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 thickener 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

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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)

\(^a\) 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.

Additional materials identified in your RAMP analysis:

- 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

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:
   - 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

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:
<table>
<thead>
<tr>
<th>Step</th>
<th>Details</th>
<th>Ask participants:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduce activity</strong></td>
<td>• Explain what polymers are and that students will be making them.</td>
<td>• How do the starting liquids look?</td>
</tr>
<tr>
<td><strong>Make worms</strong></td>
<td><strong>Direct participants to:</strong></td>
<td></td>
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<tr>
<td></td>
<td>• Fill the syringe with sodium alginate solution.</td>
<td>• What do you think is happening to produce the worm?</td>
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<tr>
<td></td>
<td>• Squirt syringe contents into the CaCl$_2$ solution.</td>
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<tr>
<td></td>
<td>• What do you think is happening to produce the worm?</td>
<td></td>
</tr>
<tr>
<td><strong>Examine resulting worm</strong></td>
<td><strong>Direct participants to:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Use a fork or gloved hand to pull out the worm and place on a paper towel.</td>
<td>• What is inside the worm?</td>
</tr>
<tr>
<td></td>
<td>• Use the side of the fork to cut open the worm.</td>
<td>• Can you “heal” a cut worm? Why does that work?</td>
</tr>
<tr>
<td></td>
<td>• Dip the cut end of the worm into the CaCl$_2$ solution</td>
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<tr>
<td><strong>Explore the kinetics</strong></td>
<td><strong>Direct participants to:</strong></td>
<td></td>
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<tr>
<td></td>
<td>Explain the polymerization reaction (See “chemistry details“)</td>
<td>• Can you control the shape of the worm?</td>
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<tr>
<td></td>
<td><strong>Direct participants to:</strong></td>
<td>• What happens if you leave the worm in the CaCl$_2$ solution for a long time?</td>
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<tr>
<td></td>
<td>• See who can make the longest worm.</td>
<td>• What happens if you dehydrate the worm?</td>
</tr>
<tr>
<td></td>
<td>• Try making spheres instead of worms</td>
<td>• What do you think sodium alginate is used for in household products?</td>
</tr>
<tr>
<td><strong>Clean up</strong></td>
<td>• Dispose of all solids from this activity in the trash.</td>
<td></td>
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<tr>
<td></td>
<td>• Dispose of all liquids down a drain with copious amounts of additional water.</td>
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<td></td>
<td>• Clean all work surfaces with water or a damp cloth.</td>
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<td></td>
<td>• Wash hands thoroughly.</td>
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</tbody>
</table>
**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.

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**Chemistry details**

*Adjust these details to match the level of your audience.*

**How Ca$^{2+}$ polymerizes sodium alginate**

In sodium alginate, each Na$^+$ ion bonds to a single carboxylate ($\text{–CO}_2\text{–}$) group on the polysaccharide.

When Ca$^{2+}$ displaces the Na$^+$, it binds to two $\text{–CO}_2\text{–}$ groups.

When the $\text{–CO}_2\text{–}$ groups are on different strands, the Ca$^{2+}$ crosslinks the alginates, creating a gel-like network.

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**References**

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