ACS Chemistry for Life®

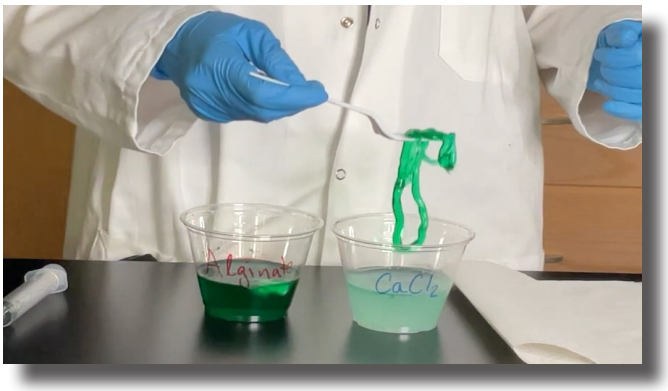
Classroom

Goo Worms

Share the science of polymerization by making wriggly, squishy worms!

Question to investigate

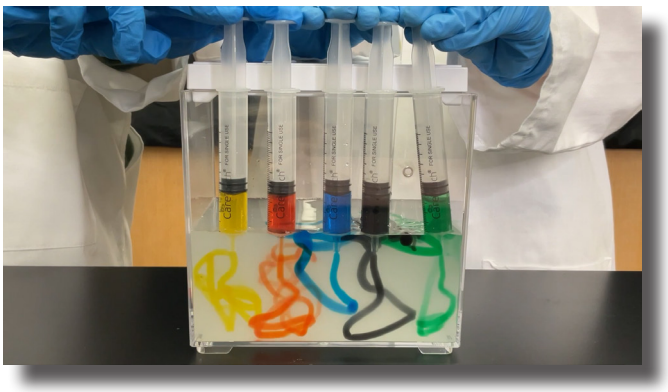
How do two clear solutions react to create stretchy “worms”?



Chemistry covered

Review with teacher or group leader to identify the appropriate concepts for your group

- ***Polymerization:*** calcium chloride crosslinks sodium alginate molecules to make a polymer
- ***Uses of alginate:*** alginate is used as a thickner because of its ability to polymerize
- ***Reaction kinetics:*** the alginate polymerizes so quickly that it captures liquid inside of it



Special considerations

- This activity can get messy; cover all work surfaces.
- This activity should be done either as a video or a demonstration with the audience at least 10 from the presenter(s)
- Potential hazards include:
  - Sensitizers (calcium chloride)
  - Spills and splashes
- Conduct your own RAMP assessment prior to presenting this activity.

Time required

Preparation: 20 minutes

Activity: 5 – 20 minutes

Age range

8 – 12 years

Group size

Participants work individually

1 presenter per 10 – 15 students

Materials

Per 30 participants:

- 150 g (~ 3 cups) calcium chloride[a]
- 60 g (~ ¾ cups) sodium alginate[b]
- Distilled water
- Food coloring or liquid watercolor paint (optional)
- 30 syringes, without needles
- 60 clear colorless 9 oz. plastic cups
- 30 forks or slotted spoons
- Paper towels
- Permanent markers
- 30 pairs of goggles
- 30 pairs of non-latex gloves

Additional materials identified in your RAMP analysis:

a Can be found among canning supplies in online or in well-stocked grocery stores, if desired.

b Can be found among molecular gastronomy supplies online or in specialty stores, if desired.

Prior to the activity

Customize activity to venue

1. Review RAMP safety worksheet for this activity.
2. Revise procedure to adapt to your specific venue and participants.
3. Review activity with the teacher or group leader.
4. List appropriate procedures for accidents, emergencies:

Identify appropriate safety practices

- Wear appropriate personal protective equipment (e.g., goggles, gloves, etc.).
- Secure loose hair, clothing.
- Prohibit eating, drinking.
- Clean work area, wash hands after activity.
- Other practices identified in RAMP worksheet:

Prepare materials

1. Prepare calcium chloride ($CaCl_2$) solution by dissolving 150 g $CaCl_2$ in 6 L water.
2. Prepare sodium alginate solution by dissolving 60 g sodium alginate in 3 L water. Add a few drops of food coloring or liquid watercolor paint, if desired.
3. For each student, label a set of 2 cups with "calcium chloride" and "sodium alginate."

Prepare on site

1. Divide calcium chloride solution among 30 labeled cups.
2. Divide sodium alginate solution among 30 labeled cups.
3. Provide each student with a calcium chloride cup, a sodium alginate cup, a syringe, a fork, paper towels, goggles, gloves, and any other appropriate PPE.

Additional set-up for your specific venue and audience:

On-site activity

Step	Details	Ask participants:
Introduce activity	• Explain what polymers are and that students will be making them.	• How do the starting liquids look?
Make worms	***Direct participants to:*** • Fill the syringe with sodium alginate solution. • Squirt syringe contents into the $CaCl_2$ solution. They should start to see what looks like a worm forming.	• What do you think is happening to produce the worm?
Examine resulting worm	***Direct participants to:*** • Use a fork or gloved hand to pull out the worm and it place on a paper towel. • Use the side of the fork to cut open the worm. • Dip the cut end of the worm into the $CaCl_2$ solution	• What is inside the worm? • Can you "heal" a cut worm? Why does that work?
Explore the kinetics	Explain the polymerization reaction (See "chemistry details") ***Direct participants to:*** • See who can make the longest worm. • Try making spheres instead of worms	• Can you control the shape of the worm? • What happens if you leave the worm in the $CaCl_2$ solution for w long time? • What happens if you dehydrate the worm? • What do you think sodium alginate is used for in household products?
Clean up	• Dispose of all solids from this activity in the trash. • Dispose of all liquids down a drain with copious amounts of additional water.. • Clean all work surfaces with water or a damp cloth. • Wash hands thoroughly.	

Chemistry details

Adjust these details to match the level of your audience.

What did you make?

You made a polymer! A polymer is a huge molecule made up of smaller molecules joined together. If those small molecules are sugars, the polymer is called a polysaccharide.

Sodium alginate is a polysaccharide found in brown seaweed. It consists of long chains of tiny clusters of sugars. On a molecular level, it looks a lot like cooked spaghetti.

How does alginate become a goo worm?

When the sodium alginate meets the calcium chloride, the calcium displaces the sodium in the sodium alginate, causing those long polysaccharide molecules to clump together. The clumped polymers form an even bigger polymer that is too big to stay in solution, resulting in a gooey worm.

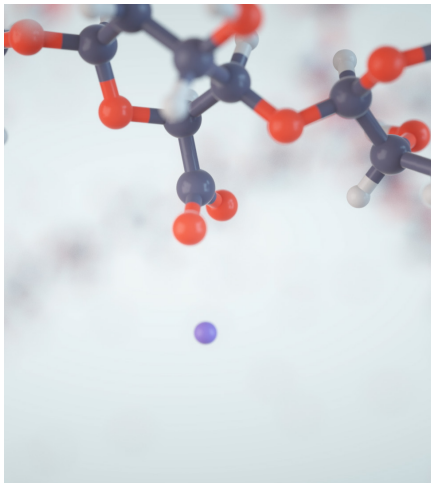
The polymerization reaction is very fast. If you cut open the worm, you'll notice that some of the sodium alginate solution was trapped inside as a result. Likewise, you can "heal" a cut quickly by dipping the cut end into the calcium chloride solution. If you leave the worm in the calcium chloride solution longer, enough calcium will eventually diffuse into the worm and react with the sodium alginate inside, resulting in a firmer worm.

Applications of alginate polymer

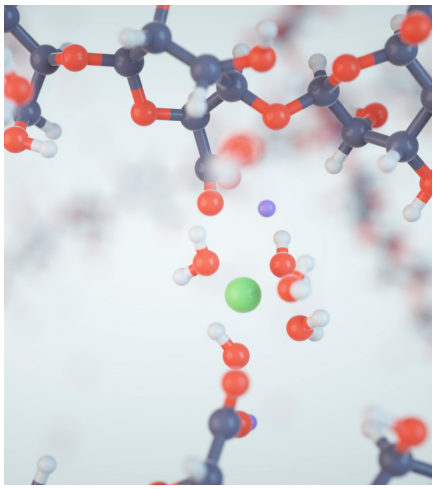
You will notice that this polymer is soft, smooth, and easily broken. These properties make it a useful thickener for foods like ice cream, yogurt, and fruit fillings for pastries. It is also used to make dental impressions and absorbent dressings for wounds.

A process similar to that for goo worms is also used to make popping boba drinks, yogurt "ravioli," and a variety of other tasty treats. Its use as an edible replacement for food wrappers is also being explored.

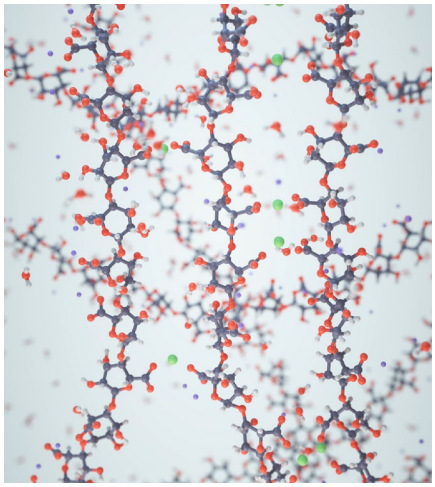
How Ca^{2+} polymerizes sodium alginate



In sodium alginate, each Na^+ ion bonds to a single carboxylate ($–CO_2^-$) group on the polysaccharide.



When Ca^{2+} displaces the Na^+, it binds to two $–CO_2^-$ groups.



When the $–CO_2^-$ groups are on different strands, the Ca^{2+} crosslinks the alginates, creating a gel-like network.

References

American Chemical Society, 2023
ACS Student Chapter at St. Louis University

