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Lesson Title	Exploring the physical and chemical properties of polymers
Grade Level	Grades 8-10
Lesson **Source** (if not original)	
Abstract/Description	This activity involves the students in an inquiry based examination of the physical and chemical properties of polymers.
Objective(s) Criteria should be measurable. • What should the students know as a result of this lesson?	Students will: • Operationally apply physical and chemical property definitions to specific examples. • Discuss that plastics are polymers that can be categorized into six types. • Identify physical and chemical properties of polymers. • Identify differences in polymers.
• What should the students be able to do as a result of this lesson?	Students will: • Test polymers for differences in physical properties. • Test polymers for differences in chemical properties. • Accurately record observations. • Compare polymer tests for similarities and differences. • Orally and in writing communicate test analysis and results.
Materials Needed	• In this activity the teacher will need to gather polymers from various food containers, recycling codes 1 through 6, so have students collect these items at home and bring them to school at least the day before the activity. • You will need the following reagents: distilled water, ethanol, acetone, 3.0 M sulfuric acid, ethyl acetate, 3.0 M sodium hydroxide, 2.5 M nitric acid, mineral oil, and 3.0 M sodium chloride. Preparation details for these reagents are in the safety section.

	• Potassium carbonate, sodium chloride, and distilled water. • Electronic balances or else use large pieces of polymers and manual balances to determine their densities. • Alcohol lamps or candles. • Beakers or small containers to hold reagents. • A fume hood (optional)
Procedures (Learning Cycle) • Engagement/ Assessment	Note: This exercise should be changed to make use of the resources available. If a fume hood is not available then delete that portion of the procedures that requires that equipment. Polymers are all around us. Polymers are versatile as you note from the various uses in the materials around and on you, and resource efficient, as polymers consume only 4 percent of the world's oil supply. Polymers reduce oil consumption and carbon dioxide emissions. This investigation focuses on the physical and chemical properties of polymers. State, "You have collected plastic containers that are made up of different kinds of plastics called polymers. If you look on the bottom of your container you will see a triangle with a number in it. This is called a recycling code and refers to the type of polymer in the container. Each type of polymer is different from another in some ways and the same in other ways. Ask, "In what ways are they different?" Accept answers. Ask, "In what ways are they the same?" Accept answers. State, "Scientists categorize these differences into physical and chemical properties." Ask, "What do you think a physical property is?" A physical property is when a substance can change without it becoming a difference substance. An example would be when you heat a metal and it melts. Ask, "What do you think a chemical property is?" A chemical property is when a substance when changed becomes a different substance. An example would be adding acid to the same metal would cause the metal to react and become a salt with hydrogen gas given off. **Assessment:** Ask students to give you examples of physical and chemical properties and qualify them by putting them on the board. Melting point, boiling point, strength, hardness, density, color, opaqueness, transparency, and electrical conductivity are among the physical properties they might mention. Chemical reactivity such as combustion and biodegradability are common chemical properties. State, "Let's test these polymers and see how they are the same and how they are different."
• Exploration / Assessment	Before beginning any handling of materials, remind students to work safely and to use materials/equipment for the intended purposes. Ask, "Which of the physical properties should we test?" Accept input. Lead them to identify the following in the procedures below: Also conduct a discussion

	how they will record their observations and tests. (Each student can test his/her own or groups can test several polymers.) For each polymer perform the following: A. Describe the polymer to include color, hardness, flexibility, opaque or transparent, odor, etc. and record your observations on the data sheet. Compare your results. B. Determine the density of your sample by placing the sample in the test solutions provided by your teacher. Record whether the sample sinks or floats in each solution and decide the approximate density. To find a more precise density for each sample, mass your sample, find the volume by water displacement, then divide mass by volume to calculate density. Compare your results with the tests you preformed at the beginning of this procedure. C. Determine the strength of your sample by attempting to tear, bend, twist, stretch etc. it. Record your results for each sample. What happens when you hit your sample with a hammer? Other tests can be performed at the teacher's discretion. Ask, "Which chemical properties should we test?" Accept input. Again lead students to perform the following: D. Use the fume hood and place a small piece of your sample in the second blue flame of a Bunsen burner. That is the part of the flame further from the barrel. Observe and record results. E. Introduce your sample close to a candle flame. Make observations and record results. State, "I have selected some chemical solutions for you to test chemical reactivity. Perform the following:" F. Place 10 mL of each of the following in separate test tubes or glass containers: water, ethyl alcohol, acetone, ethyl acetate, 3M sulfuric acid, 3M nitric acid, 3M sodium hydroxide, 3 M sodium chloride, and mineral oil and then add a small piece of your sample to each container. Stopper test tubes or place the lid on the glass containers. Make initial observations and then record results after 30 minutes, and 24 hours. State, "To test biodegradability let's do the following:" G. Place a piece of your sample in the "Is it biodegradable" container and observe monthly. **Assessment:** Have groups compare their test procedures and arrive at agreement on which procedures they will use and how they will document the test results. This could be in the form of tables or narratives but all students need to agree on the same format. Discuss why that is important.
• Explanation/ Assessment	Have students report orally and in writing their results with comparisons between the different polymers. **Assessment:** Have students compare results and communicate their findings to the entire group.
• Elaboration/ Assessment	Possibly students could form companies and test unknown polymers to determine their identity. Also students could adopt a polymer and generate a report which would include the test data. Also teachers

	could help form student advocacy groups for polymer use and education. **Assessment:** Have groups correctly identify unknowns. Have students give oral reports on their advocacy efforts.
Prerequisites	None
Best Teaching Practice(s) Promoted (see AGPA website list)	Inquiry
Alignment with Standards • National	Content: Science as Inquiry: as a result of activities, in grades 5-8, all students should develop ▪ abilities necessary to do scientific inquiry Physical Science: as a result of activities, in grades 5-8, all students should develop an understanding of ▪ properties and changes of properties in matter
• Ohio	Content Physical Science Grades 9-10 Describe the identifiable physical properties of substances, (e.g. color, hardness, conductivity, density, concentration, and ductility). Scientific Ways of Knowing grades 9-10 Explain how scientific inquiry is guided by knowledge, observations, ideas, and questions.
Content Knowledge (include any connections to technology)	Observation skills to discern physical changes chemical reactions.
Safety	To minimize safety concerns, the teacher should place the chemicals in a baby food jar or similar container that has a lid. The lid is only removed by the student to put the plastic in then quickly closed to prevent any vapors from escaping. The physical test should be supervised by the teacher. Material Safety Data Sheets should be consulted for all chemicals used in this activity. Prepare reagent as follows • Acetone is available in finger nail polish remover. • Prepare 3.0 M sulfuric acid by pouring 16.6 mL of concentrated acid into 63.4 mL of water. • Prepare 3.0 M sodium hydroxide by dissolving 12.0 grams of NaOH into enough water to make 100 mL of solution.

	• Prepare 2.5 M nitric acid by pouring 12.5 mL of acid into 87.5 mL of water. Prepare 3.0 M sodium chloride by dissolving 17.6 grams of NaCl in enough water to make 100 mL of solution.
Applications (Where is this content applied in the "real world?")	Consumers of polymer products should be knowledgeable of their properties and biodegradability. See http://www.polymerambassadors.org and www.mii.org for applications and extensions.
Assessment (overall)	Students should be able to define and give examples of physical and chemical properties of substances in general and polymers specifically.
Other Considerations Grouping Suggestions	Students should be placed in groups of two or three. However a novel idea on grouping is found in, "Cooperative Learning in the Science Classroom," by Emily Lin, the Science Teacher Vol 73 No 5 Summer 2006, pp34-39
Other Considerations Pacing/Suggested Time	Two 45 minutes periods
Worksheets	NA -- Students should devise their own data sheets based on the discussion in class.