lab coats throughout the experiment part.

Materials:

- 5% (w/v) aqueous hexamethylenediamine solution
- 20% (w/v) aqueous sodium hydroxide solution
- Adipoyl chloride solution in hexanes (95% w/v stock solution diluted to 5% v/v in hexanes)
- Graduated pipettes
- Glass chambers
- Metal forceps
- Test tube
- Water

Note: Use the graduated pipettes placed in each flask containing the solutions to measure and transfer them.

1. Carefully transfer 5 mL of hexamethylenediamine solution using the graduated pipette to a glass chamber.

2. Add 2 drops of the aqueous sodium hydroxide solution to this using the graduated pipette.

3. Carefully transfer 5 mL of the adipoyl chloride solution into a separate glass chamber using the graduated pipette.

4. Very slowly and carefully pour the adipoyl chloride solution from the flask down the inside of the glass chamber containing the hexamethylenediamine solution, while gently rotating the glass chamber as you do so. You will see two immiscible layers in the beaker now. A thin polymer film should begin to form at the interface of the aqueous layer (bottom) and the organic layer (top).

5. Use the forceps to carefully grab the film from the interface and coil it around a test tube held horizontally a few inches above the glass chamber. Spin the test tube to collect a continuous strand of nylon that keeps forming at the interface.

6. After collecting as much as nylon as possible, rinse the spool of nylon with water.

7. After finishing, please make sure to empty the glass chambers in the waste container and rinse with water and acetone. This will allow the next person to use the materials. Also, dispose of the nylon in the waste container.

Image 1: An example of the two immiscible layers in Step 4 with the aqueous layer on bottom and organic layer on top

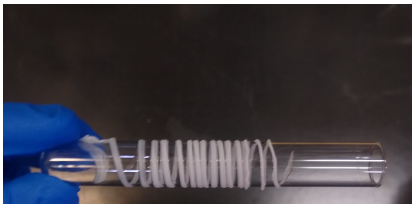


Image 2: An example of coiling the nylon around a test tube in Step 5.