# SCOPE, SEQUENCE, and COORDINATION

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# SCOPE, SEQUENCE, and COORDINATION

## Student Materials

Learning Sequence Item:

# 957

# Oils and Plastic

*March 1996*
*Adapted by: Keith Lippincott and Brett Pyle*

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This micro-unit was adapted by **Keith Lippincott** (University of Iowa, Iowa City) and
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*Student Sheet*

Science as Inquiry

# Motor Oil Is Motor Oil

Construct a data table to record the times for the ball to fall through each kind of motor oil. Repeat the test three times for each oil and take an average. From these numbers, calculate the speed of the ball in each oil. Use the following formula:

speed of ball = distance the ball traveled + time for the ball to travel the distance

1. Compare the speed of the ball in each oil to the numbers on the front of the motor oil containers. Explain any relationship.

2. In general, smaller car engines such as four-cylinder engines tend to run hotter than larger engines. Manufacturers often recommend motor oils with a higher number rating for these engines. Explain why this might be.

*Student Sheet*

Science as Inquiry

# Watch Where You’re Poking Me!

## What happens to plastic bags when they are punctured?

Take a small paper bag, hold it over a sink, and pour water into it. You should be able to fill it about half full, and if you do this experiment quickly enough, the paper bag will not come apart. Take a sharp pencil and push it through the bag so that it goes all the way through below the water level. What happens?

Now take a plastic bag and do the same thing. What happens now? How can you account for this difference? What is it about the particles making up the plastic bag that gives this result?

1. Why doesn’t the plastic bag of water burst when the sharpened pencil is inserted into the bag? Explain in terms of your model of the structure of this material.

2. Why doesn't the plastic bag tear where the pencil is inserted into the bag? Here, too, use your model to explain this result.

3. Does the plastic bag leak water? Why or why not?

4. Does the plastic bag leak water after the pencil is removed?

5. What is causing the plastic bag to behave so differently from the paper bag?

*Student Sheet*

Science as Inquiry

# The Coffee Cup from the Wizard of Oz

## The disappearing coffee cup.

Put on your safety goggles and carefully add acetone to the petri dish until the dish is about 3/4 full. Then place the empty coffee cup in the center of the petri dish and record what happens.

1. What physical properties that you have observed for polystyrene (with coffee cups or soft drink cups, for example) make this substance, called a polymer, suitable for making coffee cups?

2. What happened to the polystyrene in acetone?

3. What chemical term is used when one substance dissolves another?

4. Create, in your own words, a theory (explanation) for this phenomenon. You should, for example, include in your explanation why the coffee cup will dissolve in acetone but not in water. You should be able to predict what would happen to the coffee cup in other liquids, like alcohol or benzene. (Do not test this prediction for benzene, as it is a dangerous substance. But you should be able to find a reference that will tell you the result of such an experiment.)

*Student Sheet*

Science as Inquiry

# What a Sticky Mess!

## Glue ball chemistry (and physics!)

A polymer can be formed by the chemical reaction between two substances. You can make a polymer by mixing ordinary Elmer's® white glue and a saturated solution of borax (like 20 Mule Team borax, the kind found in Death Valley).

How does the density of a such a polymer compare with its component substances? How does the volume occupied by these reacting substances compare with the volume occupied by the polymer produced added to whatever reactant substance is left over after forming the polymer? Of course these two questions are related, since density is defined as the amount of mass in each cubic centimeter of a substance.

To answer these questions about density, you must find the density of the glue; then you must find the density of a saturated solution of borax. Finally, you must find the density of the polymer formed when these two substances react to form that polymer. To answer questions about the volume, you must carefully record the initial volumes of the glue and the borax solution, and when you have formed the polymer, you must find its volume and add that to the volume of glue and borax solution still remaining.

You can find the volume of water with a graduated cylinder, but if you try to find the volume of the glue, it will stick to the glass. You will need to "calibrate" your cup so that you will know how much glue has been placed in it before the reaction is allowed to begin. The graduated cylinder can measure the borax solution volume, since it does not stick to the glass.

You will have to remember when you find the masses of these substances to subtract the mass of the container, something you have done before when you studied density. You will also need to remember how to find the density of a solid substance by the method of displacement of water. Your teacher will provide assistance if you cannot figure out how to proceed, but make that effort first.

1. Which of the two, white glue or borax solution, is most dense?

2. What is the density of the polymer you created?

3. How does the volume of the polymer and the leftover reactants compare with the volume of the initial glue and borax solution used? Using a model or theory (explanation) that you yourself make up, how can you account for this result?

3. List three physical characteristics or properties of the glue.

4. List three physical characteristics or properties of the borax solution.

5. Based upon your knowledge of the glue and borax, use your model to predict some physical characteristics or properties of the polymer you created.

*Student Sheet*

Science as Inquiry

# Let's Make an Oily Sludge

## Do different oils become solid at different temperatures?

You have many different oils around your kitchen and garage. For example, you probably have corn oil, sunflower oil, or peanut oil in your kitchen. What is an oil? Usually you use these in cooking, where they are hot. But how do these different oils change as they are made colder? To find out, fill three paper cups about one-third full of each of three common household cooking oils. You will need to label each of these cups, and since it is hard to write on a paper cup, use a piece of masking tape and a felt pen. Put the three oils in your freezer and let them remain there overnight. Check them the next day. If you have time, and you are allowed to do so, change the freezer setting and try the experiment again. You might try several such settings over several days. What are your observations? How can you use a model for oil to account for what you observe?

1. Based upon your model for the structure of oil, how do you account for the apparent changes in the these three cooking oils?

2. What would you predict would happen if we used another type of cooking oil, whose properties you know, in comparison with the oils used in this experiment?

3. Try this experiment. Was your prediction correct?

Science and Technology

# NYLON

Take a look at the label on your jacket. You may find that it is made of nylon. If it is, you are wearing one of the first and most successful synthetic fabrics. You can hardly get through a day without encountering nylon. Do you like to go camping? If so, your backpack, tent, and sleeping bag are probably made of nylon. Do you prefer to fish, sky dive, or sail? The fishing line that almost caught the big one, the parachute that carried you through the wild blue yonder, and the sail that helped your boat go faster were made of nylon.

Nylon is a synthetic fiber—a laboratory product manufactured by the trainload. It is made from chemicals that have their origins in coal, air, and water. Compared with natural fibers, nylon is stronger, lighter, and water resistant. Such is the magic of chemistry.

But nylon can't do everything. It is not used in sweaters because it doesn't form a soft bulky yarn; it is not used in shirts because it is not as wrinkle resistant as polyester. In the clothes you wear daily, the largest amount of nylon you might discover is 10% in your socks or thermal underwear. But where the properties of nylon are suitable for a particular application, it usually supersedes the traditional natural fibers.

## Soft Landing

Soon after airplanes flew into combat in World War I, there was a demand for parachutes. They were made from a natural fiber that was strong, thin, and light—silk. However, during World War II the United States was cut off from Japan, the major supplier of the fabric. The process for manufacturing nylon had just been developed by the E.I. du Pont de Nemours Co. in Wilmington, Delaware. Nylon parachutes were manufactured

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By Sally A. Kydd. Reprinted with permission from "Nylon." *Chem Matters*, December 1990, pp. 4–6. 

by the thousands and saved countless soldiers' lives. Once the process was proven successful, many plants were built in this country and abroad.

Nylon can be manufactured with a range of properties, making it useful for different applications. Parachutes require fibers with very high strength, or tenacity. Its strength also makes nylon suitable for making ropes that are lighter, easier to handle, and more resistant to mildew than those made from natural fibers. The nylon fibers used in clothing are not as strong, but have greater stretch or extensibility.

Extensibility is very useful for the manufacture of women's hose. After it is woven from minute fibers, the stocking is pulled over a specially shaped form and set with steam. The stockings continue to maintain this shape, to a great extent, during wear. The high elasticity of nylon ensures that the stockings will not bag at the knees or ankles after each movement but will recover their original shape.

This shape retention also makes nylon suitable for women's garments and underwear. Permanent pleats and creases can be set in clothing, making it useful for skirts and pants.

Bristles, once made from hog's hair, are now made from nylon into brushes for teeth, hair, clothes, and bottles. The list of products seems endless: luggage, sails, fishing nets, reinforcing cords in airplane tires, and on and on.

Carpets made of nylon fibers can be wet-cleaned with water and soap to look like new, so they appeal to businesses with heavy traffic. Nylon carpeting lasts longer and is more economical than other natural and man-made fibers.

## Playing with Polymers

Nylon was discovered by a very creative chemist named Wallace H. Carothers. He worked at the Du Pont Company where he enjoyed the freedom to do as much basic research as he wanted. He produced many new materials that were not useful, but also some that were fabulously successful, such as nylon and neoprene (synthetic rubber).

In 1928 Carothers began to study the nature of polymers—long molecules composed of much shorter molecules—at a time when the subject was not popular with other chemists. He had no products in mind at the time, and it was not possible to predict where his pursuits might lead. Carothers knew that when an organic acid (with a –COOH group) is reacted with an alcohol (with an –OH group), the acid group would link with the alcohol group to eliminate water and form an ester (with a –COOC– group). Acetic acid, for example, reacts with ethyl alcohol to form ethyl acetate (an ester) and water:

$CH_3COOH$ + $C_2H_5OH$ —>
acetic acid ethyl alcohol

$CH_3COOC_2H_5$ + $H_20$
ethyl acetate water

Extending this pattern, Carothers reacted the di-alcohol, hexamethylene glycol (which has an –OH on each end), with adipic acid (which has a –COOH group at each end) and again formed an ester.

$HO(CH_2)_60H$ + hexamethylene glycol

$HOOC(CH_2)_4COOH$ —>
adipic acid

$HO(CH_2)_6OOC(CH_2)_4COOH$ + $H_20$
ester water

But because this ester has an alcohol group on one end and an acid group on the other, it can react with another molecule of the same kind and form yet another ester that is twice as long: $HO(CH_2)_6OOC(CH_2)_4COO(CH_2)_6OOC(CH_2)_4COOH$. Then two molecules of this ester can react to give a molecule that is twice as long again. . . and so on. By building on molecules that had reactive groups at each end, Carothers was able to form some very long molecules.

Carothers worked with these polymeric esters, or polyesters, but he found them to have no particularly useful properties. One day an assistant, whose name is unknown, dipped a glass rod into a molten mass of the polymer. He drew out some of the material that adhered to the rod. To his surprise, it stretched to form a long filament. Even after it was cold, the strand could be pulled by hand to several times its original length. Unlike rubber, it did not spring back to its former length, nor was the filament very strong.

The investigation might have stopped there but, with the rare insight of a gifted researcher, Carothers realized that the same approach that had yielded polyesters could also be used to make polyamides. So instead of the alcohol group, he turned to the amine group ($-NH_2$) and tried hexamethylene diamine, which has such a group on each end:

$NH_2(CH_2)_6NH_2$ +
hexamethylene diamine

$HOOC(CH_2)_4COOH$ —>
adipic acid

$NH_2(CH_2)_6NHCO(CH_2)_4COOH$ +
hexamethyiene diamine adipate

$H_20$
water

The result was hexamethylene diamine adipate, whose molecules could join with one another to form longer molecules. *These* molecules were very strong. They were the first nylon.

## Weight Control

The molecular weight of the nylon is crucial. It should be between 12,000 and 20,000 if the fiber is to be strong. The molecule can be stopped from growing at a particular point by a process known as "stabilization." If, instead of mixing exactly equivalent quantities of hexamethylene diamine and adipic acid, an excess of the latter is used, at a certain point all of the hexamethylene diamine will be used up and the reaction will stop. The ratio of 1 diamine to 1.02 diacid leads to a polymer with a molecular weight of 12,000, which is suitable for the production of nylon.

During the manufacturing process the polymerization takes about four hours at a temperature of 280 °C under an atmosphere of nitrogen. The molten polymer is then extruded through a slot to form a ribbon several inches wide. The hot material is quenched in cold water to prevent the growth of excessively large crystals that cannot be oriented lengthwise when the material is later stretched.

The ribbon is broken into chips and reheated. The molten nylon is pumped through a filter and extruded through tiny holes to form filaments. The filaments then pass through a cooling chamber, are wetted by steam, and are wound onto large bobbins. When the filaments are first produced, they are dull and not very strong. They are cold drawn— stretched to increase their length about 17%—to form strong, bright filaments. Stretching causes the randomly oriented molecules to align in the direction they are stretched, which adds strength to the nylon fiber. Finally, the fibers are dyed and woven to form the fabric for your jacket or knapsack.

The story of nylon is remarkable for several reasons: nylon is durable, water resistant, and strong. It is used successfully in so many products that we hardly notice it. And, after 50 years of commercial production, Wallace C. Carothers's invention is still the most widely used synthetic fiber.