Using Materials Science to Stimulate Students' "Need to Know"

Terre Trupp
RET I
Union-Endicott High School
Applied Chemistry

Project Goals

- Develop two laboratory activities designed to engage students, increase higher-order thinking skills, and acquaint students with experimental design
- Utilize everyday materials that relate more to students' learning needs

The Four Aspects of Materials Science

- Synthesis and Processing
  - Preparative conditions that determine atomic structure/microstructure
- Structure and Composition
  - Arrangement and identity of atoms derived synthetically and used to prepare the material
- Properties
  - Characteristics of the material
- Performance
  - Conditions where material maintains desirable characteristics

Using Toys to Teach Chemistry and Materials Science

- Topic interests and engages students because materials are familiar
- Unexpected material behaviors can lead to inquiry
  - Students hypothesize the answer to the question *How does this toy work?*
- Students design their own experiments to investigate additional questions they have

Mood Rings

- Physical Properties
  - Hollow glass shell filled with *liquid crystals*
  - Molecules change position (twist) according to the temperature
    - Increasing temperature: twists one direction
    - Decreasing temperature: twists in opposite direction
- Chemistry behind the mystery
  - Liquid crystals are *thermotrophic*
    - Changes in structure are induced thermally

Silly Putty

- Physical Properties
  - stretches, bounces, shears under stress
    - ***Viscoelastic*** non-Newtonian fluid
- Chemistry behind the fun
  - Long chain polymer that is cross-linked
  - Belongs to a class known as *dilatants*
    - Has both viscous and elastic abilities
    - Chains can slip over each other, flowing like a liquid

Silly String

- Physical properties
  - Polymer foam stored under pressure
  - Materials used are an unknown industry secret
- Chemistry
  - Soluble in acetone?

Happy/Unhappy Balls

- Physical properties
  - Neoprene has elastic properties at room temperature, the other does not
- Chemistry
  - Neoprene rubber
  - Elasticity is due to flexibility of bonds joining the network
  - Norsorex rubber
    - Has weak bonds resulting in a low melting point
    - Absorbs most impacts

Memory Gels "Glueballs"

- Physical properties
  - Polymer that demonstrates the properties of both solids and liquids
  - Returns to original shape when stretched
    - similar to memory alloys
- Chemistry
  - Unknown at this time

Additional Explorations

- **Mood rings**
  - Can color be matched with temperature?
- **Silly putty**
  - Does viscosity change with temperature?
- **Silly string**
  - Does the polymer behave the same as styrofoam in acetone?
- **Happy/Unhappy balls**
  - Will a change in temperature affect behavior of material?
- **Memory gels**
  - How far can they stretch before breaking? Will temperature affect "memory"?

Biopolymers

- Polymers produced naturally through biochemical reactions
- Biodegradable
- Feature oxygen or nitrogen atoms in their polymer backbones that are responsible for their biodegradability
  - Synthetic polymers have only carbon-carbon single bonds in their backbones (polyolefins) which resist biodegradation
- Produced by extracting carbohydrates, proteins from plant or animal material
  - Can also be made using microorganisms

Homemade Biopolymers

- Main components used
  - Starch (plant polysaccharide)
  - Gelatin (animal protein)
  - Agar (marine polysaccharide)
  - Plasticizers
    - Sorbitol
    - 1% Glycerol solution
      - >Increases the flexibility of the material
      - >Process is not completely understood
      - >Thought to form cross-links with starch

Discrepant Demonstration

- Used to engage students
- Styrofoam vs. Cornstarch packing peanuts
  - Leads to discussions about what materials each are made of
    - Inquiry about why each behaves differently
  - Can be used to introduce experimental design challenge

Design Challenge

- Requires students to act like scientists to meet specifications of product
- Specifications
  - Product must be flexible enough to wrap around a cardboard tube
  - Product must have the tensile strength to withstand 110 g
  - Product must be a minimum size of 8 X 10 cm^2
- Constraints
  - Product must be within cost limitations

Process

- **Experimental research**
  - Create three different mixtures without plasticizer
  - Internet research
    - biopolymers (what they are and their importance), the materials used (what kind of chemicals, where they come from), plasticizers (what they are)
- **Development of final product**
  - Students decide (based on previous experimental research) what their product recipe will be
- **Experimental tests**
  - Must have evidence that product met specifications using digital pictures
- **Product proposal**
  - Students pitch their product to the "company" using Powerpoint

Experimental Tests on the Product

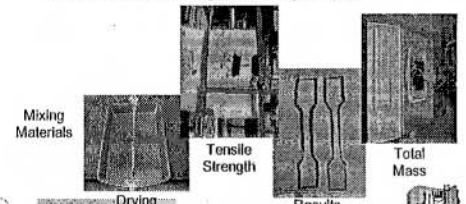
- Qualitative
  - Clarity
  - Flexibility at refrigeration temperatures
  - Permeability using vanilla extract
- Quantitative
  - Tensile strength
  - Glass temperature
    - Determines temperature range where flexibility is compromised
  - Dart test
    - Measures impact strength
    - Force of impact can be determined using a simple calculation

Further Research

- Can similar results be obtained by modifying the recipe?
- Substitute materials
  - Soy protein
  - Casein (milk protein)
  - Carrageenan (marine polysaccharide)
  - Aloe vera
  - Changing ratio of the materials used

Introductory Results

- Material was very flexible
- Texture differs from synthetic films
- Less tensile strength than synthetic



Place in Curriculum

- Toy Investigation
  - Relates to matter
  - Concepts can be reinforced in other units throughout the year
- Design Challenge
  - Organic chemistry
  - Environmental chemistry

Learning Outcomes

- Chemistry Standards
  - Explain the properties of materials in terms of the arrangement and properties of the atoms that compose them
  - Relate how the structure and arrangement of particles and their interactions determine the physical state of a substance at a given temperature and pressure
- MST Standards
  - Standard 1: use of scientific inquiry and engineering design to pose questions, seek answers, and develop solutions
  - Standard 5: Apply technological knowledge/skills to design, construct, use and evaluate products and systems to satisfy human and environmental needs.
  - Standard 7: Apply knowledge and thinking skills to address real-life problems and make informed decisions

Acknowledgements

- Dr. Geoff Coates for looking up the chemicals I needed and providing space for me to work on my biopolymer project
  - Also Yutan Getzler and all of the graduate students in Baker 472 who offered assistance and answered my questions
- Nev Singhota for helping me contact Dr. Coates and for ordering the chemicals I needed
- Ivan Johnson for loaning me his awesome iBook
- Dave Botsch for helping me work on various projects (other than my presentation!)
- Julianne and the rest of the staff for all of their help
- Anne, Mona, Ranald, and Jerry for being great to work with and valuable resources

References

- Ellis, Arthur, B., et. al. Teaching General Chemistry: A Materials Science Companion. The American Chemical Society, 1993.
- Wilson, E. S. Green Plastics. Princeton University Press, 2002.

Web References

- Brain, Marshall. *How Do Mood Rings Work?* How Stuff Works. August 15, 2002. <http://www.howstuffworks.com>
- Yu, Jessen. *How does Silly Putty work?* Science Bug Articles. August 15, 2002. <http://www.drawgroup.org/~jyu/writing/SciBug/SillyPutty.html>
- *Shape Memory Alloys.* August 15, 2002. <http://www.physics.pomona.edu/faculty/prof/TANENBAU/phys185/Smart%20Materials%20Site/Pages/Shape%20Memory%20Alloy.html>
- Matejka, Libor. *Polymer Networks.* Fakulta Chemical. August 15, 2002 <http://www.fch.vutbr.cz/mol/sbornik/matej/>
- *Virtual Textbook: Chemical Properties of Liquid Crystals.* Case Western Reserve University. August 15, 2002 <http://abalone.cwru.edu/tutorial/enhanced/files/hindex.html>
- *YesterdayLand: Silly String.* About.com. August 15, 2002. <http://inventors.about.com/gi/dynamic/offsite.htm?site=http://www.yesterdayland.com/popopedia/shows/toys/ty1069.php>