



Subject Area(s): physical science, chemistry

Activity Title: Alginate gel I: how chemistry affects solubility



Grade Level 6 (6-8)

Lesson # 1 of 2

Time Required: 1 hour

Summary: Students study how solid materials can dissolve in water, and how changing the chemistry of a material can affect its solubility (or ability to be dissolved). This activity can be used to augment a number of curricular lessons, particularly those on erosion and water ecosystems.

Engineering Connection: In this activity, students will work with a material called alginate. This biopolymer is widely used in biomedical engineering to immobilize cells and hold medicines. This lesson also deals with changes in physical properties based upon changes in chemistry. This is particularly applicable to the fields of Materials Science and Environmental Engineering.

Keywords: solution, dissolve, solute, solvent, alginate, polymer, chemistry

Educational Standards:

- Science: 3.1.7e, 3.2.7b, 3.4.7a, 3.5.7a, 3.5.7d, 4.1.7, 4.3.7a, 4.3.7b

Pre-Requisite Knowledge: Students should have knowledge that some materials dissolve in water and some do not. They should also understand that all matter is made up of atoms, and that a material’s atoms can change through chemical processes.

Learning Objectives:

After this lesson, students should be able to:

- Describe a basic definition for a polymer, as a very long molecule made of many smaller units bonded together in a chain-like fashion
- Understand how changing the atoms in a system can change physical properties (i.e. a polymer that was dissolved in liquid solution changes to a precipitated solid)
- Extrapolate and synthesize ways in which changing the chemistry of other objects (either to make them precipitate or dissolve) could effect the environment

Materials:

The materials needed for this experiment can be pre-measured and distributed by the teacher, or measured and acquired by the students themselves. A **mass balance** and a **graduated cylinder** or other device for measuring liquid volume will be needed. You will likely want to order sodium alginate powder and CaCl salt from a chemical supply company.

chemicals and equipment	amount needed (per student or group)
sodium alginate (alginate acid sodium salt)	0.15 grams
food dye, assorted colors	2-3 drops
calcium chloride (CaCl ₂)	0.6 grams
table salt (NaCl)	several tablespoons
water	40 mL
centrifuge tubes, 15 mL or larger (or other lidded mixing vessels)	2
Petri dishes (or other small sample containers)	2
pipettes or droppers (disposable are best)	2

Introduction / Motivation:

The following material can be read aloud or distributed via the included student handout.

Dissolving Stuff!

What do we mean when we say something is **soluble** in water? If a solid material is soluble in water, we mean that it **dissolves** in the water. The molecules of a solid material (the **solute**) are surrounded by molecules of a liquid (the **solvent**) and become part of a liquid **solution**. Whew, that's a lot of vocabulary words!

Have you ever mixed sugar in a glass of water? What happens to the sugar? In this case, what is the solute? What is the solvent?

As you probably know, when you mix sugar in water, it seems to disappear! The water tastes sweet, so you know the sugar has to be in there somewhere. But you can't see it! What has happened is that the small sugar molecules have been spread out and surrounded by molecules of water, making an all-liquid solution. If we let the water evaporate, eventually we'll have solid sugar again.

A glass of water can only dissolve a certain amount of sugar – if we keep adding more and more, eventually there will be so much sugar in the solution that no more can be dissolved. This is what we call a **saturated solution**. The extra sugar that can't dissolve will sink to the bottom of the glass.

Some solids, like sugar and salt, will easily dissolve in water. Other solids, like sand and dirt, don't dissolve so easily (which is why it's pretty tough to get dirty clothes clean using just water alone). This is because all these items have different **chemical structures**. They are made up of different molecules, or collections of atoms.

Alginate

Today we're going to be working with a solid material called **alginate**. Alginate (also called **alginic acid**) is a material that comes from brown algae, a type of seaweed! It is a **polymer** material, meaning it is a long chain made of hundreds or thousands of little pieces. A molecule of alginate has hundreds of thousands of these pieces, all linked together in a big chain. Each one of these individual pieces is called a **monomer**. **Mono** means "one" and **poly** means "many." That's why a chain made from lots of **monomers** is called a **polymer**! Get it?

Special kinds of engineers, called biomedical or tissue engineers, use alginate in medicines to hold cells from the body. If you have ever had a casting taken of your teeth at your dentist's or orthodontist's office, the mold material probably had alginate in it! You may have even eaten alginate in certain foods, although you probably didn't realize it!

The alginate we are going to be using today contains atoms of the metal element **sodium**. Remember that the symbol for sodium is **Na**. Can you find the sodium atoms in this figure (hint: they're attached to **oxygen** atoms, which have the symbol **O**).

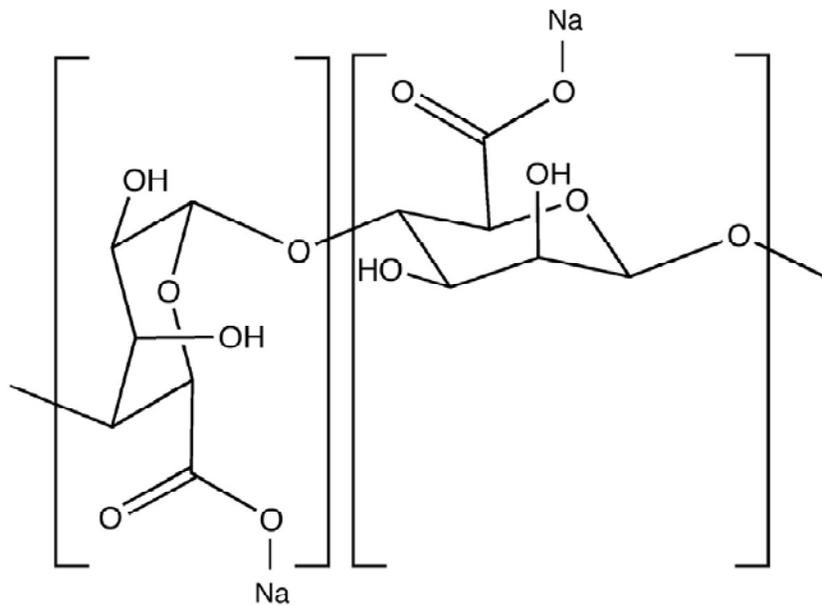


Figure 1. This is the chemical structure of alginate. The two monomers, or single chemical parts, that make up alginate are shown in brackets. Alginate has hundreds or thousands of these monomer parts linked together to form a long chain.

In chemical structure shown in Figure 1, how many oxygen atoms are attached to each sodium atom?

Each sodium atom is attached to **only one** oxygen atom. This is important, so remember it!

When we dissolve this **sodium alginate** in water, the sodium atoms leave the alginate. This leaves that oxygen atom lonely, and able to attach to something else.

We will place the alginate into some water that has **calcium** dissolved in it. The calcium will **bond** (or attach) to the alginate molecules, at the oxygen atom.

Remember, each sodium atom attached to only one oxygen molecule. Each calcium atom, on the other hand, can attach to more than one oxygen atoms at the same time.

In Figure 2, we see pieces of two different alginate chains near each other. Write in the symbol for calcium (**Ca**) where the arrow points. This calcium will be bonded, or linked, to two oxygen atoms from the two different alginate chains. It's really a little more complicated than this, but let's keep it simple for now!

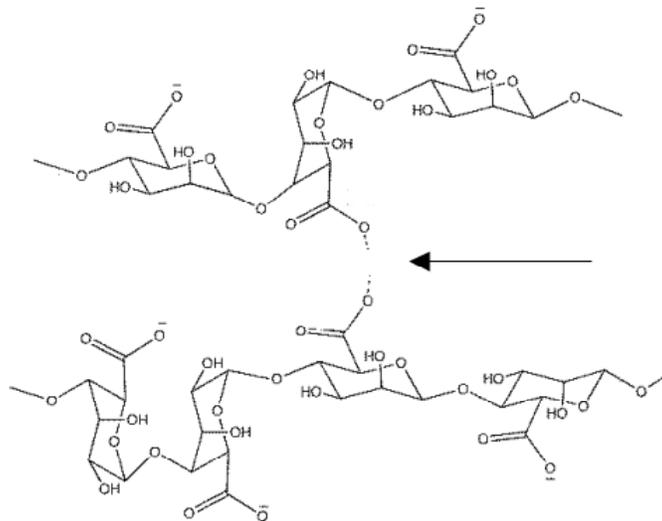


Figure 2. Here we see parts of two alginate chains that have come near to each other after being dissolved in water. The oxygen atoms near the arrow can each bond to another atom dissolved in the water solution.

Now those alginate chains are stuck together by that calcium atom! We call the calcium bonds **cross-links**, because they link together two polymer chains. It's like the two chains have been combined together to become one even bigger molecule now. Can you hypothesize how this process might affect the physical properties of the molecule? Do you think this cross-linked alginate will be easier or harder to dissolve compared to plain alginate?

Scientists and engineers have learned that when calcium cross-links alginate, it actually binds to more than two oxygen atoms. In Figure 3, the darkened circles

represent oxygen atoms that are all binding to the calcium sitting in the middle. Calcium is just the right size to fit in the little spot made by the alginate chains, just like an egg sitting in an egg carton. In fact, scientists have called this arrangement the “egg-box” configuration!

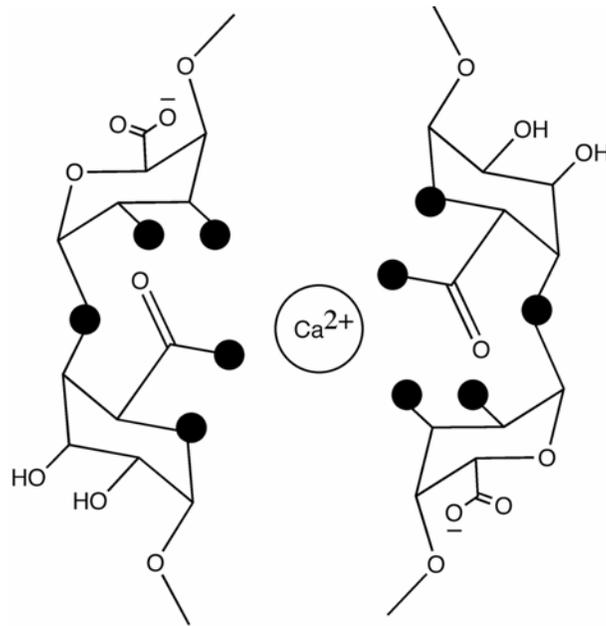


Figure 3. This is a more accurate illustration of how calcium binds together different alginate chains. The dark circles are all oxygen atoms that participate in holding the calcium in place.

Now we're ready to have some fun!

Lesson Background & Concepts for Teachers

Making alginate solutions

- Each student or group will first need one lidded tube (Falcon brand centrifuge tubes like the one pictured here work particularly well). A drop or two of food dye (to make the material more visually interesting) should be added to the tube, followed by the 0.15 g of sodium alginate powder.



- Next, 10 mL of water should be added to the tube. Students should be instructed to make sure the lids are screwed on **tight!**
- The alginate should dissolve within a few minutes, but it will require some vigorous shaking. Remind the students again to make sure their lids are firmly screwed on, and have them start shaking!



- When there are no longer any solid lumps of material visible, the alginate has fully dissolved. Some bubbles will likely remain, and shouldn't be confused for alginate particles. The solution should be thick and syrupy.

Making calcium chloride solutions

- Calcium chloride salt will quickly dissolve in water. When it dissolves, the salt breaks into its *ionized* (or charged) parts. Each calcium ion has a **+2** charge, and each chloride ion has a **-1**

charge. This is why a single calcium and two chlorines, when bonded together, form a **neutral** (or zero-charge) salt molecule ($+2 + -1 + -1 = 0$).

- We will be using a **3% weight/volume (weight-to-volume)** solution, using the following formula:

$$\frac{\text{weight solute (g)}}{\text{volume solvent (mL)}} \times 100 = \text{percent}$$

- So, a 3% w/v solution will contain 3 g of CaCl_2 per 100 mL of water. This can be pre-dissolved in bulk for the entire class, or each student/group can make their own solution by dissolving 0.6 g of CaCl_2 in 20 mL of water.
- The CaCl_2 solutions can be placed in a second centrifuge tube, or poured into a shallow Petri dish.

Making alginate gels!

- Students should be asked to observe that the tubes containing their alginate solutions have no solid material remaining within. Instruct them to draw up a small amount of alginate solution in a pipette or dropper (disposable plastic pipettes are ideal for this task).
- Have the students squeeze a drop of the alginate solution into the CaCl_2 solution. Caution them not to draw any CaCl_2 solution into this pipette (since the alginate will gel almost instantly, it will easily clog the pipette tip).
- The students should see that as soon as the liquid alginate solution comes in contact with the CaCl_2 solution, a solid jelly-like material is formed. Using a second pipette, the students can suction this gel bead from the solution and set it in a dry sample dish.



- Encourage the students to experiment and make more gels. Ask them if they can make larger blobs of gel, or long alginate “worms.” If a small spray bottle is available, CaCl_2 can be sprayed over drops and streaks of the alginate solution.
- After the students have exhausted their supply of alginate solution, have them collect all their gels in their dry sample dishes. The gels have a high moisture content, or **hydration**. Some water will leak from the gels as they sit. A folded paper towel beneath the gels will help them dry faster.



Vocabulary / Definitions:

Word	Definition
Polymer	A type of molecule made up of many smaller individual pieces (monomers) all linked together to form a long chain.
Alginate	A particular kind of polymer that is produced naturally in brown seaweed and used in engineering to surround and hold cells and to make medical products.
Soluble	Able to be dissolved in a liquid.
Solvent	The solid material that is being dissolved.
Solute	The liquid in which the solid material is dissolved.
Solution	The all-liquid combination of both solvent and dissolved solute (not to be confused with a mixture, which would have both solid and liquid together)
Precipitation	The process in which a material that is dissolved in liquid become solid.
Cross-linking	Bonds that link together different polymer chains.

Associated Activities

Lesson Closure

We have learned that by changing the **chemistry** of our material, we changed its **solubility** (how well it dissolves).

We were able to get alginate to change from a dissolved liquid state to a precipitated solid state, simply by replacing sodium (Na) atoms with calcium (Ca) atoms. Each calcium is able to link to multiple oxygen atom in two different alginate chains, holding the chains together. Since the alginate chain is so long, there are many

opportunities for this process to occur, and a large cross-linked molecules containing many linked chains can form.

As these chains link together, it becomes harder and harder for the alginate to stay dissolved. Finally, the cross-linked molecules become so large and entangled that they simply cannot stay in solution any longer. They precipitate as solid gels. These gels still contain a lot of water, so they are “squishy.”

What do you think would happen if we try putting sodium back into the structure? Try pouring some table salt, which is made up of sodium and chlorine, over your gels. How does the sodium affect the gels’ properties?

Assessment

Pre-Lesson Assessment

Making a human polymer chain!

- Have the students stand and move about the room. Explain to them that they are like **monomers**, or individual chemical parts, moving around in a solution.
- Now have each student grab the hands of others nearby. They have become a **polymer**, or a molecular chain made up of many monomer units. Have the class make two separate polymer chains.
- These two polymer chains can continue to move around the classroom. When they come close to each other, place your hands on the heads of a student in each chain and have everyone stop moving. You have become a **cross-link** that holds the two chains together.

Post-Introduction Assessment

Notebook

Students should research the vocabulary words and define them in their science notebooks. Some terms, such as cross-linking and alginate, may require use of online resources.

Lesson Summary Assessment

Alginate Gel Quiz

See attached Alginate Gel Quiz document

Homework

Journal Response

See the “Journal Response” section of the Alginate Gel Quiz document.

References:

Cathell, Matthew D. & Schauer, Caroline L. “Structurally colored thin films of Ca²⁺-cross-linked alginate.” *Biomacromolecules*. 8(2007) 33-41.

Attachments: Alginate_Gel_Quiz (PDF), Alginate_Gel_Quiz (Word version), Alginate_Handout (PDF), Alginate_Handout (Word version)

Redirect URL:

<http://gk12.coe.drexel.edu/modules/doc/Matthew%20Cathell/Alginate%20module/Alginate%20Module.pdf>

Owner: Drexel University GK-12 program, *Engineering as a Contextual Vehicle for Science and Mathematics Education*, supported in part by National Science Foundation Award No. DGE-0538476.

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Author: Matthew D. Cathell

Date: August 28, 2007

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NAME: _____ DATE: _____

Pre-Lab Reading for Students

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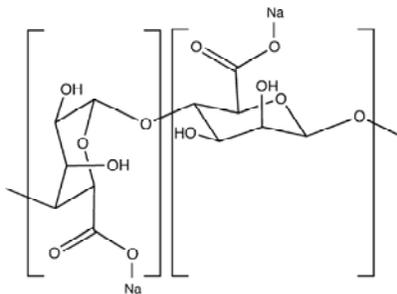


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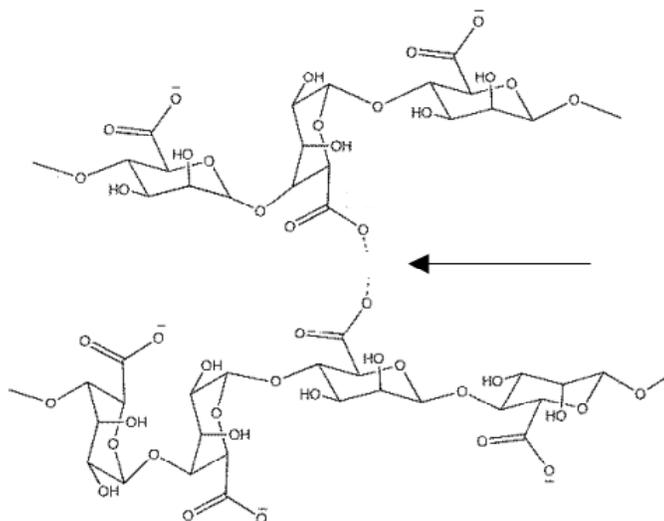


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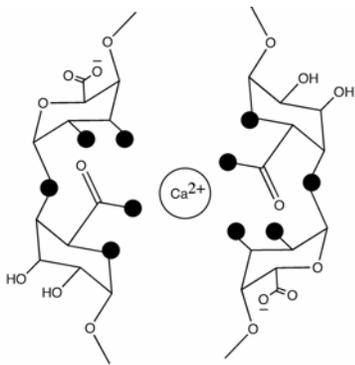


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NAME _____

DATE _____

ALGINATE GEL QUIZ

1. The polymer material we used to make gels was called _____ . This material comes from _____ .

2. Alginate was the **solute** / **solvent** (circle one) and water was the **solute** / **solvent** (circle one).

3. The metal ion **sodium** (**Na**) was able to bond to _____ (how many) **oxygen** atoms.

4. When sodium was replaced by **calcium** (**Ca**), the alginate gelled because

FUN FACT

Do you think you've ever eaten alginate before? Remember how thick and syrupy the alginate + water **solution** was? Alginate is used as a thickener in many kinds of food, including ice cream, jelly, and soup. It's also used to make the red pigment filling in olives!

JOURNAL ASSIGNMENT

We have learned that by changing the **chemistry** of our material, we changed its **solubility** (how well it dissolves). How might this concept of solubility be important in rivers and streams? Think about what might happen if the chemistry of the river changes enough to make materials dissolve from the river rocks. Research the phrase **acid mine drainage**, and report how addition of acid to water can impact the environment.

Have you ever seen a marble statue or building that has been **eroded**, or eaten away, by acid rain? What is acid rain doing to the material, and how does it apply to what we've learned in our experiment about solubility?