Making the Polymer Nylon

Objective:

Students will:

Investigate how to prepare the man-made polymer nylon from is constituent monomers.

Introduction:

This experiment is taken mainly from Colin Baker of Bedford School, (1) who believes that *Nothing tends to imprint chemical facts upon the mind so much as the exhibition of interesting experiments* - Samuel Parkes, 1816

In September 1931, American chemist Wallace Carothers, working for the Dupont Chemical laboratories, reported research on 'giant' molecules called polymers based on an understanding of the chemical structure of wool. Carothers' work focused on a polymer fiber that he referred to simply as '66', a number derived from its molecular structure. By 1935, nylon, the 'miracle fiber', was born. Nylon was touted as a man-made form of silk and was a huge success in its initial market, women's hosiery. In December 1941, the War Production Board allocated all production of nylon for military use, including parachutes and reinforcement bands of B29 bomber tires, (1)

The formation of Nylon requires two chemical compounds (monomers) both with two reactive groups; one on each end. The one molecule is sebacoyl chloride which is a diacid chloride also known as decanedioyl dichloride. The second is 1,6-diaminohexane. Nylon is a large polymer formed by the alternate linking of the two reactants. “ In an organic solvent, the decanedioyl dichloride forms an immiscible layer with an aliphatic diamine in water. At the interface, where the two colorless solutions meet, a white, long-chain polymer is formed. This polymer film can be pulled from the interface and is immediately replaced as it is removed. If you stop pulling, nothing appears to happen - the reaction stops, but it is resumed immediately when you start to pull again. The reaction can occur over several hours”, (1)

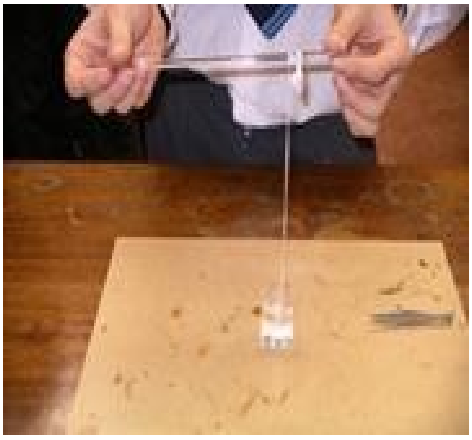

Figure 1, Pulling nylon from the reaction mixture.

Materials: (per demonstration)

- Tetra-chloroethene, 100 mL (organic solvent).
- Decanedioyl dichloride, 5.0 ml (reactant monomer A).
- Distilled water, 100 mL.
- Anhydrous sodium carbonate, 10 g.
- 1.6-diaminohexane, 5.0 g (reactant monomer B).
- Two 250 mL beakers.
- One 5.0 ml beaker.
- Tweezers.
- Glass rods.
- Centigram balance.

Procedure:

- Prepare the following two solutions:
- Solution A: *decanedioyl dichloride in tetra-chloroethene*. Put 100 mL tetrachloroethene into a 250 mL beaker, add 5.0 mL decanedioyl dichloride and stir to dissolve. This solution keeps for about four weeks.
- Solution B:*1,6-diaminohexane in aqueous sodium carbonate*. Put 100 mL distilled water into a second 250 mL beaker, add 10 g anhydrous sodium carbonate and stir to dissolve. Add 5.0 g of solid 1,6-diaminohexane and stir to dissolve.
- Pour 2 mL solution A into a 5 mL beaker. Carefully add an equal volume of solution B. Solution A contains the organic solvent, is denser than the aqueous layer, and therefore is the bottom layer. Care must be taken when adding the second solution to avoid mixing.
- Grab the polyamide film (a white solid) that begins to form at the interface of these two solutions with tweezers and slowly pull it out of the beaker. Wrap the fiber around a glass rod and continue to pull. Stop the process when one of the reactants is used up.
- Demonstrate how the fiber can be pulled out in one continuous thread and then set up a competition to see which pair of students can produce the longest fiber. They should be able to produce up to 5 m before the fiber snaps.
- Any spillage should be mopped up with absorbent paper and put in the waste.

- Safety
- Decanedioyl dichloride and 1,6-diaminohexane are corrosive. They are harmful if swallowed or inhaled, and in contact with the skin cause burns. They are severe irritants. Tetrachloroethene is a skin and eye irritant. It is harmful if inhaled or ingested and in contact with skin. This chemical has been reported to cause cancer in laboratory animals. Gloves and eye protection should be wore for this demonstration.
- Do this demonstration with adequate ventilation

Discussion:

Nylon is a polyamide, class of polymers in which the monomer repeating units are held together by amide links, -CO-NH-, (2).

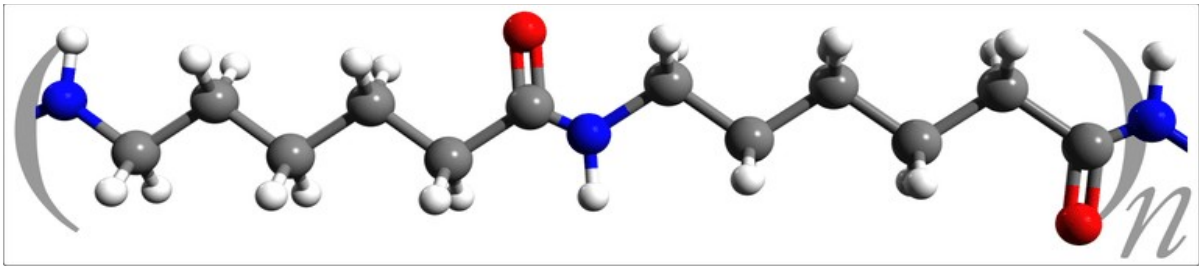

Figure 1, This is the 3-D structure of a nylon subunit, (2)

Nylon-6,10

Nylon-6,10 is made from two monomers, one contains six carbon atoms, the other 10 - hence its name. The 10-carbon monomer is sebacoyl chloride also called decanedioyl dichloride ($ClOC(CH_2)_8\ COCl$), an acid chloride with a -COCl group at each end. The other monomer is a six-carbon chain with an amino group, $-NH_2$, at each end. This is 1,6-diaminohexane ($H_2\ N(CH_2)_6\ NH_2$, also known as hexane-1,6-diamine). When these two compounds polymerize, the amine and acid groups combine, each time with the loss of a molecule of hydrogen choride:

$$n\text{ClOC-(CH}_2\text{)}_8\text{-COCl} + n\text{H}_2\text{N-(CH}_2\text{)}_6\text{-NH}_2 \rightarrow \text{-(CO-(CH}_2\text{)}_8\text{-CONH-(CH}_2\text{)}_6\text{-NH)}_n\text{-} + n\text{HCl}$$

This polymer-forming process involves the loss of a small acid molecule, HCl, and is known as condensation polymerization. This is why the sodium bicarbonate is added to the reaction, to help neutralize the HCl the molecules.

References:

1) Colin Baker, 2006. Making Nylon. Educatin in Chemistry, Website Active August 2017, http://www.rsc.org/learn-chemistry/resource/res00001005/making-nylon?cmpid=CMP00001551

2) Anna Marie Helmenstine, 2017. Nylon Synthesis. Website Active August 2017, https://www.thoughtco.com/how-to-make-nylon-608926

Name _____ Date _____

Lab Questions:

1. Which of the two reactants is was dissolved in the aqueous solution? decanedioyl dichloride or 1,6-diaminohexane. Draw the reactant's structure.

2. Which of the two reactants is was dissolved in the organic solvent? decanedioyl dichloride or 1,6-diaminohexane. Draw the reactant's structure.

3. What type of chemical reaction occurred to like the two reactants. (Addition reaction, Double exchange reaction, Condensation reaction, Hydration reaction).

4. Draw the chemical reaction of the two reactants, decanedioyl dichloride ($ClOC(CH_2)_8$ COCl), and 1,6-diaminohexane with an amino, $-NH_2$, at each end to form 1 nylon subunit and 1 HCll molecule.

Green Questions

5. If nylon is somewhat like a protein in that both are linked by many amide bonds. Do you think that nylon can be broken down by bacterial as can protein?

6. Are all man-made polymers linked by amide bonds? Give examples.

Definitions:

Define the following terms:

1) aqueous solution -

2) organic solvent -

3) anhydrous -

4) solution interface -

5) immiscible -