Biodegradable water bottles from brown seaweed - Years 8/9 – TEACHER VERSION

What is green chemistry?

Green Chemistry aims to change the mindset and practices associated with everyday chemistry, to be safe, sustainable, environmentally friendly, re-used and non-toxic.

Seaweed for the future

A biomass such as seaweed (Figure 1), is one of the most promising and versatile materials that chemists, biologists, engineers, and medical industries are trying to use to improve our future. It contains a carbohydrate called alginate that turns into a gel. Its properties can then be changed by using a crosslinker, like calcium in solution. It binds more alginate together, making it stronger. Below is a diagram of alginate with a calcium solution, and its product, calcium alginate, which encapsulates the liquid (Figures 2 and 3).

Did you know?

Alginate can be eaten, its not harmful to our body, but some do have allergies to seaweed, so please DO NOT EAT OR HANDLE if you have a known seafood allergy.

Figure 1. Brown seaweed from South Australia

Figure 2. Blue water encapsulated with alginate

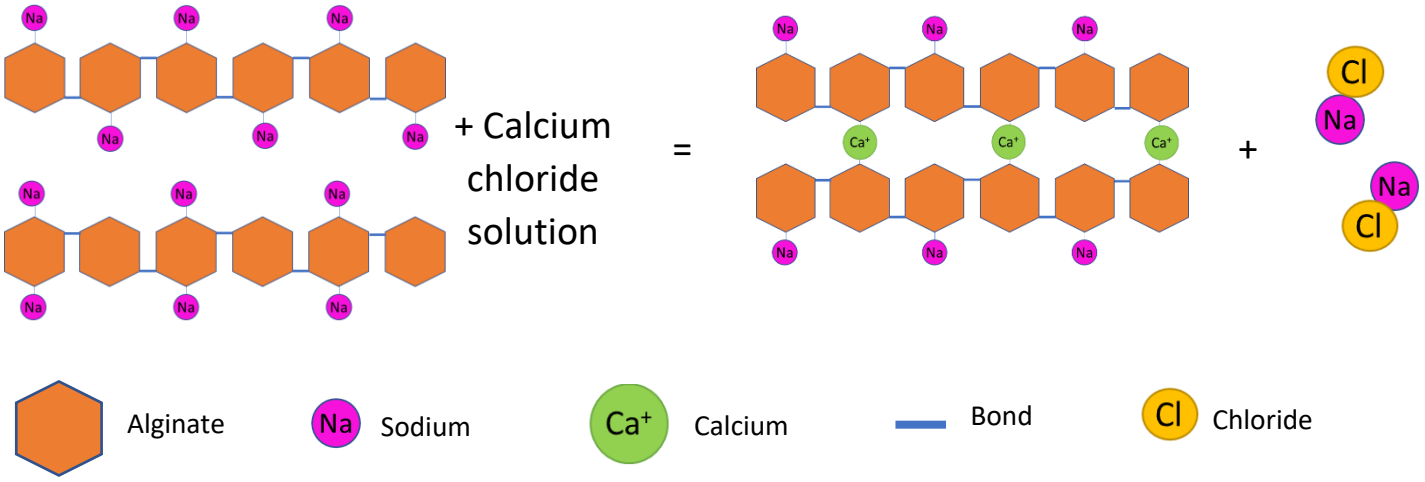

Figure 3. Alginate mixed with a crosslinker to form calcium alginate

In this experiment, you will crosslink alginate to encapsulate a liquid, like a water bottle, and see if the pH of different liquids affects this process. Think about how you can use this for different applications and what could be changed to improve the process.

Each kit contains resources for 32 students working in groups of 4.

Each kit contains:
32 clear cups
8 plastic pipettes
24 small cups
24 wooden stirrers
8 spoons
15 g $CaCl_2$. The SDS is on our website https://tcgcm.com.au/outreach. Note: $CaCl_2$ is an eye irritant (H319) and so precautions such as wearing safety glasses during solution preparation and taking care not to touch the eye area before removing gloves and washing hands should be taken.
12 g sodium alginate from brown seaweed. The SDS is on our website https://tcgcm.com.au/outreach
5 pH testing strips

Not included in the kit - orange juice, milk, food dye and additional beakers for preparing the calcium chloride solution.

Pre-class preparation

1. Prepare a 4% solution of alginate by adding the 12 g of alginate supplied to 300 mL of water and stirring. It may take some time to dissolve the alginate. This process can be sped up by using a blender.

Each group will need the following

- 4 clear cups with a different liquid in each. One containing orange juice, one containing dilute food colour, one containing milk. Approximately 10 mL of each liquid is required. Exact volumes are not essential.
- 1.5 g calcium chloride, 100 mL water and a small beaker for mixing
- 1 plastic pipette
- 1 spoon – to scoop the biodegradable water bottles from the calcium chloride solution
- 3 wooden stirrers
- 3 x 10mL of alginate solution. The small paper cups can be used for this.

The pH of each liquid can be tested as a class. The pH indicator chart is on our website https://tcgcm.com.au/outreach.

Method

1) Read through the experiment and questions first before starting.
2) Collect all materials. Label your cups so you don't get confused about which liquid is in which cup.
3) In a small beaker, mix 1.5 g of calcium chloride into 100ml of water. Mix until dissolved. Label your beaker.
4) Measure approx. 10ml of each household liquid and place separately into the clear cups. As a class, test and record the pH of each solution.
5) Add approx. 10 ml of alginate to each liquid and stir (ratio 1:1). As a class, record the pH of the solutions containing orange juice and milk again.
6) Use a pipette to drop the alginate mix into the calcium chloride solution.
7) Remove each water ball using the spoon.
8) If there is alginate solution remaining, try the reverse. Mix different liquids with calcium chloride instead and try adding this mix to the alginate solution.

Results

Group members: _____

Solution name	pH (stick or draw pH test strip here)		Write observations	Stick photo or draw diagram here
	Before	After		
Orange juice	2-3		Does not hold its shape very well.	
Food dye (1 -2 drops) mixed with water	7		Form small gel beads	
Milk	6		Form small milk balls. Will hold its shape really well due to the added calcium in solution. Students can squeeze this between their fingers to pop.	

Discussion questions

a. Observe the reaction. What happened? Can this be used for a water bottle? Why/why not?

Sodium alginate dissolves in water to form a viscous, clear solution. When reacted with calcium chloride, a double replacement reaction occurs where the calcium ions replace the sodium ions on the alginate, producing calcium alginate. The second product formed is sodium chloride which remains in solution.

Ref: https://edu.rsc.org/exhibition-chemistry/seaweed-spheres/2000059.article

https://uakron.edu/polymer/agpa-k12outreach/lesson-plans/pdf/what-bead-is-best.pdf (Extension experiment)

b. Explain why using seaweed is a sustainable source of material?

Seaweed is an abundant resource in Australia. So much of it exists that we can use the washed-up seaweed from the beach and process it for medical applications and replacing plastic. It can also be farmed without too much impact on the environment unlike farming cows and the methane emissions.

c. Did the pH effect the ability for alginate to gel? Why/why not?

Yes. Viscosity (thickness of the gel) increases as pH decreases. The carboxylate groups in the alginate become protonated (H+) and form hydrogen bonds. When added to calcium chloride, there is no replacement reaction occurring because the calcium does not have a binding site.

Ref: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223967/

d. How could you improve this experiment? What was its limitations?

Improve: students may suggest other neutral liquids. If choosing a basic or acidic substance, how could they modify the experiment to support different pH-based solutions. Students answers will vary, but their creativity may also lead to some innovative ideas. You could also try smearing the alginate mix and spraying the film with calcium chloride. This would produce something similar to the Notpla clip.

Limitations: Access to different drinks and materials. Equipment needed for larger scale, like the Notpla video.

Extension questions

e. How else could you use the properties of alginate to follow green chemistry principles?

Green chemistry principles include being reusable, non-toxic to human health, non-toxic to the environment, little to no waste, made from natural sustainable resources.

Student may need to do some research for this question as alginate is a versatile gel. It can used for drug delivery, wound healing, 3D prosthetics and other medical applications.

f. What is the word equation for the reaction between sodium alginate and calcium chloride?

sodium alginate + calcium chloride = calcium alginate + sodium chloride

(reactant 1) (reactant 2) (product 1) (product 2)

g. What is the chemical equation?

$2NaCl_6H_7O_6 + CaCl_2 \rightarrow 2NaCl + C_{12}H_{14}CaO_{12}$