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Polytails and Urban Tumble Weaves: The Chemistry of Synthetic Hair Fibers

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Introduction

I teach Chemistry and Introduction to General Science, at an urban public high school in Emeryville, California. My classes are socially, economically and academically diverse. Demographically, the student population is 68% African-American, 11% Latino, 12% Asian and 9% multiple or other. Over 80% of the student body received free or reduced lunches. The majority of the students I receive in my classroom have had little exposure to science, practical or theoretical. Their math skills are marginal or poor. Additionally, many of the students score below basic or far below basic in reading, on the standardized test administered by the State of California. While Emery Secondary School and district are small, in comparison to the neighboring Oakland School district, the demographic and learning histories are roughly the same.

Rationale

The social experiences of teenagers can be a bridge to contextualizing content and instruction in a science classroom. The opportunity to bear out the students' curiosities about their environment and the world exist when the curriculum in its design departs from the norm of using Standards only. This departure helps to drive new approaches to content and instruction. Metaphors and analogies that bespeak the real events in students' lives can promote discourse and understanding that traditional instructions miss. Social trends that manifest in clothing, dress, hairstyle, and grooming do serve as a springboard to engage students in the dialogue of science with a social lens. Exploring the science behind social trends, like tattooing, body piercing and hair weaves can be the turnkey for getting students to broaden their social self to the domain of science. The objective would be to use the students' interest to build relevancy and connectedness to chemistry concepts taught in the classroom. While there are challenges inherent in merging the social realm of teenage life to science, the rich, thorough articulations of my students making sense of their physical world in context with science concepts taught is an awesome academic exchange.

The diverse hairstyles worn by young African Americans are creative, provocative and historical. Whether

sporting traditional African braid styles, donning sculptured Afros or modeling modern day weaved couture, these young people unknowingly translate the political and social experiences of African Diasporas in this country. In the 1960s, young African American men and women paraded their natural, kinky hair without reservation to symbolize their racial identities. Decades later, young people would attempt to subdue their natural look by straightening their hair in order to gain greater access to economic opportunities, e.g. jobs, economic markets, schools. Today, African American lyrists and singers like India Arie and Erykah Badu boldly transition from locks to bald crowns bolstering their individuality, with great exclamation. While the contemporary hairstyles of young African American students can be the nexus that connects them to their culture and individual historical identities, it also serves to bear out their relationship to "popular culture."

Popular culture is temporal. It is a culture where, they (young people), themselves are commodified. It reports what is cool in the moment for music, hairstyles, clothing, dance, speech and other social practices. Within this domain, young people scout for the "latest and most hip" in commercial markets. The hair care industry is keen to this phenomenon, particularly amongst African American youth. Today, more than ever, there are a plethora of hair care products and supplies in U.S. markets. These products include hair oils, moisturizers, shampoos, relaxers, as well as styling products and accessories, such as hair dryers, diffusers, flat irons and curling irons. Dominating retailers such as Helene Curtis, Proctor and Gamble, and Alberto-Culver, garnish billions of dollars each year in revenue from sales to the American public. Local retailers stock their shelves with the varied styles and colors of wigs, weaves, and other hair care products, cashing in on the material culture.

Reportedly, in 2008, African Americans spending response to the hair care industry was \$435 billion in revenue. This rose by 16.9 percent in 2009 to \$507 billion. ¹ The products that generated the greatest revenue in the hair care industry were hair weaves. ² Many of these weave products, imported from areas outside the U.S., are Indian human hair or synthetic. Though men and women of "all ethnicities" are purchasing and wearing synthetic microfibers hair or natural fiber hairs weave products, young African American females are the burgeoning market. Thus, the distribution and marketing of these products is predominately to the African American community. On billboards, in magazines and in TV ads, industry advertisers construct images that display socially popular and accepted young African American females with hairstyles achieved with their products, only. Very often, these young females will buy hair weaves and hair extension without regard to the significance of their purchases. The socioeconomic ramifications as well as the environmental impacts are important considerations. Fundamentally, the young people cannot make informed decisions about the purchase, because they lack knowledge of the product, its composition, construction and the impacts. The opportunity to teach young people basic chemistry concepts and processes in relationship "to the hair they wear" provide many teachable moments. How these products are crafted to mimic natural hair is the catalyst to introduce students to the chemistry of polymers.

Background

Hair: A natural polymer

Essentially, the biology of hair is the same, regardless of ethnicity. Hair is a biopolymer that is "90% made out of a hard, fibrous protein called keratin. Keratin is made up of polypeptide chains of amino acids such as glycine, alanine, and cysteine. Polypeptide bonds hold these individual amino acids together and there are

multiple other complex bonds involved. ³ Taken together, the polypeptide chain that makes up human hair is an alpha helix. In one single strand of hair, three alpha helices are twisted together to form a protofibril. Protofibrils are the initial elongated unit appearing when any type of fiber is being formed. Nine protofibrils will join in a circle around two or more to form an 11-stranded cable that is called a microfibril. Hundreds of these microfibrils will cement into an irregular fibrous bundle called a macrofibril. These macrofibrils are then joined to make the cortex or main body of the hair fiber. ⁴

"Keratin has three main morphological areas, the cuticle or translucent scale like outer layer of the hair shaft, the cortex which can be conceptualized as the meat of the hair shaft, and the medulla which is the central core of the hair shaft." ⁵ "It is the shape of the hair follicle that directly influences the shape of the hair shaft and accounts for human genetic variation in texture. According to forensic scientists, Douglas Deedrick and Sandra Koch, "the morphology of hair by race reveal that Caucasian hair is oval to round shaped with even pigment and a medium size cuticle." Deedrick writes, "that it is this oval shape that gives the Caucasian hair a straight or mildly wavy appearance. For identification purposes, round hair shafts with an auburn pigment and thick cuticle are sorted into the category of Mongoloid or Asian hair. "This shape of the hair cells," he notes, "makes it appear very straight." For Negroid or African hair he explains, "hair shaft has been categorized as appearing to be primarily elliptical or flat shaped with dense pigmentation and a thin cuticle. The flat shape of the hair cells combined with naturally lower levels of scalp oil and larger amounts of sulfur gives African typed hair an extremely curly appearance. This texture of hair is susceptible to twisting or buckling, conditions that can create splits in the hair shaft. These factors work in unison to create the tightly twisted hair that is associated with people of African descent." ⁶

The versatility of African American hairstyles presents a wealth of insight into the social and cultural identities of African American people. Additionally, the hair types and fashions of non-African Americans can inform awareness of those cultures, as well. Pointedly, the varied possibilities of hairstyles for any ethnic group rest on the physiology of hair and hair textures. However, with the inception of polymers in our world, the considerations of hair texture to hairstyles has lost its merit. All types of artificial/synthetic hair products are available in the market to address styling needs and draw down genetic encumbrances to hair changeability.

Artificial Hair: A synthetic polymer

Synthetic hair like human hair is a polymer. It is composed of fine plastic fibers, manufactured to look like human hair. In its basic form, synthetic hair is made from low-grade acrylic that is heated and strung into strands to make individual hair fibers. The strands are then laced or tied into extensions and hairpieces. Typically, these types of synthetic hair fibers are used in costume wigs, and lack the movement and texture of real hair. Additionally, the appearance of these fibers is waxy and plastic. Conversely, the more sophisticated form of synthetic hair has texture and luster, and resembles human hair. Manufacturers of this artificial hair make use of polymer science to create these hair fibers. The fibers range in type from straight to kinky/curly with coarse surfaces to silky/smooth surfaces. The complex methods of spinning synthetic polymers into fibers include using volatile solvents and a spinneret to form multiple continuous filaments. Both, monofilament fibers and polyfilament fibers are used to fabricate the hair. Typically, fibers of modacrylic, vinyl chloride, vinylidene chloride, polyester, nylon are used for artificial hair. ⁷ Each of these fiber types are made by combining two or more polymers in one chain via melt spin or solvent spin processes. Rarely is one type of monofilament used. By linking the two polymers together, manufacturers of synthetic hair are attempting to develop a product that would more closely capture specific properties of natural hairs. For example, the synthetic hair fiber, modacrylic is one chain with segments of two different polymers, vinyl chloride and

carbon atoms linked by double bonds are not combined with as many atoms as those linked by only single bonds. This special feature of an alkene is central to the chemical reactivity of these molecules. Many reactions of alkenes involve the carbon-carbon double bonds. Primarily through addition chemistry, alkenes can react to form alcohols, to form halogen compounds and to become hydrogenated to form alkanes. The carbon-carbon double bonds are broken and single bonds formed with added substances. Because alkene structures are easily manipulated to form new molecules through addition reactions, a variety of polymers can be formed from this class of molecules.

Chemical Bonds

The bonds holding these macromolecules together are covalent bonds. The covalent bonds are the primary bonds of polymer molecules. These bonds are strong, directional and exist between the carbon atoms in the chain of these molecules. In addition to these bonds, there are weaker bonds between the chains called secondary bonds. Specifically, these bond types are hydrogen bonds and van der Waals bonds. Hydrogen bonds can exist between molecules of long chain polymers. They are stronger than van der Waal forces and can be used to strengthen the structure of a polymer. Like covalent bonds, they are directional; that is they point in the direction of the hydrogen atoms in the molecule. This characteristic of hydrogen bonding can account for the low density of long polymers. Van der Waals forces are the weakest of all intermolecular interactions. They are the result of electrostatic attraction between polar molecules or molecules with fluctuating dipoles and are non-directional. "Van der Waal forces exist between long polymers, as well. The presence of this weak force, between these molecules, accounts for the easy movement of the long polymer chain. This easy movement of the chains is what causes many polymers to be plastic or easily deformed." ⁸

Polymer Structure

Polymers can be linear, branched or cross linked. Linear polymers are free to move. They slide back and forth against each other easily, particularly when heated. Branched polymers contain side chains that prevent the molecules from sliding across each other easily. In cross-linked polymers, adjacent molecules in the polymers have formed bonds with each other. As a result, the individual molecules are not able to slide past each other when heated. Three methods can affect the structure and strength of a polymer. First, the introduction of atoms, such as oxygen and sulfur between chains of polymers, can inhibit their sliding over each other. This method is called crosslinking. A second method called crystallization would put chains of polymers close together over long distance. This would increase the strength of the interactions between the molecules and, thus, strengthen the polymer. The third method requires adding a large side group to the chain. This would stop bonds from rotating and also congeal the chain, making it more difficult for the macromolecules to move past each other. ⁸

Homopolymers and Copolymers

Polymers can be characterized as homopolymers or copolymers. Both, polyethylene and polyvinyl alcohol are homopolymers. The term homopolymer is used to describe polymers whose structure can be represented by the repetition of a single type of repeating unit containing one or more molecules. ¹⁰ If given a hypothetical monomer "A", the homopolymer would be:

etc.-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-etc.





Or, if the species represented is a monomer "AB", then the homopolymer would be:

etc.-AB-AB-AB-AB-AB-AB-AB-AB-AB-AB-AB-etc.

Sometimes two monomers can combine and polymerize, providing a unit "a" and a unit "b". When this occurs, a copolymer has formed. "The formal definition of a copolymer is a polymer derived from more than one species of monomer." ¹⁰ Copolymerization, in its objective, is very useful for synthesizing a polymer with the required combination of properties. Essentially, the properties of two or more monomer species are combined to create a polymer material that takes advantage of the monomers' individual characteristics. In the development of synthetic hair, this is an important process. Chemist and manufacturers of hair fibers utilize this technique to control the properties of the monomers in order to graft out hair materials meeting certain product specifications, e.g. tensile strength, combing property, and heat resistance.

There are four copolymer structures as shown and defined in Table 1 below.

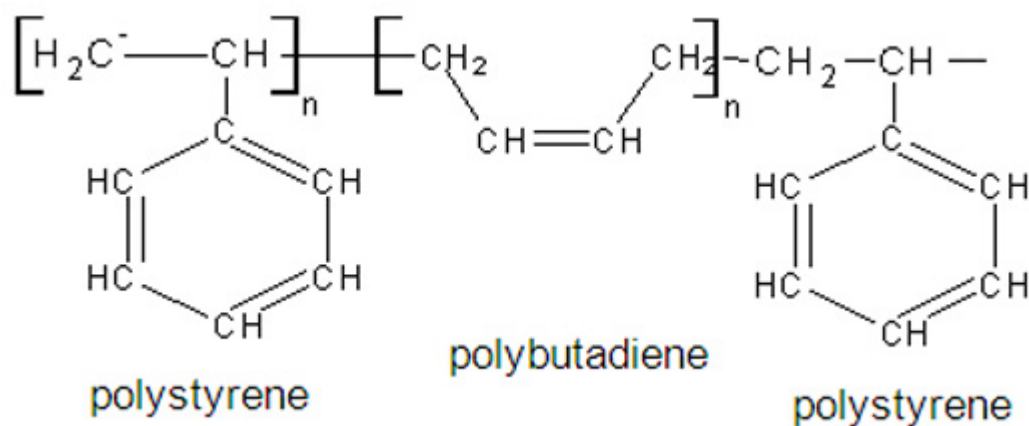
Table 1. (refer8,10,11) Types of copolymers with characterization.

		Representation of copolymer
Random copolymers	Monomers are distributed randomly, and sometimes unevenly	
Alternating copolymers	Monomers are distributed in a regular alternating fashion, with nearly equal molar amounts of each in the chain	
Block copolymers	Monomers are segmented or blocked in a long sequence	
Graft copolymers	Branched copolymer with a backbone of one type of monomer and one or more side chains of another monomer	

Styrene butadiene rubber is an example of a block copolymer. It is composed of *unit a*- $H_2C=CHC_6H_5$, styrene, and *unit b*- $H_2C=CH-CH=CH_2$, butadiene. As defined, this type of copolymer is linear with a long sequence or block of one monomer joined to a second monomer. This macromolecule would have the following units in its structure:

etc.-a-a-a-a-a-b-b-b-b-b-a-a-a-a-b-b-b-b-b-etc.

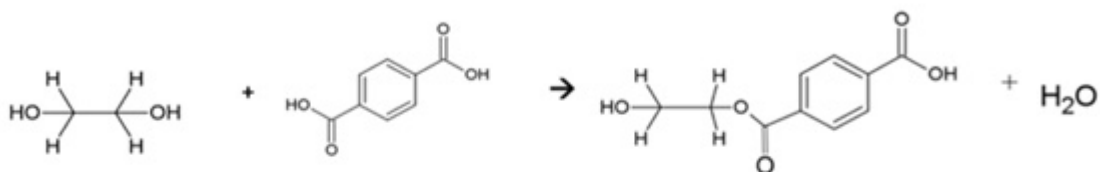
Specifically, the styrene butadiene rubber (SBS) is made up of three segments - an initial long chain of polystyrene, a long chain of polybutadiene and another long section of polystyrene.



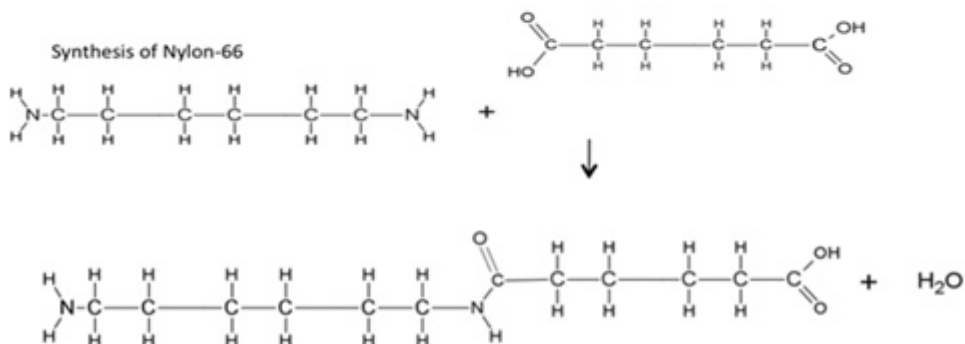
Polystyrene is a hard, resilient, transparent polymer, while butadiene is tough and hard, but brittle. Together, styrene butadiene rubber (SBS) is a hard rubber, used to make the sole of shoes, tire treads, other durable items. In combining the properties of these polymers, the resulting copolymer, SBS is more impact resistant and durable. ¹²

Polymerization Block copolymers, like other synthetic polymers do not occur naturally. The reaction that makes these polymers and others is polymerization. In general, there are two types of polymerization mechanisms, addition (chain reaction) and condensation (step reaction) polymerization. Condensation polymerization begins with bifunctional monomers. Monomers with two sites for bonding are bifunctional. Functionality is a very useful concept in polymer science. The functionality of a molecule is the number of sites it has for bonding to other molecules under the given conditions of the polymerization reaction. ¹⁰ Therefore, bifunctional monomers must have chemically active bonding sites where another molecule can link to build the polymer. The minimum functionality required for polymerization is two. These bonding sites are on the ends of the monomer. The reactions that develops at the sites are relatively slow and begins when the monomers of each molecule react to bond covalently. In condensation polymerization, the molecules are linked together by the removal of a small molecule, such as water or acid. For example, those monomers having functional groups, such as amines and carboxylic acids, can react with each other, generally grow by carbon-heteroatom bond formation (C-O and C-N), producing water as they grow. To illustrate, the condensation reaction for the synthesis of Dacron and Nylon-6,6 shows the formation of water as the polymers grow.

Synthesis of Dacron



Synthesis of Nylon-66



As presented, Dacron, a type of polyester fiber, is the result of a condensation reaction. In this example, the polyester is created using two monomers, both bifunctional, dicarboxylic acids (two carboxyl groups on each end) and diols (two alcohol groups on each end). The products are again the macromolecule, polyester and water. Similarly, nylon, a type of polyamide is formed when diacids (adipic acid) react with diamines (hexamethylene diamine) to polymerize and yield water. Figure 1, displays a corresponding reaction with bifunctional polyamides (two amines on each end) and bifunctional dicarboxylic acids (two carboxyl groups on each end).^{10,12}

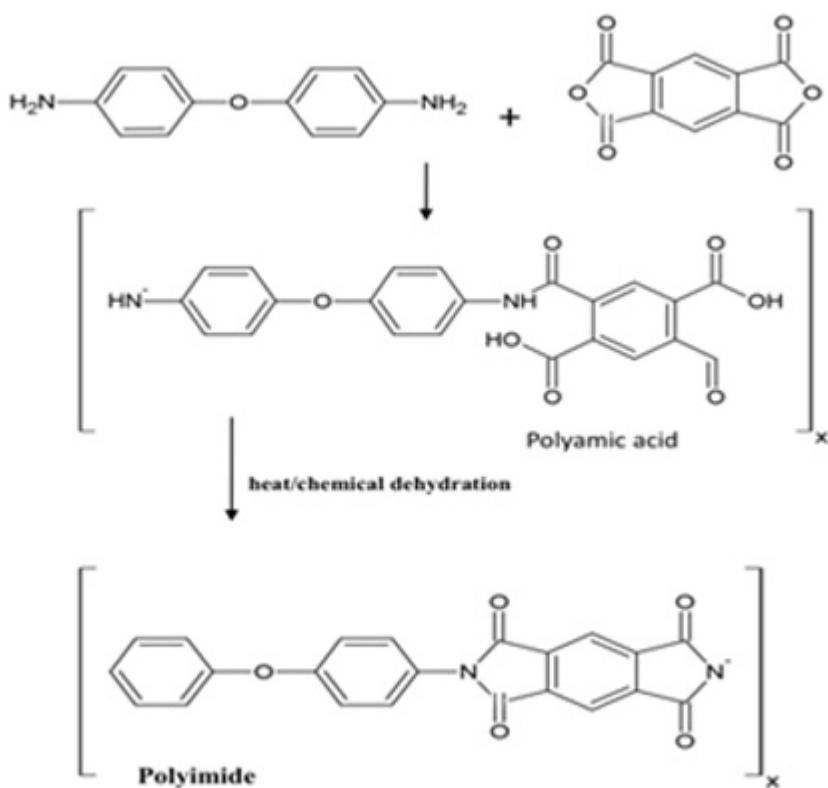
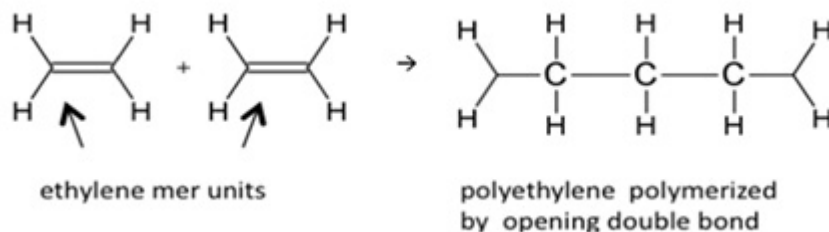


Figure 1

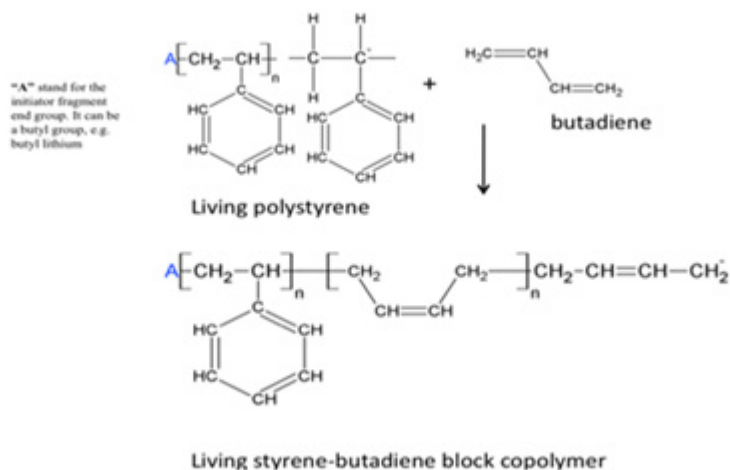
Examples of natural condensation polymers include wool, silk and cellulose. Some synthetic condensation polymers are polyamide, polyester, polyurethane, polysulphide and polysiloxane.

The addition polymerization process or chain reaction begins with a low molecular weight monomer with double bonds, such as ethylene, $\text{CH}_2 = \text{CH}_2$. Unlike the condensation process, the addition reaction results in no byproducts. Polymers formed by this mechanism do so by adding, in succession, unsaturated monomers in a chain reaction. The process involves the treatment of the double bonded monomers (alkenes) with an initiator substance to open up the double bond to release a free radical and valence electrons. Subsequently, these free electrons will join with other molecules in the reaction to form a polymer chain. For example, ethylene polymerizes to polyethylene:



In this reaction, no side products are formed and the composition of the mer or repeating unit of the polymer $-\text{CH}_2-\text{CH}_2-\text{CH}_2-$, is identical to that of the monomer $\text{CH}_2=\text{CH}_2$. These are important features of the chain polymerization process. Chain polymerization involves three processes: chain initiation, chain propagation, and chain termination. Chain initiation occurs by an attack on the monomer molecule by a free radical, a

cation or an anion; accordingly, the chain polymerization processes are called free radical polymerization, cationic polymerization or anionic polymerization. A free radical is a reactive substance having an unpaired electron and is usually formed by decomposition of a relatively unstable material called an initiator. Organic peroxides, like benzoyl peroxide are common free-radical initiators. The free radical, in general, is very active because of the presence of unpaired electrons. Free radical species can, thus, react to open the double bonds of a monomer, and add to one side of the broken bond, with the reactive center (unpaired electron) being transferred to the other side of the broken bond.¹⁰ At this point a new species is produced. It will react to attack a second monomer molecule, transferring its reactive center to the attacked molecule. This process repeats, and the chain grows as hundreds of monomer molecules are sequentially added to propagate (*chainpropagation*) the reactive center. Interference of the propagation process by termination reactions (*chain termination*) destroys the reactive center, ending the growth of the polymer.¹⁰ The subsequent polymer is extremely large and would have propagated in a short time, usually a few seconds or less. The polymer, styrene butadiene rubber (SBS), is the resultant product of an anionic vinyl polymerization.¹² The chemical mechanization is shown below:



Other examples of addition polymers include low-density propylene, polyacrylonitrile, polyvinyl acetate, and polyvinyl chloride.

Some important differences of each polymerization processes are summarized in Table 2.

Table 2.

Polymerization processes	Characteristics
Addition Addition	No by-products evolved. Fast reaction rate. Reaction at growing chain end. High molecular weight formed quickly. Time increases yield.
Condensation Condensation	By-products, H ₂ O, HCl. Slow reaction. Reaction at any molecule. Monomer disappears early. Molecular weight increases steadily. Time increases molecular weight. All molecular weight species.

Synthetic hair fibers - copolymerization

Synthetic hair fibers are copolymers. Whether addition or condensation polymers, these fibers in their design are a mix of polymeric properties characteristic of the polymers used in the grafting. Created by a process of extruding polymer materials through spinnerets, in order to form microfilaments or fine thread, most synthetic hair fibers, are a blend of the common polymers - nylon, polyester, and acrylic. Research of recent U.S., European and Japanese patents, reveal that the monomers used most often in synthesizing hair fibers were polyvinyl chloride, acrylonitrile, and polyester. For example, the intended fibers described in U.S. patent 7906209B2 would exhibit properties of bulkiness, touchable (soft) texture, dyeability, settability and gloss. To obtain synthetic fibers of these qualities, manufacturer proposed combining monomers, vinyl chloride and acrylonitrile in specified proportions (by percentage weight) and geometries. ¹³ Similarly, the idea of the European patent 0355749B1 was to develop copolymer fibers "comprising 70-85% by weight of repeating unit, vinyl chloride and 15-30% by weight of acrylonitrile." With the idea of producing artificial hair that mimics the compatibility and texture of natural hair, manufacturers employed the resilience and spiraling (curl) properties of vinyl chloride, as well as the bulky, textural appeal of acrylonitrile in designing their fiber. ¹⁴ In the U.S. Patent 3727619, a method for joining synthetic hair and human hair together, using ultrasonic vibrational energy is prescribed. Copolymerization of synthetic fibers with human hair fibers would be achieved by overlapping portions of both fibers at fixed positions to each other. The "ultrasonic vibrational mechanical energy would be introduced into the area of overlap in a proper direction and for a period of time to obtain a bond between the overlapping segments of hair." ¹⁵ Though, the science behind the design and manufacture of synthetic hair fibers is experimental and evolving, polymers are a mainstay in our society. They are part of our natural and industrial world. Thus, the science principles behind the everyday materials in our lives involve our understanding polymers - their properties and behavior.

Strategies

These lessons involve hands-on and minds-on inquiry activities that have real life connections and relevance for students. The focus is the chemistry of polymers. The goal is to introduce the subject of polymers to students in a fun and engaging way. Students will investigate the basic properties and behavior of polymers, through the lens of synthetic hair fibers. An ecological approach will be employed to teach the unit. As such, the exercises and assignments in the unit will draw from the social and cultural experiences of the students. The encapsulated view of hair, natural and synthetic, as expressed in popular media, will serve to open the discussion on polymer chemistry. In conjunction with the facilitated discussions, students will be guided to survey polymers around them. They will create and test various polymeric materials, including various types of synthetic hair. Using appropriate tools of investigation, students will observe and evaluate the properties of synthetic hair fibers along with other polymeric materials. Additionally, students will construct models that simulate polymer structure to inform their understanding of morphology of synthetic and real hair.

Guided by the California State Standards for Chemistry, students will not only learn essential facts and concepts on polymeric science, but they will also develop an understanding of their material world. The unit is designed to promote collaborative learning, to stimulate students to generate questions in order to consolidate their learning, to reinforce reasoning skills and to support laboratory skills. Daily re-looping of content and inquiry will be an essential process in assisting students to retain and learn material. A variety of pedagogical tools and strategies will be used to facilitate student learning and to assess their understanding. These include explicit teaching, small group guided discussion, laboratory experiments, student and teacher led demonstrations, visualization, oral sharing/board meetings, use of visual aids, including multimedia, and literacy techniques, e.g. Venn Diagram, KWL, vocabulary logs. Each student will maintain an interactive response journal, a daily record of content taught, questions generated, and ideas formulated.

Classroom Activities

In previous lessons and activities, students were presented concepts of chemical bonding, chemical reactivity, molecular structure and solution chemistry. The activities offered in this unit will extend the student's understanding of these concepts while developing others. The goal of the unit is to teach students about polymers while assisting them in understanding their physical world. The activities will be supplemented with text resources and multimedia. Formative assessment will be conducted throughout, using interactive notebooks and check in exercises.

Day 1

Students explore natural and synthetic materials. They will categorize materials based on physical properties. Materials will be sorted as natural and synthetic. Introduce the term "polymer." Introduce "hair" as an example of a polymer. Students will view the film clip "Good Hair". Students will record comments and notes in interactive journals. Qualitative mini-lab: How do hairs Fibers compare?" Students will compare types of hair.

Day 2

Explicit instruction – Prezi or PowerPoint presentation "What is a polymer – polymeric structure?" Re-loop: hair is a polymer.

Qualitative lab: How do hairs Fibers compare?" Students will compare synthetic hair fibers and textile fibers. Use guided questions to facilitate in-group discussions. Students will record observations and comments in an interactive journal. Students will create 3D models of polymer structures (cross linked, branched, linear) using Velcro and synthetic hair, sketch models and record in journals. Pair-share using guided questions. Whole class board meeting – Debrief activity: "How do hairs Fibers compare?" via board meeting and poster session. Use Oral report evaluation.

Day 3

Explicit instruction, Prezi or PowerPoint – homopolymer and copolymer use mini lab- Building simply polymers using gummy bears/marshmallows as mers.

Explain that synthetic hair is a copolymer.

Day 4 and 5

Lab – Making polymers.

Students will make, plate and test 2 types of polymers: Slime and cornstarch plastic

Day 7

Culminating activity: Testing synthetic hair fibers sing various solvents: acetone, water, acid solution, base solution, oil, peroxide.

Testing mechanical and thermal properties of synthetic hair fiber

Three techniques: heating to add curl, to remove curl, and using a flat iron with water and without.

Activity 1: Comparing Everyday Materials

Introduction to polymers

Objectives: Students will compare the properties of various materials and identify as natural or manmade.

Display several samples of polymeric materials (10-15) – oil, paper, synthetic hair, rope, yarn, bottle, corn syrup, acrylic nails, marshmallows, tape, denim, cereal, gelatin, glue sticks, rubber bands, coffee stirrers, etc. Have students to make a data table with the following categories in their interactive journals

- Type of materials
- Distinguishing properties
- Natural material
- Manmade material

Encourage students to use a hand lens and other appropriate tools to observe the properties of the materials.

Have the students record all their observations and predictions in the table

Ask students to compare data tables and use guided questions to engage students in small group discussions. Students' response to guided questions should be recorded in the journal. *Examples of questions:* What similarities or differences are observed in the samples? What materials could be considered, both synthetic and natural? What common properties do all synthetic materials share? What common properties do all natural materials share? Allow students a few minutes to discuss their observations and predictions with each other. Afterward, have a few students share data. *Explicit instruction:* Describe and define polymers. Select five to seven materials, including synthetic hair and natural hair, from the listed materials and display their molecular structure on the board or in a power point slide. Molecular structures can be downloaded from Google images or created using software chemsketch:

<http://www.brothersoft.com/acd-chemsketch-133131.html> Point out to students the repeating units in each molecular structure. Explain to students how each material observed is a polymer. Reference molecular structures of natural hair and fibers (polyesters, polyvinyl) used in synthetic hair. Introduce the unit, the objectives and the rationale to the students. Use an appropriate clip of the film "Good Hair" to further support the rationale and to spur student discussion.

Students will record their comments and notes on the film in their interactive journals.

Activity 2: How do hair "fibers" compare?"

Objectives: Students will

- compare the properties of synthetic hair fibers and textile fibers
- describe the fibers' texture, strength (break ability), elasticity, etc.
- create 3D models of polymer structure

Have students to make a data table with the following categories in their interactive journals

- Type of materials
- Visual representation
- Distinguishing properties with subcategories – texture, strength, elasticity

Encourage students to use a hand lens and other appropriate tools to observe the properties of the materials. Students record observations and comments in interactive journal. Use guided questions to facilitate in-group discussions. Students' response to guided questions should be recorded in the journal. *Examples of questions:* What makes each of these materials different? What do the properties suggest about the structure of the materials? How does structure effect function? What properties do the fibers share? *Explicit instruction:* Debrief activity with whole class. Use power point or Prezi to help students relate activity to content. Use background information on polymeric structure to create Prezi or power point. Images of polymeric structures can be found in General Chemistry textbooks or through Google images. Allow to time to answer clarifying questions. In the next section of the activity, students will create 3D models to represent polymer structures – branched, linear, and cross linked. Provide students Velcro, synthetic hair, 2 ring stands, 2 clamps, 1 cross bar, scissor, and images of polymeric structure. Assist students in building models by showing a prototype. Advise students that Velcro should be used for the links or branches, and you can recommend a maximum

number of Velcro links. Have students consider the fineness of the hair fibers, when attaching the Velcro. Students may want to use smaller strips between fibers. Allow time for students to construct, sketch and play with models. Use guided questions to facilitate in-group discussions. Have students sketch images of models on a dry erase board. Each model should be labeled and the polymeric structure identified. Facilitate the board meeting, using the guided questions as discussion prompts. *Possible guided questions:* How does structure effect movement? Why do some structures appear rigid? Which structure shows the least rigidity? How does structure affect various properties of hair – comb ability, brushing, curls, tangles, bounce, etc? Which model shows the greatest integrity and why?

Activity 3: Mini lab - Building simple polymers

Students will build models for polymers, polyethylene and polystyrene. Working in teams of three persons, they will construct linear and branched, homopolymers and copolymers. Prepare polymer cards in advanced, showing the molecular structure for each model. Use a power point slide to cut and paste images for the polymer cards. Images can be obtained from an internet search. Encourage students to use the cards to guide them in this activity.

Mini lab – Building simple polymers.

Pairs or team of 3 persons.

Objective: Students will build simple models of polymers using gummy bears and marshmallows.

Create a data table with the following categories in their interactive journals

- Homopolymer

o subcategories: linear and branched

- Copolymers

o subcategories: blocked, random, graft

- Visual representation

Materials: gummy bears, marshmallows, pipe cleaners, long toothpicks, and polymer cards. Special note: needle and thread may be used to link the polymers together.

Procedure:

Building the homopolymers with monomers, ethene and styrene.

The monomer, ethene will be represented by gummy bears. The marshmallows with piper cleaner are used to represent the monomer, styrene

1. Students will gather materials to build linear models of polyethylene and polystyrene.
2. Cut a minimum of six pipe cleaners in half. Each half will be used to fashion the ring structure for styrene. Bend the pipe cleaner to form a loop and place the extend end into the marshmallow. This is the monomer, styrene.

3. Follow the structural sequence shown on the polymer cards to build models.

Building the copolymers, polyethylene and polystyrene.

4. Combine the polymers, polyethylene and polystyrene, randomly to form a random copolymer.

5. Rearrange this copolymer to form a block copolymer.

6. Rearrange the copolymer again to form a graft copolymer.

Possible Post activity Questions:

How do the properties of a copolymer differ from the properties of a homopolymer?

Why would synthetic hair be a copolymer?

Polystyrene is the polymer in Styrofoam and polyethylene is the polymer in plastic storage containers; as copolymers, what properties would they exhibit?

Debrief activity by eliciting comments in whole group discussion with students. Students' response to post lab questions should be recorded in the journal.

Activity 4 - Part A: Making polymers

Students will make two types of polymers – slime, and cornstarch plastic. Each of the polymers will be plated and tested. The *slime polymer* requires a 4% solution of polyvinyl alcohol be mixed with a 4% solution of borax. To make the needed concentration of polyvinyl alcohol, dissolve 40 grams of polyvinyl alcohol in 960 grams of hot water (80 °C). The borax or sodium borate solution is prepared by dissolving 4 grams of borax in 96 grams of water. Each of these solutions should be prepared at least a day in advance. To make the cornstarch plastic, no advanced preparation is needed.

Lab: Making polymers – Slime and Cornstarch

Teams of 3 persons

Objective: Students will

- make two different polymer solutions
- observe changes in properties of the two polymer
- test the chemical and mechanical properties of the two polymers

Create a data table with the following categories in their interactive journals

- Description of polymers

o subcategories: slime and cornstarch

- Observation of process

o Subcategories: before, during and after

- Visual representation of monomers

o Subcategories: before, during and after

- Distinguishing properties with subcategories – texture, strength, elasticity, compression

Materials: For cornstarch polymers – cornstarch, oil, plastic sandwich bag, water, paper cup, food coloring, and 100-250 ml beaker.

For slime polymer – 4% borax solution, 4% polyvinyl alcohol solution, wooden stick, sandwich bag, paper cup, food coloring, 150-250ml beaker.

Procedure:

Cornstarch polymer

1. Weigh 9.6 grams of cornstarch place in a beaker.
2. Add 20 ml of water to the beaker, along with 2 drops of corn oil ~ 0.5 ml.
3. (Optional) add 2 drops of food coloring to the mixture.
4. Stir until the contents of the beaker are well mixed.
5. Pour half of the mixture into a petri dish and the other half onto a second petri dish.
6. Cover each dish with plastic. Poke small holes in the plastic covering to vent the solution.
7. Place the plated petri dishes in the microwave for 10-20 seconds on high.
8. Remove the plated petri dishes after 10-20 seconds, uncover and allow them to stand undisturbed for 24 hrs.
9. Make a second batch of cornstarch plastic. Repeat steps 1-6. Place the plated petri dishes in the microwave for 20-30 seconds on high.
10. Remove the plated petri dishes after 20-30 seconds, uncover and allow them to stand undisturbed for a few minutes.
11. Use this sample cornstarch to test the mechanical properties of the polymer.
12. Compress and stretch the sample. Test the elasticity.
13. Record all observation, questions, and comments in the journal

Slime Polymer

1. Measure 100 ml – 4% polyvinyl alcohol and place in a 250 ml beaker.

2. Slowly stirring the solution add 10 ml - 4% borax to the polyvinyl alcohol.
3. Place about one third of this solution onto a petri dish. To another petri dish, add a similar amount. Allow the plates to stand undisturbed for 24 hrs.
4. Using the remaining slime to test for compression, elasticity, strength, etc.
5. Record all observation, questions, and comments in the journal.

Possible Post activity Questions: How do the two polymers differ? Describe the cornstarch plastic upon heating? What physical changes occurred? How does adding oil to the cornstarch affect the properties of the plastic? How did the properties of the polyvinyl alcohol change when the borax was added? How would adding more borax affect the properties of the slime?

The slime activity was adapted from: <http://chemistry.about.com/od/chemistryactivities/ss/slimerecipe.htm>

The cornstarch lab adapted from: <http://www.scienceoffcenter.org/science/310-corn-starch-plastic>

Activity 4- Part B

In this activity, students test the effects of solvents on the polymers, as well as record the effect of temperature on the properties of the polymers. Students will note the time it takes for the polymer to degrade or deform.

Lab: Testing polymers - Slime and Cornstarch

Teams of three persons

Objective: Students will

- examine two different polymers after 24 hrs
- observe changes in properties of the two polymer
- test the chemical and mechanical properties of the two polymers

Create a data table with the following categories in their interactive journals

- Description of polymers - after 24 hrs
 - o subcategories: slime and cornstarch
- Observation of processes
 - o Subcategories: acid, acetone, base, boiling water, cold water, room temperature water
- Visual representation of polymers
 - o Subcategories: before, during and after processes
- Distinguishing properties with subcategories - texture, strength, elasticity, compression

Materials: 0.0001 M HCl, 0.0001 M NaOH, commercial acetone, water, beakers, thermometers, tongs, scissors, digital balances, hotplates, stopwatch.

Procedure:

1. Record observations of the polymers after 24 hrs.
2. Cut each polymer into seven - ~ 0.098 to 0.1 gram samples. Record the mass.
3. Label four beakers: HCl, NaOH, acetone, and water.
4. Add 100 ml of each solvent to a beaker, accordingly.
5. Heat the beaker fill with water to 100 ° C.
6. Obtain two more beakers - add 100 ml of tap water to one and 100 ml of ice water to another.
7. To each beaker, add approximately 0.1 gram of cornstarch. Record the time.
8. Watch for the sample cornstarch to degrade or deform. Record the time it takes for the sample to degrade.
9. Repeat steps 3-8, for the slime sample.

Possible Post activity Questions: How do the two polymers differ after 24 hrs? What changes have occurred in the structure of these polymers? What do you notice about the solutions when the polymers dissolved? How does the relative strengths of the polymers compare? How can the degradation rate be determined for each polymer given the condition?

Debrief the activity with a board meeting, using the guided questions as discussion prompts.

Activity 5: Testing synthetic hair fibers

This is the culminating activity. Be confident that students can work independently to meet the objective. They are the scientists. Student may require assistance setting up equipment or mounting the hair sample. Provide each group a sample of synthetic hair. No group will share the same type of hair. The teams will test the three strands of hair for deformation or degradation in different solvents - acetone, water, acid solution, base solution, oil, and hydrogen peroxide. Have students test for elasticity, tensile strength, comb ability, curl resilience, and heat resistance. Students will write a formal lab report for this culminating activity. Assist the students in connecting the content to the activity. Guide them to use their journal when writing their reports. Providing students a rubric may help them with the report.

Lab: Testing synthetic hair fibers

Cooperative groups of three persons

Objective: Students will

- test the chemical and mechanical properties of synthetic hair fibers
- work independently to design the experiment and write the procedure

- write a formal lab report

Create a data table. Possible categories may include:

- Description of hair fibers

- Observation of processes

o Subcategories: acid, acetone, base, boiling water, oil, peroxide

- Visual representation of hair fibers

o Subcategories: before, during and after processes

- Distinguishing properties with subcategories – elasticity, tensile strength, comb ability, curl resilience, and heat resistance.

Materials: 0.0001 M HCl, 0.0001 M NaOH, commercial acetone, water, 30% hydrogen peroxide, ring stands, clamps, cross bar, Velcro, beakers, thermometers, tongs, scissors, digital balances, hotplates, stopwatch.

Teacher Resources

Cesa, Irene, ed. *ChemTopic Labs Polymers*. Vol. 21. Batavia: Flinn Scientific, Inc, 2006.

This book contains laboratory activities and demonstrations on polymers with easy to understand explanations of the concepts.

Chanda, Manas. *Introduction to polymer science and chemistry: a problem solving approach*. Boca Raton (FL): CRC Press :, 2006.

This is book provides essential content information on polymeric science.

Mebane, Robert C., Thomas R. Rybolt, and Anni Matsick. *Plastics & polymers* . New York: Twenty-First Century Books, 1995.

Part of a series of book about the science of everyday things, this book has lots of great experiments that can be done at home.

Watt, Shirley, and Robert Lipscomb. *Polymer chemistry: a teaching package for pre-college teachers*. Revised by Robert Lipscomb. Ed. Washington, D.C.: National Science Teachers Association, 1989.

This text is good source for background information on polymers.

Films: Chris Rock and Jeff Stilson, *Good Hair*, 2009 (www.google.com/search: Amazon.com, 2011).

Funny yet thought provoking documentary that explores the hair care industry in the U.S.

Websites:

American Chemical Council. Teaching Plastics <http://plastics.americanchemistry.com/Teaching-Plastics> > (accessed July 23, 2011)

Provides background information on plastics, with activities and other teacher resources.

Society of the Plastic Industry. About Plastics <http://www.plasticsindustry.org/aboutplastics/?navItemNumber=1008> > (accessed July 23, 2011)

This website provides a wealth of resource materials, articles, and research on plastics

You tube Videos:

Polymerization [Video]. 2011 Retrieved July 29, 2011, from <http://youtu.be/7nCfbZwGwK8>

Video demonstration on nylon synthesis

How plastic bottles are recycled into polyester, [Video]. 2011 Retrieved July 29, 2011, from <http://youtu.be/zyF9MxlCltw>

Insightful video on the processing of plastic bottles into synthetic fibers

Reading List for Students

Couteur, Penny, and Jay Burreson. *Napoleon's buttons: how 17 molecules changed history*. New York: Jeremy P. Tarcher/Putnam, 2003.

The book recounts the stories of seventeen molecules and their seemingly unrelated link to historical events.

Freinkel, Susan. *Plastic: a toxic love story*. Boston: Houghton Mifflin Harcourt, 2011.

An examination of plastics through the lens of everyday objects such as a comb, a chair and a soda bottle.

Harris, Juliette, and Pamela Johnson. *Tenderheaded: a comb-bending collection of hair stories*. New York: Washington Square Press, 2002 2001.

This is a collection of individual stories, articles, poems, essays and histories about African Americans and their hair.

Schwarcz, Joseph A.. *The fly in the ointment: 70 fascinating commentaries on the science of everyday life*. Toronto: ECW Press, 2004.

This book covers a variety of topics from the science of vitamins to plastic wraps with easy to understand explanations.

You tube Videos:

Polymerization [Video]. 2011 Retrieved July 29, 2011, from <http://youtu.be/7nCfbZwGwK8>

Video demonstration on nylon synthesis

How plastic bottles are recycled into polyester, [Video]. 2011 Retrieved July 29, 2011, from <http://youtu.be/zyF9MxlCltw>

Insightful video on the processing of plastic bottles into synthetic fibers

Recycling plastic bottles into polyester yarn on "How It's Made," [Video]. 2011 Retrieved July 29, 2011, from http://youtu.be/Yhx7-DB_y4

Video shows how plastic bottles are recycled to make polyester yarn

Appendix 1 State Standards

California State Standards for Science

Grades 9-12

Chemistry Standard 10abcde

10. The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:

- a. Students know large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
- b. Students know the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
- c. Students know amino acids are the building blocks of proteins.
- d.* Students know the system for naming the ten simplest linear hydrocarbons and isomers that contain single bonds, simple hydrocarbons with double and triple bonds, and simple molecules that contain a benzene ring.
- e.* Students know how to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids. f.* Students know the R-group structure of amino acids and know how they combine to form the polypeptide backbone structure of proteins.

Endnotes

¹ Atlanta | The Atlanta Post. " *The Atlanta Post | African-American News, Business & Black Politics | Career & Small Business Advice For Entrepreneurs*. N.p., n.d. Web. 20 July 2011. <http://atlantapost.com/tag/atlanta>

² Atlanta | The Atlanta Post. " *The Atlanta Post | African-American News, Business & Black Politics | Career & Small Business Advice For Entrepreneurs*. N.p., n.d. Web. 20 July 2011. <http://atlantapost.com/tag/atlanta>

³ Dione Rosado, S. Nappy hair in the diaspora: Exploring the cultural politics of hair among women of African descent. Ph.D. diss., University of Florida, In *Dissertations & Theses: Full Text* [database on-line]; available from <http://www.proquest.com> (publication number AAT 3271096; accessed July 20, 2011).

⁴ Deedrick, Douglas 2000 Hairs, Fibers, Crime and Evidence Part 1: Hair Evidence. *Forensic Science Communications* 2(3). Electronic document, <http://www.fbi.gov/hq/lab/fsc/backissu/july2000/deedric1.htm>, accessed April 16, 2007.

⁵ Deedrick, Douglas, and Sandra Koch 2004 Microscopy of Hair Part 1. *In* Forensic Science Communications, Vol. 6. Electronic document,

http://www.fbi.gov/hq/lab/fsc/backissu/jan2004/research/2004_01_research01b.htm,

accessed April 16, 2007.

⁶ Dione Rosado, S. Nappy hair in the diaspora: Exploring the cultural politics of hair among women of African descent. Ph.D. diss., University of Florida, *In Dissertations & Theses: Full Text* [database on-line]; available from <http://www.proquest.com> (publication number AAT 3271096; accessed July 20, 2011).

⁷ U.S. Patent No. 7,759,430 B2 (issued July 20, 2010)

⁸ Thrower, Peter A. *Materials in Today's World Revised Edition*. Pennsylvania: McGraw-Hill, Inc, 1999.

⁹ Pritchard, John G. *Poly(vinyl alcohol); basic properties and uses*. London: Gordon and Breach, 1970.

¹⁰ Chanda, Manas. *Introduction to polymer science and chemistry: a problem solving approach*. Boca Raton (FL): CRC Press, 2006.

¹¹ Carraher, Charles E.. *Introduction to polymer chemistry*. Boca Raton: CRC/Taylor & Francis, 2007.

¹² Lipscomb, Robert . *Polymer Chemistry Revised Edition*. Arlington: National Science Teachers Association, 1995.

¹³ U.S. Patent 7906209B2

¹⁴ European Patent 0355749B1

¹⁵ U.S. Patent 3727619

Bibliography

Billmeyer, Jr, Fred W. *Textbook of Polymer Science*. Troy, New York: John Wiley and Sons , Inc, 1971.

Bolker, Henry I.. *Natural and Synthetic Polymers*. New York: Marcel Dekker Inc, 1974.

Mebane, Robert C. , and Thomas R. Rybolt. *Plastics & Polymers*. New York: Henry Holt and Company, Inc, 1995.

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