FOUNDATION

HOP KITS

HANDS-ON PLASTICS FROM THE SPE FOUNDATION

INSTRUCTOR'S NOTES

HOP Kits are made possible in part by

PPA SINCE 1948 Plastics Pioneers Association

THE HISTORY & **FUTURE OF PLASTICS**

WHAT ARE PLASTICS AND WHERE DO THEY COME FROM?

Plastic is a word that originally meant “pliable and easily shaped.” It only recently became a name for a category of materials called polymers. The word polymer means “of many parts,” and polymers are made of long chains of molecules. Polymers abound in nature. Cellulose, the material that makes up the cell walls of plants, is a very common natural polymer.

Over the last century and a half humans have learned how to make synthetic polymers, sometimes using natural substances like cellulose, but more often using the plentiful carbon atoms provided by petroleum and other fossil fuels. Synthetic polymers are made up of long chains of atoms, arranged in repeating units, often much longer than those found in nature. It is the length of these chains, and the patterns in which they are arrayed, that make polymers strong, lightweight and flexible. In other words, it’s what makes them so plastic.

These properties make synthetic polymers exceptionally useful, and since we learned how to create and manipulate them, polymers have become an essential part of our lives. Especially over the last 50 years plastics have saturated our world and changed the way that we live.

THE FIRST SYNTHETIC PLASTIC

The first synthetic polymer was invented in 1869 by John Wesley Hyatt, who was inspired by a New York firm’s offer of $10,000 for anyone who could provide a substitute for ivory. The growing popularity of billiards had put a strain on the supply of natural ivory, obtained through the slaughter of wild elephants. By treating cellulose, derived from cotton fiber, with camphor, Hyatt discovered a plastic that could be crafted into a variety of shapes and made to imitate natural substances like tortoise shell, horn, linen and ivory.

This discovery was revolutionary. For the first time, human manufacturing was not constrained by the limits of nature. Nature only supplied so much wood, metal, stone, bone, tusk and horn. But now humans could create new materials.

This development helped not only people, but also the environment. Advertisements praised celluloid as the savior of the elephant and the tortoise. Plastics could protect the natural world from the destructive forces of human need. The creation of new materials also helped free people from the social and economic constraints imposed by the scarcity of natural resources. Inexpensive celluloid made material wealth more widespread and obtainable. And the plastics revolution was only getting started.

THE DEVELOPMENT OF NEW PLASTICS

In 1907 Leo Baekeland invented Bakelite, the first fully synthetic plastic, meaning it contained no molecules found in nature. Baekeland had been searching for a synthetic substitute for shellac, a natural electrical insulator, to meet the needs of the rapidly electrifying United States. Bakelite was not only a good insulator; it was also durable, heat resistant, and, unlike celluloid, ideally suited for mechanical mass production. Marketed as “the material of a thousand uses,” Bakelite could be shaped or molded into almost anything, providing endless possibilities.

Hyatt's and Baekeland's successes led major chemical companies to invest in the research and development of new polymers, and new plastics soon joined celluloid and Bakelite. While Hyatt and Baekeland had been searching for materials with specific properties, the new research programs sought new plastics for their own sake and worried about finding uses for them later.

PLASTICS COME OF AGE

World War II necessitated a great expansion of the plastics industry in the United States, as industrial power proved as important to victory as military success. The need to preserve scarce natural resources made the production of synthetic alternatives a priority. Plastics provided those substitutes. Nylon, invented by Wallace Carothers in 1935 as a synthetic silk, was used during the war for parachutes, ropes, body armor, helmet liners and more. Plexiglas provided an alternative to glass for aircraft windows. A Time magazine article noted that because of the war, "plastics have been turned to new uses and the adaptability of plastics demonstrated all over again."[1] During World War II plastic production in the United States increased by 300%.

The surge in plastic production continued after the war ended. After experiencing the Great Depression and then World War II, Americans were ready to spend again, and much of what they bought was made of plastic. According to author Susan Freinkel, "In product after product, market after market, plastics challenged traditional materials and won, taking the place of steel in cars, paper and glass in packaging, and wood in furniture."[2] The possibilities of plastics gave some observers an almost utopian vision of a future with abundant material wealth thanks to an inexpensive, safe, sanitary substance that could be shaped by humans to their every whim.

GROWING CONCERNS ABOUT PLASTICS

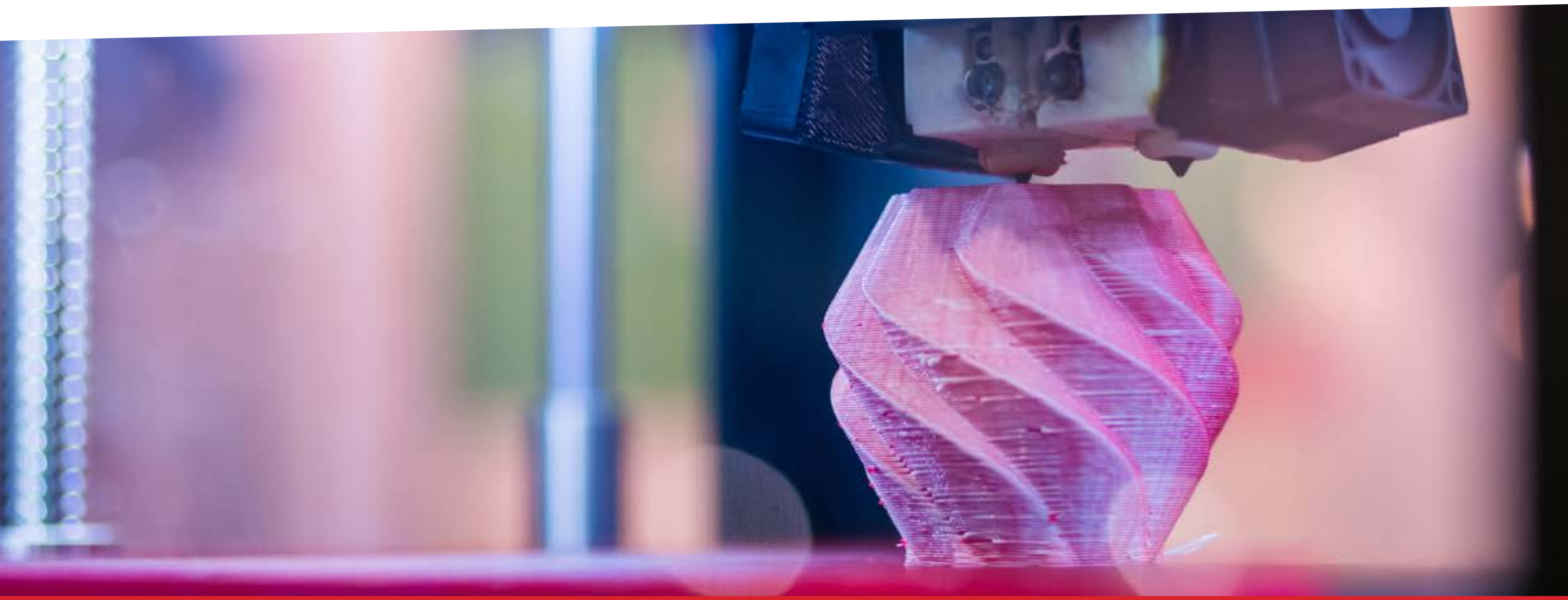
The unblemished optimism about plastics didn't last. In the post-war years there was a shift in American perceptions as plastics were no longer seen as unambiguously positive. Plastic debris in the oceans was first observed in the 1960s, a decade in which Americans became increasingly aware of environmental problems. Rachel Carson's 1962 book, *Silent Spring*, exposed the dangers of chemical pesticides. In 1969 a major oil spill occurred off the California coast and the polluted Cuyahoga River in Ohio caught fire, raising concerns about pollution. As awareness about environmental issues spread, the persistence of plastic waste began to trouble observers.

Plastic also gradually became a word used to describe that which was cheap, flimsy or fake. In *The Graduate*, one of the top movies of 1968, Dustin Hoffman's character was urged by an older acquaintance to make a career in plastics. Audiences cringed along with Hoffman at what they saw as misplaced enthusiasm for an industry that, rather than being full of possibilities, was a symbol of cheap conformity and superficiality.

PLASTIC PROBLEMS: WASTE AND HEALTH

Plastic's reputation fell further in the 1970s and 1980s as anxiety about waste increased. Plastic became a special target because, while so many plastic products are disposable, plastic lasts forever in the environment. It was the plastics industry that offered recycling as a solution. In the 1980s the plastics industry led an influential drive encouraging municipalities to collect and process recyclable materials as part of their waste-management systems. However, recycling is far from perfect, and most plastics still end up in landfills or in the environment. Grocery-store plastic bags have become a target for activists looking to ban single-use, disposable plastics and several American cities have already passed bag bans. The ultimate symbol of the problem of plastic waste is the Great Pacific Garbage Patch, which has often been described as a swirl of plastic garbage the size of Texas floating in the Pacific Ocean.

The reputation of plastics has suffered further thanks to a growing concern about the potential threat they pose to human health. These concerns focus on the additives (such as the much-discussed bisphenol A [BPA] and a class of chemicals called phthalates) that go into plastics during the manufacturing process, making them more flexible, durable and transparent. Some scientists and members of the public are concerned about evidence that these chemicals leach out of plastics and into our food, water and bodies. In very high doses, these chemicals can disrupt the endocrine (or hormonal) system. Researchers worry particularly about the effects of these chemicals on children and what continued accumulation means for future generations.



THE FUTURE OF PLASTICS

Despite growing mistrust, plastics are critical to modern life. Plastics made possible the development of computers, cell phones and most of the life-saving advances of modern medicine. Lightweight and good for insulation, plastics help save fossil fuels used in heating and in transportation. Perhaps most important, inexpensive plastics raised the standard of living and made material abundance more readily available. Without plastics, many possessions that we take for granted might be out of reach for all but the richest Americans. Replacing natural materials with plastic has made many of our possessions cheaper, lighter, safer and stronger.

Since it's clear that plastics have a valuable place in our lives, some scientists are attempting to make plastics safer and more sustainable. Some innovators are developing bioplastics, which are made from plant crops instead of fossil fuels, to create substances that are more environmentally friendly than conventional plastics. Others are working to make plastics that are truly biodegradable. Some innovators are searching for ways to make recycling more efficient and they even hope to perfect a process that converts plastics back into the fossil fuels from which they were derived. All of these innovators recognize that plastics are not perfect, but that they are an important and necessary part of our future.

[1]Nicholson JL and Leighton GR, "Plastics Come of Age,"Harper's Magazine,August 1942,
[2]Freinkel S,Plastics: A Toxic Love Story(New York: Henry Holt, 2011), p. 4.

THE MANY CHALLENGES OF PLASTIC RECYCLING

INTRODUCTION

Upwards of 100 million tons of plastic are manufactured annually across the globe. That's 200 billion pounds of new material on-market every year, ready to be thermoformed, laminated, foamed and extruded into billions of products and packages. In the past decades, it has been widely adopted by industry, and plastic has become one of the most ubiquitous and versatile materials in the world, and subsequently, one of the most difficult to reliably collect and recycle.

In the United States, our recovery rate for all plastic rests at 9 percent, according to the most recent Municipal Solid Waste report from the EPA. Most of what is recovered consists of PET and HDPE, as they clearly dominate the plastic recyclables market. Still, the recovery rates for PET and HDPE are only 29 percent and 31 percent, respectively. Even for our most valuable plastics, what are the challenges that prevent us from reaching higher overall recovery rates?

PIGMENTED PLASTIC

If plastic products were consistent in their resin composition, color, transparency, weight and size, we probably wouldn't be having this conversation, as everything could be recycled together; this is more or less the case with aluminum, which enjoys the highest rates of global recycling. With millions of different plastic products and packages on the market, clearly this is not the case. Dyed and pigmented plastics, for example, can be troubling for materials recovery facilities (MRFs) as they have a much lower market value.

Clear plastics are always preferred in the recycled materials market and have the highest material value. This is because transparent plastic can typically be dyed with greater flexibility. The next best is white, as its only limit is that it cannot become clear, but can be made into any other color. However, the colored plastics (especially opaque varieties) are often limited to become darker shades of the original dye, or black. For this reason, some recycling facilities consider certain pigmented plastics contaminants to the recycler stream, and subsequently dispose of them instead of recycle them. This issue is extenuated with the low cost of oil, as that makes it even harder for recyclers to compete with the price of virgin polymers.

Manufacturers who hope to ensure their post-consumer packaging can be properly recycled should consider the pigment and translucence of their bottles and containers. Even a PET container may not be recycled by some recycling facilities if it is colored and/or opaque.

"SUSTAINABLE" PACKAGING

Many manufacturers have turned to packaging alternatives lauded for their eco-friendly or sustainable properties. Multi-layered and other forms of lightweight packaging are one increasingly popular example. While source reduction is typically a great idea (and can certainly have practical applications), the light weighting trend does have some long-term side effects. For the most part, the sachets, flex-packs and laminated plastic pouches manufacturers are turning to are universally considered non-recyclable. This is less of a concern when recycling rates are low (sending a lightweight pouch to landfill is better than sending a heavy rigid plastic with more mass), but once recycling rates start to increase, non-recyclable lightweight options make little sense from a sustainability perspective.

Then there are bioplastics produced with renewable materials, such as plant biomass. While some varieties, especially the durable ones, can be regularly recycled alongside conventional plastics, others are viewed as contaminating materials and, as such, must be sent to landfill. Some even make claims of biodegradability, which can be misleading when you consider that many should typically be sent to industrial composting facilities to fully break down.

CONSUMER CONFUSION

In the late 80s, the Society of the Plastics Industry developed the resin identification code (RIC) to help recycling facilities identify the plastics they were processing. These small codes, printed on plastic bottles, containers and packages have helped many recycling facilities and MRFs collect, sort and process higher volumes of plastic materials with greater accuracy. This is great, but came with new drawbacks to consider.

The chief concern is that current RICs look strikingly similar to the universal recycling symbol, causing many consumers to mix non-recyclable plastics into the recycling bin. The responsibility then falls on the consumer to be aware of which resins are and are not accepted by their local municipal recycling program. In fact, many consumers have indicated that they are confused about which plastics they can and cannot recycle. Saturating MRFs with non-recyclable plastics can increase overhead sorting costs (only to be sent to landfill anyway).

There is good news ahead of us, however. In 2013, it was announced that revisions to the resin identification code would eliminate the use of the "chasing arrows" symbol in favor of an equilateral triangle, and some #7 plastics (or "Other" for miscellaneous resins) will have to identify the resin type in addition to the code. This could help limit some of the confusion for consumers, especially as the new revisions continue to be adopted by manufacturers moving forward.

GreenBlue's How2Recycle Label is another possible way forward, and is already being adopted by many of the world's largest brands and product manufacturers. By providing simple images and recycling instructions on each individual label, consumer-side confusion can be greatly mitigated. It all comes down to providing consumers with enough information to make the proper disposal choice for each component of the product or package.

THE FUTURE OF PLASTIC RECYCLING

In today's market, the only way to ensure plastics will be properly recycled is for manufacturers to make all of the above considerations when designing their products and packaging. This can be particularly challenging for products with strict packaging requirements, such as food or beverages that must use certain packaging formats to increase shelf life and preserve the product.

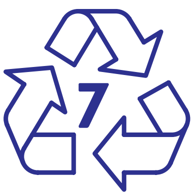
Recovery rates for plastic bottles are improving; single-stream recycling has helped increase recovery rates for many previously non-recycling communities; consumers are demanding packaging be made with more sustainable materials, and manufacturers are starting to listen; exciting innovations in plastic recycling are being developed; many states have enacted extended producer responsibility legislation for certain forms of waste; and a growing number of municipalities are banning certain difficult-to-recycle plastic products and are developing their own waste reduction and recycling goals initiatives. We are on the right path toward better recovery rates and more efficient recycling processes.

PLASTIC CONTAMINATION IN RECYCLING

From: *https://www.brentwoodplastics.com/blog/topic/ric*

Cradle-to-Cradle, Recyclability, Sustainability and Reclamation have historically been low priorities in design considerations. The biggest obstacle to these goals is dissimilar materials in the same product. Just as form follows function, selection of raw materials teamed up to do a job is determined by the properties raw materials can deliver.

Recycle Across America correctly attributes the recycling collapse and crisis to contamination, "... the collapse of recycling is primarily due to high contamination levels in the recycling stream. Contamination cripples the economics of recycling. The process to remove contamination reduces profitability, driving up the cost of recyclables, thereby preventing many manufacturers from reusing recycled materials. As a result, they continue to deplete finite resources at alarming levels."



Note how economic sustainability dovetails with environmental sustainability. The recycling business is tough at best because prices drop when there are more recycled materials are on the market. There is not enough margin to absorb the additional cost of sorting.

The more dissimilar materials are contained in a product, the more difficult it is to recycle for practical purposes. If a product contains more than one polymer, it should be labeled with a resin identification code (RIC) symbol 7.

So just make the product out of the same resin. Simple solution, right? Problem: one resin can't deliver all the attributes needed.

An example of several resins in one product is a soft drink cup with a straw and lid. It has three different polymers with three different job descriptions: The stiff and pliable straw is polypropylene, the rigid lid is polystyrene and the paper is coated with low density polyethylene. One resin is not versatile enough to do all three jobs.

Often the resolution to a problem is meeting halfway. This mailing envelope solves the debate over paper or plastic. Instead of an all polyethylene #4 recyclable envelope, it is made from both polyethylene bubble pack and kraft paper. This brilliant example of an unrecyclable #7 envelope satisfies all demographics. Proof that it satisfies the demands of the consumer for green products is its ubiquitous presence in UPS stores.

The recycler gets the cast-offs for free. The cost of goods is the cost of hauling and sorting. The bad news is that even if products could be made with only one resin, it would not be a solution. The major obstacle to recycling is indifference and confusion from the general public.

EXAMPLES OF MISUSE OF RESIN IDENTIFICATION CODES

This bag is comprised of about equal parts LDPE #4 and polypropylene #5. For practical purposes, it is not recyclable.

This bag is ostensibly high density polyethylene #2 HDPE. The mesh is #5 polypropylene and the film is low density polyethylene #4 LDPE.

This is an example of a properly executed resin identification code. The RIC #7 indicates the use of 2 dissimilar polymers which makes it a #7.

SOURCES OF RECYCLED PLASTICS

(These change from time to time)

1 POLYETHYLENE TEREPHTHALATE (PET OR PETE)
Soft drink bottles, water bottles, sports drink bottles, salad dressing bottles, vegetable oil bottles, peanut butter jars, pickle jars, jelly jars, prepared food trays, mouthwash bottles

2 HIGH-DENSITY POLYETHYLENE (HDPE)
Milk jugs, juice bottles, yogurt tubs, butter tubs, cereal box liners, grocery bags, shampoo bottles, motor oil bottles, bleach/detergent bottles, household cleaner bottles

3 POLYVINYL CHLORIDE (PVC)
Clear food packaging, wire/cable insulation, pipes/fittings, siding, flooring, fencing, window frames, shower curtains, lawn chairs, children’s toys

4 LOW-DENSITY POLYETHYLENE (LDPE)
Dry cleaning bags, bread bags, frozen food bags, squeezable bottles, wash bottles, dispensing bottles, 6 pack rings, various molded laboratory equipment

5 POLYPROPYLENE (PP)
Ketchup bottles, most yogurt tubs, syrup bottles, bottle caps, straws, dishware, medicine bottles, some auto parts, pails, packing tape

6 POLYSTYRENE (PS)
Disposable plates, disposable cutlery, cafeteria trays, meat trays, egg cartons, carry out containers, aspirin bottles, CD/video cases, packaging peanuts, other Styrofoam products

7 OTHER (O)
3/5 gallon water jugs, citrus juice bottles, plastic lumber, headlight lenses, safety glasses, gas containers, bullet proof materials, acrylic, nylon, polycarbonate, polylactic acid (a bioplast), combinations of different plastics

PLASTIC SCAVENGER HUNT PART 1

INTRODUCTION
In this lesson, students will group plastic pieces by Resin Identification Code (RIC) and physical characteristics.

CONCEPTS
1. Students will understand the recycling codes used on plastics to identify the material from which an item is made to facilitate easier recycling.

2. Students will know the definition of plastic.

3. Students will understand that plastics are ubiquitous and their importance to society and their personal life.

MATERIALS
Journals, boxes, recycling codes, found plastics

PREPARATION
Ask students to collect examples of plastic items from at least 5 of the 7 plastic recycling codes. Allow them at least a week to collect. They need to be aware of the code embossed on most plastic containers.

NOTE: Students will readily be able to find resin identification codes (RIC) 1, 2, 4, 5, and 6. You may want to focus on numbers 3 and 7 or challenge students to find plastics with those RICs. Accept plastics without RICs, as well. Stress that these containers need to be clean and dry and will not be returned. Initial collection should be in one or two large containers. Prepare seven boxes with one recycling symbol and number on the front for sorting in Part 2.

PROCEDURE
1. Students collect examples of plastic items from at least 5 of the 7 plastic recycling codes.

2. As students collect the plastic items, have them complete the student chart from this lesson. Allow them to research the answers on the internet.

3. Over an 8-hour period, write down everything you touch that is made of plastic. At the end of that period of time review your list.

    a. Cross out three things you could live without
    b. Circle three items that you could NOT give up

4. Read The History of Plastics and write a paragraph describing what you learned.

5. After completion of #1:

    a. Consider in writing what you already know about plastics and your opinion about plastics.
    b. Consider how your life would be different without the 3 items you ‘gave up’ in ‘3a.’
    c. Could you replace a plastic item from ‘3b’ with another material? What might the environmental impact of that change be? Does it cost more to make from this different material? Is it as strong? Is it as appealing with the new material? Consider similar questions when answering this question.

STUDENT CHART

Generally speaking, plastics using resin codes 1 and 2 can be placed in your curbside bin, however, different municipalities have varying rules about the other resin numbers. Contact your local recycling/waste management authority for guidelines before marking the "yes" or "no" options next to the other resin codes.

RIC	ABBREVIATION & FULL NAME	PLACE IN RECYCLE BIN?	COMMON APPLICATIONS	OTHER RECYCLING OPTIONS?
1		YES/NO		
2		YES/NO		
3		YES/NO		
4		YES/NO		
5		YES/NO		
6		YES/NO		
7		YES/NO		

PLASTIC SCAVENGER HUNT PART 2

INTRODUCTION
In Part 2, students will sort the collected plastics similar to a materials recovery facility (MRF).

CONCEPTS
1. Students will understand the difficulties of sorting recyclable materials.
2. Students will know the definition of polymer, amorphous, and crystalline.

PREPARATION
Prepare seven boxes with recycling symbol and number on the front for sorting. NOTE: Students will readily be able to find resin identification codes (RIC) 1, 2, 4, 5, and 6. You may want to focus on numbers 3 and 7 or challenge students to find plastics with those RICs. Accept plastics without RICs, as well.

MATERIALS
Journals, boxes, recycling codes, found plastics

PROCEDURE
1. Deposit all plastics students have collected (in Part 1) in one or two large containers.

2. Have students sort the plastics by RIC. Have 7 boxes with one recycling symbol and number on the front to indicate which box to deposit the plastic. Before the sorting process sneak in some metal, glass, or paper. These are contaminants in the recycling process.

3. Students answer these questions: Are there any plastics which do not have a number? Should caps be on or off the bottles? Are there any contaminants in the recycling pile–something that is not recyclable? What is the impact of contaminants at the sorting factory?

4. Discuss with students what types of materials normally have recycling codes, what plastic items are not coded for recycling, and what sorts of challenges the diversity of plastics might pose for the recycling process. (See The Many Challenges of Plastic Recycling, p.7).

5. Students read The Many Challenges of Plastics Recycling and write a summary describing what they learned.

PHYSICAL CHARACTERISTICS
Rigid, Flexible, Flimsy, Hard, Thin, Bouncy, Durable, Colored, Stretchy, Bendy, Transparent, Thick, Brittle, Soft Sound, Crackling Sound, etc.

STUDENT CHART

Physical Characteristics: Rigid, Flexible, Flimsy, Hard, Thin, Bouncy, Durable, Colored, Stretchy, Bendy, Transparent, Thick, Brittle, Soft Sound, Crackling Sound, etc.

RIC	ITEM	ITEM USE	PHYSICAL CHARACTERISTICS
1 POLYETHYLENE TEREPHTHALATE (PET OR PETE)			
2 HIGH-DENSITY POLYETHYLENE (HDPE)			
3 POLYVINYL CHLORIDE (PVC)			
4 LOW-DENSITY POLYETHYLENE (LDPE)			
5 POLYPROPYLENE (PP)			
6 POLYSTYRENE (PS)			
7 OTHER PLASTICS (O)			
UNLABELED			

LIFE OF A PETE BOTTLE

INTRODUCTION

Students watch videos (links on next page) describing the economic impact recycling has on a community and the recycling process for bottles and caps. Another video is about a company that uses recycled plastics to create new objects to sell.

CONCEPTS

1. Students will know the process of recycling water bottles and bottle caps.

2. Students will understand that plastics are thermoplastic and can be reheated and reformed to create new products.

MATERIALS

Videos (links on p. 17), cut up PETE bottles, HDPE flake from HOP kit, aluminum foil or pan, forceps, hotplate or oven.

SAFETY PRECAUTIONS

Be cautious when handling boiling water, and hot beaker. Wear protective clothing when handling melted plastic. Hot plastic can burn skin if improperly handled. The excessive smoke and fumes are harmful when melting plastic. This portion of the lesson should only be performed with proper ventilation (a fume hood is best) and under adult supervision.

VOCABULARY

HDPE: High-Density Polyethylene

PETE or PET: Polyethylene Terephthalate

MRF: Materials Recovery Facility

Pelletizing is the process of compressing or molding a material into the shape of a pellet.

Polymer: A polymer is a substance made up of a large number of smaller molecules, called monomers, that link together to form larger monomers.

A **thermoplastic** polymer is a type of plastic that changes properties when heated and cooled. Thermoplastics become soft when heat is applied and have a smooth, hard finish when cooled. A thermoplastic can be reshaped when heated.

Thermoset, or **thermosetting**, plastics are synthetic materials that strengthen when heated, but cannot be successfully remolded or reheated after their initial heat-forming. This is in contrast to thermoplastics, which soften when heated and harden and strengthen after cooling.

Stretch Blow Molding is the process of inflating a hot, hollow, thermoplastic preform inside a closed **mold** so its shape conforms to that of the **mold** cavity. A wide variety of hollow parts, including plastic bottles, can be produced from many different plastics using this process.

RECYCLING BOTTLES VIDEOS

YOUR BOTTLE MEANS JOBS

vimeo.com/190005789

The video highlights those working in the high-density polyethylene (HDPE) plastics recycling industry in the Carolinas, focusing on the North Carolina recycling supply chain. Featuring employees of NC companies such as ReCommunity, Plastic Revolutions, Crumpler Plastic Pipe and Burt's Bees, the video shows that recycling is at the intersection of the environment and the economy.

RECYCLING JOURNEY OF A PLASTIC CAP

vimeo.com/182886176

The video highlights how a typical plastic cap moves through the entire recycling process. In the video, there's a PET bottle is used in the flowchart to illustrate this process, but the same steps can be taken to recycle plastic caps on many other types of containers including: laundry detergent and other cleaning products, shampoo, conditioner, body wash, as well as condiment, snack and other food bottles.

TEACHER DEMONSTRATION

The HOP Kit contains HDPE Flakes. The HDPE flakes and PETE bottle (cut up into small pieces) can separately be melted down and reformed into new objects.

STRETCH BLOW MOLDING VIDEOS

Injecting hot PETE plastic into a metal mold and then cooling them produces test-tube-like objects called preforms. These machines produce preforms by the hundreds per minute. The preforms are shipped to the bottling companies. When the bottler wants to fill them with soda or water, the preforms are heated to soften the plastic and then blown with air into the 1-liter size using another metal mold. This is called Stretch Blow Molding. View the video below for a demonstration of injection blow molding with preforms like the one in the HOP kit.

1. **BLOW MOLDING**
   youtube.com/watch?v=NE4c1gwzPb4

TEACHER DEMONSTRATION

The HOP Kit contains a one liter preform. Since PETE is a thermoplastic, meaning it can be reheated and reused, one can heat the empty preform by pouring boiling water in it as it sits in a beaker so students can observe the deformation. The preform will soften and deform.

FIND THE **FLOATERS AND SINKERS**

INTRODUCTION:
To help students understand the concept of floating and sinking using solutions of different density. Students will be introduced to the concept of density in terms of floating and sinking of plastic pellets. The Density Table (below) will be used as a reference. Please note that you will be using flexible PVC and solid PS which has different densities.

MATERIALS *(for a class of 30 students working in pairs)*
45 cups with at least 60 mL capacity
45 craft sticks (one for water, one for alcohol solutions, and one for calcium chloride)
450 mL of 70% isopropyl alcohol. Color blue with food coloring.
450 mL calcium chloride solution. Color yellow with food coloring.
30 pairs of chemical splash goggles
60 plastic pipettes, droppers or teaspoons
6 kinds of plastic resin pellets from HOP kit – 2 each of the 6 kinds (12 pellets/group)

Advanced preparation for *Find the Floaters & Sinkers*

SOLUTION:
If students make their own solution, they will need to add two level tablespoons (~25 grams) of calcium chloride ($CaCL_2$) to 30 mL of distilled water. This is an exothermic process as the solid dissolves. The cup will get hot! (It could reach 80˚C.) The chemical can be obtained from a chemical supply company or as Prestone Driveway Heat, a product for melting ice on driveways and sidewalks. Purchase it in the winter since stores do not carry it in the summer. Be careful that the product you purchase isn't a mixture of several salts. Sodium chloride does not work for this application because its saturated solutions are not more dense than the densest of the resins.

If you prepare the solution for the class, mix 450 mL of distilled water with 2 cups of calcium chloride. This solution making process is exothermic! The 450 ml solution may get as hot as 100˚C. Prepare the solution in a Pyrex 1-liter beaker or a large glass canning jar. Place the beaker or jar in a bucket of cold water to help cool the solution as you mix it. Wear your goggles! Calcium chloride may irritate your skin. Wash with water if your skin comes in contact with the solution. Make the solution in a well-ventilated room since the water vapor from the hot solution may be irritating to breathe.

Be sure to check the calcium chloride solution to make sure that all 3 pellets (PETE, PS and PVC float). Depending on the brand of $CaCL_2$ used you may need to add more of the solute to make the solution dense enough for these pellets to float.

FLOW CHART:
Students may need help in reading a flow chart. Make a slide of the flow chart. Ask students to tell what a person should do next when two pellets of the same color are observed sinking in water? The answer should be that the pellets will be removed from the water and placed in the calcium chloride solution for further testing. Another question to ask, while reading the flow chart, is how would a student describe the behavior of pellet "M"? The answer is that "M" is a floater in water and a sinker in 70 % isopropyl alcohol.

You will need to provide waste containers for the used pellets and solutions at the end of the laboratory period. The pellets may be washed (by the teacher) and reused many times. The solutions may be disposed of by washing down the drain.

WATCH the Don't be Trashy–Recycle video (1.15 min) before this lesson at https://vimeo.com/111446483.
This video helps students understand their integral role in closing the recycling loop, by demonstrating exactly what happens to used plastics after we toss them in the bin.

EXPLANATION OF LAB ACTIVITY:

Students will be placing all six recycled resins into water to watch them float or sink. The three that float in water are less than 1.00 g/mL and these are: HDPE, LDPE, and PP. See the Density Table for actual numbers. Plastics will vary in density when they are manufactured so there is a range of densities for each kind of plastic. Pure metals have an exact density and not a range.

When the three floaters are placed in 70% isopropyl alcohol, one plastic, PP (M) will float since it is less dense than the alcohol solution that has a density of about 0.88 g/ml. By adding water (a more dense liquid) to the alcohol solution, the new solution will become more dense (about 0.94 g/mL). The next separation is when HDPE (X) still sinks in the solution but LDPE (Z) floats.

On the other side of the flow chart, the sinkers in water will be added to a very concentrated calcium chloride solution. All three resins will float since they are less dense than the 1.40 g/mL solution of calcium chloride. As water (1.00 g/mL) is added to the dense solution, the new solution becomes less dense and the first resin to sink will be PETE (Y), the most dense of the six. The second test solution has even more water added. The solution for test #2 is about 1.12 g/mL so that PVC (P) sinks and PS (W) stays floating.

TEACHER KEY TO THE FLOW CHART

Floaters in water

M. Resin sinks in 70% isopropyl alcohol and floats in 1st test solution. (PP)
Z. Resin sinks in 70% isopropyl alcohol, sinks in 1st test solution and floats in 2nd test solution. (LDPE)
X. Resin sinks in 70% alcohol and the 1st and 2nd test solutions. (HDPE)

Sinkers in water

Y. Resin floats in calcium chloride solution and sinks in 1st test solution. (PETE)
W. Resin floats in calcium chloride solution, floats in the 1st test solution, and floats in the 2nd test solution. (PS)
P. Resin floats in calcium chloride solution, floats in the 1st test solution, and sinks in 2nd test solution. (PVC)

DENSITY TABLE	
SUBSTANCE	Density (g/mL)
WATER	1.00
1-PETE	1.38-1.39
2-HDPE	0.95-0.96
3-PVC	1.16-1.35
4-LDPE	0.92-0.94
5-PP	0.90-0.91
6-PS	1.05-1.07

STUDENT LAB SHEET

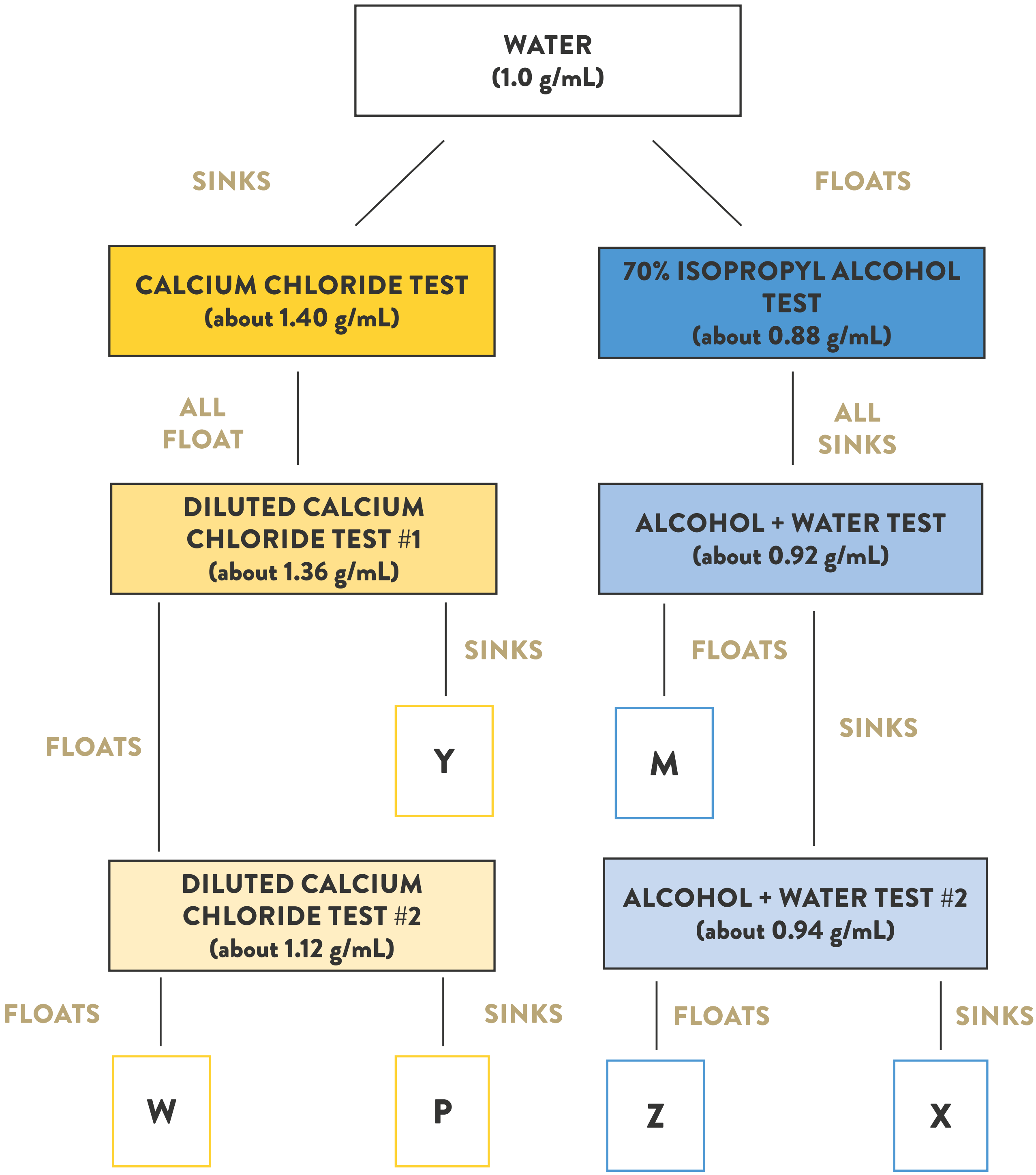
YOUR MISSION:
You are working in a plastic recycling factory. The factory takes used plastic containers and chops them up into small pieces called “flake”. The flake is melted and made into pellets. These pellets or resins are used to make more plastic items like garbage cans, carpeting, and plastic lumber. Someone lost their data sheet on the identification of the pellets. You have volunteered to help identify the pellets.

MATERIALS *(for each group of students)*
6 kinds of resins or pellets (2 pellets of each kind)
30 mL 70% isopropyl alcohol (blue)
30 mL of concentrated CaCL2 solution (yellow) 30 mL of distilled water
3 small cups
Chemical splash goggles
3 craft sticks
Plastic pipettes, spoons or droppers

PROCEDURE: *Use the flow chart to help you work with the plastic pellets.*
1. Put on your goggles. Take the 12 pellets (two of each kind of plastic resin) and place them in a small cup of water. Stir them with a craft stick to make sure no bubbles are adhering to the pellets. Observe the floaters and sinkers.
2. Scoop out the floaters and place them in 30 mL of blue alcohol solution in a small cup. Stir with a craft stick. Record your observations of the floaters. Notice their color and their behavior in water and alcohol.
3. Scoop out the floaters from the blue solution. Add squirts of water from a plastic pipette or add one half teaspoon of water into the blue solution containing sinkers. Stir with a craft stick, dropper, or pipette. Observe. Keep adding small amounts of water until you see some pellets float. Record your observations in the notes box at the bottom of the flow chart. You should now have notes on three kinds of pellets.
4. Go back to the water cup and take out the sinkers. Place all of them into the yellow calcium chloride solution. Observe. Record any notes about the pellets.
5. Using a pipette, add a squirt of water or add one-half teaspoon of water to the yellow solution. Stir with a craft stick. Observe the pellets. Add more water and stir. Continue adding water until pellets sink. Stop and record your observations.
6. Continue to add small amounts of water until more pellets sink. Stop and record your observations. At this time, you should have notes on all six kinds of pellets.
7. Take out all pellets from the cups with a craft stick or spoon. Place the pellets in the containers provided by your teacher.
8. Pour the solutions into the color-coordinated containers as directed by your teacher.
9. Clean up your work area.

EVALUATION:
Complete your notes on the flow chart of your observations for the six pellets.

SINK OR FLOAT FLOW CHART



WHY DO **THEY FLOAT AND SINK?**

(Teacher Answer Sheet)

INTRODUCTION

Float and Sink Experiment:
Let students have time to predict and write answers before the experiment. Then have students drop a penny and a cork into water. Or do as a demonstration for the whole class.

ANSWERS TO INTRODUCTORY STUDENT LAB

A. Cork will float; Penny will sink
B. More dense objects will sink
C. The penny will sink

ANSWERS TO WHY DO THEY FLOAT OR SINK?

QUESTIONS ON PAGE 2 OF STUDENT ACTIVITY SHEET:

1. Rank the least dense resins from the least dense to the most.
Least dense M, middle density Z, most dense X

2. Predict which letter from question 1 is which plastic.
Letter M is PP #5, Letter Z is LDPE #4, Letter X is HDPE #2

3. Rank the most dense resin from least dense to the most.
Least dense W, middle density P, most dense Y

4. Predict which letter from question 3 is which plastic.
Letter W is PS #6, Letter P is PVC #3, Letter Y is PETE #1

5. The plastics names are listed below:
PETE - polyethylene terephthalate
HDPE - high-density polyethylene
PVC - polyvinyl chloride
LDPE - low-density polyethylene
PP - polypropylene
PS – polystyrene

6. Why do all the names have the prefix “poly” in them?
Plastics are made out of polymers, or long-chain molecules. Poly means “many”, referring to many repeating units.

ANSWERS TO EVALUATION QUESTIONS ON PAGE 2 OF STUDENT ACTIVITY SHEET:

1. A ship carrying plastic pellets has a spill in the port of Chicago on Lake Michigan. All the containers are labeled “RECYCLED PLASTIC # 3”. What will you see on or in the water around the ship? Explain.
Lake Michigan is a fresh water port. #3 plastic is PVC; it sinks in fresh water.

2. Would it make any difference if the ship were in New York or Los Angeles? Explain.
Yes, it makes a difference because these are salt water ports. Ocean water is about 3.5% salt. Salt water is more dense than fresh water. The question now is what is the density of salt water compared to the plastic pellets? Students will need time to experiment to find the answer.

STUDENT **LAB SHEET**

YOUR MISSION:

You have just completed the task of identifying the pellets for a plastic factory. You have taken extensive notes on the pellets sinking and floating in the three liquids. Your job is to analyze the data and determine which plastic resin pellet is which plastic.

PURPOSE: To match the plastic resin pellets with the correct plastic name and symbol.

INTRODUCTORY STUDENT LAB

A. Predict what will happen when a cork and a penny are dropped into a cup of water.

Prediction: ____

Do the experiment: Drop a penny into water. Then drop a cork into water.

Explanation:

- Water has a density of 1.00 g/mL therefore those objects with a density of less than 1.00 g/mL will float in water.
- One can conclude that objects that are less dense than the liquid they are placed into will float and those that are most dense will sink.

B. What is true about objects that are more dense than the liquid they are placed in?

____

C. The calcium chloride solution has a density of about 1.40g/mL. The density of a penny is about 8.00 g/mL. If you placed a penny that sinks in water into the calcium chloride solution, what will happen?

____

1. Rank the three least dense resins from least dense to most dense based on your observations and the density table. **HINT:** 70% alcohol has a density of 0.88 g/mL and when water is added to the solution, the density of the new solution will be greater since water has a greater density (1.00 g/mL).

Place letters in the blanks (from Sink or Float flow chart).

Least dense ______, middle density ______, most dense ______

DENSITY TABLE

SUBSTANCE	DENSITY (G/ML)
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(1) PETE	1.38-1.39
(2) HDPE	0.95-0.96
(3) PVC	1.16-1.35
(4) LDPE	0.92-0.94
(5) PP	0.90-0.91
(6) PS	1.05-1.07

2. Using your notes from the flow chart and the density table of plastics, you should be able to match the plastics with the letter of the resin. Look at the density table for plastics. Predict which letter from question 2 is which plastic.

Letter ______ is PP (#5)

Letter ______ is LDPE (#4)

Letter ______ is HDPE(#2)

3. Rank the three most dense resins in order from the least dense to most. **HINT:** If you add water (1.0 g/mL) to the calcium chloride solution (1.40g/mL), then the resulting solution will be less dense.

Place letters in the blanks.

Least dense ______, middle density ______, most dense ______

4. Using your notes from the flow chart and the density table of plastics, you should be able to match the plastics with the letter of the resin.

Letter ______ is PS (#6)

Letter ______ is PVC (#3)

Letter ______ is PETE (#1)

5. Write out the full name of each plastic:

PETE: ______________________________

HDPE: ______________________________

PVC: ______________________________

LDPE: ______________________________

PP: ______________________________

PS: ______________________________

6. Why do all of the names have the prefix “poly” in them?

____

____

EVALUATE

Write your answers below.

1. A ship carrying plastic pellets has a spill in the port of Chicago on Lake Michigan. All the containers are labeled “RECYCLED PLASTIC # 3.” What will you see on or in the water around the ship? Explain.

____

____

2. Would it make any difference if the ship were in New York or Los Angeles? Explain.

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HOP KITS

HANDS-ON PLASTICS FROM THE SPE FOUNDATION

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