Chemistry of Polymers

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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: Three 45 minute classes

Objectives:

Students will review solubility/polarity and intermolecular forces while being introduced to physical properties of polymers.

Students will:

- Test a variety of plastics for solubility, density, and melting point.
- Students will use the results of their tests to build a concept map for determining the identity of an unknown plastic.
- Students will attempt to determine the identity of an unknown plastic.
- Students will analyze their concept maps and suggest improvements.
- Students will be able to explain how polarity affects solubility.
- Students will be able to explain the relationship between intermolecular forces, boiling point, and bonding.
- Students will be able to compare the mass of two different polymers when given the volume and the density.

Vocabulary:

Solubility	Polarity
Intermolecular forces	Boiling point
Polymer	Density
Mass	Volume
Bonding	Polymerization

Materials:

For Each Pair:
- Safety Goggles
- One sheet #6 plastic (day 3)
- Activity Sheets
- Set of plastic pieces
- 4 Beakers
- 70-90% isopropyl alcohol
- Mazola corn oil
- Water
- Stirring rod
- Beaker tongs
- Small tongs (to pick up plastic pieces) or forceps
- Hot plate

For teacher:
- Copper wire
- Alcohol or Bunsen burner
- Matches
- Toaster oven, aluminum foil, safety mitts (day3)

Safety:

Students should wear safety goggles during Explore activities on the first two days.

Science Content for the Teacher:

Student pre-knowledge

During the fall semester, students were introduced to the concepts of density, solubility (types of bonding), and intermolecular forces (melting/boiling points). In order to access previous knowledge and put it into long-term memory, repetition is required.

Polymer Basics

Polymers are made up of chains of smaller molecules called monomers. A biological example is protein which is made up of amino acids. Most plastics are derived from petroleum products. The physical and chemical properties of a polymer depend on the monomer that it is made of. Some differences between plastics can be seen, felt or smelled. (For example, one can burn a plastic and observe its odor, texture, and color of the flame.) Other differences that can be tested include: melting point, solubility, density, bounciness, transmission of polarized light, and glass transmission temperature*. These properties can be modified by techniques such as adding fillers, plasticizers, and pre-heating. New plastics are made by combining different monomers in order to obtain desired properties.

Intermolecular forces

The greater the intermolecular forces between molecules, the higher the melting and boiling temperatures. Polar molecules have greater intermolecular forces than nonpolar molecules because the slightly negative end of one molecule is attracted to the slightly positive end of another molecule (dipole-dipole attraction). Hydrogen bonding between molecules is a very strong intermolecular force. The bigger the molecule, the more of it there is to exert an intermolecular force so polymers generally have stronger intermolecular forces than the monomers that they are composed of.

Polyethylene is very nonpolar so it melts at low temperatures compared to many other plastics.

Kevlar is a polyamide. Amide groups can form hydrogen bonds between adjacent chains: the positive hydrogen atoms in N-H groups of one chain are strongly attracted to the oxygen atoms in C=O chains. Kevlar can withstand temperatures up to 400° C (and as low as -198° C).

*Glass transition temperature- below this temperature, plastics become brittle.

Preparation:

Teacher set-up

1. When you are setting up for this lab remember to keep flammables liquids away from hot plates and flames. Also make sure that students are wearing safety glasses and not breathing in fumes during this experiment.
2. If you do not want your students to do the copper wire test on their own, have them bring their plastics up to you for testing. (You can ask individual groups to come up every 3 to 4 minutes.)
3. Each group needs to have samples of the plastics being tested. Ten pellets of each plastic are recommended.
4. If your school doesn't allow the use of acetone, you can find it in some nail polish removers. Check the bottle to make sure that it is the active ingredient in the nail polish that you are buying. Using fingernail polish instead of acetone takes more time so check how long it takes the plastic to soften before doing this lab. Also, throw the acetone-covered pellets away in a hazardous waste container.(You need to use a fume hood with acetone).
5. Use 70 to 90 % isopropyl alcohol for the alcohol float/sink test. To prepare 100 mL of alcohol solution 65 mL of 70 % isopropyl alcohol in a 250 mL beaker with 35 mL of water.

Mazola corn oil has the correct density for separating plastic #4 and 5.

Classroom Procedure: Day 1

Engage (Time: 5-10 minutes)

Teacher asks the students what are some organic molecules in the body. (Hint: They contain carbon and hydrogen.) Teacher explains that "poly- means "many" and – "mer" means "part." (Teacher may elicit meaning of polymer.) She draws a picture of two monomers on the board and then shows how they the bonds open up when they join together during polymerization.

Explore (Time: 25 minutes)

Students collect data on how their polymers react to different tests.

Explain (Time: 10 minutes)

Students review their results and hypothesize some reasons for the differences between the plastics. The teacher leads them into a discussion of solubility and polarity.

Expand –Homework

Students look at different containers that they use at home. They should list 5 examples of containers (for example: Beautiful Hair shampoo) and their recycle number.

Classroom Procedure: Day 2

Engage (Time: 5-10 minutes)

Teacher asks a question about the properties of Kevlar (for bullet proof vests) versus polypropylene. Kevlar has a melting point of 400°C and polypropylene has a melting point of 160 to 170° C. Obviously, Kevlar must have stronger intermolecular forces. What are some examples of strong intermolecular forces? Teacher tries to elicit hydrogen bonding, polarity, structure which might cause intertwining of polymer strands (like spaghetti).

Explore (Time: 10 minutes concept map; 15 minutes testing)

Students use a template (as a scaffold) to create a concept map using density in order to determine the identity of four different plastics. Then they test the plastics and hypothesize what the four plastics were.

Explain (Time: 10 minutes)

Groups report on their results and what they could change their testing procedure to improve it. Teacher elicits how students used (or didn't use) the density data provided in order to set up their concept map. Teacher clears up misconceptions about density.

Classroom Procedure:Day 3

Engage (Time: 10 minutes)

Do now: What do you know about polymers and polymerization?

Teacher makes a KWL chart using the answers from the do-now. The teacher then asks the students if they have any questions about polymers. If the students failed to provide important concepts (or questions) about polymers, she then asks the students some questions and, either puts their answers under K or puts the question under W.

Explain (Time: 10 minutes)

a. Teacher goes over the answers to W.

b. Teacher explains the day's activity. Today we are going to use a piece of polystyrene container to show the property of memory that some plastics have. Many plastics are heated and then stretched into a particular shape. Some of these plastics will return t to their original shape when they are reheated. We are going to use this property to make necklaces. You will be assigned a monomer. Write the name of the polymer, and draw a picture of the corresponding monomer on the plastic with a permanent magic marker. You can add other designs to it. Make a hole in it where you would like to put string.

Explore (Time: 10 minutes)

Students make "shrink dinks."

Synthesis (Time: 15 minutes)

The teacher throws a potato (or other object) to one student who has to tell the class something that he knows about polymers. He then throws the potato to another student who adds another fact. As soon as the student has contributed to the class, the teacher will take the plastic artwork and put it in a 163° C (325° F) toaster oven for 4 minutes. If there isn't time for some students' work to go in the oven during class, the teacher will put it in after class and return it the next day.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain	Expand/Synthesis
1	Shows leadership in the discussion and offers creative ideas reflecting a good understanding of chemistry,	All investigations are completed in a timely manner. Data and question sheet are completely filled out. Seen to be actively participating when teacher walks around the room.	Group is able to present correct results in a clear manner. Group is able to answer questions. Group listens actively during other group presentations and asks questions.	
2	Answers do-now questions correctly in notebook in a timely manner. Listens politely to other students.	All investigations are completed in a timely manner. Seen to be actively participating when the teacher walks around the room. Data table is filled out but some discussion questions are unanswered.	Group is able to present correct answers in a clear manner. Group is able to answer questions. Group needs one or two reminders to listen quietly to other groups. No questions asked of other groups.	
3	Copies answers from board within 5 minutes after they are written down. May need to be asked to quiet down once or twice.	Data table and discussion questions are completely answered. No active participation noted.	Group is able to present some correct answers. Group needs to occasionally be asked for clarification or to speak up. Group needs two or three reminders to listen quietly to other groups.	
4	Talks to friends during brainstorm about non-chemistry topics. Doesn't take any notes.	Student is not noted by the teacher to be an active participant. Data table and discussion questions are incomplete.	Group uses some evidence that is flawed or just doesn't present answers. Several reminders are needed for the group to be quiet during other presentations.	

Extension Activities:

1- Students can do a lab investigating the density of all 6 recyclable plastics (HOP on plastics activities)
2- Students can see what happens if you burn different plastics. (Brian Niece's website)
3- Students can make polymers such as slime, glueup, nylon 66.

Supplemental Information:

The following books and websites are recommended:
Polymer Chemistry: Introduction to an Indispensable Science
By: David Teegarden, NSTA Press, 2004
www.polymerambassadors.org/index.html
www.pslc.ws/macrog.htm
www.americanchemistry.com- click on "learning center" and then "hands on plastic"
www.assumption.edu/users/bniece/Olympiad/Olympiad.html
www.matse1.mse.uiuc.edu/~tw/home.html
www.polymers.eezway.com-they sell samples of polymers

Safety:

Safety goggles should be worn at all times during the "explore" portion of the activity on the first two days.

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Activity Sheet One

Student Name______________ Period__________

Procedure:

1. Notice the test areas in the room. Some tests are to be done only at those locations, while others will be performed at your lab desk.

2. Acetone Test- Put the pellets in the fingernail polish container. Wait at least 5 minutes before removing them and testing for solubility. If one of the plastics has softened slightly, then it is plastic #5 (polystyrene). (Acetone is a nonpolar solvent.) (Note: KEEP THIS TEST AREA AWAY FROM FLAMES. Acetone is highly flammable and must be kept away from flames and covered when not in use. Have tongs or forceps available.

3. Water test
    a. Solubility-Put plastic pellets in water and stir. Since water is a polar molecule, any plastic that dissolves in water is also a polar molecule (plastic #7-other-biodegradable packing peanuts).
    b. Density- Does the plastic sink or float in water? (Density of water = 1 gm/mL)

4. Alcohol test- Does the plastic sink or float in alcohol? Use tongs or forceps to remove plastic pellets. Discard plastics in beaker or other container which has been provided for each group. (Density of alcohol solution is 0.93 g/mL).

5. Oil test-Put the plastics in the oil. Do they sink or float? Use tongs or forceps to remove and discard plastics. (Density of corn oil is 0.917 g/mL)

6. Heat test-Heat pellets in boiling water for 30 seconds. Remove with tongs and test for softening. (Note: although PET has a melting point of between 250 to 260°C, it will start to soften at 100° C). The greater the intermolecular forces holding the molecules together, the higher the melting/boiling point will be.

7. Copper wire test-Using forceps, the teacher will hold the 5 cm length of copper wire in the hot part of the flame of a Bunsen burner or alcohol burner until it is red hot. She will remove from the flame and carefully touch a plastic pellet with the hot wire. It may stick to the wire at this point so she will need to take another pair of forceps to pull the pellet off the wire. Place the wire with some plastic glob on it (not the pellet) back in the flame, observing the color of the flame that comes from the glob. You will notice a green or orange flame color. Quench the sample in a beaker of water to stop the burning and cool the wire. If there is more time, students may do this test at their lab desks.

Data table

Test	1-PETE	2-HDPE	3-PVC	4-LDPE	5-PP	6-PS	7-other
Water solubility							
Acetone solubility							
Sink/float water							
Sink/float alcohol							
Sink/float oil							
Copper wire test							
Heat test							

Questions:

1. Which three plastics had the highest density?

2. Which plastic exhibited the lowest density?

3. The density of LDPE (low density polyethylene) was between what two numbers?

4. Explain in terms of intermolecular forces, why PVC (polyvinyl chloride) has a lower melting point than PP (polypropylene)?

5. Explain in terms of molecular polarity, why the biodegradable peanuts are more soluble in water than the polystyrene peanuts.

The following are the codes and abbreviations for recyclable plastics:

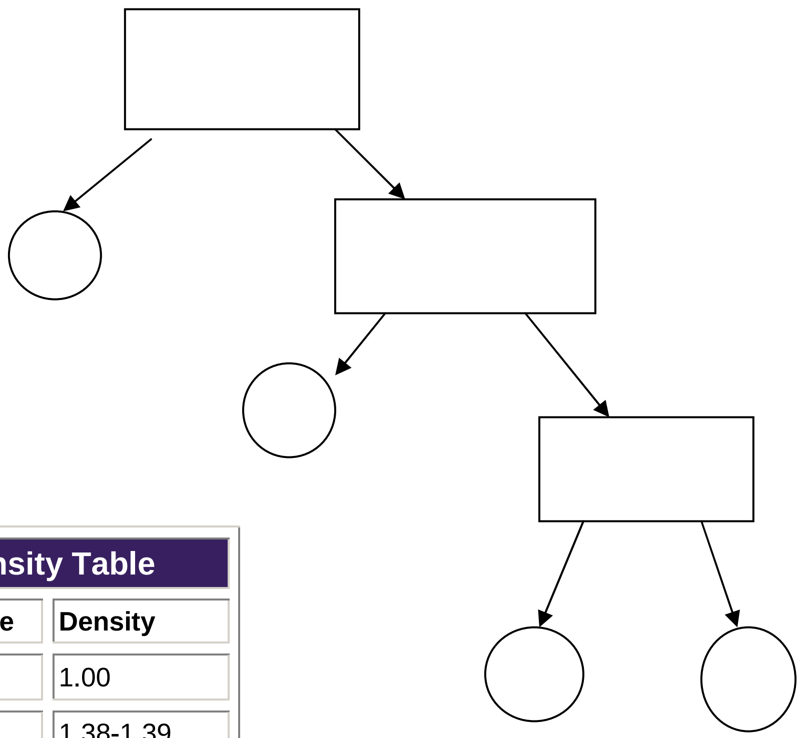
1. PET - polyethylene terephthalate
2. HDPE - high density polyethylene
3. PVC - polyvinyl chloride
4. LDPE - low density polyethylene
5. PP - polypropylene
6. PS - polystyrene
7. other

Activity Sheet Two

Today you will design and test a flow chart to distinguish between four different plastics, you will perform the experiment, and then we will discuss it as a class.

The density of water is 1.00 g/mL, the density of corn oil is 0.93 g/mL, and the density of the alcohol solution is 0.917 g/mL. The four plastics that you will be testing are PET, HDPE, LDPE, and PP. (Note: PS or PVC may be used instead of PET according to availability. (10 minutes to design concept map)

Concept Map for Determining Type of Plastic



Density Table	
Substance	**Density**
Water	1.00
(1) PET	1.38-1.39
(2) HDPE	0.95-0.97
(3) PVC	1.16-1.35
(4) LDPE	0.92-0.94
(5) PP	0.90-0.91
(6) PS	1.05-1.07

You have 10 minutes to test the plastics and determine which was which.

Questions (Each group is required to orally answer at least one question depending on time constraints)

1. Which plastic was A, B, C, and D?

2. Why would a 150 pound fat person float more easily on water than a 150 pound muscular person? Explain your answer.

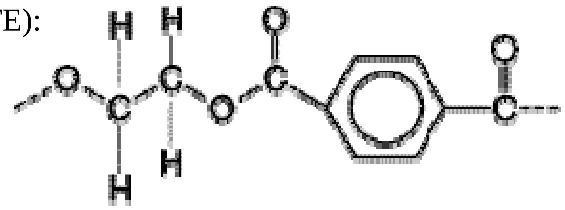
3. How easy was it for you to identify the plastics using your concept map?

4. What changes would you suggest in order to improve your concept map?

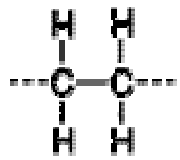
5. Could you improve your concept map by adding any other tests or observations? Explain.

Common Plastic Resins Used in Packaging

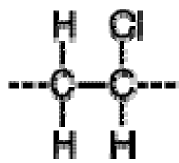
Polyethylene Terephthalate (PET or PETE):



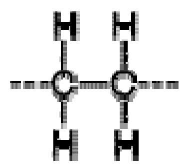
High Density Polyethylene (HDPE):



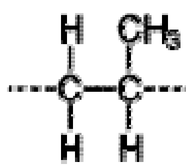
Vinyl (Polyvinyl Chloride or PVC):



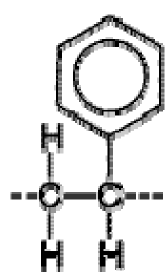
Low density polyethylene (LDPE):



Polypropylene (PP):



Polystyrene (PS):



Resin Identification Code
The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 at the urging of recyclers around the country.