Ohio Standards Connection:

Physical Sciences

Benchmark E
Summarize the historical development of scientific theories and ideas within the study of physical sciences.

Indicator 2
Explain that humans have used unique bonding of carbon atoms to make a variety of molecules (e.g., plastics).

Lesson Summary:
Students will investigate properties and common uses of some synthetic organic compounds as well as learn basic structures and properties. Students’ culminating activity will include creating a time line of the discoveries or inventions of synthetic organic compounds from the mid 1800s to the present.

Estimated Duration: Seven to eight hours

Commentary:
This lesson was designed to help students understand the unique nature of carbon through a series of activities and research projects. The creation of a time line for the development of organic chemistry provides students with the historical perspective of how scientific ideas have advanced. The basic chemistry of organic compounds is studied and the real world use of carbon compounds in plastics is explored to provide students with an overview of the importance of organic chemistry.

This lesson was field tested by teachers across the state of Ohio. Some of the teacher comments about this lesson were:
• “The time line is very good and provides context for how scientific advances have affected daily living.”
• “Excellent blend of models, lab and discussion.”

Pre-Assessment:
Introduce the term “organic” by asking the students if they prefer organic produce from the grocery store. Discuss the difference between “regular” and “organic” foods. Explain to the students that chemistry uses the word organic to describe a huge and important class of compounds, but it has a very different meaning from what they found in the grocery store. Make students aware that no matter how an orange is grown the orange is still organic according to chemists!
Tell the class that all compounds can be classified into two categories: organic and inorganic.

1. Ask students to find the definition of organic compounds in their text or give them the definition on an overhead (e.g., compounds that contain carbon - with a few exceptions such as CO and CO₂).

2. Give students five minutes to list all the items they can see in the class that are made of organic compounds. Ask them to name the organic compounds in the items.

**Scoring Guidelines:**
See Attachment A, *Pre-Assessment Rubric*.

**Post-Assessment:**
Have students respond to an essay (extended response) question such as the one below. Students may use a combination of text, drawings and illustrations in their responses.

Describe two key ideas humans have used in the unique bonding of carbon to make a variety of molecules. A complete description also provides two examples of these molecules and their uses. (4 points)

**Scoring Guidelines:**
See Attachment B, *Post-Assessment Rubric*.

**Instructional Procedures:**
1. Tell students that one of the unique properties of carbon is its ability to bond to itself to form very long chains and that this property contributes to the usefulness of carbon-based materials. Tell them they will conduct the following lab to investigate the properties of synthetic polymers that are used daily.

2. **Synthetic Polymer Identification Lab:** See Attachment C, *Synthetic Polymer Identification*. Prior to conducting the lab, tell students to read through the lab procedures and identify safety precautions, needs and any questions they may have. Discuss ideas for successful and safe completion of the investigation. After the lab, discuss students’ findings and answers to questions.

3. Provide information to the class about basic organic compounds (oral, video or electronic text). Encourage students to take copious notes that include many three-dimensional structural formulas (non-linguistic representations) of the compounds. Include such topics as organic nomenclature, the structure and properties of alkanes, alkenes, alkynes, aromatic rings, cyclo-hydrocarbons and several functional groups, especially ketones, aldehydes, alcohols and carboxylic acids. Provide a basic understanding of organic nomenclature, using C1 through C10 examples. See Attachment G, *Home Practice for Organic Compound Nomenclature*.

4. **Building molecular models:** See Attachment D, *Molecular Model-Building Activity*. Working in pairs and using ball and stick molecular model kits, have students make models and draw three-dimensional and structural formulas for selected organic compounds.
5. After students have built the models, facilitate a class discussion about the various structures, especially how the structures are similar and different.
   - Discuss how the length of the carbon chain, the type of bond (single, double, triple) and the different functional groups affect the properties of the compounds, using the built compounds as visual aids.
   - Ensure that a model of cyclohexane is built and compared to a model of benzene.

6. **Time line**
   Begin a whole-class project to develop a time line from information that students collect outside of class. Tell students that the purpose of developing the time line is to see how humans throughout time have used the unique bonding of carbon atoms to make a variety of molecules to meet human needs. Have each student contribute an entry to the time line, making his/her entry colorful so the time line will be visually attractive.
   a. Working as a whole group, have the class create a time line of discoveries or inventions of synthetic organic compounds, starting with William Henry Perkin’s discovery of the first synthetic dye in 1856.
   b. Have each student contribute one entry to the time line, submitted on a large, 4x6-index card.
   c. Examples of synthetic organic compounds can include, but not be limited to, polymers, medicines, dyes, detergents, food additives or agricultural agents.
   d. The entry should contain the following information:
      - Date of discovery;
      - Name and nationality of the scientist;
      - Name and structural formula of the organic compound;
      - Brief explanation of how the compound was discovered/invented;
      - Brief description of how the compound is (or was) used.

7. Allow students one day to choose the compound they’d like to research. Require instructor approval of topics to avoid duplicate research and to ensure that examples of compounds from different eras are represented. Allow students another evening to complete the research.

8. Place a time line, perhaps made of yarn, on a wall with marked reference dates, such as 1850, 1900, 1950 and 2000. When students bring in the cards, have them tell the class about their compounds and then place the cards in the appropriate places on the time line.


10. As an option, provide a completed vocabulary page of the terms used in this lesson.

11. To bring closure to this unit, discuss how students’ understanding has changed regarding the key ideas of the unit. Have students recognize and summarize two key ideas about the unique bonding of carbon and provide evidence of how humans have used the unique bonding of carbon to meet needs, including benefits and detriments.
Differentiated Instructional Support:
Instruction is differentiated according to learner needs, to help all learners either meet the intent of the specified indicator(s) or, if the indicator is already met, to advance beyond the specified indicator(s).

• For students having difficulty visualizing the different types of organic compounds, the kinesthetic model-building activity is a good manipulative. The instructor may wish to have the models available to provide concrete examples to compare as the students answer the follow-up questions.

• For students who have a quick grasp of the concepts and who especially enjoy laboratory activities, provide the time and materials for an exploration of slime. See Extension below for an inquiry activity that allows for a student-proposed open-ended project.

Extensions:
• Synthetic polymers comprise a very important category of organic compounds. See Attachment E, Recipes for Polymers. Provide the following instructions to students: After reviewing the recipes provided for slime and putty, think of questions you could answer about these polymers, such as, “How do their properties differ and how is this related to their structures?” or, “How would the properties of one of the polymers be changed if the recipes were varied from the given?” Devise your own experiment with these polymers and write up your results in a formal laboratory report which includes the following parts:
  I. Purpose (or Question)
  II. Procedure
  III. Data Table
  IV. Data Analysis
  V. Conclusions

• Have students search the Internet for organic modeling software and use the software to present to the class an overview of the various types of organic molecules.

• This optional homework assignment is well-suited for gifted students as a follow-up activity. Because these questions require higher-order thinking, review the answers as a class activity. Have students use their textbooks, lecture notes and lab notes to answer the following questions:

  Similarities and Differences among Organic Compounds
  1. Make a table that shows how alkanes, alkenes and alkynes are alike and how they are different.
  2. How does the addition of the hydroxyl functional group change the properties of an alkane?
  3. In hydrocarbons, what effect does the length of the chain have on the boiling point of the compound? How can this be explained?
  4. What is an aromatic ring and how do the properties of an aromatic ring differ from the properties of a cyclo-hydrocarbon?
  5. Both aldehydes and ketones contain a carbonyl functional group. Compare and contrast the properties of aldehydes versus ketones.

Homework Options and Home Connections:
Two weeks prior to this lesson, encourage students to work with their families to save the plastics they would normally throw away. Place in six separate bags, numbered one through six. Tell the students that if the plastic has a number on it, place the rinsed plastic item in the correspondingly numbered bag. (Emphasize that the plastics must be fairly clean.) This helps students see how many of each polymer they are using in their homes and also provides the needed plastics for the Polymer Identification lab.

**Interdisciplinary Connections:**
When completing this lesson, students will be called on to use the following English language arts skills:
- Organizing information from various resources
- Communicating findings
- Using a variety of communication techniques

**Materials and Resources:**
The inclusion of a specific resource in any lesson formulated by the Ohio Department of Education should not be interpreted as an endorsement of that particular resource, or any of its contents, by the Ohio Department of Education. The Ohio Department of Education does not endorse any particular resource. The Web addresses listed are for a given site’s main page, therefore, it may be necessary to search within that site to find the specific information required for a given lesson. Please note that information published on the Internet changes over time, therefore the links provided may no longer contain the specific information related to a given lesson. Teachers are advised to preview all sites before using them with students.

*For the teacher:* Chemistry text with an organic chemistry chapter or library reference books, molecular model kit (ball and stick with flexible connections for double and triple bonds), access to the Internet (search for “synthetic polymers” or “organic chemistry helper”), and for the extension: polyvinyl alcohol, sodium tetraborate, guar gum, deionized or distilled water, paper cups and wooden sticks.

*For the students:* Chemistry text with an organic chemistry chapter or library reference books, molecular model kit (ball and stick with flexible connections for double and triple bonds), access to the Internet (search for “synthetic polymers” or “organic chemistry helper”), and for the extension: polyvinyl alcohol, sodium tetraborate, guar gum, deionized or distilled water, paper cups and wooden sticks.

**Key Vocabulary:**
- organic chemistry
- hydrocarbon
- alkane
- alkene
- alkyne
Introduction to Organic Chemistry – Grade 11

- alcohol
- ketone
- aldehyde
- carbonyl
- hydroxyl
- functional group
- carboxylic acid
- free radical
- polymer
- synthetic
- single bond
- double bond
- triple bond
- aromatic ring
- cyclo-hydrocarbon
- conjugated double bonds

**Technology Connections:**
- Students may need to use the Internet to find information about an organic compound. One such Internet site is the Ohio Resource Center for Mathematics, Science and Reading. The ORC provides peer-reviewed, best-practice Web sites to give educators ideas for teaching the Ohio Academic Content Standards, including instructional, content and professional resources. The ORC URL is: [http://ohiorc.org](http://ohiorc.org)
- Numerous Web sites offer tutorials in organic chemistry.

**Research Connections:**

Taking copious notes helps students learn more efficiently than taking meager notes.


Summarizing and note taking are two of the most powerful skills to help students identify and understand the most important aspects of what they are learning. Student understanding is improved if they include nonlinguistic symbols along with their notes.

Asking students to independently identify similarities and differences increases student understanding of concepts.


Direct vocabulary instruction has been found to increase student achievement.


Research has shown that repetition does increase recall.

**General Tips:**
1. Be sure to mention to the students that there are many naturally-occurring polymers (e.g., starches, proteins), but this lesson focuses on human-made polymers.
2. If time is an issue, skip the *Synthetic Polymer Identification* lab. Instead, start with information on organic nomenclature, then work with the molecular models and, finally, make the time line.
3. Emphasize analysis and conclusions in each activity to maintain the inquiry nature of the lesson.
4. Gumdrops or marshmallows and toothpicks can be substituted for the molecular model kits, but these are inferior to the kits because the students are not forced to connect the atoms to each other at the proper angles. If the gumdrop-toothpick model is used, explain to the students the angle and number of the bonds for the carbon atoms.
5. Have students who are good independent learners do the questions immediately after they complete the model activity. Students who take longer to finish the model activity must complete their questions at home, since all students should participate in the class discussion.
6. The ingredients in the recipes in the extension activity are all nontoxic and can be safely handled by the students in an exploratory manner with little supervision from the instructor.
7. In the pre-lab activity for *Synthetic Polymer Identification*, teachers may wish to give students a mini-lecture on the six types of polymers, including the structural formulas of the monomers. See Attachment F, *Structural Formulas of Common Monomers and their Polymers* for these formulas.
8. For the lab, *Synthetic Polymer Identification*: (Note: This is a modified version of a lab from the Plastics Society.)
   a. Please stress safety. Students must wear safety goggles and aprons during the lab.
b. To build a stock supply of plastics one through six, ask the students to bring in the samples for some designated reward.

c. The sugar water is a saturated solution at room temperature.

d. The burning station MUST be conducted in a chemical fume hood. Under no circumstances should the students burn plastic in the open room. If a fume hood is unavailable, then this test should not be conducted.

e. Be sure to place the large beaker of water directly beside the burner in the fume hood. Immediately after observing the burning pieces of plastic, the polymer should be placed in the water to cool before being thrown away in a wastebasket.

f. It is wise to conduct the tests on known polymers ahead of time and make appropriate modifications to the key.

g. Here is a suggestion for how to set up the polymer lab: Set out two stations of each of the tests, except the high-temperature test, which must be conducted in the fume hood. Have students work in lab groups of two to three, moving from station to station, testing one polymer at a time and recording the data.

**Attachments:**
Attachment A, *Pre-Assessment Rubric*
Attachment B, *Post-Assessment Rubric*
Attachment C, *Synthetic Polymer Identification*
Attachment D, *Molecular Model-Building Activity*
Attachment E, *Recipes for Polymers*
Attachment F, *Structural Formulas of Common Monomers and their Polymers*
## Pre-Assessment Rubric

<table>
<thead>
<tr>
<th>Student Results</th>
<th>Teacher Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student is able to name 15 items in the room and accurately name 10 of the compounds.</td>
<td>Skip the Instructional Strategy and proceed directly to the Post-Assessment.</td>
</tr>
<tr>
<td>The student can name any number of items accurately but cannot name at least 10 of the compounds.</td>
<td>Follow through the Instructional Strategy before attempting the Post-Assessment.</td>
</tr>
</tbody>
</table>
The first part of the answer describes the key idea that carbon is the only element that can bond to itself to form chains hundreds of carbons long. The second part describes the key idea of how a variety of molecules can be made by varying the functional groups and structures of the carbon chains. The final part of the answer gives two examples of synthetic polymers and one example use for each.
I. Introduction

You’ve heard of the Stone Age, the Iron Age and the Bronze Age, right? Perhaps the best way to describe our modern age is by calling it the Polymer Age because synthetic polymers, also known as plastics, are so essential now to our way of life.

A polymer is a long molecule formed from hundreds or even thousands of smaller organic molecules called monomers. An organic compound is one that contains carbon, and indeed, the backbone of all polymers is composed of many carbons. Carbon is unique because it is the only element that can bond to itself to form chains that are hundreds of atoms long! Living organisms are made of natural polymers like proteins and nucleic acids, but plastics are man-made or synthesized, hence the name, synthetic polymer.

There are many types of synthetic polymers now being manufactured. One of the world’s most widely produced plastics is polyethylene, which is used to make things like grocery bags, milk bottles and food containers. Polyethylene is a long chain of monomers called ethane. Another type of polymer, polystyrene, is made from the monomer, styrene. This is used in insulation or furniture. Polyvinyl chloride, more commonly known as PVC, is made from the monomer, vinyl chloride. One might see PVC in rainwear, pipes or plastic seat covers.

In this lab, we will compare some physical and chemical properties of different plastics. These properties are a result of the polymer’s chemical structure, such as the length of the chain and the nature of the monomers. For example, polyvinyl alcohol has numerous polar sites so it’s very water soluble, but polystyrene is made of many styrene units, which are benzene rings and are very nonpolar so it doesn’t dissolve in water. Plastics are also different because of the way they are manufactured. For example, plastic foam cups keep beverages hot or cold well because they are made of polystyrene that has been pumped full of air. The dead air space acts as a good insulator. However, plastic forks are also made of polystyrene but with no added air so they are a higher density and would not be good insulators.
<table>
<thead>
<tr>
<th>Types of Plastic</th>
<th>Industry Abbreviation</th>
<th>Recycling Code</th>
<th>Typical Packaging Uses</th>
<th>Typical Other Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene Terephthalate</td>
<td>PETE or PET</td>
<td>1</td>
<td>soda, ketchup, liquid soap bottles</td>
<td>strapping, surfboards, paint brushes</td>
</tr>
<tr>
<td>High Density Polyethylene</td>
<td>HDPE</td>
<td>2</td>
<td>milk and juice jugs, grocery bags</td>
<td>flower pots, trash cans, toys</td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td>PVC</td>
<td>3</td>
<td>vitamin, olive oil, glass cleaner bottles</td>
<td>pipes, floor mats, hoses</td>
</tr>
<tr>
<td>Low Density Polyethylene</td>
<td>LDPE</td>
<td>4</td>
<td>vegetable bags, butter dishes, coffee can lids</td>
<td>garbage can liners, dry cleaner bags</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>PP</td>
<td>5</td>
<td>yogurt, maple syrup and spice containers</td>
<td>paint buckets, lawn mower wheels, ice scrapers</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>PS</td>
<td>6</td>
<td>egg cartons, deli tray, fast food containers</td>
<td>envelope windows, license plate holder, hanging files</td>
</tr>
</tbody>
</table>
II. Pre-lab Activity:

*Complete the following chart.*

<table>
<thead>
<tr>
<th>Name of Synthetic Polymer</th>
<th>Structure of Monomer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypropylene</td>
<td></td>
</tr>
<tr>
<td>Polystyrene</td>
<td></td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td></td>
</tr>
</tbody>
</table>
III. Procedure
1. Obtain one of each of the plastics, 1-6 from your instructor. Label each one and then conduct the following tests on each plastic. Record your results in your data table.

2. **Density Test**: Place your sample in the beaker of the sugar water. Record whether it sinks or floats. Note: The sugar water has a density of about 1.2 – 1.3g/cm³.

3. **Flexibility Test**: Gently try to bend the sample. Does it bend easily? If so, does it quickly return to the original shape, or stay curled into the new shape? Record your findings.

4. **Brittleness Test**: Use a hammer to easily strike a sample. If it does not break, try to cut it with scissors. Record your findings.

5. **Low-Temperature Test**: Using crucible tongs, dip the sample into boiling water for about a minute. Remove and cool. Test the flexibility of the sample after heating. Record.

6. **High-Temperature Test**: Do this ONLY in the fume hood. Burning plastics can produce toxic fumes. Holding the plastic with crucible tongs, put an edge of the sample in the Bunsen burner flame for a few seconds. Record the color and intensity of the flame and smoke. Immediately place the burned plastic in a large beaker of water.

7. After you have completed your data table, take it to your instructor to have it checked for accuracy with the key.

8. Obtain two unknowns from your instructor. Perform tests 2-6 on it and decide which number of plastic you were given.

**Caution: Goggles and aprons should be worn at all times during this lab!**
## III. Plastics Data Table

<table>
<thead>
<tr>
<th>Test</th>
<th>1 PET</th>
<th>2 HDPE</th>
<th>3 PVC</th>
<th>4 LDPE</th>
<th>5 PP</th>
<th>6 PS</th>
<th>Unknown 1</th>
<th>Unknown 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it float in sugar water?</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Flexibility</td>
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<td></td>
</tr>
<tr>
<td>Does it bend easily?</td>
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<tr>
<td>Brittleness</td>
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<td></td>
</tr>
<tr>
<td>Does it break easily?</td>
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<td></td>
</tr>
<tr>
<td>Brittleness</td>
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<td></td>
</tr>
<tr>
<td>Does it cut easily?</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Low Temp</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it bend after heating?</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>High Temp</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke Color</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temp</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Flame Color</td>
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<td></td>
</tr>
</tbody>
</table>

## IV. Questions/ Analysis

1. What kinds of plastics are your two unknowns?
2. Why would you not want to make a milk container out of polystyrene?
3. Which plastics would be good for making a kite? Why?
4. Why would it not be a good idea to fuel your cozy, indoor fireplace with plastics, especially one like polystyrene?
## Plastics Data Table

<table>
<thead>
<tr>
<th>Test</th>
<th>1 PET</th>
<th>2 HDPE</th>
<th>3 PVC</th>
<th>4 LDPE</th>
<th>5 PP</th>
<th>6 PS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it float in sugar water?</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it bend easily?</td>
<td>Yes</td>
<td>Stiff, but will bend</td>
<td>Yes, but whitens where bent</td>
<td>Yes</td>
<td>Yes</td>
<td><strong>Cracks</strong></td>
</tr>
<tr>
<td><strong>Brittleness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it break easily?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Brittleness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it cut easily?</td>
<td>Yes</td>
<td>Yes</td>
<td>Not easily</td>
<td>Yes</td>
<td>Yes, but can crack</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Low Temp</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does it bend after heating?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke Color</td>
<td>Smoke has waxy smell</td>
<td>Little smoke; waxy smell</td>
<td>White smoke, difficult to ignite</td>
<td>Same as PP but melts before it burns.</td>
<td>Ignotes easily, little white smoke</td>
<td>Ignite easily, black smoke</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flame Color</td>
<td>Yellow</td>
<td>Ignotes easily, blue flame</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
</tbody>
</table>
### Attachment D  
**Molecular Model-Building Activity**

<table>
<thead>
<tr>
<th>Compound Type and Number of Carbon Atoms</th>
<th>Name of Compound</th>
<th>3-D Sketch of Compound</th>
<th>Structural Formula of Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: Alkane w/ 1 carbon</td>
<td>Methane</td>
<td><img src="image" alt="Methane" /></td>
<td>( \text{H} ) ( \text{H} ) ( \text{C} ) ( \text{H} )</td>
</tr>
<tr>
<td>Alkane w/ 2 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkene w/ 3 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkyne w/ 4 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycloalkane w/ 6 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Ring w/ 6 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol w/ 7 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aldehyde w/ 8 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ketone w/ 9 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carboxylic Acid w/ 10 carbons</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
After each of these recipes is finished “curing,” answer the following questions about the properties of the polymer in terms of its structure.

a. How does the polymer feel to touch?

b. How does it behave differently when it is stretched slowly or pulled quickly? Why does this happen?

c. When rolled up like a ball, does the polymer bounce?

d. If the putty is still in the ball shape and allowed to sit, what happens to it? Why?

e. When the polymer is struck with a hammer, how does it behave?

f. Does the polymer act like a liquid or a solid?

g. Hold the slime with your fingers and let it flow freely. See how long the gel will flow.

Note: These polymers can last up to three weeks if kept in an airtight plastic bag.

CAUTION: Do not eat the polymers!!
Attachment F, Structural Formulas of Common Monomers and their Polymers

Polymer – comes from Greek
Poly = “many”    Meres = “parts”

I. Different properties of polymers are a result of:
   A. Type of monomer
   B. Structure of chain
   C. Interaction between chains

II. Many ways to classify polymers. This is only one way!
   A. Thermoplastics
      1. Polymer is a linear chain of monomers.
      2. Polymer can be softened by heat and melted.
         Example: polyethylene
   B. Thermosetting
      1. Polymer is a cross-linked between chains.
      2. Polymers do not melt.
         Example: bakelite

III. Examples of common polymers:

1. $\text{C} = \text{C} \xrightarrow{\text{catalyst}} \left( \text{C} - \text{C} \right)_n$
   ethylene
   polyethylene
   a) High density
      (toys, milkjugs, containers)
   b) Low density
      (shrink wrap, film for wrapping)

2. $\text{F} \text{C} = \text{C} \text{F} \xrightarrow{} \left( \text{F} - \text{C} - \text{F} \right)_n$
   tetrafluoroethylen
   PTFE or Teflon
   Bearings, gaskets, non-stick pan linings

3. $\text{C} = \text{C} \text{CH}_3 \xrightarrow{} \left( \text{C} - \text{CH}_3 \right)_n$
   propylene
   polypropylene PP
   Fibers, steering wheels, pipes,
   indoor-outdoor carpeting, plastic bottles, kitchenware
7. Nylons – Extremely tough! Used in cars for small gears and tire cords, fibers for clothing, stockings, carpet.


10. Polycarbonates – Used for babies’ bottles, bus shelter windows, firemen’s masks, sports helmets
Attachment G
Home Practice of Organic Compound Nomenclature

Naming Hydrocarbons
1. Count the longest continuous chain of carbon atoms and use the appropriate prefix.

<table>
<thead>
<tr>
<th># Carbon Atoms</th>
<th>Prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>meth –</td>
</tr>
<tr>
<td>2</td>
<td>eth –</td>
</tr>
<tr>
<td>3</td>
<td>prop –</td>
</tr>
<tr>
<td>4</td>
<td>but –</td>
</tr>
<tr>
<td>5</td>
<td>pent –</td>
</tr>
<tr>
<td>6</td>
<td>hex –</td>
</tr>
<tr>
<td>7</td>
<td>hept –</td>
</tr>
<tr>
<td>8</td>
<td>oct –</td>
</tr>
<tr>
<td>9</td>
<td>non –</td>
</tr>
<tr>
<td>10</td>
<td>dec –</td>
</tr>
</tbody>
</table>

2. Use the following suffixes depending on the type of bonding between C Atoms.

- ane    all single bonds (C-C)
- ene    contains a double bond (C=C)
- yne    contains a triple bond (C=C)
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examples:

\[ \text{\(\text{H-H-H}\)} \quad \text{chain of 3 C atoms with all single bonds} \quad \text{propane} \]

\[ \text{\(\text{H-C-C-C-H}\)} \quad \text{chain of 2 C atoms with a double bond} \quad \text{ethene} \]

\[ \text{\(\text{H-C≡C-C-H}\)} \quad \text{chain of 4 C atoms with a triple bond} \quad \text{butyne} \]
Self Test

Name the following:

1. \[
\begin{array}{c}
\text{H} \\
\text{H - C - H} \\
\text{H}
\end{array}
\]

2. \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{C = C - C - C - C - H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H}
\end{array}
\]

3. \[
\begin{array}{c}
\text{H - C \equiv C - H}
\end{array}
\]

Draw structural formulas for:

4. Propyne

5. Pentane
Introduction to Organic Chemistry – Grade 11

Attachment G (Continued)
Home Practice of Organic Compound Nomenclature

Answers to Self Test

1. Methane

2. Pentene

3. Ethyne

4. \[
\begin{array}{c}
\text{H} \\
\text{H – C ≡ C – C – H} \\
\text{H}
\end{array}
\]

5. \[
\begin{array}{c}
\text{H H H H H H} \\
\text{H – C – C – C – C – C – H} \\
\text{H H H H H H}
\end{array}
\]
Attachment G (Continued)

Home Practice of Organic Compound Nomenclature

**CLASSES OF ORGANIC COMPOUNDS**

1. **AROMATIC HYDROCARBONS** — Hydrocarbons that contain a benzene ring

   \[
   \begin{array}{c}
   \text{H} \\
   \text{C} \equiv \text{C} \\
   \text{H} \equiv \text{C} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   Represented as \( \equiv C \equiv \) or \( \equiv O \equiv \)

2. **ALCOHOLS** — contain an \(-\text{OH}\) (hydroxyl) group

   \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   General Formula: \( \text{R} \equiv \text{OH} \) (\( \text{R} \) stands for rest of the molecule)

   Methanol

3. **ETHERS** — contain \(-\text{O} \equiv \text{O} \)

   \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   Diethyl ether (common 'ether')

4. **ALDEHYDES** — contain \(-\equiv \text{C} \equiv \text{H} \)

   \[
   \begin{array}{c}
   \text{H} \\
   \text{H} \\
   \text{H}
   \end{array}
   \]

   Formaldehyde

5. **KETONES** — similar to aldehydes, but \( \equiv \text{O} \equiv \text{C} \equiv \) is between \( \equiv \text{C} \equiv \) atoms

   \[
   \begin{array}{c}
   \text{H} \\
   \text{H}
   \end{array}
   \]

   Acetone
6. CARBOXYLIC ACIDS — contains a carboxyl group: C—OH or written —COOH

\[
\begin{align*}
\text{ex}) & \quad \begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \text{C} - \text{OH} \\
\text{H}
\end{array} \\
& \quad \text{Acetic acid (vinegar)}
\end{align*}
\]

7. ESTERS — formed from the reaction of carboxylic acids and alcohols

\[
\begin{align*}
\text{O} & \quad \text{R} - \text{C} - \text{OH} + \text{HO} - \text{R'} \quad \text{O} \\
\text{carboxylic} & \quad \text{alcohol} \quad \text{ester} \quad \text{water} \\
\text{acid} & \quad \text{R} - \text{C} - \text{O} - \text{R'} + \text{H}_2\text{O}
\end{align*}
\]

\[
\begin{align*}
\text{ex}) & \quad \begin{array}{c}
\text{C} - \text{OH} \\
\text{H} - \text{C} - \text{C} - \text{OH} \\
\text{H} \\
\text{H}
\end{array} \\
& \quad \begin{array}{c}
\text{H} \\
\text{C} - \text{C} - \text{OH} \\
\text{H} \\
\text{H}
\end{array}
\end{align*}
\]

\[
\text{salicylic} \quad \text{methanol} \quad \text{methyl salicylate} \quad \text{water}
\]

SELF QUIZ

Identify the class of organic compounds to which each of the following belongs:

1. \[
\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \text{C} - \text{O} - \text{C} - \text{H} \\
\text{H} \quad \text{H}
\end{array}
\]

2. \[
\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \text{C} - \text{OH} \\
\text{H} \quad \text{H}
\end{array}
\]

3. \[
\begin{array}{c}
\text{H} \quad \text{H} \quad \text{H} \\
\text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{array}
\]

4. \[
\begin{array}{c}
\text{H} \\
\text{H} - \text{C} - \text{C} - \text{C} - \text{H} \\
\text{H} \quad \text{H}
\end{array}
\]

5. \[
\begin{array}{c}
\text{H} \quad \text{H}
\end{array}
\]

6. \[
\begin{array}{c}
\text{H} - \text{C} - \text{C} - \text{OH} \\
\text{H}
\end{array}
\]
Self quiz answers:

1. ether
2. alcohol
3. aldehyde
4. ketone
5. aromatic
6. carboxylic acid