Polymers -- Bouncy Balls and Spherification

Lesson Type: Module
Target Grade: Elementary or High School
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Semester: Spring 2013

Brief Overview

This lesson is based on two modules involving examples of polymer chemistry. The first involves the creation of artificial “caviar” through spherification with sodium alginate and calcium ions, and the second uses borax to create fun and easy bouncy balls. Both of these modules give some insight into what polymers are, how they behave, and the diversity in this type of material.

Teaching Goals

Polymers are a rather complicated class of materials to try to accurately describe to those without some basis of knowledge in chemistry, but a major goal of this lesson is to get across a basic idea of what polymers are and examples of polymers in everyday life.

Agenda

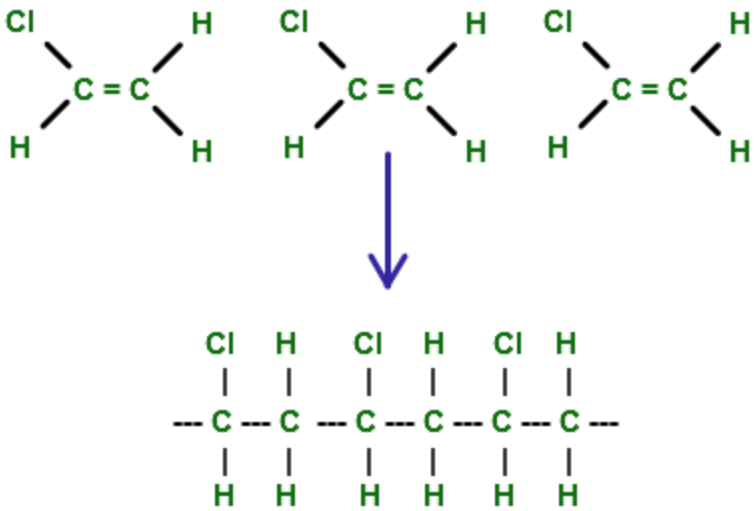
- **Introduction to polymers [one large group or smaller groups]** (~10 min)
    - Describe polymers with an analogy, e.g. a chain a paper clips. One paper clip alone is not very strong but single units can be strung together to make a strong chain with more uses and different attributes.
    - Give a few examples of polymers found in everyday life (Plastic bags, rubber, nylon, teflon, styrofoam, tupperware, etc) and ask kids if they can guess any other examples of polymers.
    - Possibly introduce the idea of polymerization -- how you take a bunch of single units and combine them together in a reaction.
- **Spherification** (30+ minutes)
    - Split into groups of several students.
    - Briefly discuss how polymerization applies to this module.
    - Assist the students in performing the spherification.
    - Discuss what happened; probe their understanding.

- **Borax bouncy balls** (20-30 minutes)
    - Ask the students if they can predict what will be happening based on the materials and the goal.
    - Describe what makes a bouncy ball bounce. Polymers can store energy in secondary bond breaking/shifting. More simply put, the polymer networks can compress and spring back to push themselves back up.
    - Work together to make the borax bouncy balls.
    - Test the balls, possibly vary the experiment to optimize the bounciness.
- **Discussion** (10+ minutes)
    - Ask the students to compare the two modules and apply what they learned
    - Recap by asking if they remember examples of things that are polymers.
    - “investigate further” by playing with the bouncy balls and eating spheres.

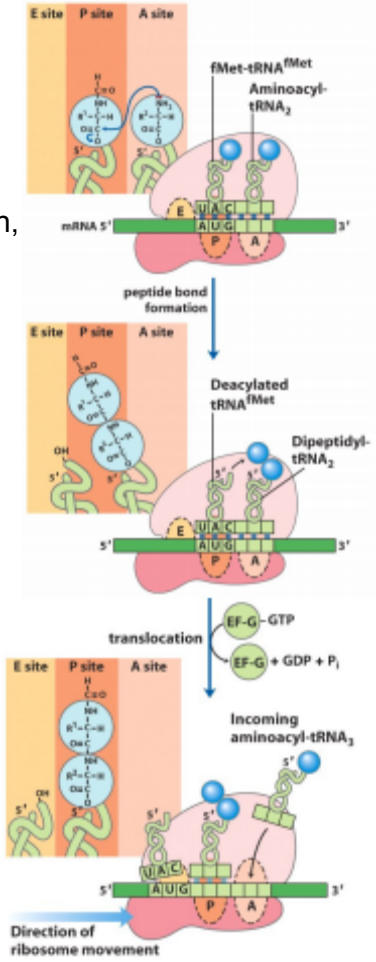
Lesson Introduction

Polymers are a class of macromolecules consisting of many repeating subunits called monomers. Most are made through one of a few types of polymerization techniques and are exist widely in natural, biological, and synthetic examples.

This lesson investigates a few examples of polymerization reactions and demonstrates their simplicity and variety. Obviously, some polymerization, like the stepwise building of polypeptides in cells (shown to the right), is much more complicated than the types of reactions we will be demonstrating, but in the end many come down to the same basic principles.



Polymerization of vinyl chloride.

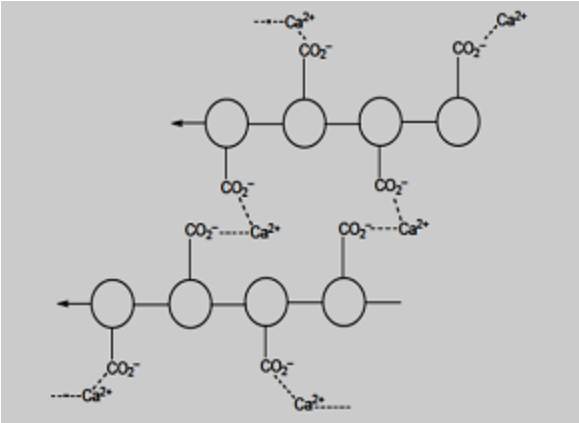


Polypeptide building

Module 1: Synthetic Caviar

Background for Mentors

In this module, calcium ions help crosslink individual alginate polymer chains (diagram and more information below) when the respective solutions come into contact. This results in the formation of an insoluble layer of gel on the outside of the juice beads, trapping the fruit juice inside and creating a relatively stable "caviar" sphere consisting of a polymeric shell surrounding juice.



Positively charged Calcium (Ca^{2+}) ions interact with negatively charged carboxylate ($R\text{-}CO_2^-$) groups from two separate alginate chains, holding them together. When many carboxylate groups from many different alginate chains interact, a stable gel forms.

Introduction

Alginate is a natural polymer that is derived from the cell walls of sea kelp and has a sticky, slimy, and gel-like texture when mixed with water. Indeed, alginate is added to many well-known commercial food products such as ketchup, Jell-O, and ice cream to serve as a thickening agent. In our experiment, we will mix dry alginate with fruit juice and observe what happens when drops or streams of these mixtures are added to a solution containing calcium ions.

Materials (per group)

- Sodium alginate powder (1.5g, or < 1/2 a spoonful for 1/2 a dixie cup of water)
- Calcium lactate (balls or powder) (~2g, or ~ 1/2 a spoonful for 1/2 cup water)
- Water
- Fruit juice
- Food coloring
- 2 Plastic cups, a bowl, and a spoon or two
- 1 or 2 plastic droppers
- Newspaper/towels

Material to Teach

The science behind the polymerization is a little complicated, so we'll keep it simple

- The calcium, "salt" essentially, helps connect (crosslink) the alginate chains and make a gel-like "shell" that holds in the fruit juice
- The gel beads are safe to consume and should be enjoyed!

Procedure

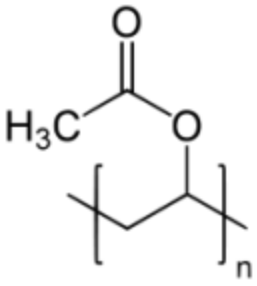
- Spread out the newspaper or towels in the area to minimize mess from spillages
- Put half a spoonful of calcium lactate in dixie cup and filled it 1/2 - 3/4 with water
- Fill a second cup about halfway with fruit juice and add about less than half a spoonful of the sodium alginate. *Stir for several minutes until the clumpiness is mainly gone and it is viscous and more homogenous*. Will take some perseverance; the solution will be fairly. Add food coloring now if desired.
- Put calcium alginate solution into the bowl for easier straining/collecting.
- Using the dropper or stirrer, add drops, strings, or clumps of the juice and alginate solution to the calcium solution and watch the beads and strings form!
- Scoop the "caviar" out with a spoon or strainer, rinse them in a clean water cup, and put them on a paper towel to observe and dry -- and afterwards to eat!
- Repeat as desired.

Examples of spherification with alginate.

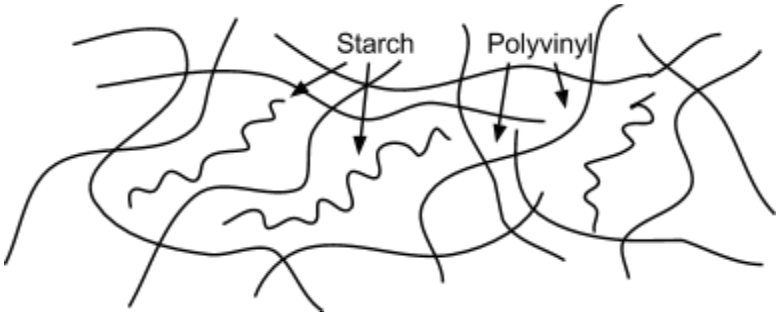
Module 2: Borax Bouncy Balls

Introduction

White glue is made up of a polymer called polyvinyl acetate (PVA) (see below) that is designed to dry when applied between two surfaces and bind the surfaces together. When mixed with borax or boric acid in an alkaline environment, the PVA chains in glue start to crosslink with each other and form networks of branched chains much like a spider's web, giving the PVA a slimy, gooey texture. Corn starch can be added to the mixture to make the product more stretchy or bendy and to create a bouncing ball. The ball becomes bouncy because the starch (a polymer itself) gets trapped between the crosslinked chains and helps to keeps the ball compact and cohesive inside.



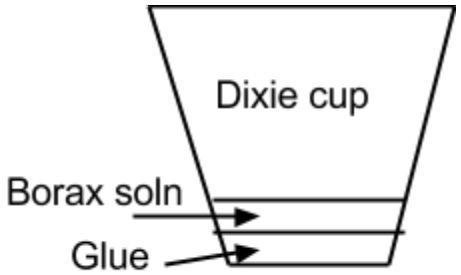
Vinyl acetate monomer



Cross-linked polymer with trapped starches

Materials

- Borax, powdered (~1/2 tsp or 1/4 spoonful)
- Corn starch (~2 tsp or ~1 shallow spoonful)
- White glue (~4 tsp, see diagram)
- Two cups & popsicle sticks
- Food coloring
- Ziploc bags (1 per student)
- Warm water



Material to Teach

- In simpler terms, the glue itself is a polymer, a bunch of long chains. The borax that gets added creates an environment that causes the chains of glue to branch and connect, forming a large gooey, stiff mass that will become a bouncy ball.

Procedure

- Use the same newspaper/paper toweled areas as before in preparation of a mess
- Combine 1/2 tsp of borax powder and 3 tsp of warm water to a cup. *Actual amounts aren't important, just the ratios*. Add food coloring if desired.
- Put the 4 tsp of white glue into a second small cup. Don't add too much!
- Add 2 tsp of corn starch in the borax solution (1st cup), then add this solution to the cup with the glue. [remember, proportions are more important than amounts]
- ***Wait 10-15 seconds for the reaction to begin and occur, then begin stirring*.**
- Stir until the solution becomes thick and difficult to stir further. At this point, remove it and knead/roll into a ball with your hands.
    - The ball should get dryer over time, but if it remains sticky you can work in some more corn starch.
- Once the ball seems to be in pretty good shape, add a little more glue to the outside surface to make a smooth, hard shell.
- The ball is ready! Bounce as desired but be aware that it will get very dirty.
- If time and resources permit, attempt to optimize the balls or observe the effects of different ratios of the materials.
- Students can take their bouncy ball home in a ziplock baggy.

Notes for Mentors

- If the ball remains slimey despite additional stirring, try to add more glue (gradually) into the mixture to react with the residual borax. If it looks like nothing is happening to the glue, try to add more borax to catalyze the crosslinking reaction. If the ball isn't bouncing very well, try to vary the amount of corn starch. Be careful with the size of the solutions -- you want the students to keep them relatively small or else they will end up with large, difficult to work with bouncy balls. Also, the balls won't always come out perfect, some may be too soft/squishy and won't bounce perfectly.

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
Borax (powdered)	1/2 tsp	$8.99 for a lot	online
Corn starch	2 tsp	$10 for a lot	store or online
White glue	4 tsp	$16 for a gallon	store or online
Plastic cups	4		
Plastic spoons	3-5		
Bowls	1		
Food coloring	1 set/site?	$4-5 for a pack	store or online
sodium alginate	3g	16 oz for ~$25	online
Calcium lactate	2g	16 oz for $15	online
Fruit juice	A cup or two	$3-5 for a site?	store
Droppers	1 or 2	??	we have these
Strainers	1 per site	$1	dollar store
Paper towels	a few sheets	1 roll/site is plenty	store, THE SCHOOL
Newspaper	a few pages max	$0 if people bring	Daily Cal :)