

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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**National Science Education Standard—Physical Science
Structure and Properties of Matter**

Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

Teacher Materials

Learning Sequence Item:

1047

Carbon Bonds in Chemistry

January 1997

Adapted by: Dorothy Gabel

Hydrocarbons, Polymers, and Organic Macromolecules. Students should examine the various ways that carbon atoms bond together in chains, rings, and branching networks to form a variety of structures (*Chemistry, A Framework for High School Science Education*, p. 62).

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3. Physical and Chemical Properties of Carbon
4. Polyvinyl Formation
5. Functional Groups
6. Similarity of Chemical Properties

1047

Learning Sequence

Hydrocarbons, Polymers, and Organic Macromolecules. Students should examine the various ways that carbon atoms bond together in chains, rings, and branching networks to form a variety of structures (*Chemistry, A Framework for High School Science Education*, p. 62).

| Science as Inquiry | Science and Technology | Science in Personal and Social Perspectives | History and Nature of Science |
|--|--|--|-------------------------------|
| <p>Carbon: The Foundation Element Activity 1</p> <p>Organic Chemicals: Varieties and Structures Activity 2</p> <p>Polymers: Bonding and Uses Activity 3</p> <p>Bonding in Trees Assessment 1</p> <p>Physical and Chemical Properties of Carbon Assessment 3</p> <p>Functional Groups Assessment 5</p> <p>Similarity of Chemical Properties Assessment 6</p> | <p>Polyvinyl Formation Assessment 4</p> | <p>Bonding in Sand Assessment 2</p> | |

Suggested Sequence of Events

Event #1

Lab Activity

1. Carbon: The Foundation Element

Event #2

Lab Activity

2. Organic Chemicals: Varieties and Structures

Event #3

Lab Activity

3. Polymers: Bonding and Uses

Event #4

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Suggested readings:

Zaugg, H., "Growing Diamonds." *Chem Matters*, April 1990, pp. 10–13.

Miller, J.K., "Ink." *Chem Matters*, February 1993, pp. 8–10.

Wood, C., "Buckyballs." *Chem Matters*, December 1992, pp. 7–9.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Carbon: The Foundation Element**How can graphite, coal, and diamonds all be made of carbon?****Overview:**

In this activity, students examine the physical properties of the allotropic forms of carbon and relate these to their bonding. This leads to the next activity that shows the wide variety of compounds that carbon forms.

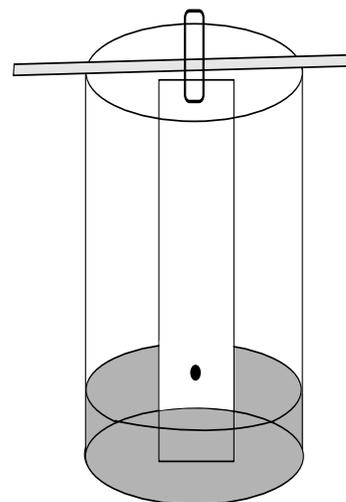
Materials (per group):

black inks—India ink, printers ink, ink from permanent marker, washable marker, fountain pen, ballpoint, etc.
graphite pencil
coal (small soft piece)
diamonds (sand may be substituted), pinch
plastic tumblers, 8
strips of filter or chromatography paper, 8
splints or popsicle sticks, 8
paper clips, 8
toothpicks, 4
oil (mineral is best), 100 mL
notebook paper

Procedure:

Have students mark paper with a graphite pencil and the various inks listed above. They should compare the marks to determine which contain carbon, recording their observations in a systematic way.

Students now use chromatography to test four of the materials (graphite, India ink or printers ink, permanent marker or fountain pen ink, and washable marker), first with rubbing alcohol as the solvent and then with oil as the solvent. Have students adjust the length of the paper strips if necessary by cutting them to about 2 cm less in length than the depth of the plastic tumblers that will be used to develop the chromatograms. They then make a small dot of the graphite on two strips of the filter paper about 1 cm from one end of each strip. One of these strips will be tested in rubbing alcohol, the other in oil. They should repeat this process with the three inks on six other strips (using a toothpick if the ink is not in a pen). They then attach the other end of each strip to a paper clip that is inserted into a splint and place these splints (as shown in Figure 1) across the tops of the eight tumblers.

**Figure 1**

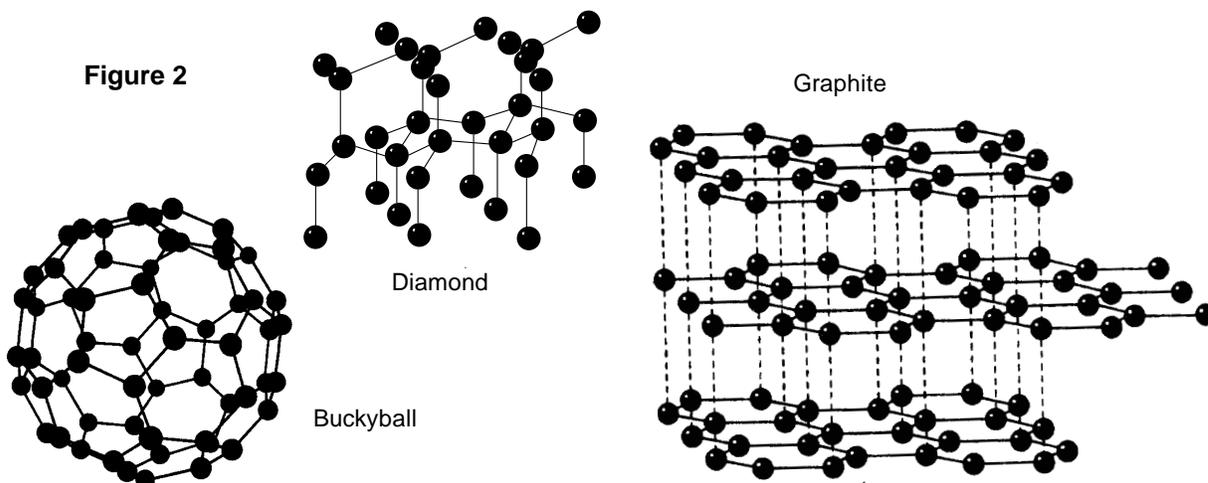
The solvent (rubbing alcohol or mineral oil) is then carefully added to each cup so that its level is beneath the position of the dot. Observations are made as the solvent moves up the strip to see if the ink separates into various colors. Black inks are usually carbon based, although those used in markers may contain other substances as well. Graphite in the pencil will not move up the strips because it is bound to clay. The darkness of the black is dependent on the size of the carbon particles present in the vehicle (dispersing liquid). Many indelible inks used in printing have an oil (linseed) base, however they are suspensions rather than solutions because the oil does not dissolve the carbon.

While the chromatograms are developing, have students compare the physical appearance of two forms of carbon (diamonds and graphite) and coal. They should observe the color, texture and feel. Sand is substituted for diamond unless a school is well endowed! Sand and diamond are similar in their network bonding.

Background:

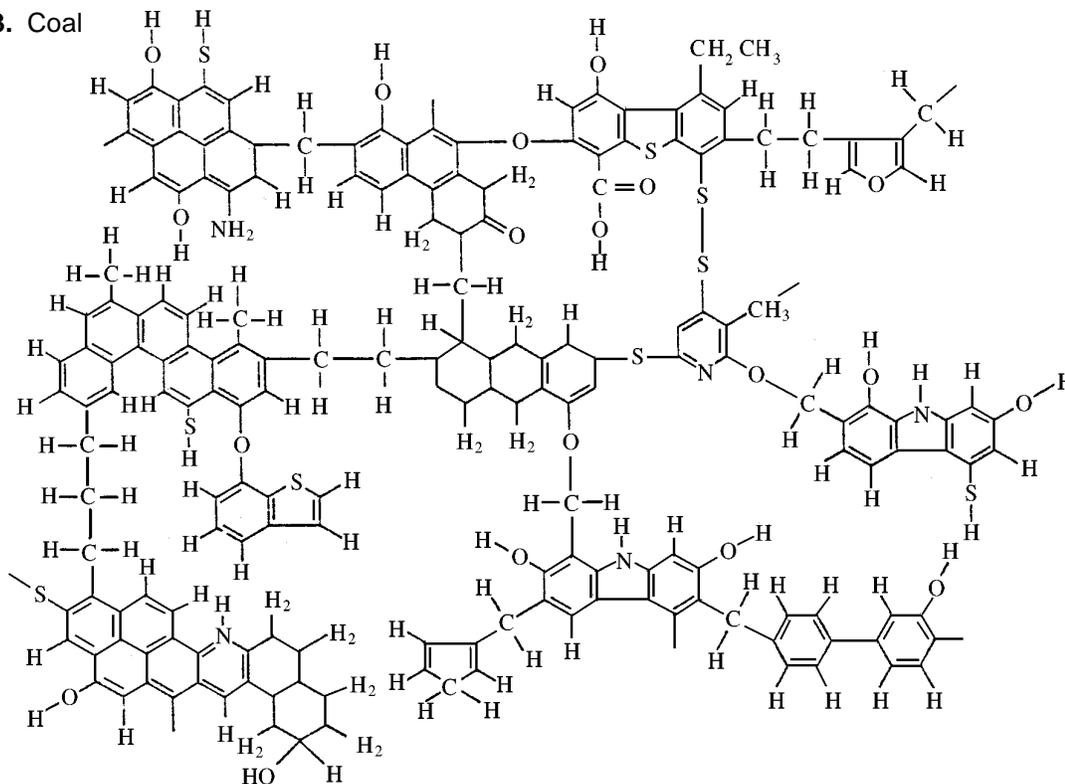
This activity shows students that the atoms that make up large chunks of carbon (diamonds, graphite) and coal must have different arrangements within their macro structures to account for the differences in physical properties of the carbon allotropes. There also appears to be some similarity of coal to graphite. Diamond consists of macro structures of carbon atoms that are bonded to each other with four equivalent bonds at the corners of a tetrahedron (109 degrees). All bond angles are equivalent, and the resulting structure is the hardest substance known. Graphite consists of flat sheets of hexagonal rings of carbon atoms (formerly thought to have alternating double and single bonds) containing mobile electrons that hold the layers together in a very weak manner and make graphite a good conductor of heat and electricity. This bonding arrangement causes graphite to absorb light of all wavelengths, hence making it black. Layers slip over one another making graphite feel greasy. See Figure 2 below.

Sometimes chemists refer to amorphous carbon, which consists of conglomerates of carbon atoms not arranged in any particular order. Amorphous carbon is commonly known as carbon black or soot. Another form of carbon, which was discovered in 1985, consists of C_{60} molecules. The atoms in each molecule consist of 12 pentagons of C atoms arranged in a ball-like structure. The name given to the structure is "buckyball," because it resembles the geodesic dome invented by Buckminster Fuller for Montreal's EXPO '67 (Figure 2).



Coal, which is similar in appearance to carbon, is really a macro structure of many different hydrocarbons containing relatively small amounts of sulfur and some nitrogen atoms. It also contains many ringed structures as shown in Figure 3.

Figure 3. Coal



Black inks contain carbon (pigment) dispersed in a vehicle such as linseed oil or other chemical. The darker the color, the larger the particle size. The particles contain millions of atoms and range in size from 1×10^{-5} mm to 5×10^{-4} mm. Pencils contain graphite mixed with clay. Hard pencils contain more clay than soft ones.

Adapted in part from:

Miller, J.K., "Ink." *Chem Matters*, February 1993, pp. 8–10.

Zaugg, H., "Growing Diamonds." *Chem Matters*, April 1990, pp. 10–13.

Information on coal was obtained from M.D. Joesten, D.O. Johnson, J.T. Netterville, and J.L. Wood, *The World of Chemistry*, Saunders College Publishing, 1991.

Science as Inquiry

Organic Chemicals: Varieties and Structures**How can chemical bonding in carbon explain why so many chemicals contain carbon?****Overview:**

In this activity students make molecular models of some common substances from the structural representations. They then examine the chemical composition of common painkillers and make cost and chemical comparisons between the three common brand-name analgesics and more generic varieties of the same chemicals.

Materials:**Per class:**

Bayer® aspirin, Tylenol®, and Advil®, 1 bottle of each, with ingredients listed and prices marked, of the same strength and type (coated or uncoated, tablets or caplets, etc.), and with the same number of tablets per container

store-brand (generic) aspirin, acetaminophen, and ibuprofen, 1 bottle of each, with ingredients listed and prices marked, of the same strength and type as the name brands listed above and with the same number of tablets per container

Materials:**Per lab group:**

molecular model kit containing balls, sticks, and springs

Procedure:

Using balls, sticks, and springs, students construct models of some simple, yet common, organic chemicals that contain various bond types, including methane, ethanol, formaldehyde, chloromethane, acetic acid, propane, propene, acetylene, and benzene. They do this by examining the structural formulas for the compounds (listed in Student Materials).

Students then examine the names and formulas of three common analgesics— aspirin, ibuprofen, and acetaminophin. This is followed by an ingredient and price comparison of three well-known brands of pain relievers with the less costly generic or store brand.

Note: In some schools care must be taken to control the number of pills available to each group as these are considered to be drugs and their use is restricted by school policy. Students could be asked to bring information for cost comparisons; however, they may not control for all the needed factors such as mass, number in bottle, type, etc. This, however, would be a good consumer exercise for them.

Background:

This unit is not expected to be a course in organic chemistry, but is meant only to show the wide variety of organic chemicals that exist in the universe. All living things, and hence the products made from them, contain organic compounds. Of the top 50 chemicals produced in the United States, 29 are

organic chemicals More than 2 million organic chemicals are known as compared to about 60,000 inorganic compounds, and the number of organic compounds is increasing by about 100,000 per year.

The chemicals used in this activity are simple chemicals that have uses that may be familiar to students (as shown in the chart contained in the Student Materials). These include saturated chemicals, unsaturated chemicals (those containing double or triple bonds that will add hydrogen to become saturated); the ring structure of benzene; and organic chemicals containing functional groups such as aldehydes, alcohols, acids, and halides. In their third year, students study the various functional groups in more detail. This unit merely introduces students to the groups with the expectation that it will lead them to the conclusion that there is a great variety of organic compounds because of the four valence electrons of carbon, which bond not only with other carbon atoms but also with a number of other atoms such as hydrogen, halides, oxygen, sulfur, and nitrogen.

The structures of the three analgesics (see Student Materials) are introduced to reinforce the idea that organic molecules are complex and that the complexity of different functional groups is related to their activity. Doing a cost analysis of the three most common analgesics of about 60 currently available helps students become more thoughtful consumers. Students should compare not only their prices but their different effects on the body. Much of the latter information can be obtained from the advertisements of Bayer® aspirin, Tylenol®, and Advil®. Another outcome of the exercise is that students can see that the generic or house brands of these substances contain the same basic chemicals as their more advertised counterparts.

Chemistry in Context contains an excellent description of how these chemicals work in the body. The brief description that follows provides suitable background for students. Aspirin and other nonsteroidal anti-inflammatory drugs are effective because of their ability to block the action of other molecules, in particular, enzymes that speed up reactions and hence produce heat (causing fever) and swelling. Aspirin's other functional groups have effects such as suppression of pain receptors, and in certain specialized cells, blockage of the transmission of chemical signals that trigger inflammation. Aspirin also has the ability to inhibit blood clotting. Acetaminophen blocks the same enzymes as aspirin, hence reducing fever and swelling, but has little anti-inflammatory action. Since it does not prevent blood clotting, it is useful for pain and fever reduction in surgical patients and for those suffering from ulcers. Ibuprofen is a better enzyme blocker and specialized cell inhibitor than aspirin and hence a better fever reducer and pain reliever. It has fewer functional groups, which may result in fewer side effects.

Adapted from:

Operation Chemistry, American Chemical Society, 1994

Woodward, L. *Polymers All Around You*, Middleton, Ohio: Terrific Science Press, undated.

Chemistry in Context, American Chemical Society, 1994

Science as Inquiry

Polymers: Bonding and Uses**How does bonding in different varieties of plastic determine characteristic properties?****Overview:**

Part 1. The densities of the six main types of plastic differ from one another. By determining the relative densities of the six types of plastic according to the way they sink or float in various liquids, and by then calculating and comparing the density of an unknown piece of plastic, students can identify the unknown sample.

Part 2. Students examine the properties of the six types of plastics to determine differences and relate these properties to the bonding and chemical compositions of the plastic types.

Note: This activity consists of two parts. The first part is almost identical with Activity 3 in Micro-unit 910. If students have already done 910, it is not necessary to have them repeat it. The materials for the second part include the plastic samples identified according to types 1-6.

Materials:**Part 1 (per lab group)**

vegetable oil, 100 mL
rubbing alcohol, 100 mL
glycerin, 100 mL
water, 100 mL
plastic strips of types 1–6, 4 of each type
plastic cups to hold the liquids, 4
scissors
plastic, 1 piece unidentified by type
graduated cylinder, 25–100 mL
balance (0.1 g)

Part 2 (per lab group)

plastic strips of types 1–6, 4 of each type
Bunsen burner
tongs
spatula
cork (small)
copper wire, 5 cm
beaker, 500 mL
litmus strips, red and blue (or neutral)
matches

Procedure—Part 1:

Have students obtain four pieces of each of the six coded plastics and drop them into cups of the various liquids, recording whether they sink or float. They should organize data into chart form indicating the behavior of each of the plastics.

In addition to obtaining relative densities by sinking and floating behavior, students can also calculate density by obtaining the mass and volume of a given sample. Each type of plastic can be cut into several pieces so that a sample will fit into a graduated cylinder and the volume of the sample obtained by volume displacement. The density is then calculated by dividing mass by volume. Each lab group can be assigned a plastic and the densities recorded on the table of class data.

Students should then be given an unknown type of plastic that you have numbered for identification purposes. They should identify the plastic (1–6) by its behavior in the liquids. To confirm their results, students can calculate the actual density of the sample of unknown plastic and compare this to the densities of plastics 1–6 on the class data table.

Students can be asked to bring in samples of as many different forms of plastic (1-6) that they can find and expand the list of the examples of the various types.

Procedure—Part 2:

Students examine samples of plastic in each of the six categories and try to relate the properties to the bonding. Therefore, samples from various sources should be used for each of the plastic categories. In addition to physical appearance (color opaqueness, flexibility, and texture) and densities, students melt the plastics, test for chlorine, test for acidity, and watch each plastic burn.

Melting. Students melt a piece of plastic from each category by placing a small sample on the end of a spatula, putting the spatula in a burner flame, and heating it carefully so as not to let the sample catch on fire. After cooling, students again examine the samples for physical appearance.

Presence of chlorine. Students then test for the presence of chlorine by melting a small quantity of the plastic on a piece of copper wire that has been inserted in a cork that serves as a handle. The free end of the wire is heated in the burner flame and touched to the plastic so that a small sample melts on the copper. It is then placed in the burner flame. A slight flash of luminous flame with a tinge of green indicates the presence of chlorine.

Burning. Students should also observe each of the six types of plastic burn. Because this must be done in a hood, it is recommended that teachers demonstrate this. Using a pair of tongs, one end of a piece of plastic from each category is held in the burner flame until it burns. While it is giving off vapors, hold a piece of wet litmus paper in the vapors to determine whether the fumes produced are acidic or basic. The flame is extinguished by dropping the burning plastic into a beaker of water. Students should note the color of the flame during burning, whether the vapors emitted produce a lot of smoke, whether the plastic continues to burn after being removed from the flame, and any color change in the litmus.

After compiling all of the observations on a data table, students are given the structures of the various types of plastics (in Student Materials) and asked to relate their observations to the structures. Characteristics of the plastics are then related to uses as shown in the summary tables in the Background section.

Background:

This activity demonstrates a practical use for density while simultaneously emphasizing density as a characteristic property. Plastics are coded according to type. The accompanying chart gives the type with examples and chemical formulas.

| Code | Type | Example | Monomer |
|------|----------------------------|----------------------|---|
| 1 | polyethylene terephthalate | soft drink bottles | $\text{OOC} - \text{C}_6\text{H}_4 - \text{COOC}_2\text{H}_4\text{O}$ |
| 2 | high-density polyethylene | milk bottles | $\text{CH}_2 = \text{CH}_2$ |
| 3 | vinyl/polyvinyl chloride | cooking oil bottles | $\text{CH}_2 = \text{CH} - \text{Cl}$ |
| 4 | low-density polyethylene | wrapping film | $\text{CH}_2 = \text{CH}_2$ |
| 5 | polypropylene | yogurt containers | $\text{CH}_2 = \text{CH} - \text{CH}_3$ |
| 6 | polystyrene | foam cups and plates | $\text{CH}_2 = \text{CH} - \text{C}_6\text{H}_5$ |

About 70% of all plastics fall into one of the six types shown. The formulas of the plastics given in the charts are monomers. Monomers are the building blocks of plastic. Many of these monomers combine to form long chains of molecules called polymers. Note that the monomers for plastics 2 and 4 are identical. In both of these monomers the chain length can vary from several thousand monomer units to millions. When the chains are packed tightly together, high-density plastic 2 is formed. Other formations of the same monomer chains result in low-density plastic 4.

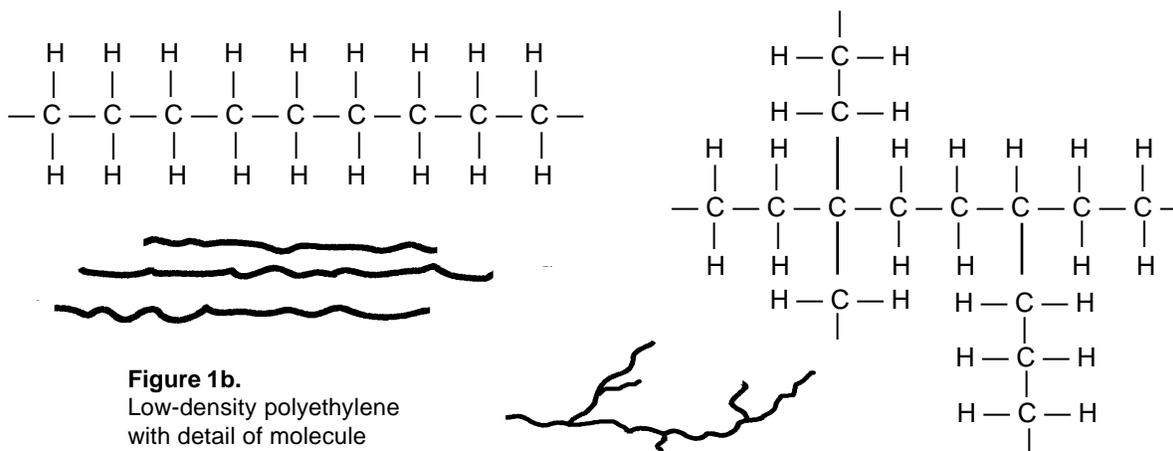
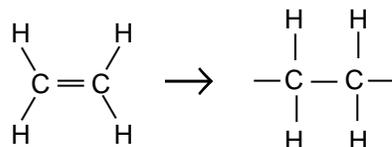
The bonding in polymers is basically of two types: chains and branches. In types in which linear chains are formed, these chains are generally arranged in a regular pattern, thus producing a crystalline form of the polymer that tends to be of high density and rigidity, such as in plastic 2. In plastics that are formed of branches, the molecules tend to become entangled, resulting in an amorphous structure of low density that is soft, such as plastic 4.

Polymers are basically formed by two processes: addition and condensation. In addition, the double bond breaks, and molecules form straight or branched chains. Both the length of the chain and the entanglement will have an effect on the properties of the plastic produced. In condensation polymers, two organic chemicals react, eliminating water from the structures. This is the case in plastic 1, which results from the reaction of ethylene glycol and terephthalic acid.

In this introductory unit, only addition reactions of monomers are considered. Both plastics 2 and 4 are made from ethylene. The double bond breaks to form monomers that react with one another as shown in the following figure.

Figure 1a.

In addition reactions, the double bond breaks and is converted into single bonds.

**Figure 1b.**

Low-density polyethylene with detail of molecule bonding (above)

Figure 1c.

High-density polyethylene (left) with detail of molecule bonding (above).

Plastics do not break down naturally in the environment. To recycle, the types must be separated so that they can be treated by the appropriate chemicals.

Some of the properties of the various types of plastics are given in the chart below:

| Code | Properties of Polymer |
|------|---|
| 1 | Transparent, high-impact strength, not reactive to acids and atmosphere. |
| 2 | Opaque, flexible, soft, white, dense, rigid. |
| 3 | Rigid, thermoplastic (can be melted and shaped), transparent, high-impact strength, does not react with oils. |
| 4 | Less opaque and dense than plastic 2, flexible, soft, white, nonreactive to acids and bases, low melting point, oxidizes with sunlight. |
| 5 | High melting point, opaque, low density, rigid, impermeable to liquids and gases. |
| 6 | Clear, glassy, rigid, brittle, low melting point, soluble in organic liquids. |

Adapted from:

Operation Chemistry, American Chemical Society, 1994.

Woodward, L., *Polymers All Around You*. Middleton, Ohio: Terrific Science Press (undated).

Chemistry in Context, American Chemical Society, 1994.

Science as Inquiry

Bonding in Trees**Item:**

Cellulose is a substance that is found in both wood and wood products such as paper. When a log needs to be cut into smaller pieces, it is sawed in one direction and split using an ax in the other direction. Tear a piece of newspaper in each direction. Repeat with each layer of a double tissue. How does the paper tear?

What information does the above information tell you about the structure of cellulose? Does the structure of cellulose resemble that of diamond or graphite? Explain.

Answer:

Cellulose is a linear molecule. When trees grow, they are very strong in length because there are many strands that are in themselves quite strong. Hence it is difficult to cut through the strands, and therefore a saw is used to make cuts perpendicular to the length. The bonding between strands of the molecule are weak, so it is easy to split logs in the direction of the height. Therefore there is some similarity to the structure of graphite in that the bonding between layers is weak and one layer slides over another. Diamond is equally strong in all directions indicating very strong bonds throughout the structure.

Science in Personal and
Social Perspectives

Bonding in Sand

Item:

Sand is silicon dioxide and its formula is $(\text{SiO}_2)_n$. The formula for diamond is C_n . In both cases the n stands for any number of atoms or groups of atoms depending on the size of the piece of substance under consideration. Why do you think that sand is hard like diamond but not hard enough to be used in a dentist's drill?

Answer:

Sand and diamond are both network solids that have strong bonds in all directions. Because sand is made of more than one kind of atom (silicon and oxygen), the bonds are not all equal in strength, and this reduces its strength as a solid.

Science as Inquiry

Physical and Chemical Properties of Carbon**Item:**

The physical properties of diamond and graphite are quite different. Describe the differences and explain the cause of these differences. Do you think that the chemical properties would be different? Explain.

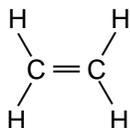
Answer:

Physical properties depend on the bonding between atoms. In graphite, the atoms are arranged in hexagonal structures in plates. Plates exist in layers that slide over one another, giving graphite a slippery feel. Free electrons cause it to absorb light in all directions, making it appear black and causing it to be a conductor of electricity. Diamond is a network solid that has strong, equivalent bonds in all directions with no free electrons. This causes diamond to be very strong and a nonelectrical conductor that is colorless. Chemical reactions depend on the chemical composition as well as on the bonds between atoms. Although difficult to do, diamonds have been burned to produce carbon dioxide, the same product produced when graphite burns.

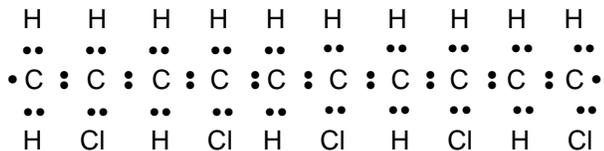
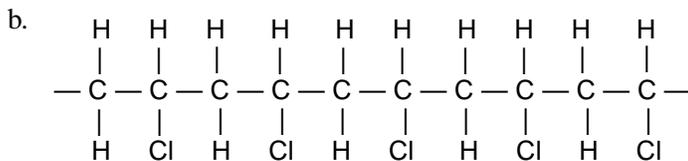
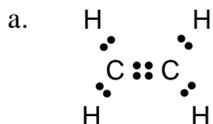
Science and Technology

Polyvinyl Formation**Item:**

Polyvinyl, a plastic, is made from the polymerization of the monomer given below.



- a. Draw the structural formula of the monomer using electron dots.
- b. Draw the structural formula of a polymer made from five monomers using both dashes to represent electron pairs and electron dots.

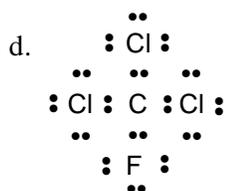
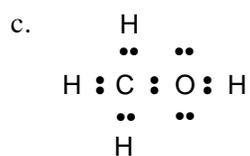
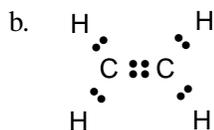
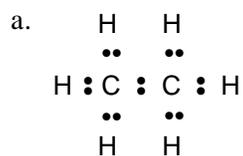
Answers:

Science as Inquiry
Functional Groups

Item:

Draw electron dot formulas for each of the following compounds:

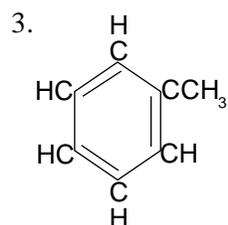
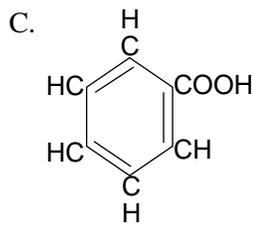
- CH_4
- C_2H_4
- CH_3OH
- CFCl_3

Answers:

Science as Inquiry

Similarity of Chemical Properties**Item:**

Which of the following compounds would have similar chemical properties? Match the substance in column I with one in column II that has similar chemical properties. Explain your matching.

I**II****Answer:**

Substances are matched according to their functional groups.

1. B. Both have an OH and are alcohols.
2. C. Both contain COOH, an acid group. This is more important than the cyclic nature of C.
3. A. Both contain only hydrogen and oxygen and have no functional groups even though 3 is cyclic.

| Consumables | | |
|---|-------------------------------|-----------------|
| Item | Quantity per lab group | Activity |
| aspirin, acetaminophen, and ibuprofen (store brand, with ingredients and prices listed and of the same type and size as the name brands below) | 1 bottle of each (per class) | 2 |
| Bayer® Aspirin, Tylenol®, Advil® (with ingredients and prices listed, of the same type—caplets, tablets, coated, etc.— and with the same number of tablets per bottle) | 1 bottle of each (per class) | 2 |
| black inks (India ink, printers ink, inks from permanent marker, washable marker, fountain pen, ballpoint) | — | 1 |
| coal (small, soft piece) | 1 | 1 |
| copper wire | 5 cm | 3 |
| cork, small | 1 | 3 |
| diamonds (or sand) | pinch | 1 |
| glycerin | 100 mL | 3 |
| graphite pencil | 1 | 1 |
| filter or chromatography paper | 8 strips | 1 |
| litmus strips, red and blue (or neutral) | — | 3 |
| matches | — | 3 |
| notebook paper | — | 1 |
| oil (mineral oil is best) | 100 mL | 1 |
| plastic strips, types 1–6 (see Activity 3) | 4 of each type | 3 |
| plastic strip, unidentified by type | 1 | 3 |
| rubbing alcohol | 100 mL | 3 |
| splints or popsicle sticks | 8 | 1 |
| toothpicks | — | 1 |
| vegetable oil | 100 mL | 3 |
| water | 100 mL | 3 |

| Nonconsumables | | |
|---|-------------------------------|-----------------|
| Item | Quantity per lab group | Activity |
| balance | 1 | 3 |
| beaker | 1 | 3 |
| Bunsen burner | 1 | 3 |
| graduated cylinder | 25–100 mL | 3 |
| molecular model kit containing balls, sticks, and springs | 1 | 2 |
| paper clips | 8 | 1 |
| plastic cups | 4 | 3 |
| plastic tumblers | 8 | 1 |
| scissors | 1 | 3 |
| spatula | 1 | 3 |
| tongs | 1 | 3 |

Key to activities:

1. Carbon: The Foundation Element
 2. Organic Chemicals: Varieties and Structures
 3. Polymers: Bonding and Uses
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Activity Sources

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Joesten, M.D., D.O. Johnson, J.T. Netterville, and J.L. Wood, *The World of Chemistry*, Saunders College Publishing, 1991.

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