Food Packaging:
A Learning Cycle of Activities

Written by NMLSTA members
Mary Harris, Chairperson, St. Louis, MO
John Burroughs School, 755 South Price Road, St. Louis, MO 63124
email: mharris@jburroughs.org **Polymer Ambassador from Missouri**
Wayne Goates, Goddard, KS **Polymer Ambassador from Kansas**
Lynn Higgins, Maywood, IL **Polymer Ambassador from Illinois**
Sandra Van Natta, Cincinnati, OH **Polymer Ambassador from Ohio**

Preface for the teacher:

The learning cycle activities, in this module, assumes that middle level students have experienced the learning cycle activities presented in the *Hands On Plastics* kit. This kit was written by members of National Middle Level Science Teachers' Association (NMLSTA) and produced by the American Plastics Council (APC). If you want to join NMLSTA: send your name, address, and $12 payable to NMLSTA to Wayne Goates, NMLSTA Membership, Goddard Middle School, 301 S. Main, Goddard, KS 67052. The kit may be ordered FREE from APC on their Web site at: handsonplastics.com

This module assumes students have worked with plastic containers and have some sense of what the recycle codes mean. They have a working knowledge of how to use physical and chemical properties to identify the six common recycled plastics. They have heard the terms for the six recycled plastics such as HDPE for high density polyethylene and PS for polystyrene. It is recommended that students do some of these activities in the kit before they start with the food packaging module. Each investigation has links to technology, and also includes other areas of the curriculum such as mathematics, fine arts, language arts, physical science, and life science.

The module contains:

- National Science Education Standards
- What is a Food Package?
- A Short History of Food Packaging with studyguide questions.
- Exploration of Food Packaging
- Concept Introduction - Eight Activities
- Application or Assessment of learning
- Teacher Notes
- Extension Activity

ChemMatters (October 2000) is a special issue on "The Chemistry of Food". One article, "Food Packaging - Wrapping up Freshness" by Brian Rohrig is a nice supplement to these module. There are also several investigations suggested on page 11. *ChemMatters* is produced by the American Chemical Society, 1155 16th Street NW, Washington, DC 20036. Subscriptions are $10 per year for four issues. The teachers guide is online at: www.acs.org/education/curriculum/chemmatt.html

National Science Education Standards addressed:
Science Teaching Standards:
A: Plan an inquiry-based science program
B: Guide and facilitate learning
C: Engage in assessment of student learning
D: Design and manage learning environments
E: Develop communities of science learners
Assessment of Science Education:
A: Consistent with the decisions they are designed to inform
B: Achievement and opportunity to learn science
C: Technical quality of the data collected matches interpretation
D: Fair
E: Sound inferences from assessments
Science Content Standards for grades 5-8
A: Unifying Concepts and Processing
1. Systems, order, and organization
2. Evidence, models, and explanation
3. Consistency, change and measurement
4. Form and function

B: Science as Inquiry
C: Physical Science:
1. Properties and changes of properties in matter

D: Science and Technology:
1. Abilities of technological design
2. Understanding about science and technology

E: Science in Personal and Social Perspectives
1. Natural resources
2. Science and technology in society

F: History and Nature of Science:
1. Science as a human endeavor
2. Nature of science
3. History of science

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What is a food package?

A wrap, pouch, bag, box, cup, tray, can, tube, bottle and jar are some of the many forms of packaging that contain food products. It must contain a food product as well as protect and preserve it for a specific length of time. Each package must, by law, display product information for the consumer.

What are the purposes of a food package?

Imagine a container of milk. This is a gallon cloudy-white plastic (made out of HDPE - high density polyethylene) jug that contains 2% pasteurized milk not a milk-carton holding an individual serving or even a small plastic bottle of chocolate milk. Now everyone is all thinking of the same item! What are the purposes of that plastic jug?

- It is a package for the milk processor to ship the milk to the grocery store.
- It is a package for the grocery store manager to display for his/her customers.
- It is a package to hold the milk so that you the consumer can carry it home.
- It is a package for you to keep in the refrigerator.
- It is a sealed package indicating to the consumer that it is not contaminated.
- It has a label telling the consumer the contents, nutritional information, name of the dairy or brand name, bar code for pricing, and expiration date. (Required by law)
- It is easy to use. It has a handle and reusable screw top.
- This HDPE container is also recyclable and has a recycle code of #2 embossed on it.
- It is chemically non-reactive with the milk. In other words, the plastic container does not interact with the milk to produce an off-flavor nor does the milk cause holes to form in the container.
- It is durable and can withstand the stress of the transportation, storage and the consumer pouring milk from it for a week or more.

Some general purposes of food packages are to:

Contain	Motivate
Carry	Promote
Dispense	Glamorize
Preserve	Disguise!
Measure	Adhere to the law
Inform	Protect
Display	Endure

Assignment: Does the Wonder bread package meet these purposes? Write a short paragraph describing the package the Wonder Bread Company has chosen to sell their product. Pay close attention to the design on the package that promotes the food inside.

A Short History of Food Packaging:

Glass containers were first used around 2500 B.C. in Egypt and Babylon. The Syrians discovered the art of blowing containers from molten glass about the first century A.D. The procedures for making a bottle remained unchanged from Roman times into the nineteenth century. In 1821, molds were introduced to allow the neck and body of a bottle to be blown together. These still used lung power! The screw top was invented in 1872. The crown bottle cap was invented in 1892 in St. Louis so that beer would keep better. Anheuser-Busch ordered 500,000 caps in 1896! Coca-Cola® and its famous shaped bottle is a worldwide icon for American-ness. The coke "curvature" is evident in bottles and cans. Coca-Cola® is also known for the red color. When people are asked to think about products, 71% responded that red represents Coca-Cola®.

Wrapping the product for the consumer in the late 1800's was not a science! Packaging was anything the seller had on hand. Newspaper and cloth sacks were best known for wrapping meat and holding flour or sugar. Tinfoil was first used in France in 1840 for wrapping individual candies. In 1850, a composite package of a foil inner layer and an outer layer of stain-resistant paper was developed for the Cadbury chocolate. The first paper-bag-making machine was developed in 1852 in Bethlehem, PA. The introduction of the paper bag increased sales wherever they were used since refilling canisters brought from home were not needed. Many products like flour, sugar, and dog food come in paper bags today.

The paperboard box lead to the mass-marketing of many products. A box did not tend to rupture and attract vermin. Boxes were suited for printing, standing straight, and looking attractive on shelves. In the early 1900's, food was being shipped from the farm to the city and new containers, like boxes, were in demand. It is hard to believe that the technology to make boxes involves nearly a thousand patents! Today less than 3% of Americans live and work on farms so the need for food packaging is even greater. American farmers can feed more than 240 million Americans and millions overseas due to technological advances in agriculture, distribution systems, and packaging.

Canning food, to preserve it for a long period of time, was invented in the early 1800's when Napoleon wanted higher quality diets for his armies. The canning industry came into existence in 1874 with the invention of the pressure cooker. Food is cooked at elevated pressures so that food cooks at temperatures higher than the normal boiling point of water of 100°C. By 1890, semiautomatic processes kept the canners producing cans of food for consumers at a rapid rate. By 1900, production was up to 6,000 cans per hour. Tin and steel cans were the acceptable containers for canned food during World War II. Many of the name brand companies of today started in the early part of this century. Campbell Soup produced a very successful brand identity for canned goods. Their first labels were cluttered. They removed all pictures and highlighted the Campbell name. Red and white were chosen to give a background for the gold medallion representing the gold medal from the 1900 Paris Exposition Universelle. In 1994, Campbell's can underwent a major change with the bottom of the label having a picture of the soup to be found inside except for Tomato, Chicken Noodle and Cream of Mushroom. The label has been redesigned again. Look at the label on the Cream of Mushroom soup!

Du Pont licensed the patent for moisture-proof cellophane (a chemical cousin to rayon) in 1923. The clear, flimsy product was used as a protective covering for food. Cellophane allowed a packager to display products in an attractive way by placing "windows" in a paper package. Cellophane wrapping encouraged the growth of self-service stores. Cellophane, like paper bags before, accelerated the purchasing and consumption of food products. The consumer was lead to believe that the glistening food inside the package was fresher, cleaner, safer and generally better than those products in conventional opaque wrappers.

Polyethylene, one kind of plastic, was introduced on the eve of World War II. The federal government wanted to shut the plastic-packaging industry down for the length of the war. Du Pont, Dow Chemical, and Union Carbide were needed to play a vital role in producing products for the war effort. These same companies finally demonstrated the use of plastics in otherwise steel, wood, tin and rubber products so that the military was convinced of the value of plastics. The army canteen with a screw cap was made out of ethyl-cellulose. Every GI was issued a clear plastic envelope to hold his paybook. Rigid plastics were used to ship drugs, ammunition and spare parts. The two-liter bottle did not appear until 25 years after the war.

The supermarket concept came into existence only in the last fifty years. The American consumer can shop for meat, diary products, cookies, soda, and bread all at one store. One does not have to wait in line for the seller to scoop, weigh, and package most items. Since the 1950's, plastics have entered the packaging scene to replace many steel, glass, and paper containers. Plastic containers are less expensive and easier to produce, and they are lighter in weight, resistant to breakage and less expensive to ship. Have you noticed the amount of "flexible" packages available now? These are packages that are made from plastic film (or sheets), aluminum foil, paper or a combination of the three. A good example is a "bag" of cookies and not a box. These flexible packages are lightweight and durable. They are much cheaper to transport from the manufacturer of the food product to the consumer. For example, the flexible vacuum pack coffee bag weighs 90% less than the metal can it replaces and occupies 20% less space on the store shelf, and takes up far less space in our landfill when the package is discarded.

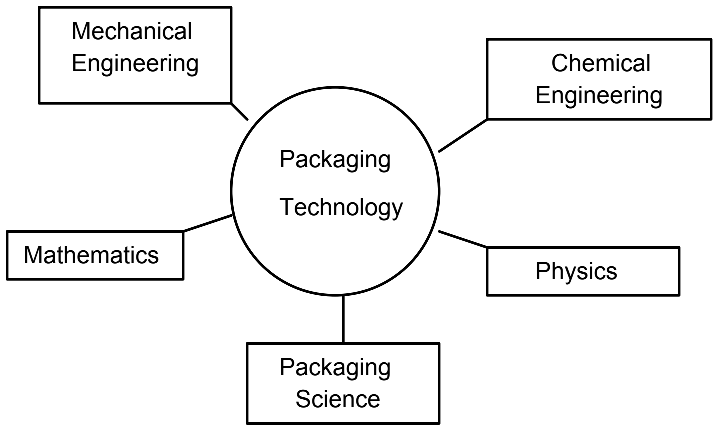
Food packaging has a real impact on the lifestyle of Americans. The average grocery store contains more than 10,000 different products. Consumers are demanding:

- Fresh fruits and vegetables be available all year round.
- Fresh ocean fish be available in the Midwest.
- Kansas beef in New York.
- One-stop shopping.
- Wide range of choices in quantity and size of packages.
- Reasonable prices.
- Uncontaminated and undamaged packages.
- Light weight and durable containers.

- Food that does not spoil in a day so the package must have some kind of barrier from light, bacteria, and gases.
- Food that tastes good because the flavor and aroma are locked in.

Packaging industries cannot work in isolation. They work with several groups or companies to sell a particular product to the consumer.

Packaging Technology Network



Packaging of food products is not a simple operation. One must consider many questions dealing with safety, shelf life, convenience, appearance, cost of raw materials, transportation costs, handling, law, manufacturing, equipment, and more. The "packaging science" arms of the diagram includes marketing, art, graphics, psychology and law. The chemical engineer has to consider the chemistry of the food within the package and its reaction with the package material. The mechanical engineer is concerned with the machines to make the package. Physics and mathematics deal with size, shape, mass and structure of the package. Team work is needed to sell the product and make a profit.

The consumer must be willing to pay for the packaging too. A well-designed package must meet the needs of the purchaser. These may be psychological desires or practical applications. The package must have visual impact but it might also address the sense of touch or texture. The size and shape of the container have an impact since the consumer is considering if it will fit on the shelf at home. The dispensing of the food is important in some cases. Does the consumer want to squeeze the product out or lift it out or spray or pour?

Inappropriate disposal of packaging sometimes causes a pollution problem. Litter is a social problem that people are more aware of today than ever before. Litter is an insult to the people who live, work and play in the places where others have thrown their trash. This trash is sometimes packaging and it tends to be a forerunner of large-scale, illegal waste disposal in vacant lots and open areas. Packaging also contributes to our landfill operations. If we don't recycle the packaging materials, then the trash trucks must transport it to our landfills. Recycling paper, cardboard boxes, plastics, glass and metals is really the best way for the consumer to help our environment by reducing the amount of waste in our system, conserve materials and energy and slow the growth of landfills.

The resin coding system on plastic containers was introduced by The Society of the Plastics Industry, Inc. (SPI) in 1988. Recyclers wanted some way to identify each kind of plastic container. The SPI code was developed to meet this demand as well as to provide manufacturers a uniform system for the nation. There are seven codes or numbers inside a triangle of chasing arrows. The resin abbreviation is printed underneath each symbol. The code was not intended to be a guarantee to consumers that a given item would be recycled. SPI urges manufacturers to not use the term “recyclable” in proximity to the code so that the consumer does not assume that the package is recyclable. “As of 1995, 39 states had adopted legislation regarding the use of the resin identification codes on bottles of 16 ounces or more and rigid containers of 8 ounces or more.” The SPI resin code for #1 plastic containers is PETE for polyethylene terephthalate while the reference to this kind of material has the abbreviation of PET.

Choosing products packaged to minimize space or volume is another environmentally conscious decision. This is called “source reduction” when the product uses less material to make it. Items like thinner aluminum cans and lighter plastic soda bottles are examples of source reduction. Aluminum cans have reduced in weight by 25% between 1972 and 1989. The amount of PET in a soda bottle has also decreased by 29% between 1977 and 1998. The Clorox bottle of the 1960’s was in amber glass and had a weight of 3.5 lbs. empty. The first plastic bottles weighed 135 grams. Now the Clorox bottle is down to 87 grams in the winter and 104 grams in the summer! In the summer, the plastic softens with heat and so the bottle needs more strength in order to be stacked for shipping.

Study Guide Questions on the History of Packaging:
Answer these on a separate sheet of paper and in complete sentences.

1. Imagine you are five years old, living in the year 1850, and shopping for flour in the general store with your mother. How would the flour be packaged?
2. What methods did Campbell Soup use to promote a very successful brand?
3. Name one food product that has a window made out of cellophane or plastic on the package.
4. Polyethylene is one kind of plastic. Is it in HDPE? Explain. Is it in PP? Explain.
5. Name a “flexible” package not mentioned in the reading.
6. If the PET soda bottle has a mass of 48 grams in 1998, find the mass of the PET bottle in 1977.
7. What is the meaning of the symbol of a number inside the chasing arrows?
8. What was the most interesting item or fact you learned in this reading?

Exploration Phase of the Learning Cycle

Purpose: To discover the reasons for certain types of packaging

Materials: For each pair of students
- empty but clean containers of:
  - individual paper milk carton
  - PETE (#1) 2-liter soda bottle
- sink or large pan
- boiling water (safety concern)

Time: One laboratory period

Procedure:
1. Take a clean but empty paper individual milk carton and tear it apart. Look at the inside and the outside of the container. What is it made out of? How many layers are present? How much milk will it hold? Describe what you observe below.

Observations of the milk carton:

2. Take a PET 2-liter soda bottle and examine it closely. Can you find the five kinds of plastics used to market the soda in the bottle? Fill in the table below:

Bottle parts	Kind of plastic
1. the bottle itself	
2. cap	
3.	
4.	
5.	

Place the 2 liter bottle in a sink or pan on its side. Have your teacher pour boiling water on the side the bottle. Observe. What happens to the bottle?

3. Think about plastic food packaging. Using the list of packaging below, give a reason for the kind of plastic used on particular food item.

Packaging	Reasons
HDPE for milk jugs	
LDPE bags for dry noodles	
PVC for vitamin pills	
PET for ketchup	
PP for honey	
LDPE for mustard	
PET for peanut butter	
HDPE for salad dressing	
PS for deli sandwich container	
HDPE for butter tubs	

Conclusions:
1. When you buy a smelly fabric softener package and a paper carton of milk at the store and they are packed into one grocery bag, does the milk taste like fabric softener? ___________ Why or why not?

2. Can a bottler who is using PET bottles to contain a drink, use a sterilizing machine to heat the liquid before filling the soft drink bottles? Explain

3. If the bottler needed to sterilize a drink, what kind of container would be best? Think about containers that hold juices.

4. What would be a method to identify the different kinds of plastics used to make a 2-liter soda bottle?

5. Suppose the cap was made out of LDPE and not PP, how would you test for this?

6. What kind of plastic is used to make the label? ____________

7. When you filled in the reasons for each kind of plastic, did you have any problems answering the question? If so, why was it a problem?

Teacher Notes on Wonder Bread Assignment:

The red, yellow and blue balloons on the Wonder bread wrapper are there to catch the eye of the consumer. They demand recognition! The white background is representing purity. The bold lettering surrounded by the balloons is intended to communicate a sense of animation. The bread, of course, cannot convey energy and enthusiasm but the package can and does. The package does an excellent job of protecting the bread from many people handling the bread before the consumer purchases it. The plastic wrap (LDPE) keeps the bread fresh. It retards moisture so the crust becomes tough and leathery as the water vapor travels from the bottom to the top crust of the loaf. Students should be able to write about most of these purposes just in this one package. (French and Italian breads are sold in perforated plastic bags so that the crust stays crisp and moisture can escape.)

Answers on the History of Packaging Questions

1. The year 1850 was before the first paper bag was invented. The flour had to be placed in the canister that the mother brought to the store or in cloth sack.
2. Campbell Soup used red and white colors to attract attention to the product. The name was prominent and the label was very plain.
3. Yes, windows are present in food packaging today. Most pastas have windows and some cookie packages do too. Some of the windows are cellophane and some are made of other plastics.
4. HDPE is high density polyethylene and PP is polypropylene. The HDPE is one type of polyethylene.
5. Flexible packaging answers must <u>not</u> include a bag of cookies or the vacuum pack coffee in the reading.
6. If the 48 grams in 1998 is 29% smaller than the bottle was in 1977, then $.71x = 48$ grams. Therefore $x= 68$ grams. OR the bottle had a mass of x grams in 1977, 48 grams is 71% of the mass it was in 1977.
7. The SPI code is a symbol for the resin that was used in the manufacture of the container. It is not to imply that the container is recyclable.
8. Answers will vary.

Teacher Notes on Exploration Phase:

1. Paper milk cartons are not just paper! They have a thin layer of polyethylene (LDPE) on the inside and outside to keep out odors, keep moisture from softening the paperboard, serve as an adhesive to seal the opening shut, and reduce spoilage and bacteria. The paperboard provides the strength and rigidity. Students may or may not observe these barrier layers. There can be significant nutrient loss in milk due to light exposure in supermarkets. Exposure to 400-550 nm wavelength light is responsible. The most efficient light barrier is paperboard cartons with a PE coat. The printing on the box is important to block the light and the best colors are (in order): black, brown, green, blue, yellow, and red.

2.-6. Two-liter bottles are made out of PETE or #1 recycled plastic. The cap is made out of polypropylene (for Pepsi® and Coca Cola®) or low density polyethylene for water bottles like Evian® and Avalon®, the liner in the cap is made out of EVA or ethylene-vinyl acetate with a density of .93 g/cc and the label is made out of polypropylene film. The glue is ethylene-vinyl acetate copolymer (EVA) hot melt adhesive and it sticks best to polypropylene. One can run hot water over the glue and it will soften. NOTE: Some bottle caps do not have separate liners and some labels are shrink-wrapped with little or no adhesive. All of these parts can be tested using the flow chart and tests described in the *Hands On Plastics* kit. Since both LDPE and PP float in water and the isopropyl alcohol-water solution test, they have to be identified with the corn oil test. The LDPE will sink in the oil and the PP will float. (If one were to test the EVA cap liner or the glue, they would behave like LDPE.) PET bottles cannot withstand high temperatures. Pouring boiling water into the bottle will cause the bottle to deform. Some juice containers are made out of little paper boxes with foil liners or glass.

Density Table:

Substance	Density (g/mL)
Water	1.00
(1) PETE	1.38-1.39
(2) HDPE	0.95-0.97
(3)PVC /V	1.16-1.35
(4) LDPE	0.92-0.94
(5) PP	0.90-0.91
(6) PS	1.05-1.07

Teacher Demonstration:

Fiber Formation from PET Soda Bottles

Recycled soda bottles, of poly(ethylene terephthalate) PETE or PET, are made into fiberfill for jackets and sleeping bags as well as into carpeting. To demonstrate how a fiber can be made, cut part of a bottle into small (one centimeter) pieces. Place 8-10 pieces in an aluminum foil "pan" on a hot plate. Heat the sample slowly until it melts but do not let the pieces become discolored. Insert the tip of a wooden craft stick into the sample and hold it in the melted polymer for a few seconds. Slowly pull the splint away at a constant speed. Try to produce a long fiber. Place it on the counter top to cool and then test it for elasticity.

7. Students will have difficulty answering this question because there are reasons concerning all the following that a packaging engineer must consider are:

Flexible or rigid
Transparent or translucent or opaque for light transmission
Oxygen and water vapor permeability
Safety in handling
Storage and shelf life of the food
Filling the package at the plant
Displaying the package in the store

The answers are complicated and very involved. This question is asked to get students thinking about packaging and making them curious.

Packaging	Reasons
HDPE for milk jugs	Milky white, excellent chemical resistance, good water vapor barrier, great impact resistance, high volume recyclable
LDPE bags for dry noodles	Flexible, inexpensive, clear
PVC for vitamin pills	Clear, hard, durable, safety from tampering
PET for ketchup	Tough, clear, recyclable, high-speed bottle processing, good barrier to gases, light weight, cheaper to transport than glass
PP for honey	Chemical resistance, stiffness, strong, low odor/taste transfer
LDPE for mustard	Chemical inertness, ease of processing, flexible,
PET for peanut butter	Same reasons as mentioned for ketchup
HDPE for salad dressing	Same reasons as mentioned for milk jug
PS for deli sandwich container	Clear, light weight, high speed processing
HDPE for butter tubs	Colored for appeal, same reasons as mentioned for milk

Concept Introduction of the Learning Cycle
There are eight investigations and each are stand-alone experiments.

I. Breathable Lettuce Bag Investigation

Purpose: To find out if the "breathable" bag really lets gases come into and out of the bag so that seeds will stay alive and well.

Background: Seeds respire when they germinate. This means they breathe like we do to stay alive. The seeds take in oxygen and let out carbon dioxide. Once they are green plants, they can photosynthesize and continue to grow. When plants photosynthesize, they take in carbon dioxide and give off oxygen.

Links: Technology, Life Science

Time: One laboratory period to set the experiment up and one week to observe.

Materials: (for each pair of students)

One strip of <u>Saran Wrap</u> - about 60 cm long (make sure this is Saran Wrap)
One "breathable" lettuce bag - make sure the bag says <u>breathable</u>
(These are the lettuce bags that contain chopped lettuce in the produce department of the grocery store.)
20 pea or bean seeds
9 large paper clips
two paper towels
marker
aluminum foil (optional)
metric rulers

Procedure:

1. Take the two paper towels, fold each into four layers, and wet them with water. You want them to be moist but not dripping.
2. Place 10 seeds on top of one of the wet towel layers. Place the towel with the seeds into the bag and press out the air. KEEP THE SEEDS ON THE WET TOWELS but visible through the bag. Fold over the top of the bag three times. Use three paper clips to keep it closed. Keep the bag flat so the seeds don't roll off!
3. Place 10 seeds on top of the other towel layers. Place the towel with the seeds on the sheet of Saran Wrap. Fold the wrap over the seeds to form a tight pocket with no air. Fold the two open edges over three times. Secure the folded edges with three paper clips on each side. Label each packet with your names. Place the two packets in the dark or cover them lightly with aluminum foil. Start your data table.
4. Observe your seeds everyday for a week. Measure any roots with a metric ruler. Do not let the seeds roll off the towels. DO NOT OPEN ANY PACKET DURING THE EXPERIMENT.

Data Table:

Date	Observations

Conclusions:

1. After a week, what can you conclude about the health of your germinated seeds in each packet?

2. Do you think the breathable bag allowed gases to come in and out of the bag during this experiment? What evidence do you have to support your conclusion? Did the Saran Wrap packet allow gases to come in and out? Explain.

3. Empty and clean the lettuce bag. Now blow into the bag and see if you can fill the bag with gas. What happens?

4. Take the breathable bag with your breath inside and place the twist tie on it or just twist and hold it closed. Press gently to see if you can make the gas go out through the plastic. What happens to the bag?

5. Explain why chopped lettuce is marketed in these bags? Does lettuce need to breathe?

6. What can you say about the "shelf life" of lettuce in these bags?

Teacher Notes for Breathable Lettuce Bag Investigation:

The breathable plastic bags for lettuce allow oxygen gas from the atmosphere to enter the bag to help maintain aerobic metabolism of the lettuce. In addition, the carbon dioxide must exit the package to avoid buildup of this gas that results in spoilage of the lettuce. The plastics chosen for these purposes must have high gas permeability characteristics. In this case, one cannot detect "holes" in the bag like you can when you buy a box of vegetable bags to use at home. Gases adsorb onto the surface of the packaging film, migrate into the film, diffuse through the film, transfer to the opposite surface, and vaporize from that surface. These breathable bags rely on a concept called "Modified Atmosphere Packaging" or MAP. These bags selectively allow gases to pass through the plastic into and out of the bag. The rate of the exchange of gases is controlled by the selection of the polymer. Iceberg lettuce will discolor if the carbon dioxide concentration exceeds about 2.5%. Vegetables are packed into these bags which are filled with a mixture of gases that is low in oxygen. Then they are shipped at 40 degrees F and kept cold in refrigerated trailers. The shelf-life of the produce is extended while keeping the produce healthy and safe to eat. The convenience to the consumer is also enhanced by this kind of packaging. These bags are marketed by Fresh Express Inc., Dole, Tanimura&Antle and others. The polymer for the bags are produced by Dow Chemical Company, Exxon, and Mobil Chemical. The films are made by Cryovac, Cypress Packaging, and Mobil Chemical Films Division.

Saran Wrap is not permeable to oxygen gas. Other wraps such as Handi Wrap® are permeable to gases. Even zip lock bags made out of LDPE are somewhat permeable to oxygen gas. This experiment compares the impermeable Saran Wrap with the breathable lettuce bag.

A link to literature in regard to preserving and shipping lettuce is to read *East of Eden* by John Steinbeck. Adam Trask used ice to preserve lettuce shipped by rail to New York from California. The lettuce arrived soggy and a mess! Adam Trask was told to let his refrigeration idea die!

Typical Data for a week of germinating seeds is in the data table below. (Germinating radish seeds did not have the noticeable differences that peas and beans presented.) You might want to start the experiment on a Friday so students can observe the final results on a school day.

Data Table:

Date	Observations
Day 1	Started experiment
2	Nothing to report.
3	3 roots visible in each packet
4	All 10 seeds germinated in both
5	3 roots of lettuce bag were 5 cm long no long roots in Saran Wrap

6	10 stems visible in lettuce bag only 2 cm roots and no stems in Saran
7	10 stems visible in lettuce bag only 2 cm roots and no stems in Saran

1. Pea or bean seeds are very healthy in the breathable bag and starting to grow leaves. In the Saran Wrap, the seeds have slower growth.
2. The pea or bean seeds were starting to form leaves. They need oxygen to live. The bag must have provided gas exchange to take place. The Saran Wrap seeds were not growing as fast and could be due to lack of oxygen.
3. The bag inflates.
4. The breathable bag does deflate when you press on it.
5. Lettuce respires too. The gas exchange helps to prevent the lettuce from spoiling.
6. The shelf life of lettuce in these plastic bags is greatly enhanced.

II. Juice Container Investigation

Purpose: To discover the reason for paper boxes and plastic containers for individual juice servings.

Background: Juices are sold in paperboard boxes, HDPE containers, cans, and glass. Why is the consumer seeing these little boxes? Are they special is some way? These were introduced into American supermarkets in 1983.

Links: Technology, Chemistry

Time: One laboratory period.

Materials: (for each pair of students)

One empty clean juice box with ingredients listed (expiration date noted and record the date of purchase)
Magnifying glass or binocular microscope
One empty clean HDPE juice container with ingredients listed (expiration date noted and record the date of purchase)
Flashlight or sunlight
Pan of hot water for the class (safety concern)

Procedure:

1. Look very carefully at your juice box. What is the expiration date? __________
2. How many months and days is the shelf life of this box? _______________
3. Is there any vitamin C present? ____________ How much? ___________
4. Look very carefully at the HDPE juice container. What is the expiration date? __________
5. How many months and days is the shelf life of the HDPE container? _______
6. Is there any vitamin C present? _________ How much? _____________
7. Take the box and make a tear in it so that you can look at the "layers" of the box using a magnifying lens or binocular microscope. How many layers are present? What are the layers made out of? Can you see any plastic? Paper? Metal? Glass?

   Draw a picture of the layers and label each.

8. Hold the box and the bottle up to the sunlight or a flashlight and see if you can see through them. What did you observe?

9. Put your torn box into some hot water. Does it deform or get smaller like the PET soft drink bottle? Try this with the HDPE bottle too.

Conclusions:

1. The box has multilayers and the HDPE bottle does not. What would be reasons for the box to have these layers? Answer the questions below:
    a. Do you want oxygen to enter and degrade Vitamin C? _________
    b. Do you want sunlight to enter and change the color of the juice? ________
    c. Do you want bacteria to grow in the container? _________
    d. Do you want bad flavor? __________
    e. Do you want long shelf life? ___________
    f. Do you want protection from tampering? ____________

2. There is a layer of aluminum foil in the layers of the box. Did you find it? ______ Aluminum foil is an excellent barrier to gases and light.

3. Juices are acidic and have a sour taste. This means the liquid can react with aluminum. Where is the layer of aluminum layer located?

4. The multi-layer box is an aseptic container. What does that mean?

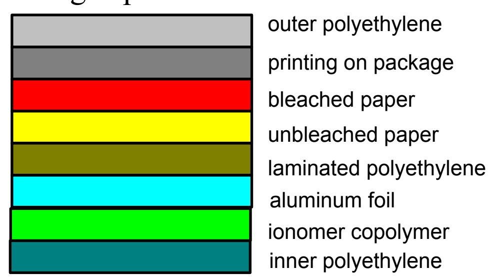
5. Why does the box have such a long shelf life? Why does the HDPE container have a short shelf life?

6. The box of juice is a safe container for the consumer. Explain four reasons why it is considered safe.
    a.
    b.
    c.
    d.

7. There are three main materials in the box. Place the following functions next to the material that is associated with the function. (gas barrier, stiffness, tight seal, light barrier, keeps package dry on the outside, printing surface, efficient brick shape)
    a. Paper -70% of the package -
    b. Aluminum - 6% of the package -
    c. Polyethylene - 24% of the package -

Teacher Notes for Juice Container Investigation:

The multipart single juice box is an aseptic package. Aseptic means the absence or exclusion of any unwanted organism from the product or package. Canning is the sterilization of the can and its contents together. Aseptic packaging sterilizes the containers separately from their contents and fills them in a sterile environment. Juices in the plastic film/aluminum foil/paperboard package have a shelf life of 4-6 months. They don't have to be refrigerated! Vitamin C in juices are very sensitive to acid levels, trace metals and oxygen gas. Packages must contain barriers to oxygen gas entering and degrading Vitamin C. The ionomer or acid copolymer (DuPont's Surlyn or Dow's Primacor) is a layer of a polymer that has a metal ion instead of a proton on an acid group. This layer adheres extremely well to the metal layer. Ionomers have the properties needed to withstand an acid environment. HDPE juice containers cannot stop the degradation of Vitamin C. A typical layering of the paperboard laminate carton, for high acid fruit juices, for aseptic filling is pictured below:



Paperboard Carton Layers

The high density polyethylene (HDPE) container is not a "bad" container. It is just not the best for barriers to gas and light, and aseptic filling. HDPE containers are also used in 1-gallon milk jugs, shampoo bottles, butter containers, detergent bottles, bleach bottles and more. HDPE is the one of the largest-volume plastics used in packaging today. HDPE is permeable to gases and this tendency is dependent on its density. The longer, more entangled chains of the polymer allows small molecules like oxygen gas or water vapor to take a winding path through the plastic. HDPE is highly impact resistant. It is also recycled across the nation and made into plastic lumber for park benches, patio furniture, fencing, and boat docks.

1. The answers are NO except for e and f!
2. and 3. Aluminum foil is just inside the two inner plastic layers next to the juice.
4. Aseptic means the absence or exclusion of any unwanted organism from the product or package.
5. The long shelf life is possible because the package is sterile and the juice is sterilized using an ultra-high temperature process.
6. The box is safe for a number of reasons: sterile contents, long shelf life, shatter-proof, tamper resistant (outside plastic coating on the set of six boxes), straws are sealed separately, no preservative needed etc.
7. Paper for stiffness, printing surface, and brick shape
   Aluminum for gas barrier, and light barrier
   Polyethylene for tight seal, and dry package.

III. Polyethylene Bag Investigation

Purpose: To discover the physical properties of low density polyethylene (LDPE) and high density polyethylene (HDPE) bags used in packaging food.

Links: Technology, Chemistry

Time: One laboratory period.

Materials: (for a pair of students)

- One zip-type bag - quart size or sandwich size
- One HDPE grocery bag
- Sharp pencil (safety concern)
- Sink or pan to catch water
- Scissors
- Ruler

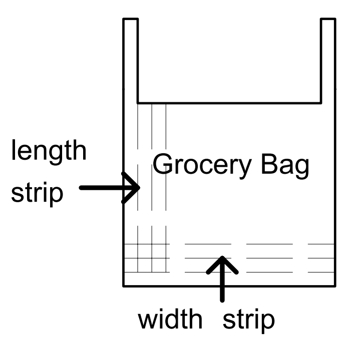
Procedure:

1. Take the zip-type bag (LDPE) and inflate it by blowing air into it. Seal it. Squeeze it. Does the air come out? Is the seal good? Write your observations.

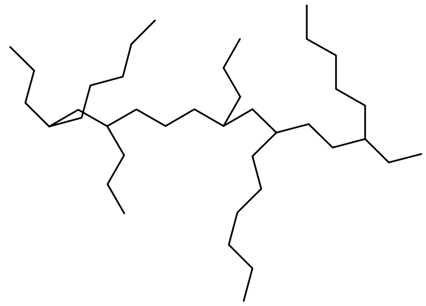
2. Unseal the bag and half fill it with water. Zip it closed. Hold the bag over a sink or pan. Take a sharpen long pencil and insert it into the bag so that the point goes in one side and out the other. What happened to the water in the bag?

3. While the bag is still over the sink or pan, gently remove the pencil. What do you observe? ____

4. Take the HDPE (high density polyethylene) grocery sack and cut strips of the bag with scissors. Cut two inch or 5 cm wide by 7 inch or 18 cm long strips following this pattern. Cut two strips for each direction and make four total strips. Label a strip "L" for length and "W" for width. Gently pull on each strip until you break it.
What did you observe?



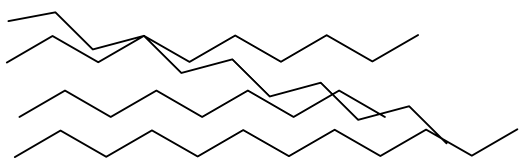
Conclusions:
1. The plastic zip bag is made out of low density polyethlyene (LDPE). This molecule looks like this:



How would you explain the "pencil in the bag of water" observations?

2. LDPE allows light to pass through the plastic. Is this bag transparent?

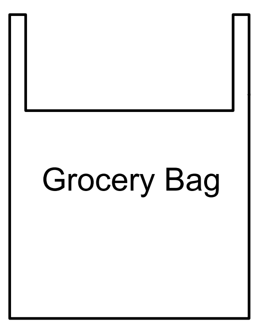
3. The grocery bag is made of HDPE where the molecules have a similar structure to the picture of LDPE. There is a difference! Here is HDPE.



How would you explain the tearing of HDPE based on this molecular structure?

4. HDPE does not allow light to pass through. Is this bag transparent?

5. The "bag machine" in the factory making grocery bags must arrange the molecules of HDPE in a certain direction. If you were the mechanical engineer in charge of this machine, how would you have the HDPE extruded or squeezed out of a machine to make the bags? Here is a sketch of the bag. Place the molecule chains in the direction appropriate to make the strongest bag for the customer. (Place them lengthwise, widthwise or diagonal.)



6. When an HDPE grocery bag gets wet, what happens to its strength?

7. Write an experiment to test your hypothesis about the wet bag question. List the steps of your procedure.

a.

b.

c.

d.

e.

f.

g.

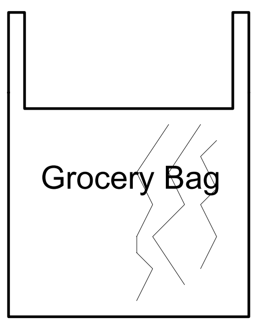
8. If the consumer did not have LDPE sandwich bags, zip-type bags and food wrap, what are some alternatives for storage of food products? Would the alternatives keep the food fresh as long as the plastic bags?

Teacher Notes for Polyethylene Bag Investigation:

The pencil can be inserted into the LDPE bag filled with water and it will not leak so long as the pencil is in place. The polyethylene molecules will be moved apart by the pencil but will "bunch" around the pencil to make a temporary seal. When the pencil is removed, the hole through the plastic is present and water will leak out.

LDPE is one of the most widely used packaging materials in the market. It is low in cost compared to wood and metal. It very tough, flexible, a barrier to moisture, chemical resistant, and light weight. Sixty-five percent of the LDPE used in the world is for films and sheets to make garbage bags, grocery sacks, garment bags, shrink film, stretch film, pond liners, construction and agriculture film and food packaging. Grocery sacks made of LDPE are soft and do not have a “rustle” sound. They are transparent. Fresh produce bags are sometimes made out of LDPE

The HDPE grocery bag is extruded from the machine where the length of the bag has the molecules going in the long chain direction. So when you pull on the lengthwise piece, the chains stretch and then break the bonds. When you pull between the chains on the width strip, they separate easily. The bag is designed so that the stretch is in the lengthwise direction.



High density polyethylene is one of the largest volume plastics in packaging today. Some of the products made from HDPE are: gallon juice and milk jugs, cosmetic bottles, caps, pails, crates, bag liners, grocery bags, cereal wrappers, snack-food wrappers, diary cups, pallets, tubs, water tanks, and shipping containers. Milk jugs are manufactured to keep the container light weight while the jugs for bleach are designed for higher environmental stress-crack resistance. HDPE containers are opaque or translucent but never transparent due to the molecular structure of the polymer. HDPE grocery sacks have a “rustle” sound when you squeeze or rub them. A survey in 1995 found that over a third of all HDPE milk, juice and water jugs are being recycled.

Take a PS cup (polystyrene cup – clear and brittle) and crack it. Where does it crack? It tends to crack along the lines of the polymer chains. The crack is parallel to the chains.

HDPE grocery bags do not decrease in strength when they are wet. Students’ procedures will vary about their ideas for testing their hypotheses. LDPE bags preserve food for us. They also keep food fresh. Alternatives, that are not very good, are wax paper, aluminum foil (expensive) or paper boxes.

IV. Potato Chip Bags, Candy Bar Wraps, and Single-Serving Ketchup Pouches Investigation

Purpose: To discover the unique properties of potato chip bags, candy bar wraps and single-serving ketchup pouches.

Time: One laboratory period.

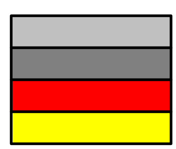
Links: Technology, Physical Science

Materials: (for a class of 30 working in pairs)

- 15 small potato chip bags
- 15 small candy bar wraps (Milky Way or Snickers)
- 15 single-serving ketchup pouches which are UNOPENED (different brands)
- flashlight or sunlight
- 15 1-liter or 2-liter PET empty soda bottles with caps
- one box of Kosher Salt from the grocery store
- 15 small squares of aluminum foil (5 cm x 5 cm)
- 5 markers
- 15 cups that can hold a cup of water
- 5 tablespoons

Procedure:

1. Take your empty potato chip bag and examine it closely. How many layers can you detect? Label a sketch of the layers: (Hint: One of the layers is the sealing medium for the seams.) The top layer is the outside of the package.

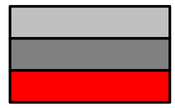


Potato Chip Bag

2. Hold the potato chip bag up to a light source (sunlight or flashlight) with the shiny foil side toward you and the printing toward the light. Can you see the printing on the package? Place the letter "A" on one side of the aluminum foil square with a marker. Hold the square of aluminum foil up to the light with the "A" toward the light. Can you see "A" through the foil? Based on these observations, is the potato chip bag made with a layer of aluminum foil? Explain.

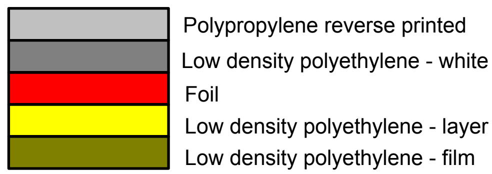
3. Potato chip bags use a hot seal to make the edges of the package stick together with a strong bond. Examine the wrap from the candy bar. Would you want to use a heat seal for this package? Why or why not?

4. Take your empty candy bar wrap and examine it closely. How many layers can you detect? Label a sketch of the layers: (Hint: One of the layers is the sealing medium for the seams and may be present only in the seal area.) The top layer is the outside of the package.



Candy Bar Wrapper

5. The ketchup single-serving pouch is more complicated than the other two. Here is the layering of this package: DO NOT OPEN THIS POUCH!



Ketchup Single-Serving Pouch

6. The acid in the ketchup needs a very good oxygen barrier which is provided in this package by a layer of aluminum foil. The inner low density polyethylene film is the adhesive layer for heat-sealing. The next low density polyethylene layer protects the foil from the acidic ketchup. Ketchup packages do contain some gas. Feel your pouch and see how soft it is. The inside contents are ketchup and a gas. You are to determine if your package of ketchup is less dense than water or more dense. Place it in a cup of water and see what it does. Does it float or sink? Push on it with your finger to dislodge any bubbles. If you have a floater go to step 7. If you have a sinker, go to step 8.

7. Fill an empty soda bottle almost to the top with water. Place your unopened ketchup pouch in the bottle by folding is over to make it fit in the top of the bottle. Screw on the cap of the bottle. Squeeze the bottle. This is called a Cartesian diver. What did your pouch do when you squeezed the bottle?

8. Fill an empty soda bottle almost to the top with water. Place your unopened ketchup pouch in the bottle by folding is over to make it fit in the top of the bottle. Your pouch is a sinker and will go to the bottom of the bottle of water. You need to make the water more dense so that the pouch will float. Add a tablespoon or so of Kosher salt to the bottle. Shake to dissolve the salt. If the pouch does not float, add more salt and shake until the pouch floats. Screw on the cap of the bottle. Squeeze the bottle. This is called a Cartesian diver. What did your pouch do when you squeezed the bottle?

Conclusions:

1. Potato slices are fried in fat before they are packaged as chips. The packages must provide an excellent barrier to oxygen gas, light, and moisture to keep the chips from going rancid and having an unacceptable taste. Have you ever seen a clear bag of potato chips? Why or why not?

2. In the labeling of the potato chip bag, one of the layers is an adhesive that holds the printed film to the metallized aluminum layer. Which layer is the metallized layer: first, second, third or fourth?

3. In the candy wrap, there is an “overlacquer” layer covering the printed layer. Now label the layers.

Candy Bar Wrapper

4. When one squeezes the bottle to make the pouch dive, do you increase the pressure of the gas in the bottle or decrease it?

5. As the pressure changes in the bottle upon your squeezing, the volume of the pouch changes slightly. Does the pouch get smaller or larger? The mass does not change since the ketchup stays in the pouch.

6. Using the definition of density as mass divided by volume, explain why the diver dives by squeezing the bottle. (D=M/V)

7. If one did not have the technology of plastic films, what would be the consequences of purchasing snack foods like potato chips and candy bars?

Teacher Notes for Potato Chip Bags, Candy Bar Wraps, and Single-Serving Ketchup Pouches Investigation:

Snacks with a high fat content are usually packaged with a high salt content too. Salt is a catalyst for oxidative rancidity of the snack. Packaging must block water vapor transmission and light transmission. Light harms these products so packaging is usually opaque. Most flexible bags are multilayered. The pigmented plastic films prevent light from entering. Metallized films are barriers to gases and light. To metallize a plastic like PP or PET, the aluminum is introduced into a chamber at a temperature of 1500-1800°C. The aluminum vaporizes into tiny particles that migrate to the plastic film. If air molecules are present, they would deflect the aluminum so the whole process is done in a vacuum chamber. Also the presence of oxygen would cause the aluminum to be dull and one wants a highly reflective surface of shiny aluminum on the plastic to reflect light away from the contents. If you can see the printing on the front of the package when it is back lit, this is evidence of a metal coating on the plastic and not an aluminum sheet bonded to the plastic. It is much cheaper for the manufacturer to metallize a film rather than use a thin layer of aluminum foil in the package. Vending machines frequently rely on metallized films for packaged food since the marketing environment is poorly controlled.

Opening a potato chip bag can be quite a chore! The long back seam in the back must be strong so to resist splitting in handling. The top and bottom seals of the same bag are made equally strong since the same adhesive and temperature settings are used.

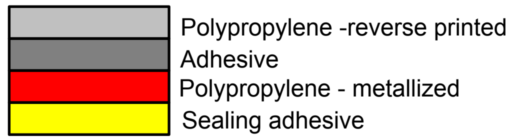
Corn chips are made from a corn flour paste called "masa". The masa is rolled into sheets and then cut into chips. The chips are baked and fried at high temperatures to toast slight amounts of corn to give the chips their characteristic taste. The package must have a moisture barrier but an oxygen barrier is less important. The oxygen in the bag will cause rancidity in 10 to 12 weeks. No light barrier (low fat content) is needed so these bags tend to be transparent.

The use of ketchup pouches to make Cartesian divers is not a new idea. It is fun, however! Some pouches float in water and some sink. Try to get a selection of brands from different fast food restaurants for this activity. Using Kosher salt will keep the water clear and transparent. Using table salt, makes a cloudy solution. Any size PET bottle will work, even the "spring water" bottles. If students add too much salt so that the pouch floats and will not dive, just pour off some salt water and add pure water to the bottle and shake. NOTE: Jack-In-The-Box ketchup pouches are <u>not</u> foil-packed.

Conclusions:

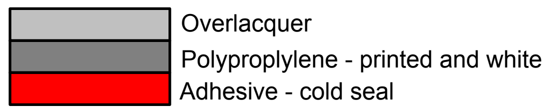
1. Potato chip bags are opaque to prevent light from oxidizing the chips and making them go rancid.

2. The potato chip bag layers are:



Potato Chip Bag

3. The candy wrap layers are:



Candy Bar Wrapper

4. The pressure in the bottle is increased when you squeeze the bottle.

5. The volume of the pouch decreases slightly. As the pressure on the gas in the bottle increases, the pressure on the gas in the pouch also increases and the volume of the pouch decreases. This is Boyle's Law.

6. Suppose we put some numbers into the formula:

$D = M/V$ Situation One: D = 4g/5 mL = .8 g/mL and the object floats
Situation Two: D = 4g/3 mL = 1.3 g.mL and the object sinks

When the mass does not change and the volume decreases, the density must increase so the diver dives.

7. Without plastic films, snack foods would deteriorate a lot sooner. The shelf life would be shorter. Prices would be higher if one had to use aluminum foil.

V. Microwave Popcorn Investigation

The microwave popcorn boom is just one example of how manufacturers and packaging experts have combined their talents to bring a convenient product to the consumer.

Purpose: to discover the unique design of microwave popcorn packages and to investigate brands, kinds and percent popped.

Time: two class periods for all the observations and conclusions

Links: Technology, Mathematics

Materials: several brands and kinds of unpopped and popped bags of microwave popcorn, have the price of each box of popcorn available, a pair of students needs one unpopped and one popped bag, balance

Procedure:

A. Investigate the mass of the total package:
Give a pair of students one unpopped microwave bag of popcorn (with no clear outer packaging). Find the mass of an unopened bag of popcorn and record. Note if this is light or regular popcorn. Compare your numbers with others in the class.

B. Investigate the number of kernels per brand:
Look at the ends of the popped bag of popcorn. What do you observe about the seal? Count the number of popped kernels and unpopped kernels of popcorn in a bag. Calculate the percent popped for your brand and kind of popcorn. (% popped = [#popped/total number of kernels] times 100) Prepare a data table for this information. Put your data with the class data for all to see.

C. Investigate the packaging
Determine the layers in the package and the purpose for each layer using the popped bag from procedure B. Find the special layer that can absorb microwave energy and reradiate it as infrared energy to increase the temperature inside the bag? Where is this layer located in relation to the position of the bag in the oven? Sketch a cross section of the layers in the bag. What is the shape of the absorbing layer (rectangle, triangle, circle)?

Conclusions:
1. Compare the masses of packages of unpopped popcorn. Is there a difference between regular and light? Is there a difference between brands?
2. How did the seals on the ends of the popped bag look before you opened the bag?
3. Do all brands of microwave popcorn have the same number of kernels? Which brand had the most? Least?
4. Which brand had the most percent popped? Least?
5. Calculate the cost per bag and the cost per kernel for each brand.

6. Compare your sketch in Part C with others. Is the layer for absorbing microwaves in the same position in all brands? Is it the same shape/size?
7. How does this absorbing layer differ from the outside layer of the package?
8. Explain how popcorn pops. What is the white fluffy stuff?

Teacher Notes on Microwave Popcorn:

This activity has students design their own data tables and encourages them to take notes. If a class needs more direction, provide them with tables to fill-in as students progress through the procedure.

The microwave popcorn bags vary in construction. One has a paper outer layer with a PET (same polymer that is found in the two-liter bottle) inner layer. The PET layer prevents the fat and oils to be absorbed by the paper outer layer. Paper is very inexpensive. There is a low melting adhesive for the ends so that when the popping cycle is almost complete, the seal melts in the steam, and opens the ends for gases to escape. The special layer for reradiating energy is located under the paper layer and inside the inner layer of a polymer film. This layer is called the susceptor and it is a metallized PET film. Aluminum is sprayed onto the film in a vacuum chamber to prepare this metallized film. All producers of these packages now use a susceptor in one geometry or another. They do not have to cover the entire package. The susceptor is placed on the bottom of the microwave oven with the corn resting on top. Other packages might use OPP (oriented polypropylene) for an overwrap which costs less than PET. The package is still evolving since manufacturers are striving to minimize unpopped kernels.

Data Table of mass measurements for packages of microwave popcorn:

Brand of Popcorn (No clear outer packaging present on package.)	**Mass of unopened package #1**	**Mass of unopened package #2**	**Mass of unopened package #3**	**Average Mass/package**
Orville Redenbacher Light	101.39 g	99.84 g	101.11 g	100.78 g
Orville Redenbacher Regular	119.48 g	117.36 g	119.03 g	118.62 g
Pop Secret Light	103.40 g	102.55 g	102.35 g	102.77 g

The three kinds of popcorn (in the table) had rectangular-shaped susceptors. Orville Redenbacher popcorn had an average of 94% popped (for 3 minutes on high) with about 460 kernels per bag.

Popcorn contains mostly the translucent endosperm as opposed to the opaque endosperm. This endosperm is penetrated by the high pressure steam while the popcorn is heating. The starch granules change into gelatinized gobules and then expand into thin fusable bubbles as the pericarp is burst by the pressure of the water vapor. The pericarp is the protective layer on the outside of the kernel. It breaks at about a pressure of 9 atmospheres. (*ChemMatters* October, 1984)

VI. Saran Wrap Investigation

Purpose: to discover the "memory" of Saran Wrap at various temperatures

Background: The potential energy stored in the extended molecules of Saran Wrap has "elastic memory". When the plastic is reheated near its orientation temperature of the manufacturing process, it shrinks, as the molecules tend to return to the original spatial arrangement in the sheet of plastic.

Links: Technology, Mathematics

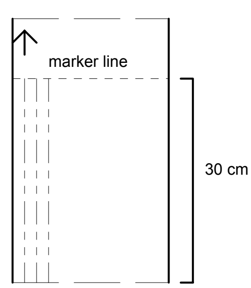
Time: One laboratory period

Materials: (for a class of 30 working in pairs)

- One roll of Saran Wrap made by S.C. Johnson a Ziploc® Brand
- 15 scissors
- 15 - 30 cm rulers or meter sticks
- 15 markers
- hot water bath at an assigned temperature with a thermometer
- stirring rod or spoon
- tongs (optional)
- one poster board with axes drawn and transparent tape

Procedure:

1. Tear off a piece of Saran Wrap approximately 40 cm long. Make sure the torn edge is straight. If it is not, use scissors to make it straight and perpendicular to the outer edge.
2. Use a marker to draw a small arrow at one end to indicate the direction in which the sheet came off the roll.
3. Holding the sheet along the width edge (not the 40 cm length edge), use a ruler and a marker to make a mark at the 30 cm position on the lengthwise direction.
4. Make two more marks in the same way, one in the middle and one at the other edge of the sheet.
5. Draw a line connecting the three marks.
6. Cut the sheet along this line.
7. Mark off strips in the direction of the arrow that are 3 cm wide. Cut three strips.



Saran Wrap

8. Get your assigned temperature or your temperature bath from your teacher. Heat a beaker half filled with water to the assigned temperature or make sure your temperature bath is at the assigned temperature before you proceed. Check the temperature with a thermometer.
9. Put one strip of Saran Wrap into the water.
10. Stir the strip with a stirring rod or spoon. Make sure the strip is under the surface of the water for part of the time.
11. After about one minute, pull the strip out with a pair of tongs or "catch" it with the spoon. Be careful some strips will be very hot.
12. Place the strip on the counter or tabletop to cool if needed. Try not to tear the strip as you straighten it. Measure its length in cm. Record in the data table below.
13. Repeat steps 9-12 for the other two strips.
14. Choose a strip, which is intermediate in length, and give it to your teacher. Make sure to tell your teacher the temperature bath for your strip.

The teacher will place each strip from each temperature bath on the poster.

Data Table: Original length of Saran Wrap strip = ________ cm

Temperature bath = _______ ° C	**Length of strip after being in water bath**
Strip #1	
Strip #2	
Strip #3	
Average length in cm	

Conclusions:

1. One strip from each temperature bath is now displayed on the poster graph for the class. Do you see any trend in the length of the strip compared with the temperature? Explain.

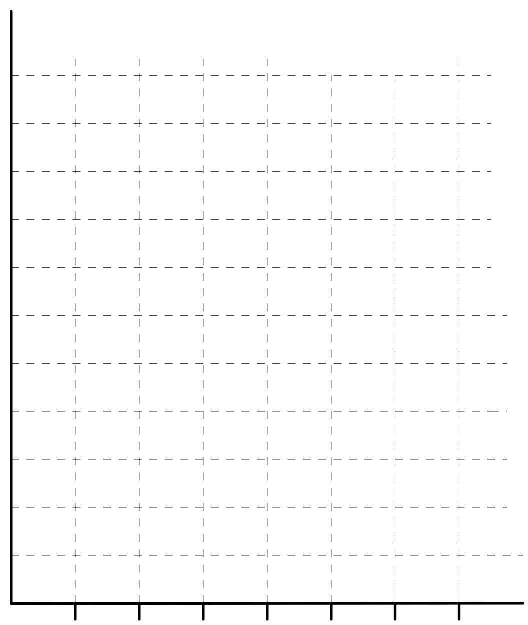
2. Calculate the average length of your three strips and place that number on the data table. Show your work here.

3. Find the <u>average</u> length of each strip for all the various temperature baths. See the chalk board of the class data or visit other groups to get the data. Record the results

below: (remember each strip started out at 30 cm) Fill the other columns by doing the math requested.

Temperature bath in ° C	**Average length in cm**	**Difference in length in cm**	**Percent difference = (Difference/30 cm) x 100**
40			
50			
60			
70			
80			
90			
100			

4. Make a line graph of the class data for the percent difference in cm length. Place the independent variable on the X axis and the dependent variable on the Y axis. Label the axes and title your graph.



5. Which temperature had the greatest shrinkage in the food wrap? ______________
6. Which temperature had the least shrinkage in the food wrap? _____________
7. How does your line graph compare to the poster bar graph? Explain.

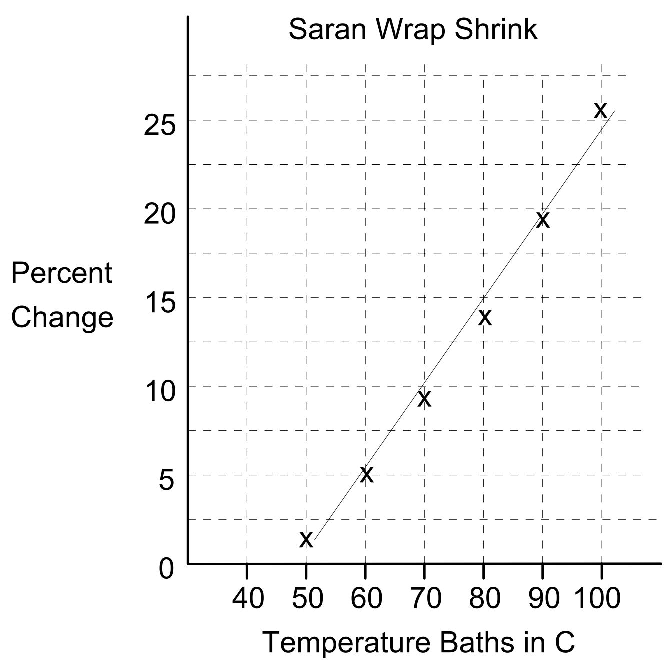
8. Does the shrink-ability of Saran Wrap make it an inferior food wrap?

Teacher Notes for Saran Wrap Investigation:

Saran was the first shrink film. It is a copolymer made out of poly(vinylidene chloride) with vinyl chloride. It has a symbol of PVdC. It shrinks below 100°C while most other films shrink at temperature exceeding 100°C. The potential energy stored in the extended molecules has "elastic memory". Making Saran Wrap involves blowing a bubble of hot Saran, and using air to cool the bubble into a film. During this process, orientation of the molecules is introduced which causes the wrap to "de-orient" when exposed to hot water. When the plastic is reheated to its orientation temperature of the manufacturing process, it shrinks, as the molecules tend to return to the original spatial arrangement. Other food wraps may not demonstrate this "memory".

The teacher needs to provide several hot plates with 250 mL or 400 mL beakers of water heated to various temperatures depending upon how many temperatures are being studied. The recommended temperatures are 40, 50, 60, 70, 80, 90, and 100° C.

1. The poster graph is a large poster board with the axes drawn. The x axis is the temperatures starting at 40°C and going up to 100°C. Allow for each strip to be 3 cm wide with a one cm space between each strip. This makes the axis at least 30 cm long. The y axis is the length of the strips in cm. The maximum height will be 30 cm. Use transparent tape to stick the strips to the graph. The 40°C bath will have a strip 30 cm long since no shrinkage is seen at this temperature.
2. The average length is calculated by adding the three strip lengths and dividing by three.
3. The percent difference will range from 0% at 40°C to about 25% at 100°C.
4. A typical line graph for this experiment looks like this:



5. The greatest shrinkage is at 90°C or 100°C.
6. The least shrinkage is at 40°C or below.
7. The two graphs represent the same data. One is the average length at each temperature and the other is the percent change.
8. Saran Wrap is an excellent food wrap and one does not usually heat the wrap so this shrink property is not a concern.

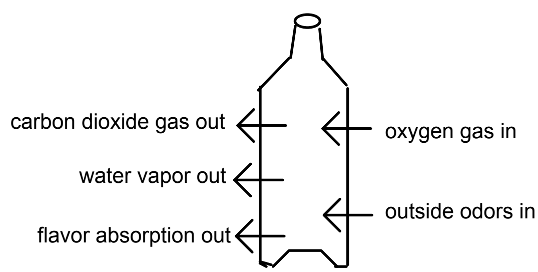
   Saran Wrap provides a barrier to oxygen, water, and odor that other plastic wraps do not provide. To demonstrate the barrier property, wrap one-half an onion in Saran Wrap and the other half in Glad Wrap or Handi-Wrap. Wait 10 minutes and smell both wrapped packages.

VII. **PET Bottle Demonstration and Two Investigations**

Purpose: (Demonstration)To discover the time it takes for soda to go flat while packaged in PET. (Investigation One) To compare the volume of a PET 2-liter soft drink bottle to that of a PET 1.89-liter juice bottle (Ocean Spray®) before and after exposure to boiling water. (Investigation Two) To use mathematics to predict the size of a square on the surface of a PET bottle.

Links: Technology, Mathematics, History, Physical Science

Background: In the spring of 1977, the PET soda bottle was introduced by Pepsi® followed soon by Coca-Cola®. The early designs had a round base which was enclosed in a HDPE cup. This added problems for the recyclers since the two plastics had to be separated at the recycling plant. Now the PET bottle has four or five protuberances on the base that form feet. A 1-liter bottle weighs 34 g and a 2-liter bottle weighs 48 g. There are many factors that influence the taste of carbonated beverages. Below is a figure of a PET bottle and some of the factors that packaging people must consider.



Schematic Drawing of a PETE Bottle

PET is a plastic that can successfully provide a clear, strong bottle, and one that is mostly impermeable to carbon dioxide. Bottles, larger than one-half liter, have a shelf life of three months. Bottles less than one-half liter cannot hold the pressure that long.

Wholesalers of “Spring” water or “Natural” water sold in plastic containers have many choices for packaging their product since these are not carbonated like soda or “pop”. Europe has used PVC bottles with their clear, high gloss appearance and consistent taste of the water for years. The U.S. market has stayed away from PVC since the 1974 scare about residues in the plastic causing cancer. This problem is now solved but the adverse publicity lingers. HDPE containers are translucent and would not display the clear water very well to the consumer. PP containers are not in the recycle loop. So the PET bottle is the most widely used. About 70-80% of the resin consumption is used for soft-drink bottles.

Producers of barbecue sauce also use PET bottles which allows for the oxidation of the sauce by oxygen gas going into the bottle. The sauce turns brown! However, the sauce is brown already. The browning of red ketchup would not be acceptable to consumers. In 1991, Heinz announced that it would be using a construction of

PET/EVOH/PET/EVOH/PET with only 1.5 % EVOH. (EVOH is ethylene-vinyl alcohol copolymer.) These layers can be easily separated and so the bottle is recycled.

Time: Part of one laboratory period to start the demonstration. The total time will be one year. One laboratory period for the volume comparisons of PET bottles in investigation one and one more laboratory period for investigation two.

Demonstration:
Materials for demonstration:

One six pack of Coca-Cola® or Pepsi® in small PET bottles (16.9 oz or 24 oz)
6 balloons - 10 in or 12 in
tape measure

Procedure for demonstration:
1. Take a new bottle of soda, remove the cap and place a balloon over its neck. Make sure you can hold the neck of the balloon tight to the neck of the bottle.
2. Shake the bottle to release the carbon dioxide into the balloon. Keep shaking and collecting until no more gas evolves. Measure the circumference of the balloon.
3. Test another bottle after 3 months, 6 months, 9 months and 12 months. Record.

Investigation One:
Materials for investigation one: (for a pair of students)

One empty 2-Liter soda PET bottle
One empty 1.89-Liter PET juice bottle (Ocean Spray®)
Source of boiling water- 4 liters
Graduated cylinder - 100 mL or larger is preferred
Sink or tub that will hold the bottles

Procedure for investigation one:
1. Fill the 2-liter soda bottle to the brim with water. Pour the contents of the bottle into the graduated cylinder (many times) to measure the exact amount of water that the container will hold. Record the total volume of the bottle.
2. Fill the juice bottle to the brim with water. Pour the contents of the bottle into the graduated cylinder to measure the exact amount of water that the bottle will hold. Record the total volume of the bottle.
3. Place both bottles in a sink or tub. Have your teacher pour 4 liters of boiling water over the two bottles. Let them cool.
4. Find the total volume of water that each bottle will hold. Record.
5. Calculate the percent change for each bottle. Percent Change =([volume of original - volume of heated bottle]/ volume of original) x 100

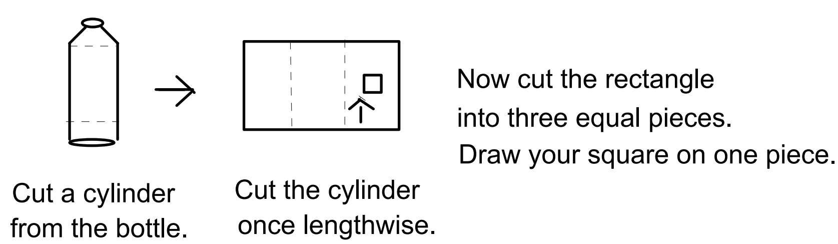
Data Table:

Bottle Type	Total Volume in mL	Total Volume in mL after boiling water	Percent Change
PET 2-Liter soda			
PET 1.89-Liter juice			

Conclusions:
1. Compare your data of percent change with others in the class. What can you conclude?
2. Based on your observations, which liquid (soda or juice) was heat-filled as it was packaged? Why?
3. Besides the shape of the two bottles, what do you notice about the differences in the two bottles?
4. Explain the behavior of the PET soda bottle when exposed to boiling water using a "molecular" description. In other words, what are the chains of PET doing to explain your observations? (Hint: Think about the Saran Wrap experiment.)

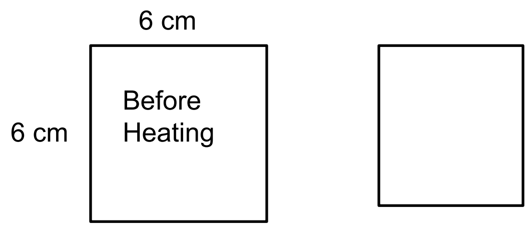
Investigation Two:
Materials for investigation two: (for a pair of students)
- One empty 2-Liter PET soda bottle
- Scissors
- Permanent marker
- Metric ruler
- Boiling water and tongs

Procedure:
1. Cut a cylinder from the PET soda bottle. Cut the cylinder with only one cut through the cylinder. See the diagram below:



2. Cut the rectangle of PET plastic into about three equal 11 cm wide pieces.
3. Using a permanent marker, draw a square 6 cm x 6 cm in the center of one of the 11 cm pieces. Draw an arrow on the plastic piece to show the lengthwise direction.
4. Place your plastic in boiling water for 15 sec. Remove with tongs. Let cool.

5. Measure the rectangle in cm. Record the new dimensions on the rectangle below.



6. Using your skills in mathematics, calculate the rectangle that must be drawn on the second piece of PET plastic so that when it is exposed to boiling water, the resulting figure will be a square with 5 cm dimensions. Remember the width and length shrink at different rates!

7. Draw your rectangle on the PET piece and place it in boiling water for 15 sec. Remove with tongs and let cool. Were you successful? If not, there is one more piece of plastic to draw your second rectangle.

8. Turn in the plastic piece with the best 5 cm x 5 cm square to your teacher. Add your names to the plastic with the permanent marker.

Teacher Notes for PET Bottle Demonstration and Two Investigations:

The maximum shelf life for a 1.5 -2 liter bottle is about 16-17 weeks. At the end of this time, the carbonation will have dropped and the flavor of the product will have deteriorated. Reclaimed PET is in demand for fiber, sheeting, nonfood containers, strapping, and molding compounds. The demand for recycled PET will approach 1 billion pounds by the end of the 90's.

PET oven trays allow frozen food to go directly into the oven. These trays are a fast-growing new market for PET. They are heat-set to prevent deformation during cooking. They will not change shape when boiling water is poured over them like when PET soda bottles are subjected to boiling water. The new trays are suitable for the conventional oven and the microwave. They are light weight and attractive to the consumer.

PET film has great tensile strength, chemical resistance, light weight, elastic and is stable from -60 to 220°C. So this makes it ideal for a "boil-in-a-bag" idea. It is fine to take the frozen product and put it in boiling water. The film is stabilized by annealing or heat-setting it under restraint. This reduces the tendency to shrink under heat. The juice bottles are also stabilized by heat-setting so that this container can withstand heat filling of the juice. The neck of this particular juice bottle is white compared to the neck of the soda bottle which is clear. Note: Not all heat-set PET bottles have white necks.

Bottle Type	Total Volume in mL	Total Volume in mL after boiling water	Percent Change
PET 2-Liter soda	2048	1460	28.7%
PET 1.89 L juice	1980	1980	0%

In investigation two, students must be able to solve problems using proportions. All PET soda bottles will shrink in size when exposed to boiling water. The sides of the bottle are used in this experiment. Students need the "cylinder" of the bottle only. This may be cut from the bottle before the laboratory if scissors are a safety concern with students. Permanent marker will not wash off in the boiling water. One pot of boiling water for the class is fine since it only takes 15 seconds to shrink a piece of PET. Both colorless, clear and green bottles will work. Not all bottles shrink the same amount but since all do shrink some amount, any soda bottle will be fine for this experiment. A Pepsi® clear bottle had this data:

6 cm x 6 cm square was reduced to 4.9 cm x 5.4 cm rectangle after exposed to boiling water.
The width measurement decreased more than the length.
Students are asked to draw a rectangle of the correct size so that the square will be 5 cm x 5 cm after the plastic is put into boiling water. The mathematics are: $\frac{6\text{ cm}}{4.9\text{ cm}} = \frac{x\text{ cm}}{5\text{ cm}}$ for width $\quad \frac{6\text{ cm}}{5.4\text{ cm}} = \frac{x\text{ cm}}{5\text{ cm}}$ for length

x = 6.1 cm for width x= 5.6 cm for length

Allow for the dimensions of the square to be 4.9 to 5.1 cm per side.

History Link: Slogans for Coca-Cola®

1886 Drink Coca Cola.
1900 Good to the last drop. (Maxwell House Coffee picked it up later.)
1904 Delicious and refreshing.
1922 Thirst knows no season.
1929 The pause that refreshes.
1952 What you want is a Coke.
1958 The cold, crisp taste of Coke.
1963 Things go better with Coke.
1970 It's the real thing.
1982 Coke is it!
1986 Catch the wave.

VIII. Vacuum Packing Demonstration

Purpose: To simulate vacuum packing coffee or other foods**.**

Background**:** Vacuum packaging involves placing a perishable food inside a plastic film package and then removing the air inside the package so that the packaging material remains in close contact with the product surfaces. By the removal of air and keeping products under refrigeration, the prevention of chemical and microbial deterioration of the food is greatly reduced. Once the air is expelled and the package is sealed, oxygen levels continue to drop and carbon dioxide levels increase. This low oxygen concentration reduces the growth of normal spoilage organisms, which allows for longer shelf life.

The key to extending the life of any product is to select top quality and fresh foods and to prepare them in a sanitary manner. Some products such as cheeses and meats need refrigeration of the vacuum package while others like nuts and coffee do not require refrigeration. Some of the methods of air-removal are:

- Putting a nozzle connected to a vacuum pump inside the open end of a bag or pouch. (used for poultry, vegetables, fresh meats, fish, nuts)
- Placing the product inside the flexible plastic film which is loaded into a chamber where the whole chamber is put under a vacuum. (use for fresh meats, processed meats and natural cheeses)
- Placing the produce between two layers of multilayer films where the bottom is heated and then vacuum and pressured formed. (used for hot dogs, luncheon meats, sliced bacon, natural cheeses)

Legend has it that around 1200 years ago in Ethiopia, a goat herder named Khaldi disovered the magic of coffee. Then around 575 A.D., the Ethiopians began cultivation of the wild coffee plants. In 1723, a French naval officer named Gabriel Mathieu de Cheu stole a coffee seedling on the Caribbean Island of Martinique bringing it to Brazil and Columbia which now produce over 90% of all coffee production. In 1878, roasted coffee was packed and sealed in cans for the first time by Chase and Sanborn. Then in 1890, Hills Brothers in San Francisco were the first to vacuum pack roasted coffee in cans.

Metal cans of coffee are being replaced by flexible packaging. The carbon dioxide remaining in the ground coffee slowly escapes along with other volatile aroma gases. The gases reach equilibrium in several weeks with a positive pressure of 2-5 pounds per square inch. The design of the flexible package must allow for this pressure increase over time. Ground coffee must be kept in a vented bin for four to six hours to allow residual carbon dioxide to escape before packaging. The vac-bag becomes soft and can balloon like a football if the coffee has not been sufficiently degassed. Some packages have a carbon dioxide absorber in the package which is a little pouch filled with calcium oxide and activated charcoal. The "brick" pack is a heat-sealed laminate of layers. One such laminate is: PET, polyethylene (PE) or polypropylene (PP), aluminum (Al) foil and finally polyethylene. The Al layer is the gas barrier. The PET layer is tough and resists puncturing by sharp ground bean fragments. The PE layers are sealants. The whole process of making a brick pack of coffee takes about 5 seconds. A one pound coffee can with a plastic overcap costs about $0.18. The four-ply vac bag for one pound of coffee costs about $0.09. The vac bag is in the shape of a brick for easy packing, handling and shelving.

Links: Technology, Physical Science

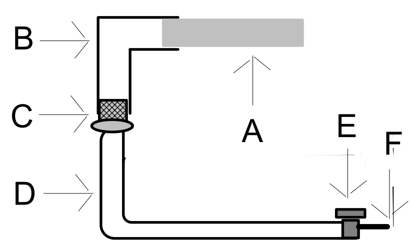
Time: a few minutes to demonstrate vacuum packing of coffee

Materials:

- 24 inches of ¼ inch braided PVC tubing (D)
- Waxman 07-852 nylon male adapter (threaded) (C)
- ¾ inch x ½ inch PVC elbow (B)
- ¼ inch metal hose clamp (E)
- basketball inflating needle (F)
- 6-8 inch ¾ inch 40-PVC pipe (A)
- hand vacuum or larger Shop Vac
- polyethylene bag with ground roasted coffee inside - heat sealed
- duct tape

Procedure:

1. Construct the vacuum packing adapter as illustrated in the diagram. If the nozzle on either the Shop Vac or hand vac is not ¾ inch, then it may be necessary to modify the adapter to fit your cleaner. The ¾ inch PVC schedule 40 piece should be inserted into the Shop Vac nozzle and sealed with the duct tape to form an air-tight seal.



Adapter for Vacuum Packing

2. Puncture a small hole in the heat-sealed coffee bag with the needle.
3. Insert the needle into the hole and turn on the vacuum machine.
4. Watch the air being removed from the bag. The coffee gets quite hard and this simulates a "brick-type" package.
5. As soon as the vacuum is turned off the air rushes in and the hard brick of coffee is no longer under vacuum.

Conclusions:
1. The misconception that air is "sucked" out of the bag is common. Newton never used the word "suction" but rather words like push and pull to describe forces. Describe this demonstration using push and pull.
2. Would it be possible to use a thicker or less flexible container for vacuum packing? Explain on the molecular level.
3. Which container, the metal can or the flexible bag, is more environmentally friendly? Explain.

Teacher Notes for Vacuum Packing Demonstration:

1. The air in the bag is pushed out of the bag by atmospheric pressure acting on the flexible bag wall as the vacuum machine decreases the inside pressure. As the pressure in the bag begins to decrease, the volume will decrease to reestablish equilibrium with atmospheric pressure on both sides of the flexible wall. Thus, when a flexible bag is connected to a vacuum pump, the volume is decreased while the pressure inside the bag remains essentially constant. If the pump were connected to a rigid container, the interior pressure would be decreased but the volume would remain constant.
2. A thicker container would not be as good since the bonds are stronger or there are more of them so that the polymer strands could not bend around the food product for a tight seal.
3. The flexible bag is more environmentally friendly since it crushes into a smaller space in the landfill. A disadvantage of this package is that it is not biodegradable.

Application or Assessment Activity for the Learning Cycle

Purpose: to play the role of a packaging engineer and rate food packages based on the various functions that food packaging must meet.

Links: Language Arts, Technology

Time: One laboratory period for the evaluation of the packages and more time will be needed to answer the conclusion questions.

Materials: (for a classroom of students)

A selection of empty food packages that include:

small box from raisins, small box or bag from breakfast cereal, bag from mini-carrots from the produce department (some have no holes while others do), bag that had cookies, bag that had pretzels, bag from popped popcorn, paper wrapper from bubble gum or Tootsie Roll®, Astro Pop® sucker, others of your choice

Procedure:

1. Look over the food packages you are given. Be very observant. There are reasons for each package as you have discovered doing the activities in this module.
2. Using the scoring rubric on the next page, rate each package.
3. You must add one more category to make the total 40 points for each package. Suggestions for an additional category might include the following:

   shelf display in the store, promotion of the product by its design, reusable, or other categories
4. Total the scores for each package.

Conclusions:

1. Write a short report about your ratings. Which package rated the best score and why? Which package ranked the lowest and why?
2. Which category did you pick for the last column of the evaluation? Why?
3. Is the best-ranked package the safest for the consumer?
4. Using the food package that ranked the <u>lowest</u>, describe how a packaging engineer might improve the package. Label any diagrams or sketches.

Scoring Rubric for Evaluation of Food Packages

Rate each package in each category with 4, 3, 2, 1 or zero points.

4= Excellent, does the job well. 3= Good, but one minor problem.

2= Fair, obviously has a problem 1= Poor, definitely has problems. 0= Not acceptable, fails to do the job.

Package	Preserves freshness	Easy to dispense	Easy to open	Uses minimum of resources	Easy to reseal	Protects from bugs and dirt	Protects from tampering	Durable during transport	Easy to store in the home		Total Points (40 pts. max)
Raisin box											
Cereal box or bag											
Carrot bag											
Cookie bag											
Pretzel bag											
Popcorn bag											
Gum or Tootsie Roll® wrapper											
Astro Pop®											

Teacher Notes on Assessment Activity:

Small raisin boxes come packaged in a plastic bag to preserve freshness. The box alone will not do a very good job of keeping the raisins moist.

The packages of cereal vary greatly due to the specific cereal inside:

- Kellogg's Corn Pops has a foil liner. (for highly sweetened and moisture sensitive products)
- Kellogg's Special K and Crispix have plastic liners. (Two polymers, HDPE and EVA, extruded together to keep the cereal dry.)
- Most boxed cereals have waxed paper liners. (overwaxed paper saturated with PVA or other polymer which are low cost but excellent barriers to moisture and oxygen)
- Quaker Cereals in bags. These are very durable and thick. They are made out of a laminate of a saran coated oriented polypropylene and an oriented high density heat sealable film. (Quaker Bagged Cereals has seen a huge increase in sales. Bagged cereals as a whole is up 31% in 1997.)
- Off brands in bulk bags. These are thinner and less durable.

Some mini-carrot bags have holes to let the gases move in and out. The ones without holes make the carrots "mushy" with time.

Cookie bags are either paper with a plastic liner or just plastic. Some are easy to reseal and others are not. Some have another layer of liner such as a tube of cookies inside the original bag.

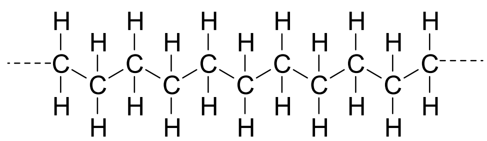
Popcorn bags have foil on the inside to prevent sunlight reacting with the oils on the popcorn to cause spoilage. Pretzel bags do not have to have this foil layer.

Coated paper gum wrappers do not keep the bubble gum nor Tootsie Rolls® fresh for very long.

An Astro Pop® is a unique package. The liquid sugar syrup is poured into the cone wrapper and it hardens in the paper mold. Most suckers are wrapped after the sucker is hardened.

Extension Activity - Making a Flip Book for the Life Cycle Of "Poly Ethylene"!

A flip book is a series of pictures that tell a story when the pages are flipped in rapid order. The story is about "Poly Ethylene" . She is the giant molecule that comes from crude oil. The oil is under high temperature and pressure to produce molecules of ethylene or C_2H_4. Later ethylene is polymerized to make polyethylene which is a molecule like this:



The first few pages for the flip book are given on the next page and a blank set of pages for the book is also included.   The story begins with "Poly" being made from a barrel of oil. Your task is to complete the story by adding the ending. Polyethylene in the form of LDPE or HDPE can be made into any number of products. You choose the product or food package for your Poly. Show it by drawing a series of pictures on the "pages" of the book. To make the frames "move" in the movie, draw a sequence of pictures that change just slightly in location on the page. After the product is made, you need to finish the story of Poly Ethylene. She can be recycled, reused, or she becomes waste that goes to the land fill. Draw your story and let others figure out the ending.

Here are some facts about plastics in packaging that might be of interest to you and your story-making endeavors:

- Plastics occupy about 7% by weight and about 18% by volume of municipal solid waste in the U.S. These figures have remained unchanged in the last 20 years, despite increased use of plastics packaging. The increased amount of food packaged in plastics has been offset by increased efficiency in terms of the amount of packaging required per unit weight of food.
- We can no longer go back to paper packaging. Paper cannot perform the functions that are demanded by consumers like moisture, light, and gas barriers. It has been estimated that replacement of plastics by traditional packages would double the volume of packaging waste and quadruple the weight.
- Less than 2% of <u>all</u> plastics produced in the U.S. is recycled compared to about 30% for paper and 50% for <u>aluminum containers</u>. Aluminum in foil or other packages is not recycled. 5% plastic packaging is being successfully recycled. PET and HDPE are the most recycled.
- Some items may be excessively packaged, but they consume a tiny fraction of the total packaging materials that are used. Economic factors tend to minimize the amount of excessive packaging for most items. Upon further study, many components of packages turn out to serve a function that may not be immediately obvious to consumers.

Cut out your pages, place them in the correct order, and staple the left edge. Use a paper cutter to cut a very small amount off the right edge to make the pages exactly line-up for easy flipping.

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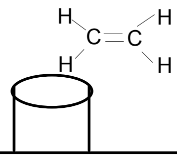

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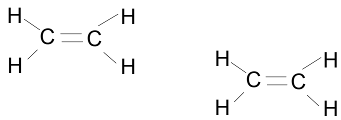

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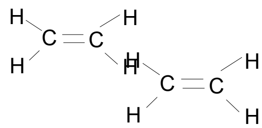

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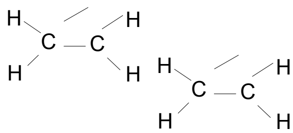

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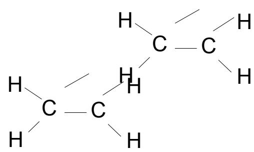

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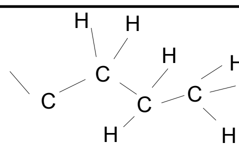

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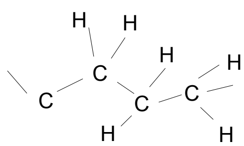

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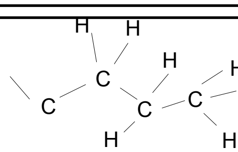

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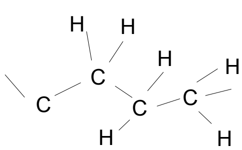

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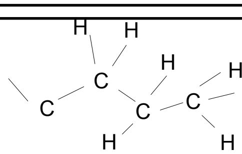

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Poly Ethylene

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Poly Ethylene

Poly Ethylene

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Poly Ethylene

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Poly Ethylene

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