Polymer Investigations

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Lesson Subject: Introduction and investigation of different polymeric materials.

Audience:
- High School Chemistry Students - Grades 10 through 12

Objectives:
Students will be able to:
1) Understand what is a polymer and how they are synthesized.
2) Explore common uses of polymers.
3) Recognize the SPI resin identification coding system and know the names and symbols for common recyclable plastic materials.
4) Observe, analyze and compare the properties of petroleum based recyclable polymers.
5) Synthesize various bio-polymer films and conduct experiments to examine their properties.

Teacher Notes and Information:

There are different activities included in this lesson which can be incorporated in part into a Unit on Organic Chemistry or as a whole Unit on Polymer Chemistry.
Additional ideas that could be developed to extend these lesson activities are listed below:
1) Perform composting of the different bio-polymers made by the students.
2) Have students research and do Powerpoint or poster presentations of findings on:
   a) Uses for biodegradable polymer materials
   b) Use of natural polymers - DNA, starch, cellulose or vitamins
   c) Use of polymers for biomedical applications

3) Invite a Materials Science Researcher or manufacturer to speak with students or visit their University or manufacturing facility.

4) Have students investigate some of the many informative and interactive web-sites devoted to polymers.

Internet Resources:

Polymer Lessons:
- www.usm.edu/mrsec/LINKS.htm
- www.psrc.usm.edu/macrog/natupoly.htm (natural polymers)
- www.chemheritage.org/EducationalServices/FACES/teacher/poly/activity/nylon6.htm
- www.jobwerx.com/industries/plastics_resources.html
- www.agpa.uakron.edu/k12/lesson_plans/intro_to_polymers.html
- www.sciencenetlinks.com/lessons.cfm?BenchmarkID=3&DocID=150

Waste Management/Recycling Guide
- www.obviously.com/recycle/guides/common.html
- www.campusprogram.com/reference/en/wikipedia/w/wa/waste_management.html
- www.earthodyssey.com/symbols.html
- www.recycle-more.co.uk/default.asp?referer=oldsite&SectionID=510

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Materials Needed For Lab Activities

- Hot plate with magnetic stirrer
- Stir bar or paper clip
- Plastic weighing dish
- Hot-hands or oven mitts
- Thermometer
- Wood splint or glass rod
- Aluminum dish or foil
- Scissors
- Ruler
- Samples of various recyclable polymers
- Balance
- Starch (potato or corn)
- Agar
- Gelatin
- 1% glycerol solution (glycerine)
- Non stick pan (1 per group)
- Glass stirring rod
- Beakers 400 mL or 600 ml
- Water, tap or distilled
- Graduated cylinders
- Plastic bags with "zip-type" closure

Day 1
Introduction Activity: What are Polymers?

Students will be introduced to Polymers with a 'show and tell' discussion of some common polymers (objects, such as Kevlar, Nylon, Plastics, Starch, Proteins, etc…,) will be on display for students to pass around the room. There will be some notes to explain how polymers are made of small units (monomers) that are joined together in long chains to form a polymer (like paper clips in a long paper clip chain). Example of the synthesis reactions, addition and condensation reactions will be discussed as well as the topic of cross-linking.
Examples and some uses of both synthetic and natural polymeric materials will briefly be discussed.
Students will work in pair to learn more about the polymers we use through an interactive web-site:

Polymers are everywhere - *www.psrc.usm.edu/macrog/floor1.htm*

Polymers up close sand personel - *www.psrc.usm.edu/macrog/floor2.htm*

How they work - *www.psrc.usm.edu/macrog/floor3.htm*

Makin' Polymers - *www.psrc.usm.edu/macrog/floor4.htm*

Getting Polymers to talk (how polymers are tested) - *www.psrc.usm.edu/macrog/floor5.htm*

Each group will be asked to share information about a given polymer and its uses by writing the information on the board and discussing it with the class.

Students will be asked prior to this lesson to bring in some recyclable materials for the next activity where students make observations about recyclable plastics. *Recyclable Plastics (Polymers) and Fiber Formation*

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Day 2
Class discussion to review results of investigation of recyclable plastics. Discussion on what polymers are recyclable and explanation of trash audit activity. Trash Audit Forms and *Waste Audit Protocol* was developed by Tania Schusler for the Cornell Science Inquiry Partnership (CSIP).

Day 3
Class discussion on trash audit results. Internet search on different waste management practices

www.obviously.com/recycle/guides/common.html
www.campusprogram.com/reference/en/wikipedia/w/wa/waste_management.html

Discussion on the various waste management practices and how can we reduce our waste stream.

Introduction to biodegradable polymers and bio-polymers/ bio-plastics and the research being conducted to develop these materials and some of the proposed uses.

Making of bio-polymer films - *Making and Testing Properties of Bio-Plastics Films.* The preparations given in this activity were derived from the variations given in Green Plastics: An Introduction to the New Science of Biodegradable Plastics by E.S. Stevens. Also referenced procedure prepared by Terre Trupp for Research Experience For Teachers (RET 2003)

Teacher's Notes
Cast-Film preparation

1. Make a stock solution of 1% glycerol solution by mixing 10 mL of glycerol per liter of distilled water.
2. After students have poured their Cast-Film into the Teflon pan, place them in a safe place for drying. To speed up the drying process, place the pans in a drying oven at 40 °C

Day 4
Introduction on how polymers are tested. Getting Polymers to talk-www.psrc.usm.edu/macrog/floor5.htm
Continuation of Day 3 Lab Activity where studetns are testing bio-polymer films - Making and Testing Properties of Bio-Plastics Films
Group discussion to compare results for the different films tested.
Sharing of ideas on possible uses for and possible changes to the recipe for the films.

Extension
Research on uses and disposal of petroleum based and/or bio-polymer materials
Group presentation (poster, power point) of polymer research results

Information Resources:

Absorbable and biodegradable polymers. Shalaby, S.W., CRC Press, Boca Raton, 2004.

Degradable polymers, recycling and plastics waste management. Albertsson, A., Marcel Dekker, Inc. New York, 1995.

Green plastics: an introduction to the new science of biodegradable plastics. Stevens,E.S., Princeton University Press. Princeton. 2002.

Mixed plastics recycling technology. Hegberg, B.A., Noyes Data Corporation. Park Ridge, 1992.

Plastics materials. Brydson, J.A., Butterworth Scientific. London, 1982.

Whittington's dictionaty of plastics. Whittington, L.R., Technomic Publicating Co., Inc. Westport, 1978.

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Recyclable Plastics (Polymers) and Fiber Formation

Lab # _____

Name: ___________________________ Date Performed: ___________

Partner: ___________________________ Date Due: ___________

INTRODUCTION:

Plastic is not any one material. Rather, it is a family of related materials with varying properties that can be engineered to meet the requirements of a broad range of applications. The success of a product often is dependent on matching the right plastic - with the right properties - to the right application.
The same is true when the material in question is a recycled plastic. As a result, there is a premium placed on the purity of post-use plastics. The more uniform the post-use plastics going in, the more predictable the properties of the recycled plastic coming out. Coding enables individuals to perform quality control (i.e., sorting) before recycling, ensuring that the recycled plastic is as homogenous as possible to meet the needs of the end markets.

Another potential benefit of coding is that it may facilitate the recovery of plastics not currently collected for recycling. If there is a readily identifiable supply of a given material in the waste stream, it may drive recycling entrepreneurs to explore means of recovering that material in a cost-effective manner.
These benefits of resin identification have led a number of entities to develop coding systems, including SPI, the Society of Automotive Engineers (SAE), the American Society for Testing and Materials (ASTM) and the International Standards Organization (ISO). Except where laws may require the use of a particular code, manufacturers have the option of selecting the coding system most appropriate for their product.

The SPI Resin Identification Code

The SPI introduced its resin coding system in 1988 at the urging of recyclers around the country. A growing number of communities were implementing recycling programs in an effort to decrease the volume of waste subject to rising tipping fees at landfills. In some cases, these programs were driven by state-level recycling mandates.

The SPI code was developed to meet recyclers' needs while providing manufacturers a consistent, uniform system that could apply nationwide. Because municipal recycling programs traditionally have targeted packaging - primarily containers - the SPI coding system offered a means of identifying the resin content of bottles and containers commonly found in the residential waste stream.

Type 1 - PETE Polyethylene Terephthalate (PET)
Soda & water containers, some waterproof packaging.

Type 2 - HDPE High-Density Polyethylene
Milk, detergent & oil bottles. Toys and plastic bags.

Type 3 - PVC Vinyl/Polyvinyl Chloride (V/PVC)
Food wrap, vegetable oil bottles, blister packages.

Type 4 - LDPE Low-Density Polyethylene
Many plastic bags. Shrink wrap, garment bags.

Type 5 - PP Polypropylene
Refrigerated containers, some bags, most bottle tops, some carpets, some food wrap.

Type 6 - PS Polystyrene
Throwaway utensils, meat packing, protective packing materials.

Type 7 - OTHER Usually layered or mixed plastic.
No recycling potential - must be landfilled.

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Most plastics can be easily recycled. There are several uses of polymers in industry, construction, in consumer goods and in the biomedical field. Plastic types 1, and 2 are commonly recycled. Type 4 is less commonly recycled and the other types are generally not recycled. There are many different polymer materials being used but not all commonly used plastics have recycling numbers.

Some other common plastics or polymers are Kevlar, Nylon, Starch, Proteins, Cellulose, etc… While many plastic/polymer materials are petroleum based materials, note that there are many naturally occurring polymers (DNA, starch, cellulose, proteins and some vitamins). Whether natural or synthetic all are made of small units (monomers) that are joined together in long chains to form the polymer. Each type of polymer has distinct properties and characteristics. Polymers can be synthesized through various reactions (addition, condensation or cross-linking of monomers) and goods produced using different process methods (injection molding, thermal). Polymers are recycled based on a couple of factors: the cost of recycling a polymer as compared to the market value for the recyclable materials, which depends on the consumer demand for products made from recycled materials; and whether it can be recycled which depends on the type of polymer and how it behaves when heated.

PURPOSE:

The objective of this experiment is to investigate and compare the properties of a variety of recyclable plastics by warming the material and drawing fibers for each sample and comparing the properties of the materials before and after heating.

MATERIALS NEEDED:

- Hot plate
- Aluminum dish or foil
- Ruler
- Wood splint or glass rod
- Scissors
- Samples of recyclable plastic (e.g. PETE, HDPE, LDPE, PS, PP)

GENERAL SAFETY GUIDELINES:

- Safety Glasses/Goggles must be worn at all times for this activity.
- Use caution when heating with the hot plate. To prevent burns never handle heated materials. Always use tongs and wood splints to handle materials once heating begins.
- After lab activity is completed and lab area is cleaned, hands should be washed.

PROCEDURE:

1. Cut polymer samples (PETE, HDPE, LDPE, PS, PP - from yogurt lids, plastic wash bottles, etc.) into pieces of approximately 1cm x 4cm.
2. Place the sample pieces into an aluminum dish (this may be fashioned from aluminum foil - try to keep the bottom as flat as possible for good heat transfer).
3. Place the aluminum dish on a hot plate and slowly heat the samples (using hot plate setting #2) until the samples begin to soften and becomes molten.
   Note: If the plastic starts to brown or discolor, decrease the temperature of the hot plate. It is best to remove samples that are discoloring from the heat source to avoid inhaling any decomposition products. If the sample is very discolored, it may be necessary to repeat with a new sample.
4. Insert the tip of a wooden splint into the sample and hold it in the molten polymer for a few seconds.
5. Slowly pull the splint away at a constant speed. Try to produce the longest fiber possible. The withdrawal speed may need to be adjusted depending on the polymer being used.
6. Try to "cold-draw" the fibers you have formed by stretching them after they have cooled. How far can they be extended before they break? What happens to the strength as the fibers are stretched? Why might the strength change upon stretching?

DISPOSAL: All materials can be discarded in the trash once they cool to room temperature.

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DATA and OBSERVATIONS:

Polymer Type	Polymer Name or Abbreviation	T_m (°C) Melting temperature	Observations
1			
2			
3			
4			
5			
6			

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OBSERVATIONS and ANALYSIS QUESTIONS:

1. Were you able to draw fibers for each of the polymer samples? ___________________

   Which polymer produced the longest fiber? ____

2. Which polymer do you think would be the easiest to recycle and why? _________________________

   ____

   ____

   ____

   ____

3. Did the melting temperatures listed for the materials correspond to the relative order in which you observed the materials melting and becoming molten? ___________________
   Why do you think this happen? ____

   ____

   ____

CONCLUSION: Summarize your observations, discuss any problems you encountered or changes you Would make to your investigation and discuss any additional investigations you would perform.

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Waste Audit Protocol

We will conduct an audit of waste generated in the high school classrooms, main office, and cafeteria during a single day. We will use that data to calculate the waste generated on weekly, monthly, and annual bases. We will also sort the waste to identify its composition and then make specific recommendations for reducing and recycling waste based on our results.

Procedure for classrooms/main office:

For each classroom (or a random sample of total classrooms) and the main office:

1. Label a large, clear garbage bag with the room number and the word "trash." Dump all garbage from trash cans in the room into that bag.

   If the room has recycling bins, also label a large clear with the room number and the word "recycling" and dump the contents of recycling bins into that bag.

2. For each room's waste, weigh the bag(s) collected and record the mass on the data form under "total waste." Repeat for recycling.

3. Then dump the waste and sort according to the categories on the data form.

4. Weigh and record the mass of each category for that classroom on the data form.

Materials:

Labels and markers
Large, clear bags for collecting trash from rooms
Scale(s) (preferably digital)
Plastic tarp to sort trash on
Plastic gloves
Data sheets

Procedure for cafeteria:

On a given Friday for each lunch period, students will observe all trashcans and record the waste thrown in them on data forms. At the end of the last lunch period, we will weigh the total amount of waste. We need to ask the cafeteria staff to set aside any trash bags removed from their cans before the final lunch period so that they can be included in the total mass.

Materials: Clipboards
Pencils
Data forms
Large Scale

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Observation schedule:

Lunch Period	Observers	Trash Cans

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Classrooms and Main Office Waste Audit Data

TOTAL WASTE		
DATE		
CLASSROOM/OFFICE NUMBER		
# TRASH CANS		
# PAPER RECYCLING BINS		
# RECYCLING BINS FOR OTHER MATERIALS (Glass, Aluminum, Plastic)		
TOTAL MASS OF WASTE COLLECTED FROM TRASH CANS		
TOTAL MASS OF WASTE COLLECTED FROM RECYCLING BINS		
	MASS	
WASTE CATEGORIES	**In Trash**	**In Recycling**
PAPER		
CARDBOARD		
GLASS		
PLASTIC BOTTLES #1 & #2		
OTHER PLASTICS		
ALUMINUM CANS		
STEEL CANS		
FOOD WASTE		
OTHER WASTE List examples here:		

Anything unusual that makes you think this data is not representative of a typical day in this room?

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Cafeteria Waste Audit Data

Date: _______________ Lunch period: ____________

Location of trash can you are observing: ____________________________

Observer (your name): ______________________________________

Start time: _______________ Finish time: ________________

For each waste category, place a tick mark for every item you see thrown away.

FOOD	A little	A lot
MILK/JUICE CARTONS		
PLASTIC BOTTLES #1 & #2		
PLASTIC SILVERWARE		
OTHER PLASTIC (yogurt containers, straws, plastic wrap, etc.)		
NAPKINS		
ALUMINUM CANS		
STEEL CANS		
OTHER - List examples here:		

Comments?

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Cafeteria Waste Audit Data - TOTAL MASS

Date: ____________________ Time: _________________

Persons weighing total waste: ____

Trash Bag	Mass
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

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Making and Testing Properties of Bio-Plastics Films

Lab # _____

Name: ___________________________ Date Performed: ___________

Partner: ___________________________ Date Due: ___________

INTRODUCTION:

Plastics have become a vital part of our everyday existence. Plastic technology has evolved into an exact science with plastics for any use imaginable. Different plastics also have different properties that make them suitable for a variety of uses. Currently, we rely on the use of fossil fuels to produce plastics. In an effort to reduce our dependence on finite resources, new research has discovered natural materials that can be made into plastics. Some of these plastics are comparable to synthetic plastics in their behavior under certain conditions. Do these bio-polymers really share enough of the same properties to substitute them for synthetic polymers?

PURPOSE:

The objective of this activity is to make a biodegradable plastic film and to test its properties.

MATERIALS NEEDED:

Hot plate with magnetic stirrer
Thermometer
Digital balance
Teflon nonstick pan (~38cm x 25cm)
10 ml graduated cylinder
Starch
Agar
stir bar or small paper clip
Hot-hands or oven mitts
Plastic weighing dish
400 ml or 600ml beaker
100 ml graduated cylinder
Gelatin
1% glycerol solution

GENERAL SAFETY GUIDELINES:

- Safety Glasses/Goggles must be worn at all times for this activity.
- Use caution when heating with the hot plate. To prevent burns never handle heated materials. Always use tongs and wood splints to handle materials once heating begins.
- After lab activity is completed and lab area is cleaned, hands should be washed.

PROCEDURE:

1. Use the table below to measure the correct amount of materials needed to make your bio-plastic. Note any differences in physical properties (color, state, odor) in your data section.

Material	Agar Film Amounts	Gelatin Film Amounts	Starch-Gelatin-Agar Film Amounts
Starch	---	---	1.5 g
Gelatin	---	2.25 g	0.50 g
Agar	2.25 g	---	0.25 g
1% Glycerol	100 ml	100 ml	100 ml

2. Once all materials have been measured, mix all of the dry materials in a clean 400 mL beaker.
3. Add the stir bar or a small paper clip to the beaker and place on to a hot plate/magnetic stirrer.

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4. Slowly add the glycerol to the beaker while mixing using the magnetic stirrer. Continue to mix until all solid material has dissolved in the glycerol. You may have to break up larger chunks using a glass-stirring rod.

PROCEDURE: continued

5. Once all solids are in solution, heat the mixture until it begins to froth. DO NOT allow the temperature to go above 95 °C.
6. Turn off the heat after mixture has begun to froth. Continue to stir for 5 minutes. No visible lumps should be present.
7. Once the mixture has cooled slightly, carefully pour the mixture into a level Teflon pan.
8. While you are waiting, take a sample of polyethylene. Observe and record physical properties of the plastic such as color, transparency, thickness. Record these in your data section.
9. Next, perform the tests listed below (see testing procedures section):
   - Density
   - Flexibility in cold/hot water
   - Hardness
   - Acid/Base Test
10. Record all observations from each test in your data section.
11. Pour the mixture as evenly as possible over the surface as a thin layer. Label the pan with your group names and allow it to sit overnight.

Next Class

12. Carefully remove the Bio-plastic film from the Teflon pan. You might need to use a metal scoopula to lift some of it away from the pan. Note its physical properties (color, transparency, thickness). Record in your data section.
13. Perform the tests listed below on the Cast-Film (see testing procedures):
    - Density
    - Hardness
    - Flexibility in cold/hot water
    - Acid/Base Test
14. Share your results with the other groups and compare the results you obtained for each type of plastic.
15. Save all of your Cast-Film in a Zip-lock bag with your name on it.
16. Clean up your area when finished. Answer all conclusion questions.

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PLASTICS TESTING

MATERIALS NEEDED:

Penny	Triangular file	100 mL graduated cylinder
Digital balance	Tongs	250 mL beaker (2)
Watch glass	Plastic pipet	Wooden stir stick
2 M HCl	2 M NaOH	

GENERAL SAFETY GUIDELINES:

- Safety Glasses/Goggles must be worn at all times for this activity.
- Extra care should be taken when handling corrosive materials. If a spill occurs, alert your teacher immediately
- After lab activity is completed and lab area is cleaned, hands should be washed.

PROCEDURE:

Density; Quantitative

1. Using the electronic balance, find the mass (in grams) of the sample to be tested.
2. Fill a 100 mL beaker to the 40 mL mark. Place a piece of the plastic sample in the water.
3. Observe whether the plastic sinks or floats. Make sure there are no air bubbles sticking to the plastic.
4. Record the new volume of water. Subtract the original volume from the final volume.
5. Determine the density of the sample by using the equation: $D=m/v$.

Hardness

1. You are testing the ability of the material to be scratched. A scratch is defined as groove on the surface that can easily be seen.
2. Use the following materials to scratch the surface of the plastic: fingernail, penny, triangular file. Rate the hardness of the material on a scale of 1-5 (1=softest, 5=hardest).

Flexibility

1. Take the sample of plastic and fold it in half. Check for any folds, creases, cracks, or a color change in the sample.
2. Repeat this test after exposing the sample to ice water (for 5 min) and hot water (for 5 min). The hot water should be at least 80 °C. Remove the sample using tongs.
3. Record your results for the three temperatures.

Acid/Base Test

1. Place a small sample of the plastic (at least the size of a penny) on the watch glass. Fill a pipet with 2M HCl. Count the number of drops it takes before the sample begins to change. Check the sample using a wooden stir stick. Record your results. Rinse the sample with large amounts of water and dispose of in the trash.
2. Take another of the same size of the sample. Repeat the same test using the 2M NaOH. Record your results. Rinse the sample with large amounts of water and dispose of in the trash.
3. Wash your hands thoroughly.

References

Green plastics: an introduction to the new science of biodegradable plastics. Stevens,E.S., Princeton University Press. Princeton. 2002.

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