SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center
Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center
Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center
Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers
Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center
Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers
Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center
Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers
Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center
Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers
Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*
Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site
UPR Lab H.S.

* * * * * * * * * * * *

Pilot Sites
Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C., William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

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Student Materials

Learning Sequence Item:

965

Properties of Useful Carbon Compounds

March 1996
Adapted by: Ruth Mann, Jessie Jones and Dorothy Gabel

Contents

This micro-unit was adapted by **Ruth Mann** (Northside H.S., Pinetown, N.C.), **Jessie Jones** (Rocky Mount, N.C.), and **Dorothy Gabel** (Indiana University, Bloomington)

Science as Inquiry

Family Characteristics

How do compounds in the simplest organic family, the alkanes, resemble one another?

Overview:

The alkanes are hydrocarbons (compounds containing only hydrogen and carbon) that have a single bond linking one atom with another. Members of the alkane family or series differ from one another by one carbon atom and two hydrogen atoms. Although alkanes can exist as straight and branched chains, in this activity you will examine only the straight alkanes. After observing the properties of a few alkanes, you will write the formulas and construct molecular models of several members of the series.

Procedure:

Observe the demonstration of the burning of methane, the simplest of the alkanes. Then construct a molecular model using balls to represent the atoms and sticks to represent the bonds between the atoms. Light the butane lighter. What do you think are the products of the combustion of butane?

Set up a ring stand and ring and place a can lid covered with aluminum foil on the ring. Place a burner beneath the iron ring. Place one drop of gasoline and one drop of mineral oil near the circumference and a piece of paraffin about the size of a match head in the center of the lid. Gently heat the lid and note the melting behavior of the solid and the point at which each material burns.

Your teacher will then give you a table on alkanes to complete. Complete the table, construct molecular models of the alkanes indicated, and predict values of the melting and boiling points from those given.

1. Several different hydrocarbon series exist. For example, some alkenes are C_2H_2, C_3H_3, and C_4H_4. The general formula for the alkenes is C_nH_{2n}. What is the general formula for the alkanes? What is the formula of an alkane with 30 carbons?

2. What relationship exists between the size of an alkane and its melting and boiling points? Are there any exceptions to the relationship?

3. Make a graph with the number of carbon atoms of the alkanes on the horizontal axis (leave space for extrapolations to 30 carbon atoms) and the boiling point on the vertical axis (leave space for extrapolations). Use your graph to make predictions about the boiling point of an alkane that has 12 carbon atoms and one that has 30 carbon atoms. Which prediction would most likely be accurate?

4. From your experimental results, compare the number of carbon atoms that you would expect to find in mineral oil, gasoline, and paraffin. Is there any other clue from their physical appearance that would enable you to judge their relative molecular sizes?

Science as Inquiry

Variations in Structures

How do alkanes with the same molecular formula differ from one another?

Overview:

Molecules having identical molecular formulas but different structural formulas are called isomers. Each isomer is a different chemical species and hence has a different set of physical properties, such as boiling points and melting points. Using ball and stick models construct isomers of some of the alkanes.

Procedure:

Construct ball and stick models of the first eight alkanes and draw the structural formulas. ***The table on the following page will be useful in organizing your data***. If there are more than six isomers of a given alkane, write the additional structural formulas on additional paper.

1. For pentane, you should have constructed three isomers. Their boiling points vary from 36.1 for the five-carbon straight chain to 27.8 for the four-carbon chain and 9.5 for the three-carbon chain. Why would you expect that this is the case?

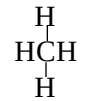
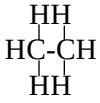
2. Would you expect the densities of these three isomers of pentane to be identical? Explain.

3. Would you expect the number of carbon dioxide and water molecules to be the same from burning one gram of each isomer of pentane? Explain.

4. Would you expect the amount of heat produced to be the same when one gram of each isomer of pentane burns? Explain.

5. Would you expect each isomer of pentane to burn at the same rate? Explain.

Alkane Series

# of C	# of H	Molecular formula	No. of isomers	Isomer 1	Isomer 2	Isomer 3	Isomer 4	Isomer 5	Isomer 6
1	4	CH_4	1						
2	6	C_2H_6	1						
3	8	propane	1						
4		butane	2						
5		pentane	3						
6		hexane							
7		heptane							
8		octane							

Science as Inquiry

Identifying Materials–Solids

What tests can be performed to distinguish one material from another?

Overview:

Many different types of solids exist in the universe. Some of these are metals, ceramics, glasses, plastics, and fibers. Examine some of the properties that distinguish these solids.

Procedure:

Follow the procedure outlined below. ***Use goggles and aprons for this lab.***

You will be using six tests/observations on five different materials. Make a data table to record your observations for each test for each of the five solids.

The numbered samples of materials you have been given are metal, ceramic, glass, plastic, and fiber. Examine each sample and record your observations as "yes " or "no" in the table you have constructed. Use Table 1 to help you draw conclusions as to the identity of the five solids.

Table 1: Physical and Chemical Properties

Type of Material	Typical Properties
Metals	• Malleable, can be bent • Conduct heat and electricity well • May react with air, water, and acids
Ceramics	• Brittle • Strong when compressed, weak when stretched • Chemically unreactive
Glasses	• As for ceramics but also transparent
Plastics	• Flexible • Easily melted and molded • May burn when heated in air
Fibers	• Form long hairlike strands • Flexible • May burn when heated in air

(a) Place a few drops of 6.0 M hydrochloric acid (HC1) solution on each sample and examine each with a magnifying glass or a low-power microscope. ***Caution: Follow safety procedures for using acids.***

(b) Try to bend each sample at three points.

(c) Use an insulated pair of tongs to hold each sample in the Bunsen burner flame to observe the high-temperature behavior of the material. ***Caution: Perform the experiment in a hood or well ventilated area.***

(d) Use a multimeter or conductivity apparatus to measure the electrical conductivity of each sample.

(e) Wrap each sample in a cloth and try to cause a fracture by gently striking it with the hammer, observing whether it is brittle and opaque or brittle and transparent.

1. Which two materials identified in this lab are usually used as containers for concentrated sulfuric acid?

2. Which property of fiber is its most distinguishable characteristic?

3. Write a brief paragraph explaining how your arrived at your conclusions.

4. List three applications of each type of material from your personal experience and relate the use to the properties you determined in this lab.

5. Which material is the most reactive?

6. Identify each numbered sample.

Student Sheet

Science and Technology

What Is the Aroma?

How can an ester with a pleasing aroma be produced?

Overview:

Esters are organic compounds that occur in nature in substances that are used for flavorings. Flavorings can be made artificially in the laboratory by reacting alcohols with acids to produce esters.

Procedure:

Use goggles and aprons

Put one drop of the acid and one drop of the alcohol on opposite sides of a piece of filter paper. Describe the odor of the acid and alcohol. Add the indicated number of drops of the alcohol and the indicated number of drops of acid to the test tube. Swirl gently to mix contents. Have your instructor adds one drop of concentrated sulfuric acid to the test tube. Place the test tube in a boiling water bath for one minute. Add a boiling chip to the test tube. Transfer a drop of the reaction mixture to a clean sheet of filter paper. Describe the odor of the new compound. Do as many combinations as indicated by your teacher.

Table 1. Acid and Alcohol Identification

Alcohol		Acid		Ester	Odor
iso-amyl alcohol 20 drops	+	acetic acid 10 drops	→	iso-amyl acetate	
ethyl alcohol 20 drops	+	acetic acid 10 drops	→	ethyl acetate	
methyl alcohol 15 drops	+	salicylic acid 1 scoop (0.1g)	→	methyl salicylate	
ethyl alcohol 8 drops	+	butyric acid 10 drops	→	ethyl butyrate	
benzyl alcohol 12 drops	+	butyric acid 10 drops	→	benzyl butyrate	
ethyl alcohol 15 drops	+	propanoic acid 20 drops	→	ethyl propionate	
ethyl alcohol 20 drops	+	benzoic acid 1 scoop (0.4 g)	→	ethyl benzoate	

1. Why was concentrated sulfuric acid, H_2SO_4, used in this experiment?
2. Why was it important to keep the test tube free of water during heating?
3. How can the amount of ester produced be increased?
4. Write a word equation for the production of the ester.
5. What is the difference between a natural flavoring and an artificial flavoring?

Science and Technology

From Wood to Paper

How can cellulose be recovered from wood?

Overview:

A primary component of wood is cellulose. Remove the other components of wood and cellulose will remain!

Procedure:

Pour sawdust into a 300-mL beaker. Add 100 mL of sodium hydroxide solution. In the hood, add 25 mL of sodium sulfide solution. Heat this mixture until it boils, and then boil gently for 15 minutes. Remove the beaker from the heat and let the wood pulp settle to the bottom. Describe the appearance of the liquid.

Fill the beaker with water, stir to mix, and let the pulp settle again. Then pour off the water layer. Repeat this process two or three times to remove the sodium hydroxide and sodium sulfide. Add 200 mL of laundry bleach. Let the pulp soak in the bleach overnight.

The next day, pour off the bleach and wash the pulp several times. Describe the product.

1. What role does sodium hydroxide play in this experiment?

2. Notice the appearance of the liquid. What does this suggest about the composition of wood?

3. Explain the appearance of the final product. What is the biological name of it?

4. How can cellulose be used to make paper?

Science and Technology

Color It Lavender

How can a lavender paint pigment be prepared?

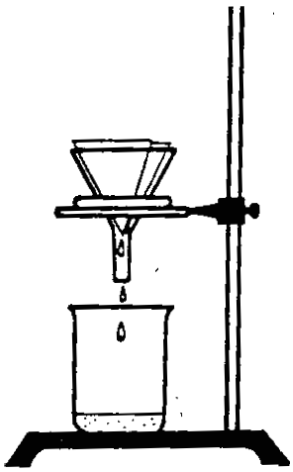
Overview:

Make a paint pigment using cobalt chloride.

Procedure:

Use goggles and aprons

Dissolve 0.2 g of cobalt chloride in a test tube containing 10 mL of warm water. Add 0.2 g of sodium carbonate. Shake it thoroughly and filter. Discard the filtrate and save the precipitated pigment on several watch glasses.



1. Describe the precipitate. What is its chemical name?

2. Write the word equation for the preparation of the pigment.

3. What is the ionic equation for this reaction?

4. In this experiment, an inorganic pigment was prepared. What does this mean?

5. Explain the primary use of pigments.

Science and Technology

Painting a Picture? Use Milk!

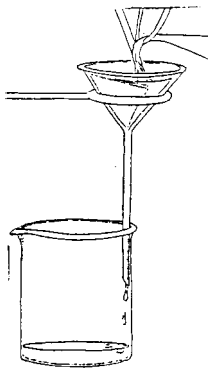
How can skim milk be used to paint a picture?

Overview:

Remove the casein from milk to use as a binder for pigment.

Procedure:

Add 10 mL of vinegar to 188 mL of hot skim milk. Describe the formation of the precipitate. Let the milk settle. Then decant the almost-clear liquid from the beaker and remove water from the precipitate. Chop the casein into a fine powder.



Place a small amount of casein in an evaporating dish. Add just enough water to make a thick paste. Add about the same amount of the lavender pigment. Mix the casein and the lavender pigment until the desired color is obtained. Finally, paint a picture!

1. Describe the role of vinegar in this lab.

2. Why is it necessary to use a binder such as casein in making paint?

3. What properties of a pigment make it useful as a paint?

Science in Personal and
Social Perspectives

Sugar in Beverages

How can the presence of sugar in apple juice be determined?

Overview:

Many juices contain sugar. Test for sugar using Benedict's solution.

Procedure:

Heat 2.0 cm^3 of 1 M HC1 solution and 2.0 cm^3 of apple juice in a test tube for five minutes in a boiling water bath; then add 2.0 cm^3 of 1 M NaOH solution. ***Caution: Acids and bases burn skin and eyes.***

Test with red litmus paper. What happens? If it remains red, add drops of NaOH until it just turns blue. Add 2.0 cm^3 of Benedict's reagent to the test tube, and heat in the boiling water bath for 10 minutes. Record observations.

1. Describe your observations when HC1 and NaOH were added together.

2. Describe your observations when Benedict's solution was added to the test tube.

3. If someone is trying to lose weight, should an increase in consumption of fruit juice be recommended? Explain.

4. Explain the use of the two tests performed in this lab exercise.

5. Design a procedure for determining what percentage of sugar was in the apple juice you tested in this lab activity.

Science in Personal and
Social Perspectives

Extracting Caffeine from a Beverage

Is there caffeine in tea?

Overview:

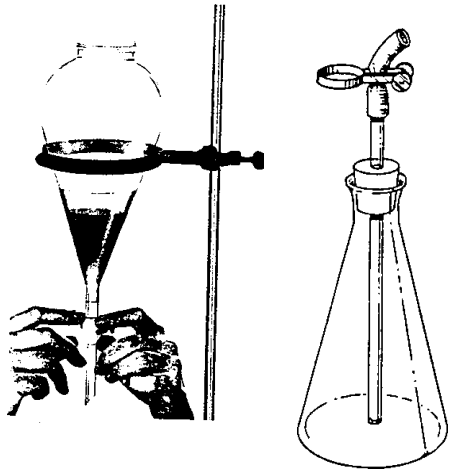
Many beverages contain caffeine, including soft drinks, coffee, and even chocolate. Determine if tea contains caffeine.

Procedure:

Mix 30 cm^3 of tea, 30 cm^3 of chloroform, 1.5 cm^3 of 6 M NH_3 (aq) solution and 1.5 cm^3 distilled water in a separatory funnel and shake gently for 30 minutes. When the lower, denser layer becomes clear, drain off 20 cm^3 into a labeled evaporating dish. Allow evaporation to take place overnight in a fume hood.

Caution: Chloroform is harmful if inhaled. Avoid breathing vapor, and avoid contact with eyes, skin, and clothing. After handling, wash thoroughly.

After evaporation occurs, dissolve the residue in 0.2 M H_2SO_4 solution. Heat very gently for 15 seconds, then cool for five minutes. Add 3–5 drops of iodine test solution.



1. Describe what happens when iodine is added.

2. What does this indicate?

3. Why does the mixture separate into two layers?

4. What does the lower layer contain? Explain.

5. Caffeine is classified as an alkaloid. Why was NH_3 (aq) solution added to the mixing? Why was H_2SO_4 added to the residue?

Science and Technology

The Blue Jeans Story

How can the oxidation-reduction of indigo dye be demonstrated?

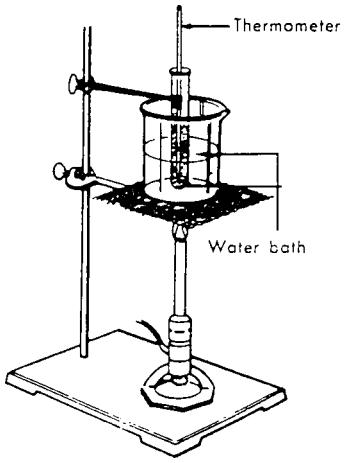
Overview:

Prepare some indigo dye and use it to make blue jeans cloth!

Procedure:

Place 15 cm^3 of solution A in a test tube and put the test tube in a beaker of water heated to 50 °C. At 50 °C, stir the solution well and then add 0.2 g of sodium hydrosulfite ($Na_2S_2O_4$). Wait 30 minutes, keeping the temperature at 50 °C and stirring occasionally.

Dip a clean strip of white cotton in the solution. What happens? Lift the strip out with forceps, blot off the excess liquid with a paper towel, and hang the strip in the air to dry. Describe what happens.



1. Describe your observations.

2. Explain the change that took place when hydrosulfite ($Na_2S_2O_4$) was added.

3. Why is indigo called a vat dye? A fast dye?

4. Explain why this lab is called “The Blue Jeans Story.”

Science in Personal and
Social Perspectives

Hydrogen + Natural Gas = Hythane

By blending hydrogen with natural gas, researchers at the Florida Solar Energy Center in Cape Canaveral and the University of Central Florida in Orlando have concocted a new fuel that generates almost no pollutants and costs about the same as gasoline.

Both hydrogen and natural gas have been tested extensively as alternative fuels, but both have drawbacks. Natural gas, while cheap and abundant, reduces pollution only moderately, and pollution-free hydrogen is costly and tricky to store.

The new fuel, dubbed hythane, consists of roughly 30 percent hydrogen and 70 percent natural gas. Hythane releases a meager 11 parts per million (ppm) of oxides of nitrogen—far less than natural gas—in a lean-burn cycle in indoor laboratory tests on a Chevrolet eight-cylinder engine.

The low hydrogen content means hythane should cost about the same as gasoline per mile traveled. Furthermore, ordinary internal-combustion engines can consume hythane with only slight modifications.

Hythane's key disadvantage is that it provides only 70 percent of the horsepower of pure natural gas, and about half that of gasoline. Head researcher Robert Hoekstra nevertheless believes hythane is suitable for many light truck fleets: He's negotiating with NASA to test hythane vehicles at the Kennedy Space Center.

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