Gummy Worm Polymer

Preparation of Polymers

Introduction

The enormous size of polymer molecules and their flexible, chain-like structures give polymers unique and useful properties. Sodium alginate, a natural polymer obtained from kelp and seaweed, is an important food additive. Let's look at some of the unusual properties of this natural "gummy worm" polymer!

Concepts

- Polymers
- Cross-linking
- Polymer gels
- Polysaccharides

Materials

Calcium chloride solution, $CaCl_2$, 0.1 M, 100 mL	Erlenmeyer flask, 250-mL
Copper(II) chloride solution, $CuCl_2$, 0.05 M, 100 mL	Forceps
Sodium alginate solution, 2%, 10 mL†	Jumbo pipet
Sodium chloride solution, NaCl, saturated, 100 mL	Magnetic stirrer or stirring rod
Water, distilled	Paper towels
Balance, 0.1-g precision	Wash bottle
Beakers or flasks, 250-mL, 3	Waste beaker, 1-L

†See the Preparation section.

Safety Precautions

Copper(II) chloride solution is toxic by ingestion. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Sodium Alginate Solution, 2%: Measure 2.0 g of sodium alginate into a 250-mL Erlenmeyer flask. Add 100 mL of distilled or deionized water and a stir bar. Stir on a magnetic stirrer for about one hour or until the solid dissolves. For best results, allow the mixture to sit overnight to give a uniform solution.

Procedure

1. Label three beakers or flasks A, B, and C and add approximately 100 mL of the appropriate solution to each, as shown in the following table.

Beaker	**A**	**B**	**C**
Solution	Calcium chloride	Copper(II) chloride	Sodium chloride

2. Draw up a pipet-full of sodium alginate solution into a clean, jumbo pipet. Slowly squeeze the pipet bulb and add the sodium alginate solution *in one continuous stream* into the calcium chloride solution in Beaker A.
3. Repeat step 2, adding sodium alginate into the *copper(II) chloride solution* in Beaker B.
4. Wait about 1–2 minutes for products to form.
5. Using clean forceps, gently remove several insoluble polymer "worms" from the solution in Beaker A.
6. Rinse the calcium alginate with distilled water from a wash bottle and place the product on a paper towel. Observe the

texture, form, and appearance of calcium alginate.

7. Repeat steps 5 and 6 with the copper alginate product from Beaker B.
8. Using forceps, transfer several calcium alginate "worms" into the saturated sodium chloride solution in Beaker C.
9. Stir the mixture in Beaker C for 2–3 minutes. Observe any changes in the appearance of the polymer and the solution. (See Question #3 on the demonstration worksheet.)

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Polymer gel products obtained in this demonstration may be disposed of in the trash according to Flinn Suggested Disposal Method #26a. Excess calcium chloride, copper chloride, and sodium chloride solutions may be disposed of down the drain with plenty of excess water according to Flinn Suggested Disposal Method #26b.

Tips

- A demonstration kit, Sodium Alginate—A Natural "Gummy Worm," (Catalog No. AP7087) is available from Flinn Scientific and contains enough materials to perform the demonstration as written at least seven times: 4 g of sodium alginate powder, 500 mL each of calcium chloride and copper(II) chloride solutions, and 1 L of saturated sodium chloride solution. The calcium chloride and copper(II) chloride solutions may be reused from one demonstration to the next after the polymer "worms" have been removed. Use fresh sodium chloride solution for each demonstration.
- Sodium and calcium alginate are nontoxic. Pass the polymer "worms" around the classroom to allow students to observe their texture and properties.
- A polymer gel is a type of colloidal solution consisting of a cross-linked polymer network swollen in a liquid medium such as water. The properties of a gel depend on the interaction of these two components. The liquid component, or solvent, prevents the polymer matrix from collapsing into a hard, insoluble mass. The polymer matrix helps to retain the solvent.
- This activity may be extended by testing the solubility of the polymer in other metal salt solutions. Sodium alginate will precipitate with most polyvalent metal ions and gives colored gels with many transition metal cations, including Fe^{3+} or Co^{2+} salts.
- Seaweeds have been tested to see if they can be used in water treatment to remove metal ion contaminants from water. Will sodium alginate decolorize a solution of copper(II) chloride?
- Help students build connections between chemistry and food science by having them conduct a kitchen or grocery store search for foods containing sodium alginate or other alginate food additives.

Discussion

The word polymer is derived from two Greek words, *polys* (many) and *meros* (part). Polymers are large, chain-like molecules that contain many copies of one or two "repeating units," called monomers, which have been joined together by a chemical reaction. It is not unusual to have thousands of monomer units in a single polymer molecule. Because of the enormous size of polymer molecules and the flexibility of polymer chains, many polymers have unique and useful properties. Polymers can be formed into fibers, drawn out into thin films, or molded into a variety of solid objects. Many polymers will swell up in contact with water to give gels, with properties that appear to be intermediate between those of a solid and a liquid. The properties of a polymer depend on the chemical nature of the monomer, the length of the polymer chain, and how the monomers are joined together. Many biological molecules and materials, such as DNA, proteins, starch, cellulose, and wood, are examples of natural polymers.

Sodium alginate is a natural polymer obtained from kelp and seaweed, brown algae belonging to the phylum *Phaeophyta*. The polymer is a principal component of the cell wall in brown algae, comprising up to 40% of the dry weight of large species such as giant kelp. Worldwide, about 25 million pounds of sodium alginate are produced each year for use in the food, textile, medical, and pharmaceutical industries. The giant kelp *Macrocystic pyrifera* is the principal source of sodium alginate harvested in the United States. This is the largest seaweed in the world, growing at a rate of 50 cm a day. A single attached plant can be as large as 65 m in length.

Sodium alginate is a polysaccharide composed of thousands of oxidized sugar "units" joined together to form an ionic polymer. The repeating units are six-membered rings containing negatively charged $–CO_2^-$ groups. The C-1 carbon atom of one ring is connected via an oxygen atom to the C-4 carbon atom of the next ring in the polymer chain (see Figure 1).

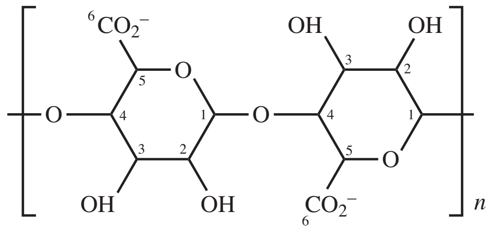

Figure 1. Structure of Sodium Alginate.

The presence of ionic $–CO_2^-$ side chains, as well as numerous –OH groups, make this natural polymer extremely *hydrophilic* or "water-loving." The resulting solution is thick, viscous, and smooth. Sodium alginate is used as a "thickening agent" in many processed foods, including ice cream, yogurt, cheese products, cake mixes, and artificial fruit snacks. The nontoxic food additive absorbs water, helps to emulsify oil and water components, and gives foods a smooth texture. Replacing the sodium ions in sodium alginate with calcium ions leads to cross-linking between the polymer chains and gives an insoluble gel, calcium alginate. Each Ca^{2+} ion can bind to at least two carboxylate groups in the polymer. If the two $–CO_2^-$ groups are on different (adjacent) polymer molecules, then the effect of adding divalent cations is to tie together or cross-link individual polymer molecules into a large, three-dimensional network. The cross-linked polymer swells up in contact with water to form an nsoluble gel. Studies have shown that the polymer behaves like a giant chelating ligand (similar to EDTA), and that each Ca^{2+} ion is bound to four $–CO_2^-$ groups. Calcium alginate has a number of uses in the medical and pharmaceutical industries. It is used to make wound dressings, dental impression materials, as a radiography agent, and to diagnose and treat intestinal or gastric diseases.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Process: Grades K–12
Systems, order, and organization
Evidence, models, and exploration

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard F: Science in Personal and Social Perspectives; science and technology in society.

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter
Content Standard F: Science in Personal and Social Perspectives; science and technology in local, national, and global challenges

Answers to Worksheet Questions *(Student answers will vary.)*

1. Describe the appearance, form, and texture of (a) sodium alginate solution, (b) calcium alginate, and (c) copper alginate.

   a. Sodium alginate forms a colorless, slightly cloudy, thick, viscous solution.

   b. Calcium alginate is a smooth, flexible, semi-solid, translucent, gel-like substance that precipitates from water in the form of—worms! The "worms" have the consistency of gummy candy. The product seems to float in the calcium chloride solution.

   c.Copper alginate has the same form, texture, and relative density as calcium alginate, but it is a pale blue color.

2. *a*. What causes the calcium and copper products to appear swollen and translucent?

   The calcium and copper alginate polymers are hydrophilic and thus readily absorb water. Water causes the polymer to swell and to appear translucent.

   b. What evidence is there that copper ions are incorporated into the alginate polymer?

   The blue color of the insoluble polymer product in Beaker B indicates that copper(II) ions have been incorporated into the polymer network.

3. How and why does the appearance of calcium alginate change when it is placed in saturated sodium chloride solution?

   Adding the insoluble calcium alginate "worms" to saturated sodium chloride solution causes the worms to break down and disintegrate. The pieces do not completely dissolve however. The sodium chloride solution turns cloudy and little pieces of solid settle to the bottom of the beaker.

4. Polymer solutions form solid gels when numerous long-chain polymer molecules interact to build a three-dimensional "network." Explain how calcium and copper ions bind alginate molecules together to form a network.

   Calcium and copper(II) ions are both divalent, with +2 charges. Each metal cation can bind to at least two $–CO_2^-$ *groups via ionic bonds. If the two carboxylate groups are on different (adjacent) polymer molecules, then the effect of adding divalent cations is to tie together many different polymer molecules into a large, three-dimensional network.* ***Note to teachers:*** *Studies have found that the alginate polymer acts like a giant chelating ligand (similar to EDTA), and that each* Ca^{2+} *ion is bound to four* $–CO_2^-$ *groups.*

5. Calcium alginate is spun into fibers that are used to make gauze-type dressings for burns and other wounds. Suggest some possible advantages of calcium alginate wound dressings compared to other types of materials.

   Calcium alginate dressings absorb water from wound secretions and promote healing. The dressings are also biodegradable. The calcium alginate fibers essentially form gels and are very easy to remove without tearing or injuring the wound. Simply rinsing the dressing with saline solution (NaCl) washes away the dressing!

Reference

This activity was adapted from an experiment in *Polymers*, Volume 21 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific Inc.: Batavia, IL (2006).

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Gummy Worm Polymer* activity, presented by Irene Cesa, is available in *Preparation of Polymers*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Gummy Worm Polymer* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Sodium Alginate—A Natural "Gummy Worm" Polymer Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP7087	Sodium Alginate—A Natural "Gummy Worm" Polymer Demonstration Kit
C0234	Calcium Chloride Solution, 0.1 Molar, 50 mL
C0382	Copper(II) Chloride Solution, 0.1 Molar, 500 mL
S0445	Sodium Alginate, 25 g
S0236	Sodium Chloride Solution, Saturated, 500 mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Gummy Worm Polymer Worksheet

1. Describe the appearance, form, and texture of (a) sodium alginate solution, (b) calcium alginate, and (c) copper alginate.

2. *a*. What causes the calcium and copper products to appear swollen and translucent?

   b. What evidence is there that copper ions are incorporated into the alginate polymer?

3. How and why does the appearance of calcium alginate change when it is placed in saturated sodium chloride solution?

4. Polymer solutions form solid gels when numerous long-chain polymer molecules interact to build a three-dimensional "network." Explain how calcium and copper ions bind alginate molecules together to form a network.

5. Calcium alginate is spun into fibers that are used to make gauze-type dressings for burns and other wounds. Suggest some possible advantages of calcium alginate wound dressings compared to other types of materials.