Polymerization Reactions

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Subject: Chemistry/Organic Chemistry

Grade Level: High School

Standards: Next Generation Science Standards (www.nextgenscience.org)

HS-PS1-2
Construct and revise an explanation for the outcome of a chemical reaction based on knowledge of the patterns of chemical properties.

HS-PS1-7
Use mathematical representations to support the claim that atoms and mass are conserved during a chemical reaction.

Schedule:

CCMR Lending Library Connected Activities:


Objectives:	**Vocabulary:**
1. To identify unique features of polymers. 2. To compare and contrast purpose of reagents in a reaction. 3. To apply the scientific process by designing and documenting experiments.	Monomer Polymer Polymerization reaction Catalyst Reactant Product
Students Will: - Students will discuss and propose reasons for structural differences in flexible and rigid polyurethane. - Students will synthesize polyurethane using different formulations and record observations during reaction. - Design their own experiment to determine cell size and density of a sample.	**Materials:** ● Polyurethane foam kit (Carolina Biological Supply Company) ● Glass vials ● Disposable pipettes ● Food coloring ● Plastic cups ● Wooden sticks
Safety	Personal protective equipment (PPE) such as gloves, goggles and aprons must be used. Solution A and solution B may cause skin irritation. Wear gloves

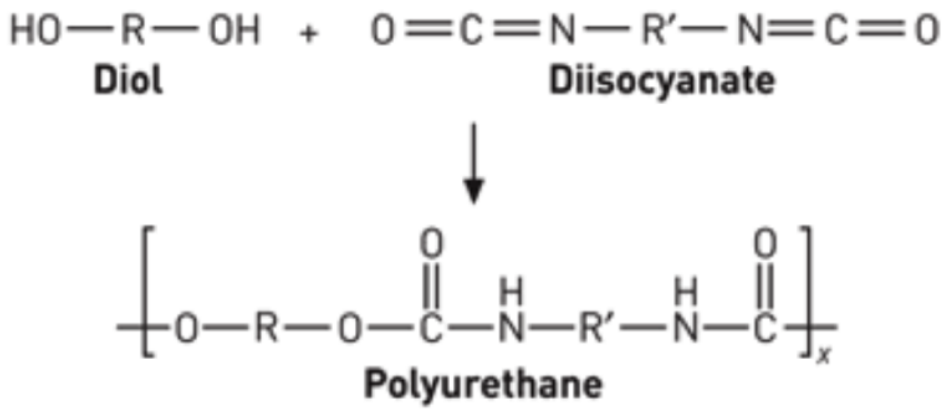
	when handling these solutions. Mix solutions in a fume hood or provide adequate ventilation. Hardened foam can be discarded in the trash.

Science Content for the Teacher:

Polymerization Reactions

Polymer chemistry is a branch of materials science that deals with the synthesis and properties of macromolecules. Single molecular units or “monomers” can be linked together in long chains to form “polymers.”

According to the US Department of Energy, heating and cooling costs amount to approximately 56% of the energy used in the average American home. Polyurethanes are used extensively in heating and cooling products. Polyurethanes are typically produced by a polymerization reaction. In this reaction a polyol (an alcohol with more than 2 reactive hydroxyl groups per molecule) reacts with diisocyanate in the presence of catalyst and additives.

There are 2 major types of polyurethane. Flexible and rigid. Flexible polyurethane foam is widely used as cushioning in consumer and commercial products, including bedding, furniture, automotive interiors, carpet underlay and packaging. Flexible foam is light and durable. Meanwhile, rigid foam is commonly used for insulation. Rigid foams can significantly cut energy costs and increase heating and cooling efficiency. Moreover, rigid foam maintains an uniform temperature and lowers noise levels in homes and businesses. Rigid foams can also be used in roof and wall insulation, windows, doors and sealants.

In the polymerization reactions module, students will complete a “Think, Pair and Share” activity. Then, students will synthesize a polyurethane foam. Ultimately, students will design their own experiment to test properties of polyurethane foam. These properties are cell size and density.

Classroom Procedure:

Activity #1

Think, Pair, Share

Students will discuss and propose reasons for structural differences in flexible and rigid polyurethane. Students must complete the corresponding template in the “Polymerization Reactions Activity Sheet.”

Activity #2

Synthesis of Polyurethane Foam

Materials:

- Polyurethane Foam Kit (Part A and Part B)
- Glass vials
- Disposable pipettes
- Food coloring
- Plastic cups
- Wooden craft sticks


Procedure:

1. Put on gloves and goggles. Wear them at all times when handling chemicals.
2. Take 3 glass vials and label them. Each groups will be asked to perform 3 different reactions.
3. Add 1 drop of food coloring to each vial.
4. Add 1 full pipette (1 mL) of diisocyanate (part A) to each vial.
5. Add the following amounts of polyol (part B) to each vial:
    a. Vial 1: ½ pipette (0.5 mL)
    b. Vial 2: ¾ pipette (0.75 mL)
    c. Vial 3: a full pipette (1 mL)
6. Stir each vial with the wooden stick for a minute or so to mix the components.
7. Avoid touching the foam as is still tacky. After 10 minutes, the foam should be hard.
8. Record the volume used of diisocyanate and polyolfor. Furthermore, include time, endothermic or exothermic and any pertinent observations in table 1.

Common Student Misconceptions

Students may think that the foaming is the result of polyol (solution A) reacting with the polyisocyanate (solution B). However, the foam is the result of the water in the mixture reacting with some polyisocyanate in a decomposition reaction. One of the products of the reaction is carbon dioxide gas. The production of CO2 causes the polyurethane to expand many times its original volumen.


Activity #3

Designing their own experiment.

Part A. Cell Size

Procedure:

Students will work in groups and write a hypothesis, materials needed, a detailed procedure and safety considerations prior to initiating the investigation. Experimental design must include equipment and supplies available in the lab. Students should defend their proposal and answer questions from classmates or teacher. Template is provided in “Polymerization Reactions Activity Sheet.”

Example #1

1. Students will obtain samples for testing. Using a blade, a thin sample from their polymer is attained.

2. Thin sample is placed on a glass slide. Students will estimate the cell size within a 1 cm x 1 cm grid. Sample is placed under the microscope and observations are recorded.

Guiding Questions:

- Is there a difference on the size of the cells in the sample?
- How can you explain the differences on cell size?
- How many cells did you count in the chosen area?


Furthermore, students may draw what they see under the microscope and determine the scale.

Part B. Density Calculation

Procedure:

Students will work in groups and write a hypothesis, materials needed, a detailed procedure and safety considerations prior to initiating the investigation. Experimental design must include equipment and supplies available in the lab. Students should defend their proposal and answer questions from classmates or teacher. Template is provided in “Polymerization Reactions Activity Sheet.”

Example #2

1. Students will obtain samples for testing. Using a blade, a thin sample from their polymer is attained. Mass and volume of sample are calculated.

2. With the mass and volume, students will determine the density of the sample.

Alternatively, volume can be measured by displacement. Sample may be placed in a graduated cylinder with water and the volume is determined.


Assessment:

Assessment of learning objectives will include several methods. Teacher will conduct direct observation by circulating the classroom and engaging students. Students will be asked to complete the "Think, Pair and Share" template. Groups will share their possible reasons for the differences between flexible and rigid polyurethane foam to the classroom.

Subsequently, students will be assessed in their ability to collect data, interpret information and safely synthesize polyurethane foam. Then, students will be required to design their own experiment. Experiment must include a hypothesis, materials and safety. Upon approval of their experiment, students may initiate their investigation.

Students will complete an individual reflection on polymerization reactions and submit via Google Classroom.


Resources:

American Chemistry Council. (2018). Introduction to Polyurethanes. Polyurethane Applications. Retrieved from https://polyurethane.americanchemistry.com/Applications/

Carolina Chemonstrations. (n.d). Polyurethane Foam Teacher's Manual.

Polymer Science Learning Center. (2016). Molecular Weight. Retrieved from https://pslc.ws/macrog/weight.htm

Ting, J., Ricarte, R., Schneiderman, D., Saba, S., Jiang, Y., Hillmyer, M., Bates, F., Reineke, T., Macosko, C. & Lodge, T. (2017). Journal of Chemical Education. Polymer Day: Outreach Experiments for High School Students. Retrieved from https://pubs.acs.org/doi/abs/10.1021/acs.jchemed.6b00767


Extra Activities:

Extension #1

Number average molecular weight (Mn) and weight average molecular weight (Mw) are essential concepts in polymer chemistry.

1. Students will define Mn and Mw in their own words.
2. Students will choose 3 cities in Hudson county, NJ and find the approximate population.
3. Groups will calculate the simple average and weighted average for these 3 cities.

Extension #2

Create a poster describing the impact of biodegradable polymers in the environment.

1. Students will conduct online research on biodegradable polymers.
2. Alternatively, students may create a presentation that will be shared with the class and included in their digital portfolio.

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