YumScience™

MOLECULAR GASTRONOMY WORKSHOPS

SPHERIFICATION KIT

HIGH SCHOOL EDITION

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CAUTION: Work with parents, the school nurse and other appropriate school personnel to determine if any modifications are needed to make sure that students with food allergies or dietary restrictions can participate fully in class activities. MSDS available upon request.

LESSON OVERVIEW

In this lesson, students will learn how molecular gastronomy chefs use chemical reactions to turn ordinary food into extraordinary dishes. Students will learn valuable skills and techniques to create their own edible molecular gastronomy dishes. Imagine, experiments you can eat!

For this lesson, in part 1 and 2 students will use the Reverse Spherification technique to create delicious strawberry spheres with a thin gel membrane on the outside and delicious strawberry puree on the inside. In Part 1, students will learn about Gelation, Spherification and Diffusion. In Part 2, students will learn Osmosis. In Part 3, students will use the Basic Spherification Technique to create cranberry "caviar", small spheres with liquid inside that pop in the mouth. In Part 3, students will learn about Acids, Bases and pH and "The Effect of pH in Alginate Gels".

WHAT CONCEPTS WILL STUDENTS LEARN?

- Chemistry is used in a wide variety of professions.
- Science and cooking are closely related.

Gelation

- A gel is a jelly-like substance mostly composed of liquid that behaves like a solid thanks to a three-dimensional cross-linked network within the liquid.
- There are different gelling agents used in molecular gastronomy.
- Gelatin is manufactured by partial hydrolysis of collagen, a connective tissue of animals.
- Gelatin works by protein denaturation through application of heat and coagulation.
- Sodium Alginate is manufactured from brown seaweed.
- Sodium Alginate is a polymer that forms a gel when cross-links form in the presence of ions.
- Sodium Alginate gels form an irreversible phase transition from liquid to solid.
- Gelatin forms a reversible phase transition since it can be melted.

Diffusion and Osmosis

- Diffusion is the process in which molecules move from high concentration areas (hypertonic solution) to low concentration areas (hypotonic solution).

- During the experiment, calcium molecules travel to the outside of the strawberry sphere and come into contact with the alginate to produce a gel. Why? The alginate molecules are too big to go inside the sphere. (diffusion of ions)
- When cooking, heat is also transferred through food by diffusion.
- Osmosis is the process in which water seeps through a membrane to make concentrations more equal. Osmosis is the diffusion of water.
- The lower the PH, the more acidic the solution and the higher concentration of hydronium ions which are positive.

pH and its effect in sodium alginate gels

- The pH scale is a measure of the hydrogen ion concentration. It spans from 0 to 14 with the middlepoint (pH 7) being neutral (neither acidic or basic).
- When alginate molecules are in contact with a liquid with both calcium ions and a low pH, many of the molecules will react with the hydrogen ions instead of the calcium ions, preventing the formation of a gel.
- The pH value is a logarithmic function of the hydrogen ions in the solution: $pH = -log10[H+]$

WHAT SKILLS WILL STUDENTS LEARN?

- How to measure time and weight precisely.
- How to reproduce sequential steps following recipe instructions.
- How to engage in collaborative discussions with team and teachers.
- Use scientific thinking processes to conduct investigations and build explanations: observing, communicating, comparing and organizing.

INTRODUCTION

Science and Molecular Gastronomy are closely related. Science is knowledge of the natural world. Molecular Gastronomy is using scientific knowledge to prepare and modify ingredients to create interesting and unique dining experiences.

Whether in the science lab or in the kitchen, scientists and chefs have something in common, they rely on measurements. To create a recipe, a chef will measure ingredients just like a scientist.

Good chefs, like good scientists, create recipes sequentially. That means they do things in a certain order. Even when they are inspired, there is something they do first, then second, third, and so forth until their work is complete. By completing something in an order more than once creates a routine. Chefs, like scientists, hope for the same successful outcome each time.

WHAT IS MOLECULAR GASTRONOMY?

The term Molecular Gastronomy is commonly used to describe a style of cuisine in which chefs explore culinary possibilities by borrowing tools from the science lab and ingredients from the food industry. Formally, the term molecular gastronomy refers to the scientific discipline that studies the physical and chemical processes that occur while cooking. Molecular gastronomy seeks to investigate and explain the chemical reasons behind the transformation of ingredients, as well as the social, artistic and technical components of culinary and gastronomic phenomena. Molecular Gastronomy also refers to experimental restaurant cooking driven by the desire of modern cooks to explore the world's wide variety of ingredients, tools and techniques. Molecular gastronomy research starts in the kitchen where chefs study how food tastes and behaves under different temperatures, pressures and other scientific conditions.

GELATION

In physics, it takes either a large amount of energy or a significant change in pressure to transform a liquid into a solid. Modernist chefs achieve this monumental feat with just a few sprinkles of powder to form a gel! A gel is a jelly-like substance mostly composed of liquid that behaves like a solid because of a three-dimensional cross-linked network within the liquid.

Gelation is a phase transition that turns a liquid into a solid, by forming a cross-linked network. A critical density of cross links is needed for this phase transition to occur. The cross links can form through a variety of different processes, including physical (e.g. entanglement of polymers) or chemical (bond formation).

Gels are very common in food. Jell-O is the obvious example. But what about eggs? Eggs are gels even in their uncooked form. Cook an egg and the gel solidifies into a thermoirreversible hard gel. Tofu is also another culinary gel.

Food additives can be used to make a liquid (e.g. water at room temperature) have elastic properties, or exhibit elastic behavior.

Example of Gelling Agents used in molecular gastronomy:

Gelling Ingredient	Origin
Gelatin	Animal
Agar	Seaweed
Gellan	Microbes
Sodium Alginate	Seaweed
Pectin	Plants

But not all of these gelling agents work the same way. Let's look at gelatin and sodium alginate for example.

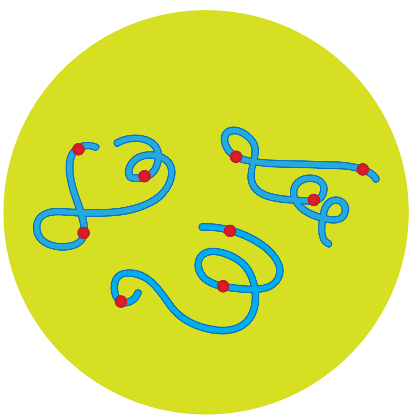
Gelatin: Protein Denaturation and Coagulation

Gelatin is a protein gelling agent usually extracted from the skin, bones, and connective tissues of animals such as domesticated cattle, chicken, pigs, and fish. Gelatin works by denaturation and coagulation. The gelatin proteins must be heated in order to denature, then cooled so that the proteins can bond with one another.

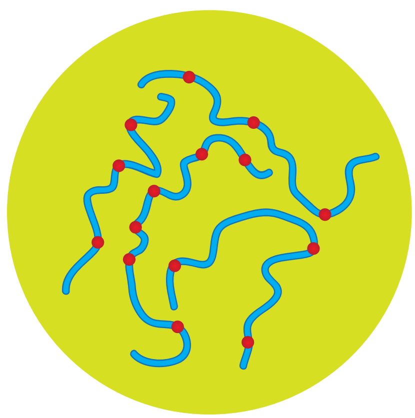
In their natural state, proteins like gelatin are soluble in water. Most of their hydrogen bond forming parts are tucked inside the folded structure of the protein, making them unavailable for forming bonds with other molecules.

Heating the gelatin solution denatures the protein. A denatured protein unfolds, as many of the hydrogen bonds that preserve the three dimensional structure of the protein are broken by the added heat energy. Instead of a uniform solution of molecules that are all the same shape, in a denatured protein, the molecules can take a staggering number of different shapes.

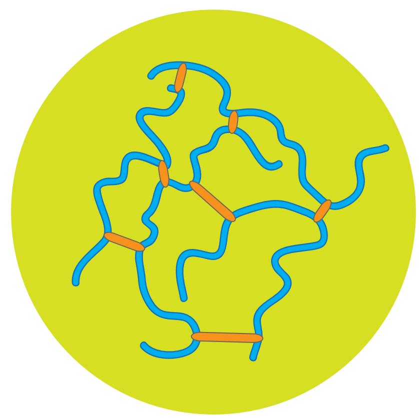
The unfolded molecules also have more bond forming areas exposed on the outside, and they form bonds with one another, forming larger random three-dimensional structures that entrap water molecules and coagulate to form a solid or gel. The new large molecules become insoluble in water.



Folded Gelatin Protein



Denaturation



Coagulation

Sodium Alginate: Polymer cross-linked in the presence of ions
Alginate is a seaweed derived carbohydrate polymer that is able to cross-link in the presence of calcium and form a gel. Sodium Alginate is manufactured from brown seaweed that grows in cold water regions.

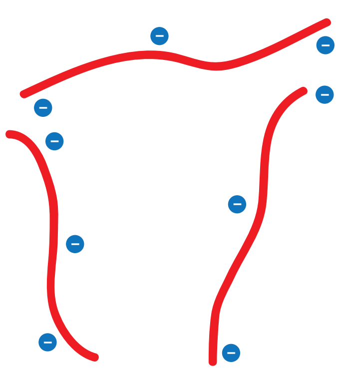
Alginate polymers are carbohydrates (polysaccharides) and are negatively charged so when in a solution they repel each other.

If you add sodium chloride (NaCl), the sodium ions have a single positive charge. These positively charged ions will stick to the negative charges of the alginate, neutralizing them and decreasing the strength of electrostatic repulsion between the alginate polymers.

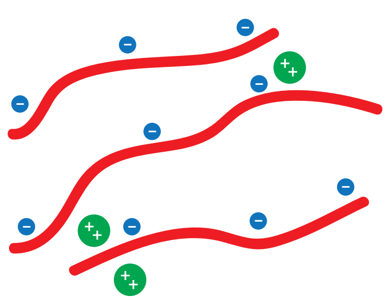
But if you add a calcium salt such as calcium lactate gluconate, calcium ions in the solution have two charges. These multivalent ions stick to a negative charge in the alginate strand but there is still another negative charge available which sticks to another negative charge in another alginate strand, thus causing the two alginate strands to stick together. A cross-link is formed with the calcium ion as the binding agent.

Alginate gel stiffness can be changed by changing alginate concentration and/or calcium concentration. The cross link distance and elasticity of an alginate gel can be affected by the quantity of charges. By increasing the calcium concentration you are adding more positively charged ions to the gel, which in turn can decrease the crosslink distance and therefore making the gel stiffer. The crosslink distance and elasticity can also be increased by increasing alginate (polymer) concentration.

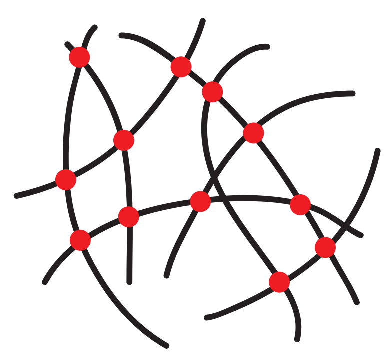
To form a gel with sodium alginate, the presence of calcium ions is necessary. To form a gel with gelatin, heating is necessary. The gels formed with sodium alginate are a type of irreversible phase transition from liquid to solid. Gelatin forms a reversible phase transition as it can be melted by increasing the temperature.



Strands of sodium alginate polymer are negatively charged and in solution they repel each other.



Adding a multivalent ion like a calcium ion with two positive charges causes the strands to stick together. The calcium ions act as binding agents.



Cross-linked sodium alginate gel.

SPHERIFICATION HISTORY

The Spherification technique was introduced in 2003 by Chef Ferran Adria at his world famous restaurant el Bulli in Spain. This marked an inflexion point in molecular gastronomy. As with many other molecular gastronomy techniques, spherification was discovered by working together with a leading company in the food industry and, of course, the genius of Ferran Adria and the rest of el Bulli team. In 2003, Ferran Adria and el Bulli team were visiting a company called Griffith España to see their installations when they came across a Mexican sauce that contained little balls in suspension which added acidity and spice when eaten. This reminded him of a drink he knew that contained little spheres made by immersing a liquid with sodium alginate in a bath of calcium. In both cases, the spheres were solid and did not have a liquid filling.

They got a sample of the alginate and when they returned to el Bulli Taller, the experimentation began. Their first spherification experiment was with water as the main ingredient and a syringe to form little drops of the alginate solution. Because they used water in a water bath they couldn't see any spheres but when they strained the liquid they discovered that they had been able to create small balls with liquid inside (now called caviar). They then tried with a spoon instead of a syringe to create a larger sphere and now the first "spherical ravioli" was created.

SPHERIFICATION TECHNIQUE

The spherification technique consists of a controlled jellification of a liquid which forms spheres when submerged in a bath. The spheres can be made of different sizes and have been given names like caviar when they are small and eggs, gnocchi and ravioli when they are large. The resulting spheres have a thin membrane and are filled with flavored liquid. A slight pressure on the sphere makes it burst and release an amazing explosion of flavor. The spheres are flexible and can be carefully manipulated.

There are two main kinds of spherification techniques and each of them has its advantages and disadvantages which make them more suitable for certain recipes. The Basic Spherification technique consists of submerging a liquid with sodium alginate in a bath of calcium. The Reverse Spherification technique consists of submerging a liquid with calcium content in a bath of sodium alginate. When the liquid drops into the bath, a thin coat of gel forms around the droplet as the calcium reacts with the sodium alginate.

THE SCIENCE OF SPHERIFICATION

Sodium Alginate is a natural polysaccharide product extracted from brown seaweed that grows in cold water regions. In presence of calcium, sodium alginate forms a gel. No heat required.

In Basic Spherification, the gelling occurs thanks to the diffusion method in which the crosslinking calcium ion diffuses from an outer reservoir into an alginate solution. Gels form when a calcium salt is added to a solution of sodium alginate in water. The gel forms by chemical reaction, the calcium displaces the sodium from the alginate, holds the long alginate molecules together and a gel is the result. No heat is required and the gels do not melt when heated. The gel coating is formed inside the droplet. Because the calcium ions continue diffusing towards the center of the droplet even after removing the sphere from the calcium bath, the gelification process continues and will eventually form a solid gel sphere.

In Reverse Spherification, the calcium ions diffuse from the droplet into the alginate bath, forming a gel coat outside the droplet of flavored liquid. Because the calcium ions are diffusing from the inside out and no alginate molecules are getting into the droplet, the gelification process stops as soon as the spheres are removed from the alginate bath. This allows you to store the spheres for later use.

The different processes have three main consequences that affect the chef:

1. Basic spherification spheres do not last long with liquid inside for one simple reason – there are too many alginate strands within the sphere to go unreacted for an extended period of time. There are plenty of unbound calcium ions in the membrane that will find a way to react with the remaining alginate molecules inside the sphere. As they do so, the huge network of atoms that makes up the membrane will extend inwards. The liquid inside the membrane will eventually all be part of the network and it will feel more like a squishy gel than caviar. This does not happen with reverse spherification because the calcium ions within the membrane have nothing to react with; the alginate strands have either already all reacted or been rinsed of after spherification. This leaves the liquid on the inside with its original lack of a rigid structure.

2. Basic Spherification cannot be used with ingredients that have calcium content such as yogurt or cream as it will react with the sodium alginate and gel before you pour the flavored ingredient in the calcium bath.

3. Basic Spherification is the preferred method for producing “caviar” (small spheres) since the viscosity of the bath is thin allowing the small droplets to cohere into a spherical shape in the bath and the spheres don’t stick together because the membrane grows inwards.

DIFFUSION

In the process of reverse spherification, we submerge a liquid droplet with calcium content in a bath of sodium alginate. The bath is a sodium alginate solution, with water as the solvent and sodium alginate as the solute.

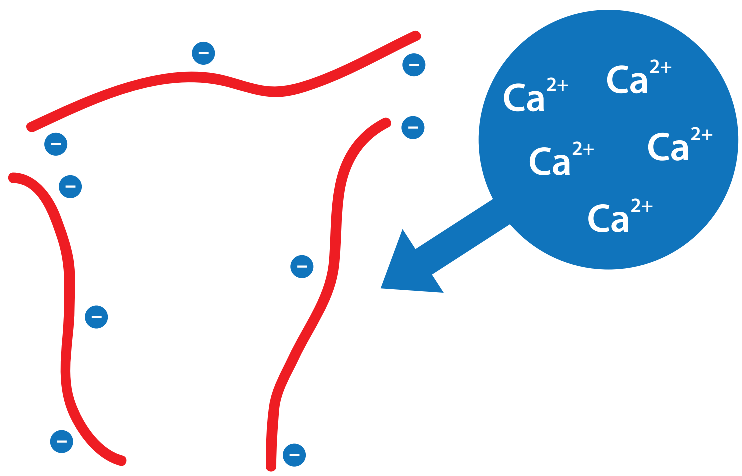
Once the liquid droplet is submerged in the bath, the calcium ions diffuse from the droplet into the alginate bath, forming a gel coat outside the droplet of flavored liquid. Diffusion is the process in which molecules move from high concentration areas (hypertonic solution) to low concentration areas (hypotonic solution). In this case, there is a high concentration of calcium molecules in the droplet but there are none in the sodium alginate solution. So the calcium diffuses from the droplet into the bath and forms cross-links in the alginate solution forming a gel membrane around the sphere.

The gel forms a semi-permeable membrane through which water and calcium ions can pass through but sodium alginate molecules can't because they are too large to go through. Because the calcium ions are diffusing from the inside out and no alginate molecules are getting into the droplet, the gelification process stops as soon as the spheres are removed from the alginate bath. This allows you to store the spheres for later use.

How fast alginate gels and the thickness of the gel can be calculated using the diffusion equation:

$$\text{Membrane Thickness} = \sqrt{D_{Ca}\,\pi\, t}$$

The thickness of the sodium alginate membrane is a function of the diffusion constant of calcium and time. The thickness of the membrane roughly doubles for every factor of four increase in the time.



Calcium diffuses from the droplet into the bath and forms cross-links in the alginate solution forming a gel membrane around the sphere.

When cooking, heat is also transferred through food by diffusion and since the dominant component of all foods is water, the characteristic law for a food to be heated or cooled is the same as heat transfer through calm water, and is thus identical in essentially all foods.

An example of diffusion in gases occurs when a bottle of perfume is opened at the front of a room. Within minutes people further and further from the source can smell the perfume.

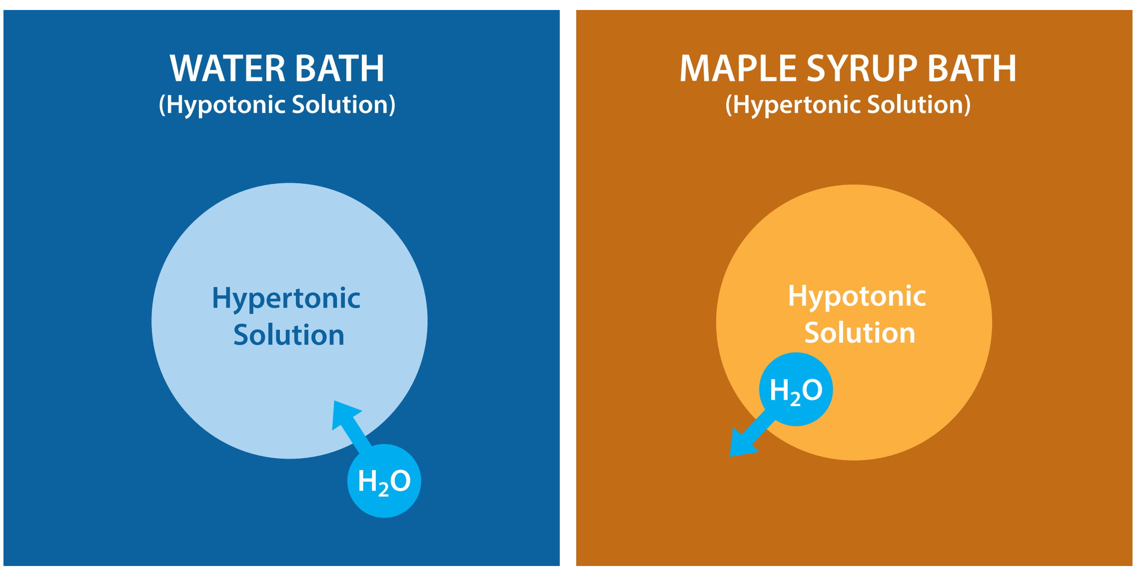
OSMOSIS

What happens if you let the sphere sit in a water bath for a long time? There are lots of different molecules inside the sphere from the food ingredient (strawberry puree) that are usually too large to pass through the alginate membrane. So these molecules can't diffuse from high concentration areas to low concentration areas. Instead, water will flow from the bath into the sphere.

But if you let the sphere sit in a maple syrup bath, the high concentration area is the bath instead of the strawberry puree in the sphere. So in this case water will diffuse from the sphere into the maple syrup bath.

When water flows through a semi-permeable membrane, it is called osmosis. Osmosis is the process in which water seeps through a membrane to make concentrations more equal. Osmosis is the diffusion of water.

When storing the spheres, chefs don't use a water bath because it will dilute the contents of the spheres as water diffuses into it. Instead, chefs will store the spheres in a bath of the same flavored liquid (e.g. strawberry juice).



Water diffuses from the bath into the sphere

Water diffuses from the sphere into the bath

ACIDS, BASES AND PH

What does it mean for a solution to be acidic or basic (alkaline)? It all has to do with hydrogen ions (abbreviated with the chemical symbol H^+). In water (H_2O), a small number of the molecules dissociate (split up). Some of the water molecules lose a hydrogen and become hydroxide ions (OH^-). The “lost” hydrogen ions join up with water molecules to form hydronium ions (H_3O^+). For simplicity, hydronium ions are referred to as hydrogen ions H^+. In pure water, there are an equal number of hydrogen ions and hydroxide ions. The solution is neither acidic or basic.

An acid is a substance that donates hydrogen ions. Because of this, when an acid is dissolved in water, the balance between hydrogen ions and hydroxide ions is shifted. Now there are more hydrogen ions than hydroxide ions in the solution. This kind of solution is acidic.

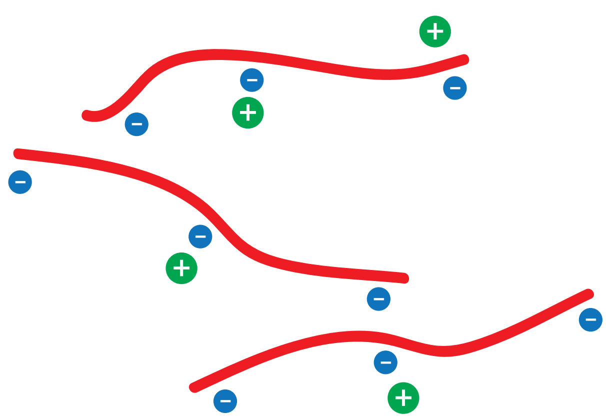
A base is a substance that accepts hydrogen ions. When a base is dissolved in water, the balance between hydrogen ions and hydroxide ions shifts the opposite way. Because the base “soaks up” hydrogen ions, the result is a solution with more hydroxide ions than hydrogen ions. This kind of solution is alkaline.

The pH scale is a measure of the hydrogen ion concentration. It spans from 0 to 14 with the middle point (pH 7) being neutral (neither acidic or basic). Any pH number greater than 7 is considered a base and any pH number less than 7 is considered an acid. The lower the PH, the more acidic the solution and the higher concentration of hydronium ions which are positive.

The pH value is a logarithmic function of the hydrogen ions in the solution: $pH = -\log_{10}[H^+]$

THE EFFECT OF PH IN ALGINATE GELS

When alginate molecules are in contact with a liquid with both calcium ions and a low pH, many of the molecules will react with the hydrogen ions instead of the calcium ions. Hydrogen ions have only one positive charge and sodium ions have one negative charge, so they will not need to bond with other alginate strands to complete their electron shells. As a result, the alginate strands will remain as flexible as they were with the sodium ions and no gel will form. We must add sodium citrate, which is basic and acts as a buffering agent, to liquids with low pHs to react with the excess hydrogen ions. This allows the calcium ions to react with the alginate strands more readily.



Negatively charged sodium alginate strands being neutralized by the hydrogen ions.

Capacity per kit:
- 60 experiments
- 8-10 children working simultaneously (2 groups of 4-5 students)

Kits and additional tool sets available at: **www.YumScience.com**

ABOUT THE KIT

The YumScience Spherification Kit has tools for two teams, we recommend groups of 4-5 students.

There is enough quantity of ingredients to experiment over 60 times. 30 Reverse Spherification experiments (Part 1 and 2) and 35 Basic Spherification experiments (Part 3). If more teams need to be working simultaneously, a set of tools for two teams (no ingredients) can be added by purchasing the YumScience Spherification Tools (2 teams). For a class of 25, teachers should purchase one kit and at least two YumScience Spherification Tools (two teams). This will provide 6 tool sets for 6 teams to work simultaneously and enough ingredients for 30 complete lesson plans so it will accommodate 5 classes of 25 students.

INCLUDED IN THE KIT

Tools (for two teams)

- 2 Perforated Spoons (one for each team)
- 2 Measuring Spoons (one for each team)
- 1 High Precision Digital Scale (shared)
- 2 Syringes (one for each team)
- 4 Weighing Dishes (two for each team)
- pH Indicator Paper (upgrade to PH meter and buffer solutions)

Ingredients (for 60 experiments)

- 2 x 3 oz. Sodium Alginate (enough for 30 baths of 500g each and 50 cranberry batches of 300g each)
- 3 oz. Calcium Lactate Gluconate (enough for 30 batches of strawberry puree of 125g each).
- 3.5 oz Calcium Chloride (enough for 35 baths of 500g each)
- 4 oz Sodium Citrate (enough to reduce acidity of over 50 batches of cranberry/lemon juice of 11g each)

Kits and additional tool sets available at: **www.YumScience.com**

WHAT ELSE YOU'LL NEED (not included in the kit)

For the class

- Regular blender to make sodium alginate bath before the class and immersion blender for strawberry puree and cranberry juice would be ideal but you can make any blender work for both tasks. You need at least one immersion blender with blender cup for the class but if you can get more then you could allow each team to prepare the solutions themselves or at least share it between teams.
- Sieve for teacher to strain the strawberry puree for Part 1.

For each team (for part 1)

- Two containers per team that can hold about 500ml of liquid. Medium sized bowls would be ideal. One will be used for the sodium alginate bath (or the calcium bath in part 3) and the other one will contain plain water for rinsing the spheres. The container needs to have a wide mouth so it is easy for the students to maneuver the spoon and the right size to have a couple of inches of liquid or more when filled with 500g of sodium alginate.
- 2 beakers, cups or small bowls to mix strawberry puree with other ingredients for each team and cranberry juice with sodium citrate
- Fork or small whisk for each team
- Small plate for each team to let strawberry spheres and cranberry caviar rest
- Chronograph or watch for each team to measure time. (Not necessary, but could be an opportunity to expand student measurement skills)
- 150g of strawberries for each team
- 10g of sugar for each team
- Salt for each team
- Distilled water 500ml per team

For each team (for part 2)

- Quarter cup maple syrup for each team, enough to cover a sphere
- 2 plastic cups per team

For each team (for part 3)

(in addition to the tools used for Part 1)

- 300g Ocean Spray Cranberry juice cocktail per team
- 22g lemon juice per team
- 3 plastic cups per team
- Immersion blender with blender cup (at least one for the class, but if you can get more you could allow the teams to create the cranberry solutions themselves)

NOTE: pH of cranberry juice and lemon juice can vary so you may want to test it before the class. We used Ocean Spray Cranberry Juice Cocktail which is not very acidic (pH >3.5) and does not inhibit sodium alginate from forming a gel. With the addition of 11g of lemon juice per 100g cranberry we reduced the pH to ~2 which prevents the alginate from forming a gel. Adjust quantities as necessary.

PRE-LESSON 1 PREPARATION

To save time during Part 1 class, it's best to make the sodium alginate bath the night before your experiment. This will allow the air bubbles that form when blending the bath to disappear. Also, make the strawberry puree prior to the lesson to save time. You'll need 500g of sodium alginate bath and 125g of strawberry puree per team.

HOW TO MAKE THE SPHERIFICATION BATH

1. Mix the 2.5g of sodium alginate with 500g distilled water using the blender to make a 0.5% sodium alginate solution for each team.
2. Make sure the sodium alginate is completely dissolved. Be patient, this may take a little longer than you think.

HOW TO MAKE THE STRAWBERRY PUREE

1. Wash strawberries thoroughly and remove the stems.
2. Using an immersion blender, puree the strawberries.
3. Pass the strawberry puree through a fine sieve. Strain the mixture and store it in the refrigerator covered in plastic wrap overnight to eliminate the air bubbles.

   Note: you can take the mixture to the classroom in a pitcher or another container that is easy to pour so students can measure their 125g for the recipe.

PRINT RECIPE CARDS AND STUDY QUESTIONS

Print the Recipe Cards and Study Question starting on page 19. Or, if you prefer, you can guide students through the recipe and questions yourself.

PART 1 GELATION & DIFFUSION
Discovering Sodium Alginate Gels

Background discussion questions

1. Who uses chemistry in their jobs?
There are many professions like Scientists, Engineers, Pharmacists and many more.

2. Did you know that many Chefs use chemistry in their cooking?
Many of these chefs have degrees in chemistry. This knowledge helps these chefs transform food into a variety of textures, shapes, and sizes. There's all kinds of magic in chemistry and chefs have come up with creative ideas to make gel foods.

3. What do you think will happen if you drop a spoon of strawberry puree into a glass of water?
Will it stay together or spread? Will it float or sink? Ask students to drop a spoon of strawberry puree in a glass of water and describe what happens. You can also do this demonstration for the entire class yourself or choose a student to do it.

4. What gel foods do you know about? *Jell-O, gummy bears, flan, scrambled eggs*

5. What is a gel? *A gel is a jelly-like substance mostly composed of liquid but that behaves like a solid thanks to a three-dimensional cross-linked network within the liquid. Gelation is a phase transition that turns a liquid into a solid, by forming a cross-linked network.*

6. What happens when you leave Jell-O outside the fridge?

7. Does someone know the origin of gelatin/Jell-O? *Gelatin is derived from collagen, a substance found in skin and bones of various animals, pork being the most common.*

Making strawberry spheres using Reverse Spherification

1. Ask students to follow the recipe card for strawberry spheres. Give each student the chance to create their own sphere and try it.

2. Ask students to make two strawberry spheres. Ask them to let sit one on a plate for a while and let the other stay in the bath for 10 minutes instead of 1.

3. While they wait 10 minutes, ask students to start answering Part 1 questions.

4. Once students have answered all questions you can start a class discussion by calling each team to share their answers.

5. Explain Sodium Alginate: Polymer cross-linked in the presence of ions

6. Explain Diffusion

7. Share the story of Spherification and Chef Ferran Adria.

8. If you are planning to do Part 2, complete the first step so you can continue with Part 2 at least 3 hours later or the next day.

PART 2 OSMOSIS
Discovering Semi-Permeable Membranes

In this section students will place strawberry spheres in water and maple syrup. By measuring weight before and after they are submerged in the liquid for several hours, students will find that water is diffusing in different directions in each case due to osmosis.

1. Ask students to create two spheres and weigh each of them individually using the weighing dishes and record the results on their worksheet. Students should pat dry the bottom of the perforated spoon when holding the spheres before weighing.

2. Ask students to place one sphere in water and the other one in maple syrup. Place them in the refrigerator if students will consume them later. If not, just make sure they throw them away after measuring the weight.

3. At least 3 hours later or the next day, ask students to remove the spheres from the liquid using the perforated spoon, let the liquid drain thoroughly and weigh them again. Remind them to throw them away if they were not properly refrigerated.

4. Ask students to record weights and answer Part 2 Questions.

5. Once students have answered all questions you can start a class discussion by calling each team to share their answers.

6. Explain Osmosis.

PART 3 MEASURING PH:
Discovering Basic Spherification

1. Explain Acids, Bases and pH

2. Ask students to follow the recipe card for cranberry caviar using each of the three solutions and answer Part 3 Questions.

3. NOTE: you can just have one or two supervised blender stations equipped with an immersion blender and a blender cup for the class. When it is their turn, each team would proceed to blend the 3 sodium alginate solutions. Each team would take 4 to 5 minutes to do this.

4. Explain the effect of PH in alginate gels and the difference between basic spherification and reverse spherification.

RECIPE CARD: MAKING THE SPHERES

In this recipe you'll be making strawberry spheres using Reverse Spherification.

Ingredients

- 125g (4.4 oz) strawberry puree
- 5g (0.35 oz) sugar
- Pinch of salt
- 2.5g calcium lactate gluconate (2%)
- 500g of sodium alginate solution 0.5% (supplied by teacher)

Steps

1. Using a scale, weigh all ingredients precisely. Measure powders in supplied weighing dish.
2. Using a fork or whisk, thoroughly mix strawberry puree, sugar, salt and calcium lactate gluconate.
3. Fill bowl with 500g of sodium alginate solution. Fill another bowl with 500g of clean water. You'll also need a 1 tbsp. measuring spoon (to make large spheres), a watch and a slotted spoon from your teacher.
4. Grab the measuring spoon; fill it with the strawberry puree and carefully pour it into the sodium alginate bath. Wipe the bottom with a paper towel, place the spoon over the bath slightly touching its surface and flip it to pour the liquid into the sodium alginate bath.
5. Stir the bath gently with the slotted spoon without touching the sphere. Don't let the sphere sit in the bottom of the bath or float, making sure it is always covered with the sodium alginate solution.
6. Using the watch, count down 1 minute.
7. Carefully remove the sphere from the sodium alginate bath using a slotted spoon and rinse it in the bowl with clean water.

PART 1 STUDY QUESTIONS:

1. What happened when you removed the strawberry puree from the alginate bath after waiting one minute?

2. Break the sphere on a plate. What do you see?

3. Why do you think a gel membrane formed around the strawberry sphere?

4. What was different in the process when compared to making gelatin?

5. Is the gel membrane forming outside or inside the strawberry puree? Hint: check the color of the membrane by rinsing in water the skin of a broken sphere. What is this telling you?

6. What happens with the gel membrane when you leave the sphere at room temperature for some time? How does this compare to gelatin?

7. What's happened to the sphere you left in the bath for 10 min instead of 1? Is the gel membrane thickness the same? Why do you think this happened?

PART 2 STUDY QUESTIONS:

1. Fill in the table below:

	SPHERE A (in water)	**SPHERE B** (in syrup)
Weight BEFORE resting in solution		
Weight AFTER resting in solution		
Difference in weight		

2. What happened to sphere A? Why?

3. What happened to sphere B? Why?

RECIPE CARD: MAKING FAUX CAVIAR

In this recipe you'll be making cranberry "caviar" using Basic Spherification. We'll use three different cranberry solutions and compare results.

Ingredients

- 3 x 100 g (17.6 oz) cranberry juice
- 3 x 0.5 g sodium alginate (0.5%)
- 2 x 11g lemon juice
- 2g sodium citrate

Calcium Chloride Bath

- 500 g (35 oz) water
- 2.5 g calcium chloride (0.5%)

Prepare 3 Cranberry Solutions

In each cup prepare the following solutions by mixing the ingredients with a fork and label each cup

- Solution 1: 100g cranberry juice

- Solution 2: 100g cranberry juice plus 11g lemon juice

- Solution 3: 100g cranberry juice, 11g lemon juice and 2g sodium citrate

Mixing with Sodium Alginate

1. Using an immersion blender, mix each solution with 0.5g sodium alginate. Pour the contents from the cup into blender cup, sprinkle the sodium alginate on top, blend thoroughly and return the sodium alginate solution to your labeled cup.

RECIPE CARD: MAKING FAUX CAVIAR (cont.)

Preparing the Calcium Bath for Basic Spherification

Prepare the calcium bath in a bowl by dissolving the calcium chloride in the water.

Creating the Spheres in the Calcium bath

1. You are now ready to start creating the caviar! Repeat the process with each solution and compare results.

2. Fill a syringe with the cranberry-alginate mixture and expel it drop by drop into the calcium bath. The syringe needs to be high enough (about 3 inches from the bath surface) for the drops to sink and to prevent the formation of a tail. Don't go too high or the drops may break into smaller drops creating "baby" drops.

3. After a minute, remove the caviar spheres from the calcium bath and rinse them in a clean water bath.

PART 3 STUDY QUESTIONS:

1. Solution 1 - Cranberry juice pH: ________

2. Is the cranberry juice an acid or a base?

3. Tap water pH:________

4. Is tap water an acid or a base?

5. Solution 2 - Cranberry + lemon juice pH:________

6. Solution 3 - Cranberry + lemon juice + sodium citrate pH:____________

7. What is more acidic between solutions 2 and 3? What is this telling you about sodium citrate?

8. Make cranberry "caviar" pearls with the 3 different solutions

9. Compare the pearls created with each solution. What do you notice? Hint: place the pearls on your hand and roll them lightly with your finger.

10. Create a larger sphere using a measuring spoon and let it rest in the bath for a couple of minutes. Break the sphere on a plate and take a look at its membrane. Is it transparent like the membrane of the strawberry spheres? What is this telling you about the diffusion of ions in basic spherification?

11. Could you use basic spherification to create spheres with an ingredient such as yoghurt or cream? Why?

NOTES:

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