SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

Student Materials

Learning Sequence Item:

1047

Carbon Bonds in Chemistry

January 1997
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Lab Activities

Readings

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This micro-unit was adapted by **Dorothy Gabel** (Indiana University, Bloomington)

Science as Inquiry

Carbon: The Foundation Element

How can graphite, coal, and diamond all be made of carbon?

Overview:

In this activity you will compare the marks made by various writing instruments to see whether they contain carbon. You will examine the physical properties of graphite and diamond (the allotropic forms of carbon) and relate these properties to the bonding between the carbon atoms. How does graphite compare with coal? What role does carbon play in ink?

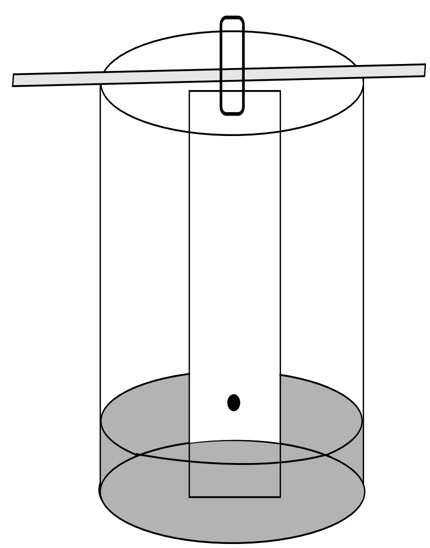
Procedure:

Make marks on a clean sheet of paper with a graphite pencil and the following black inks: India ink, printers ink, permanent marker, washable marker, fountain pen, and ballpoint. Record your observations in a systematic way. Do you think that all of the streaks that you made contain carbon? Are there any differences in the streaks? Are you able to explain the differences?

Using chromatography, you will now test the marks made by the graphite pencil and three kinds of ink—India or printers ink, permanent marker or fountain pen, and washable marker—to determine whether they contain one or more substances. Chromatography is the separation of the colored components of a mixture. Because oils are used in some inks and water-alcohol mixtures in others, you will test the pencil and ink marks in both rubbing alcohol (alcohol and water) and oil.

Obtain eight tumblers, paper clips, and filter paper strips. 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.

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. Repeat with the three inks on six other strips (use a toothpick if the ink is not in a pen). Then attach the other end of each strip to a paper clip that is inserted into a splint. Place these splints (as shown in figure) across the tops of the eight tumblers.



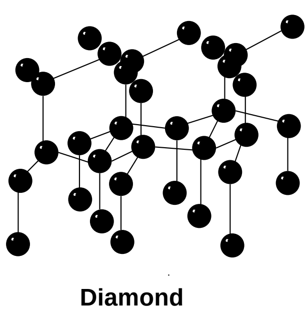
Check that each strip is close to the bottom of the cup but does not touch it. Then carefully add rubbing alcohol to four of the tumblers and mineral oil to the other four so that the liquid levels lie beneath the dots but over the tips of the filter papers. Record your observations as the liquids move up the strips to see if the inks separate into various colors.

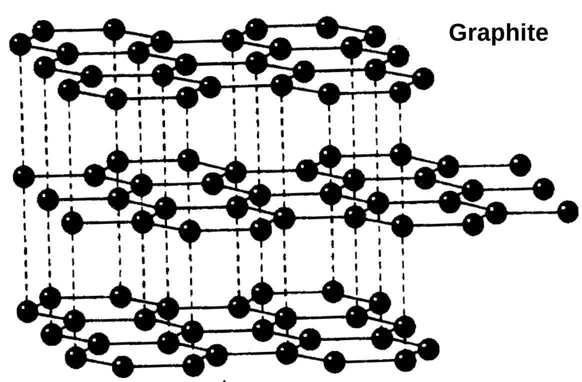
While the chromatograms are developing, compare the physical appearance of the two forms of carbon (diamond and graphite) and coal. Observe and record the color, texture, and feel of the samples. Your instructor may substitute sand for diamond because of the similarity between the network bonding in the two substances.

Questions:

1. Do you think that graphite, diamond, and coal contain carbon? What evidence is there from the activity you just did? What are the similarities and differences among the three materials?

2. Diamonds consist 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 the graphite a good conductor of heat and electricity. Sketches of the atoms of the two substances are shown below.

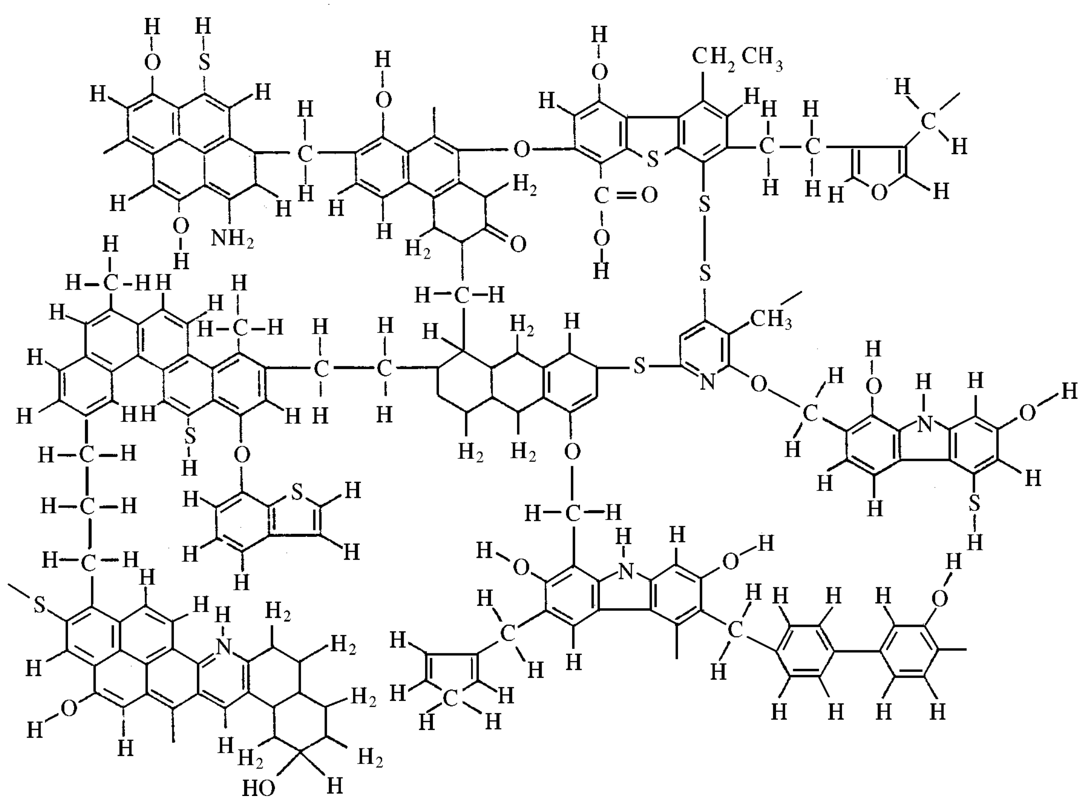




Based on this description, explain why graphite can be used in pencils whereas diamond cannot.

3. Use the sketches of the atoms of diamond and graphite given in Question 2 to draw a picture of a small piece of diamond and a small piece of graphite using pairs of dots to represent electron pairs or bonds.

4. Examine the sketch below of the molecular structure of a sample of coal. Compare it to the sketches of diamond and graphite in Question 2. Based on their chemical structures, which pair of materials are more alike, graphite and diamond or graphite and coal? Explain your answer.



5. Explain the results of the chromatography experiment. What does it tell about the carbon found in pens?

6. Explain the difference between the way pencil “lead” works in writing and the way ink works.

Student Sheet

Science as Inquiry

Organic Chemicals: Varieties and Structures

How can chemical bonding in carbon explain why so many chemicals contain carbon?

Overview:

Here you will examine the structure of simple carbon compounds using molecular models. Then you will make a cost and chemical comparison of some common pain relievers.

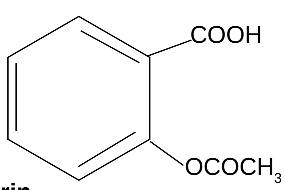
Procedure:

There are many common organic chemicals. Some contain single bonds. Others contain double and triple bonds. Some even contain rings of various types. Using a molecular model kit containing balls, sticks, and springs, construct models of the compounds listed on the last sheet of this activity. Sketch a picture of the model you have made. Do this before proceeding to the next part of this activity.

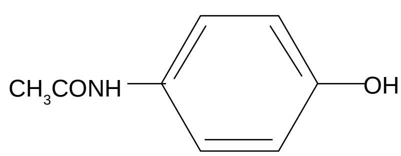
There are three main varieties of painkillers or analgesics on the market. These are marketed under different brand names. For this part of the activity, your teacher will provide you with information about the cost of six bottles of analgesics of these types, three name brands and three store brands (or ask you to collect the information yourself at a drug store).

Make a table that includes information about the six bottles of analgesics so that you can make a cost comparison. What information will you need to collect? Determine the cost of a single tablet of each of the painkillers. Using this information and the dosage information on the bottles, determine which analgesic would be the “best buy” assuming that they are equally effective in relieving pain.

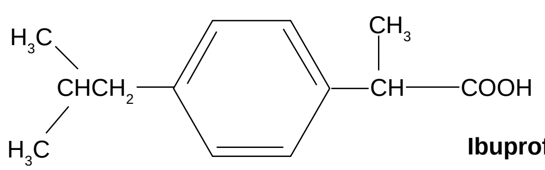
Now look at the structural formulas of the compounds. How are they the same? How are they different? Name some other brand-name analgesics that contain the same chemicals. You may need to check labels in a drugstore to do this.



Aspirin



Acetaminophen



Ibuprofen

Questions:

1. All of the compounds for which you made ball-and-stick models are considered simple organic chemicals (containing carbon and hydrogen). Looking only at the structural formulas of the models that you made, explain why there are so many carbon compounds in the universe.

2. More complex compounds can be made by substituting longer chains of hydrocarbons (carbon-hydrogen-only molecules) for the CH_3 groups. These chains may contain a few carbons or hundreds of them. Compare the structures of methane and propane. How are the two similar? How are they different? Draw the structural formula of a carbon-hydrogen chain that has 12 carbons. How many hydrogen atoms would it have?

3. Imagine substituting carbon chains of any length for a CH_3 group in any of the compounds for which you made models. How would this add to the diversity of organic chemicals in the universe?

4. Some of the compounds you made contain single bonds, others contain double or triple bonds represented by double or triple dashes. Assuming that each dash represents a pair of electrons, draw Lewis-dot formulas for all the compounds for which you made models except benzene. How many electrons surround each carbon atom? Each hydrogen atom? Each oxygen atom? Each chlorine atom? Explain why this is the case.

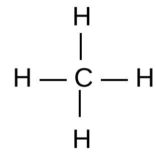
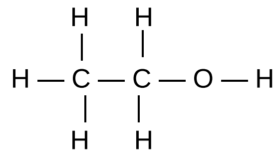
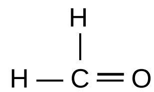
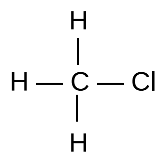
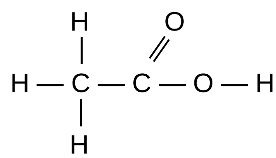
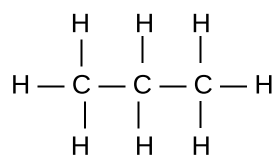
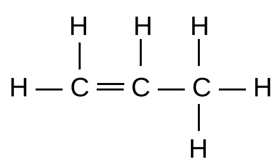
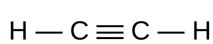
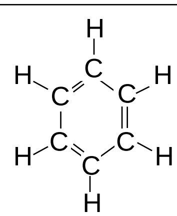
5. Look at the structural formulas of the three types of painkillers. What are the similarities? What are the differences? Do they resemble any of the compounds for which you made molecular models? Would you expect these three painkillers to act the same way on your body?

6. Which painkiller was considered to be the “best buy”? Discuss other factors in addition to the cost that must be considered when purchasing good painkillers.

7. What differences do the manufacturers of Bayer® aspirin, Tylenol®, and Advil® make for their products? Explain.

8. If your doctor suggested that you take two tablets of ibuprofen a day, would you take Advil® or the store brand? Give reasons supporting your choice?

9. Your doctor suggests that you take two tablets of Tylenol® every six hours, and you substitute aspirin. Would this be a wise move on your part? Explain.

Name/Use	Structural Formula	Structural Formula (with dashes)	Model Sketch
Methane (natural gas)	CH_4		
Ethanol (alcoholic beverages)	C_2H_5OH		
Formaldehyde (preservative)	CH_2O		
Chloromethane (local anesthetic)	CH_3Cl		
Acetic Acid (in vinegar)	CH_3COOH		
Propane (fuel)	$CH_3CH_2CH_3$		
Propene (to make plastic polypropylene)	CH_2CHCH_3		
Acetylene (fuel for torches)	CHCH		
Benzene/ Aromatic Compounds	C_6H_6		

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 according to the way they sink or float in various liquids, and by then calculating the density of an unknown piece of plastic, you can identify the plastic type of the unknown sample.

Part 2. The six types of plastic also differ in other physical and chemical properties. After determining the properties, you will relate the differences to the bonding and chemical compositions of the plastics.

Procedure—Part 1:

Obtain one piece of each of the six types of plastic (numbered 1–6) and drop each piece into 100 mL of the four different liquids provided by your teacher (water, rubbing alcohol, glycerin, and vegetable oil). Record whether each sinks or floats. Organize the data into chart form indicating the behavior of each plastic.

Now collect data to calculate the exact density of one of the six plastics, which will be assigned by your teacher. Devise a procedure to obtain the mass and volume of the plastic. Then calculate the density and record your results on the table of class data.

Next obtain a piece of plastic of unknown type from your teacher. Record the identifying number assigned by your teacher so that he or she can check your results. Identify the unknown plastic by comparing its floating/sinking behavior to that of plastics 1 through 6. To confirm your results, collect data to calculate its actual density, and compare this to the actual densities of plastics 1 through 6 on the class data table.

Check around your home to determine what types of plastic are available. Make a list of what you find. Your teacher may ask you to bring to class samples of different forms of plastic (1-6) that you have found.

Procedure—Part 2:

Here you will determine other properties of the six types of plastic and relate these properties to the bonding and chemical composition of each type. Make a chart to include the following properties of each class of plastic: color, opaqueness, flexibility, texture, density (from Part 1), melting, chlorine test, burning, and litmus test.

Melting: Melt a piece of plastic from each category by placing a small sample on the end of a spatula and putting the spatula in a burner flame. Heat the samples carefully so that they do not catch on fire. After the plastics have cooled, examine them for physical appearance.

Presence of chlorine: Test for the presence of chlorine by melting a small quantity of each plastic type on a piece of copper wire that has been inserted in a cork. Holding the cork, heat the free end of the copper wire and touch it to the plastic sample. Then heat the copper wire containing the sample in the burner flame. A slight flash of luminous flame with a tinge of green indicates the presence of chlorine.

Burning: Observe the burning of each of the six categories of plastics (done under a hood) as demonstrated by your teacher. While the plastic is giving off vapors, note any changes to the wet litmus paper held in the vapors to determine whether the fumes produced are acidic or basic. Also note the color of the flame during burning, whether the vapors emitted produce a lot of smoke, and whether the plastic continues to burn after being removed from the flame.

Questions:

1. Identify the plastic group to which your unknown sample belongs using the table in Question 3. How does the actual density compare with the density of the plastic that you identified from its sinking and floating behavior?

2. What is meant by "characteristic property"? How does this experiment show that density is a characteristic property of plastics?

3. Make a list of common household containers, etc., made from the different kinds of plastic in the chart below. Plastics are coded according to the types shown below. The chemical formulas of the monomers from which each category of plastic is made is also given below.

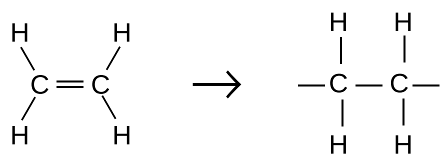
Code	Type	Example	Monomer
1	polyethylene terephthalate		$OOC — C_6H_4 — COOC_2H_4O$
2	high-density polyethylene		$CH_2{=}CH_2$
3	vinyl/polyvinyl chloride		$CH_2{=}CH — Cl$
4	low-density polyethylene		$CH_2{=}CH_2$
5	polypropylene		$CH_2{=}CH — CH_3$
6	polystyrene		$CH_2{=}CH — C_6H_5$
7	all others		

4. Examine the data in the table that you constructed for Part 2. Which of the plastic types are considered high density, and which are considered low density? Relate the physical characteristics to the densities of plastic types where possible.

5. The formulas of the plastics shown in the charts are monomers. Monomers are the building blocks from which plastic is made. Examine the formulas. Which plastic types did you find to contain chlorine or an acid/base? How does the property relate to the chemical composition of the monomer from which the plastic is made?

6. The monomers shown in the table combine to form long chains of molecules called polymers. Notice that the monomers for plastics 2 and 4 are identical. In both of these the chain length can vary from several thousand monomer units to millions. Write the electron dot structure for the monomer from which plastics 2 and 4 are formed.

7. Polymers are basically formed by two processes: addition and condensation. At this grade level, you will only study addition polymers. In addition reactions, the double bond breaks and is converted into single bonds as shown below.



Draw each bond as an electron pair, as you did in an earlier micro-unit, and explain how the monomer could attach to other monomers to form a chain.

8. Monomers can form straight and branched chains. When the chains are packed tightly together, high-density plastic is formed. Other formations of the same monomer chains result in low-density plastic. 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. In plastics that are formed of branches, the molecules tend to become entangled, resulting in an amorphous structure of low density that is soft. Using your data table and the table given in Question 3, discuss how the physical appearance of the two plastic types made from the same monomer relate to the structure of the chains from which they must be formed.

9. 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.

Draw straight-chain and branched-chain polymers of the two plastics made from the same monomers. Use dashes to represent electron pairs. Explain or show how the branched-chain polymers are more likely to become entangled and amorphous. Explain how the physical characteristics are related to the structure.