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Natural Plastics

Plastics are Everywhere

Imagine a world without plastics as you learn about early natural and synthetic polymers.

Extensions

- EXPLORE: A Plastics Timeline: https://tinyurl.com/y5ejotre
- EXPLORE: Research smokeless gun cotton.
- EXPLORE: Hydrolysis reactions; build/draw a model of a cellulose nitrate reaction, investigate polymerization.
- EXPLORE: Look around your room, what examples of plastic can you find?
- DO: Take a week to look at your plastic usage. Take notes and points of interest to discuss during the next class.
- DEMONSTRATE: the flexibility of polymer structures. Hold one end of a beaded necklace (like the Mardi Gras beads in the video) and move the end back and forth sideways to demonstrate how easily the chain moves.

Discussion Points

- Why are plastics flexible and shapable?
- What kinds of things do you use that are made of plastic?
- What does the word plastic mean?
- Do we want to, or can we live without plastics?

Career Pathways

Chemist, Polymer Scientist

Vocabulary

Cellulose nitrate
Hydrolysis
Ozone
Plastic
Polymer
Polymerize
Sustainability
Ubiquitous
Christian Schönbein

The Games Plastics Play

How early natural and synthetic polymers replaced ivory billiard balls and modernized materials for the entertainment industry.

Extensions

- EXPLORE: Investigate plastics in the entertainment industry
- EXPLORE: How much is the $10,000 prize offered to the inventor of a new material for billiard balls in 1863 worth today?

Discussion Points

- What kinds of materials did plastics replace?
- Alexander Parks made the first moldable plastic by adding what to it?
- What do you think people used before the first plastic?
- Approximately, how old are plastics?

Career Pathways

Mechanical Engineering, Injection Molding

Vocabulary

Cellulose acetate
Parkesine
Shellac
Alexander Parkes
George Eastman
Hyatt Brothers

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The First Plastics

Make your own milk plastic, discover the first synthetic plastic and how chemical engineering is important in the plastics industry.

Extensions

- EXPLORE: Make your own Milk Plastic: https://tinyurl.com/y626264a

Discussion Points

- What is the most interesting plastic invention you learned about today?
- What was the first plastic made of?
- Other than Erinoid what other material was important in the plastics industry?
- What evidence of a chemical reaction (or change) did you see?
- What is meant by the "Fourth Kingdom"?
- Why was formaldehyde important in the early years of synthetic plastics? (HS only)

Career Pathways

Chemist, Chemical Engineering, Color Specialist, Mechanical or Industrial Engineer, Material Scientist

Vocabulary

Bakelite
Casein
Erinoid or milk plastic
formaldehyde
pH
polymerization
polymers
George Davis

Macromolecular Theory

Early polymer scientists changed the world and helped us understand the need for bold independent-thinking science pioneers.

Extensions

- EXPLORE: List and draw molecules with covalent bonds—are any of them polymers?
- EXPLORE: Find the names of common synthetic polymers that we use to make everyday things.
- DEMONSTRATION: Pull Mardi Gras beads (3-4 ft in length) from a cup (as shown in video). Staudinger studied molecular weights of flexible materials and hypothesized the existence of polymers. Look at the model of beads and think about "molecular weight" of the whole chain versus each individual bead. Can you explain what Staudinger was thinking?
- DO: List natural polymers.

Discussion Points

- Why are math skills important when making scientific discoveries?

Career Pathways

Polymer Scientist, Polymer Engineering

Vocabulary

Aggregate theory
Colloids
Covalent bonds
Macromolecular compounds
Hermann Staudinger

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Synthetic Plastics

Where Does Plastic Come From?

Plastic comes from renewable and non-renewable resources such as crude oil, natural gas, and agricultural feedstocks.

Extensions

- DO: Describe polymers by making a chain from strips of colored construction paper or paper clips.
- DO: Describe the process of making plastics from raw materials by making an infographic.

Discussion Points

- What raw materials from the Earth are used to make plastics?
- Bioplastic play dough recipe (see page 5)
- Plastic play dough recipe (see page 5)
- Describe the process of making plastics from raw materials to a finished product.
- What is the difference between renewable and nonrenewable natural resources?

Career Pathways

Chemical Engineering, Process or Manufacturing Engineer/Specialist, Applications Engineer/Specialist

Vocabulary

Bioplastic
Distillation column
Formulation
Fossil fuels
Monomer
Polymer
Plastic
Raw materials

Polymeric Structure

Monomers make up polymers, the difference between amorphous and semi-crystalline polymers, and product application engineering.

Extensions

- DO: make a list of things in your house or school that are made of polymers. Are they natural or synthetic?
- EXPLORE: Good information on amorphous & crystalline polymers: https://tinyurl.com/yybsqv5u
- EXPLORE: Create a model of polymer chains using paper clips.
- EXPLORE: Manipulate polymers of a balloon with a skewer.
- FIND: The resin identification code for HDPE.

Discussion Points

- Describe the difference between semi-crystalline and amorphous polymers.
- What are 3 factors that affect the degree of crystallinity of polymers?

Career Pathways

Product or Applications (Automotive, Packaging, Sports, Toys) Engineering

Vocabulary

Amorphous polymers
Crystalline polymer
HDPE
Natural polymers
Monomer
Polymer
Polystyrene container
Semi-crystalline polymers
Synthetic polymers

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Biomimicry & Nylon

See a nylon pulling demonstration and learn that through organic chemistry nylon was created to mimic strong natural polymers.

Extensions

- EXPLORE: Provide examples of biomimicry.
- EXPLORE: biopolymer nylons e.g., Arkema's castor beans: https://www.youtube.com/watch?v=kpKZBLu6CjM
- EXPLORE: Find a way to compare the strength of natural silk and nylon.

Discussion Points

- What other examples of nylon can we see in everyday life?
- Read your clothing and shoe labels and find something made of nylon? Why do you think nylon was used in this item? What are the material benefits of nylon?

Career Pathways

Material Scientist, Application Engineer, Chemical Engineer, Chemist, Organic Chemist

Vocabulary

Catalyst
Monomers
Nylon fiber
Polyamides
Polymerization
Adeline Gray
Wallace Carothers

Thermoplastics & Recycling

Thermoplastics can be reheated, remolded, and recycled. How single-use water bottles are manufactured and recycled.

Extensions

- DO: Investigate the invention of scotch tape.
- DO: How Toys are Made: https://tinyurl.com/y7qgcmpc
- DO: Simulate the blow molding process by blowing up a balloon.
- DO: Go on a scavenger hunt: Find non-pigmented (clear or milky white) and pigmented (colored) thermoplastics.
- DO: Investigate plastics manufacturing processes of injection molding and extrusion blow molding.
- CRITICAL THINKING: Define and compare bulk density and material density.
- WATCH: Stretch Blow Molding https://www.youtube.com/watch?v=NE4c1gwzPb4
- EXPLORE: What products are made of polyethylene? Research online.
- DISCOVER: Ask your family about recycling plastics and if they participate.
- READ: About thermoplastics: https://www.mnrubber.com/Design_Guide/5-2.html

Discussion Points

- What are ways we can increase the number of plastic bottles recycled at our school or at home?
- What are some 'unconventional' uses for Post It notes and Scotch Tape?
- What are some advantages of using preforms?
- What is the abbreviation and resin code for polyethylene terephthalate?
- What is a thermoplastic? Why are most thermoplastics recyclable?
- Explain the difference between a single use item and a multiple use material.

Career Pathways

Engineer, scientist, technician in recycling or blow molding industry, Supply Chain Manager, Process Engineers, Chemistry & Design of color in plastics

Vocabulary

Bulk density
Injection molding
Monomer
Polyethylene terephthalate
Preform
Resin
Shipping volume
Stretch blow molding
Thermoplastic
Fawsett and Gibson

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Thermosets are Here to Stay

Crosslink thermoset polymers through chemical reactions. The difference between thermoplastics and thermosets.

Extensions

- WATCH: Composites video from Science Bob: https://tinyurl.com/y56bq3uj
- DO: Make papier mache composite: https://tinyurl.com/ycnu3fra
- DEMONSTRATE: The epoxy reaction from the video. Wear safety glasses and gloves.
- READ: This New Type of Glue Is Activated by Magnetic Fields: https://tinyurl.com/ybf5zqzr
- READ: About thermoplastics https://www.mnrubber.com/Design_Guide/5-2.html

Discussion Points

- Besides smell, what are other indicators of a chemical reaction? (HS)
- If an exothermic reaction is heat leaving the reaction, what would an endothermic reaction be?
- What are useful applications of thermoset plastics?
- What is evidence of the epoxy chemical reaction?

Career Pathways

Sales Engineer, Appliance Design, Automotive Engineer, Electrical Engineer, Chemical Engineer, Polymer Scientist, Thermoset careers

Vocabulary

Celluloid
Composite
Chemical reaction
Cross-linking
Epoxy
Exothermic
Kevlar
Monomer
Resin
Thermosets
Stephanie Kwolek
John Wesley Hyatt

POLYMER PLAY DOUGH: Toolkit: Wooden spoon, saucepan, parchment or waxed paper
1 cup water (Add food coloring to the water for a colorful plastic)
1 cup flour
2 teaspoons cream of tartar
½ teaspoon salt
1 Tablespoon cooking oil

Make a dry mix of the flour, cream of tartar and salt. Heat the water and oil until very warm to hot. Add the dry mixture into the pan and cook over low heat until a dough forms. (2-3 minutes).
Let the hot dough cool for a few minutes on a sheet of parchment or waxed paper. Then knead the warm dough for a few minutes to give it a mor elastic texture.

BIO-PLASTIC PLAY DOUGH: Toolkit: Wooden spoon, saucepan, silicone spatula, aluminum foil
2 Tablespoons of corn or tapioca starch
½ cup of water (Add food coloring to the water for a colorful plastic)
2 teaspoons glycerin
2 teaspoons white vinegar

Mix all the ingredients in a non-stick saucepan before adding heat. Then put the saucepan on a stove and heat to a boil. Stir constantly, turn the heat down so the liquid boils for 2 minutes. The texture should start as a milky liquid when cool, then move to a gel stage as it warms and finally a bubbly gel as it boils. Use a silicone spatula to remove the plastic from the pan onto a sheet of aluminum foil or into a silicone mold. When, cool, the plastic cut be cut with cookie cutters. The plastic will harden over a few days.

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Processes and Material Science

What is Plastic Foam?

Plastic foams are used for cushioning, packaging, insulation, and shoes. See chemistry at work as we create a polyurethane foam.

Extensions

- EXPLORE: Find or take pictures of different types of foam at home or school.
- EXPLORE: How to make an EPS cup: https://tinyurl.com/y69kaftb
- WATCH: Open & Closed cell foam in construction: https://tinyurl.com/y6o3lsqo
- DEMO: Spray Great Stuff foam insulation in different disposable containers and notice what happens. Foam expands and takes on shape of container. Follow all safety recommendations on the can!
- DO: research foams used in football helmets, hockey helmets, motorcycle helmets, martial art headgear, fall mats and similar applications. (HS)

Discussion Points

- Are foams recyclable in your community?
- What are different applications of plastic foam?
- What is the evidence of a chemical reaction while the plastic foam is made?

Career Pathways

Application engineers, Packaging engineers, Product or Sales Engineer (Automotive, Coatings & Sealants, Construction, Medical, Packaging, Seating, Sports, Toys Industries)

Vocabulary

Chemical reaction
Closed foam cell
Exothermic reaction
Endothermic reaction
Open foam cell
Polystyrene foam
Polyurethane foam
Otto Bayer

Build a Better Bouncer (Middle School)

Demonstration of happy and sad balls to show energy absorption and return. Experimenting with fillers to create the "bounciest" ball.

Extensions

- EXPLORE: Have students bring in a ball or a sporting goods item that would help manage the energy of impact. Compare and discuss the items' design and materials purpose or usefulness.

Discussion Points

- Would you design an automotive bumper system with energy absorbing or energy transferring materials? Explain your thinking.

Career Pathways

Material Scientist, Application Development Engineer, Product designer for energy management (Automotive, Medical, Packaging, Sports, Transportation Industries), Polymer Engineer

Vocabulary

Compounding
Cross-linking
Energy absorption
Energy transfer
Polychloropene
Polynorbornene
Polyvinyl acetate

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Non-Newtonian Fluids (High School)

Oobleck and slime, crosslinked polymers, demonstrate the difference between non-Newtonian and Newtonian fluids.

Extensions

- DO: Oobleck recipe: https://www.thoughtco.com/easy-recipe-to-make-oobleck-605996
- DO: Measure the flow of honey or corn syrup at different temperatures. Does this follow Newton's Law?
- RESEARCH: Look up Newton's Law of Viscosity.
- EXPERIMENT: Test different fluids to see if they are shear thickening or shear thinning.

Discussion Points

- If viscosity is the resistance to flow, what would have a higher viscosity, mountain dew or honey?
- What are different examples of stressors? This can be from the video or your own understanding
- What is a non-Newtonian fluid?
- What is the difference between a compressive force and a shear force? What are examples of each type of force?
- Describe the difference between shear thickening and shear thinning fluids.
- What happens to a fluid experiencing die swell?

Career Pathways

Manufacturing Engineer, Material Scientist, Mechanical Engineer

Vocabulary

Newton's Law of Viscosity
Shear stress
Shear thickening fluids
Shear thinning fluids
Strain rate dependence
Stress
Viscosity
Weissenberg effect
Sir Isaac Newton

Slime

Slime is an example of endothermic chemical reactions. Join us in the viscosity race and discover alien slime!

Extensions

- DO: Slime recipe: https://www.teachengineering.org/activities/view/uoh_opslime_activity1
- DO: Graphing the speed of slime: https://tinyurl.com/yyljr3dg
- EXPERIMENT: 'Race' liquids of different viscosities of equal volumes down inclined flat surface. Examples: glue, water, putty, milk, oil.

Discussion Points

- Is the making of slime a physical or chemical change? Is it exothermic or endothermic?
- What are different additives that you can put in slime?
- How does crosslinking polymers help keep them in place?
- What are different characteristics of a phase change in slime?
- What evidence did you observe that would prove a chemical change took place?

Career Pathways

Material scientist or engineer, Toy Designer, Polymer Engineer

Vocabulary

Chemical change
Crosslinking
Endothermic reaction
Exothermic reaction
Limiting reagent
Polymer
Strain rate
Viscosity

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Thirsty Polymers

What are hydrophilic, hydrophobic and oleophilic polymers and their everyday uses?

NOTE: SPA is an eye and nose irritant. Wear safety glasses. Teacher should pass out the SPA to students.

Extensions

- EXPLORE: the difference/similarities of osmosis and diffusion.
- EXPLORE: Investigate oil spills and clean up procedures.
- EXPLORE: What products are made of polypropylene? Research online.
- READ: Article on SPA and water irrigation: https://tinyurl.com/yxpz85zu
- READ: Super Slurper: a corn-based superabsorbent polymer: https://tinyurl.com/y5brnn65
- RESEARCH: What is the Resin Identification Code (RIC) for polypropylene?
- DO: Super Absorbent Polymer hands on experiment: https://tinyurl.com/y6lydywq

Discussion Points

- What are key differences between hydrophobic and hydrophilic polymers?
- What is the abbreviation for polypropylene?
- What three plastic polymers are in a baby diaper? What purpose do the polymers serve in the product?
- What is the difference between AB-sorption and AD-sorption?

Career Pathways

Material scientist

Vocabulary

Absorption
Adsorption
Chemical change
Density
Diffusion
Hydrophilic
Hydrophobic
Osmosis
Permeability
Petrophililc
Physical change
Polyethylene
Polypropylene
Sodium Polyacrylate (SPA)
Super-absorbent polymers

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Take Action!

Mechanical Recycling

Learn what happens to a water bottle after the recycling bin and what you can do for better recycling.

Extensions

- DO: How to recycle in your community: https://recyclingpartnership.org/recycling-101/
- WATCH: This MRF in action: https://www.youtube.com/watch?v=4FpsH_ETT7c
- EXPLORE: Find different plastics around your house. Group them by the resin identification code.
- INVESTIGATE: The specific density of different plastics. Which will sink in water? Float?

Discussion Points

- What do you think is the hardest part in mechanical recycling?
- What does sustainability mean for plastics?
- Different plastics have different densities, what implication could this have for our environment and marine ecosystem?
- Why can we separate different plastics in a water bath?
- What is the name of your Waste Management (WM) company? What materials are accepted for recycling? Are recycle symbols or pictures of packaging on your WM website to help you?
- Why don't we all recycle? How can we be change agents for more recycling?

Vocabulary

Additives
Chemical Reaction
Crosslinking
Density
Viscosity
Wish-cycling

Protect Your Watershed

Resources to understand what a watershed is and how to protect it by taking action.

Extensions

- RESEARCH: What is a watershed? https://www.cwp.org/watershed101/
- RESEARCH: Find your local watershed. https://water.usgs.gov/wsc/map_index.html
- READ: Trash free water: https://www.epa.gov/trash-free-waters

Discussion Points

- How does a watershed help mitigate water run off?
- How can you protect the watershed?

Vocabulary

Stream site
Watershed

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Marine Debris

Understanding the importance of the waste management hierarchy solutions to curb marine debris around the world.

Extensions

- DO: Consider using a reusable water bottle and see how much of a difference in plastic you make.
- READ: The Great Pacific Garbage Patch! https://www.youtube.com/watch?v=vrPBYS5zzF8
- RESEARCH: The Alliance to end Plastic Waste at: https://endplasticwaste.org/
- RESEARCH: Search *Boyan Slat* online. Brainstorm invention ideas to help stem the tide of plastic waste.
- EXPLORE: Marine debris clean-up of U.S. rivers: https://www.livinglandsandwaters.org/what-we-do/our-projects/river-cleanups.html

Discussion Points

- What is the difference between a single use item & a multiple use material?
- What is Energy Management Recovery?
- What are the five countries that are contributing to more than half of the global marine debris?
- What are the 5 steps the Plastics Industry is implementing to help these countries reduce their waste getting into the ocean?
- What can we do in our own household, classroom, or community to reduce marine debris?
- Where does our trash waste belong?

Career Pathways

Plastics Engineers, Inventors, Entrepreneurs

Vocabulary

Boyan Slat
Energy Management Recovery
Gasification
Land-based trash sources

Recycle Your Wrap

Learn how to recycle your plastic films and flexibles at local stores using symbols and sounds.

Extensions

- VISIT: Learn more about recycling https://www.plasticfilmrecycling.org or https://how2recycle.info/sdo
- EXPLORE: Tent made of complete plastic wrap: https://www.youtube.com/watch?v=0lYPrwQgDUc
- EXPLORE: What different objects and items could you make with plastic wrap? Write about an idea that you have where recycled plastic wrap could aid.
- EXPLORE: Have a scavenger hunt of the plastic wraps at home or school. Make a list of what can be recycled through the Store Drop off program. Teach your family about plastic wrap recycling or make posters for your school or community.

Discussion Points

- Where would you go to recycle your plastic wrap?
- What different kinds of wrapping can you find around your house? Think of packaging Amazon sheets and plastic wrapping around toilet paper.
- What can we do locally to encourage more recycling of plastic wraps?

Career Pathways

Distribution, Supply Chain or Transportation Management

Vocabulary

Material Recovery Facility (MRF)
Symbol-Sound-Stretch
Wish-cycling

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The Future of Plastics

Bioplastics

Renewable vs. non-renewable plastics feedstocks. What's the difference between biodegradable and compostable plastics? What's photosynthesis have to do with it?

Extensions

- WATCH: NatureWorks Ingeo Applications Development Facility
- EXPLORE: Environmental Benefits Calculator
- DO: Find different types of packaging around your house and see if any parts may be substituted with bioplastic

Discussion Points

- Why are we interested in making biopolymers?
- What is the difference between a renewable resource versus a non-renewable resource? Provide examples.
- What are some applications for biopolymers?
- How can you determine if a plastic material is a biopolymer or a polymer from fossil fuels?
- What is the difference between compostable and biodegradable?
- What makes bioplastic degradable?
- Compared to traditional plastics, how long does it take bioplastics to degrade in a landfill?
- Why are bioplastics, like PLA compostable?

Career Pathways

Chemist, Chemical Engineer, Polymer Engineer, Polymer Scientist, Applications Development Engineer, Business Analyst

Vocabulary

Biomass
Biodegradeable
Biopolymer
Compostable
Glucose
Hydrolysis
Lactic acid
Non-renewable resource
Photosynthesis
Polylactic acid (PLA)
Renewable resource

Transformational Recycling

Using chemical or thermal processes to take plastic back to its original building blocks for reuse.

Extensions

- RESEARCH: Find the Transformational Recycling Center closest to your zip code.
- RESEARCH: Find examples of chemical & thermal recycling. What are challenges of transformational recycling?
- CONSIDER: Why do so many plastics become waste?
- ASK: Can you engage your school food service to collect food service plastics for recycling?

Discussion Points

- Why is Transformational recycling important?

Career Pathways

Chemist, Chemical Engineer, Polymer Engineer, Polymer Scientist

Vocabulary

Advanced recycling
Chemical recycling
Mechanical Recycling
Methanolysis
Post-Consumer Recycle (PCR)
Pyrolysis

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What's a Circular Economy?

Learn the difference between a linear economy of take, make and waste, vs. a circular economy of reduce, reuse, recycle.

Extensions

- READ: https://www.ellenmacarthurfoundation.org/

Discussion Points	**Vocabulary**
• What are the steps in a consumption based economic model? What is meant by “structural waste”? **Career Pathways** Business Analyst, Economic Analyst, Distribution and Supply Chain Analyst, Public Policy maker or advocate, Social Scientist, Chemical Engineer, Material Engineer	Circular economy Linear economy Upcycle

Sustainable Materials Management

The evaluation of all environmental impacts involved in the lifecycle of materials using a Life Cycle Assessment or Analysis.

Extensions

- COMPARE: Find 2 similar packages, each made of a different material such as a metal soup can and a tetra-pak soup carton. Discuss the advantage of each package. Include ideas that impact the carbon footprint.
- COMPARE: Can you try to do a simplified Life Cycle Analysis of a product made from 2 different materials, such as glass versus plastic ketchup bottles?

Discussion Points	**Vocabulary**
• How is Sustainable Materials Management different from a Circular Economy? • What is a Life Cycle Analysis (LCA)? **Career Pathways** Business Analyst, Economic Analyst, Distribution and Supply Chain Analyst, Public Policy maker or advocate, Social Scientist, Chemical Engineer, Material Engineer	Carbon footprint Life Cycle Analysis

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