Polymerization

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Subject: Chemistry
Level: High school
Standards: New York State – www.emsc.nysed.gov/ciai/
Standard 1 – Analysis = inquiry and design
Standard 4 – The physical setting
Standard 6 – Interconnectedness; common themes
Standard 7 – Interdisciplinary Problem solving
New York State – Chemistry core curriculum
VII.6 – Types of organic reactions include addition, substitution, polymerization, esterification, fermentation, saponification and combustion.
Schedule: 2 to 3 45 minute class periods

Objectives:

Prepare two different polymers.
Apply their knowledge of polymerization reactions to the synthesis of nylon and slime.

Students will:

- Learn about polymers
- Learn about condensation and addition polymerization reactions (the two main types of polymerization reactions)
- Synthesize nylon
- Synthesize slime
- Identify the monomers and polymer in the synthesis reactions they performed

Vocabulary:

Polymerization
Polymer
Synthesis
Monomer
Newtonian fluid

Materials:

For Each Pair: Nylon Synthesis

- 2 – 250 mL bottles/jars with a cover
- 100 mL graduated cylinder
- 250 mL beaker
- At least 4 sheets of paper towel
- Food coloring (various colors)
- Glass rod with hooked end
- Scale

For Each Pair: Slime Synthesis

- 2 – 100 mL graduated beakers
- 25 mL graduated cylinder
- Stirring rod
- Saturated Sodium borate (7.6g $Na_2B_4O_7 \cdot 10H_2O$ in 100 mL of water)
- 4% Polyvinyl Alcohol (4g PVA in 96 mL of water)
- Scale

Safety:

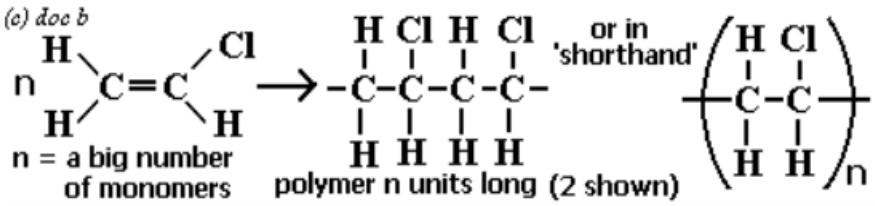
Gloves should be worn and a fume hood utilized although they are not necessary (slime only). Avoid getting chemicals on skin, in eyes, excess inhalation, etc. Safety goggles must be worn. Do not discard synthesized material in the sink.

Science Content for the Teacher and Procedure

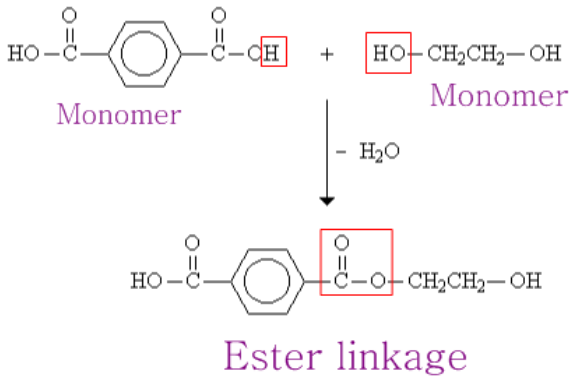
Day/Period 1

Polymerization - Formation of large polymers
Polymers = organic compounds made up of smaller chains covalently bonded together.
Each individual unit = monomer
Ex of polymers = synthetic plastics, nylon, proteins, starch, cellulose

2 Types of polymerization reactions
Addition Polymerization - joining of monomers of unsaturated compounds.



Condensation polymerization - bonding monomers by removing water from hydroxyl (-OH) groups & joining monomers by an ether or ester linkage.



http://faculty.uscupstate.edu/llever/Polymer%20Resources/step3.gif

Practice – have students show the polymerization reaction of the following monomers:
Organic acid + Amine
An alkene

Students should:
- Draw the structural formula of each monomer
- Name all the substances
- Identify the type of polymerization taking place

Organic Acid + Amine	Alkene(monomer)

Day/Period 2 – Polymerization Reactions

Slime

Materials:
- 100 mL graduated beakers (2)
- 25 mL graduated cylinder
- Stirring rod
- Saturated solution of sodium borate (7.6g $Na_2B_4O_7 \cdot 10H_2O$ in 100 mL of water)
- 4% Polyvinyl Alcohol (4g PVA in 96 mL of water)
- Food coloring (optional)

Procedure:
1. Dissolve 2.0 grams of poly(vinyl alcohol) in 50 mL of water by heating.
2. Once the poly(vinyl alcohol) solution has cooled add 1 or 2 drops of any food coloring (if desired)
3. Dissolve 0.76g borax (sodium borate) in 10 mL of water by heating.
4. Mix the poly(vinyl alcohol) and borax solutions together.
5. Stir with a glass rod or wood splint until the slime becomes consistent

Analyze the properties of the slime you produced:

1. Pull the slime apart slowly. State what happens to the slime.

2. Pull the slime apart quickly. State what happens to the slime.

3. Roll a piece of the slime into a ball. Drop it on the floor. State what happens to the slime.

4. Place a piece of slime on the table. Hit it with your hand. State what happens.

5. Why do you think slime is called a "non-Newtonian liquid"?

Questions 1 – 4 adapted from: David A. Katz, 2005: PolyVinyl Alcohol Slime.

Questions:

1. The formula of vinyl alcohol is C_2H_3OH. Draw the structural formula of vinyl alcohol.

2. Draw the structural formula of the borate ion $B(OH)_4^{-1}$ (the ion in Borate) Hint: Boron is the central atom connected to four hydroxide ions.

3. Redraw the vinyl alcohol molecule with the double bond broken, ready to bond with two other molecules.

4. Of the types of polymerization reactions you learned – which is most similar to the reaction that produced the slime?

5. What is the molar mass of a single vinyl alcohol monomer? Show all work. Record your answer to the nearest hundredth.

6. If most poly(vinyl alcohol) polymer molecules have a molar mass of 60,000 g/mol. How many vinyl alcohol monomers must be linked to produce a polymer of this molar mass? Show all work.

Questions 1 – 7 Taken from:
http://www.phs.princeton.k12.oh.us/departments/science/dstuder/CP%20Chemistry/Ch.5&6Bonding/SlimePolymerWkst0708.pdf

Day/Period 3 – Polymerization Reactions

Nylon (must have fume hoods and gloves available to do this experiment)

Materials:

- 12 – 250 mL bottles/jars with a cover
- 100 mL graduated cylinder
- 250 mL beaker
- At least 4 sheets of paper towel
- Food coloring (various colors)
- Glass rod with hooked end
- Scale
- 0.5M Hexamethylenediamine $H_2N(CH_2)_6NH_2$
- 0.5M Sodium Hydroxide (NaOH)
- 0.2M Sebacoyl chloride $ClOC(CH_2)_8COCl$
- Hexane

Preparation:

Solution A –

- Place a bottle of hexamethylenediamine in warm water (about 45^0C) to melt it.
- Weigh 6.0g of the hexamethylenediamine and place it into a bottle.
- Add 2.0g of sodium hydroxide and 100 mL of water to the bottle.
- Cap the bottle tightly and shake to dissolve the mix.

Solution B –

- Place 2.0g (1.6mL) of sebacoyl chloride into a bottle.
- Add 100 mL of hexane to the bottle.
- Cap the bottle tightly and shake to mix.

Producing the Nylon

1. Measure an amount of solution A into a beaker (between 25 and 50. mL.
2. Add 1 or 2 drops of food coloring if desired.
3. Measure the same amount of solution B and slowly pour it down the side of the beaker being careful not to disturb the interface between the two solutions.

4. Place the glass rod with hooked end into the beaker. At the interface where the two liquids meet – nylon should form.
5. Pull the hooked end slowly out the beaker. The hook will snag the nylon that has formed at the interface of the two solutions.
6. Wrap the strand of nylon around the glass rod and wind the nylon strand onto the rod at a steady pace.
7. When finished, safely discard the excess hexane to minimize the exposure to hexane fumes.

"Nylon Rope Trick" taken from
(http://www.chem.umn.edu/services/lecturedemo/info/Nylon_Rope_Trick.html)

Questions:

1. List at least 3 things that nylon is currently used to make.

2. Be creative – in the future, what do you think nylon could be used for?

3. Nylon and slime are two examples of polymers – using your knowledge (and/or the internet) what are two other common polymers?

Supplemental Information:

Show the following internet video to demonstrate how the solutions should be mixed to produce the nylon.
http://www.youtube.com/watch?v=y479OXBzCBQ
or
http://boyles.sdsmt.edu/nylonsyn/nylon.htm (Click on Amber introduces the demonstration)

Safety:

Use safety goggles at all times.
If available, use a fume hood and safety gloves (desirable but not necessary)
To make nylon – the experiment should be done in a fume hood.
Due to the use of food coloring, avoid contact with clothes.

Acknowledgments:

Cornell University Department of Chemistry and Chemical Biology: Materials Science Workshop 2000 – 'Recipe for Slime'

Princeton High School – Questions 1-7 in slime analysis

David A. Katz, 2005: Polyvinyl Alcohol Slime (Questions 1-4 Analysis adapted from his work)

University of Minnesota, Joseph Franek: Nylon Rope Trick