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Making Plastic Polymers from Milk

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DO IT AT HOME!

The goal of this experiment is to create a moldable plastic while exploring bonding. It is easily done in the classroom and even at home! All you and your student will need is:

- ☐ 1 cup milk (2% works best, but any kind works!)
- ☐ 4 teaspoons acid (lemon juice, vinegar, soda, or any other type of safe household acid you can find at home or the grocery store)
- ☐ Measuring cups
- ☐ Measuring spoons
- ☐ Disposable cups that hold at least 1 cup of milk
- ☐ Paper towels, cheesecloth, or gauze
- ☐ Plastic spoons
- ☐ Microwaveable container

A detailed protocol is included in the accompanying student worksheet. Briefly, you will:

- ☐ Heat the milk in the microwave for about 2 minutes, or until it is about as warm as you want for hot chocolate. 5 minutes on 50% power also works well.
- ☐ Once the milk is warm, add the acid of your choice and begin to stir the mixture. You will see clumps forming immediately but continue stirring for about 30 seconds to 1 minute.
- ☐ Once you are done, take the curds out of the liquid and squeeze the excess liquid out using the paper towels.
- ☐ Begin kneading the plastic until it becomes smooth – it can now be molded into any shape you want!

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TRY SOMETHING NEW!

One of the most fun parts of an experiment is coming up with new ideas with your student and seeing what happens when you change something! Try brainstorming some questions with your student, make predictions about what you think will happen, and then repeat the experiment to see what is the same and what is different!

Here are some questions to get started:

- What do you think will happen if we use more milk or more acid?
- What do you think will happen if we use a different type of milk?
- How do you think the polymer might be different if we use cold milk? What about boiled milk?
- What are some different types of acid? How might they change the type of polymer we get?

This experiment is meant to strengthen your student's STEM identity – to show that science is all around them and can be done anywhere. Cool experiments like these are easily done at home and can have a lasting impact on their future and careers.

HOW DOES IT WORK?

The milk plastic in this experiment forms due to a chemical reaction between small proteins in milk. This is called a *polymer*.

A polymer is a chemical or molecule composed of repeating units. Polymers can take on different shapes. They can be three-dimensional (like a cube), two-dimensional (like a sheet of paper), or one-dimensional (like a chain). Think of a Lincoln log structure for 3D, a mesh net for 2D, and a paper or paper clip chain for 1D.

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Polymers are covalently linked together by bonds between the repeating units. Polymers are found in nature but can also be created for specific purposes. The most abundant example of a natural polymer is DNA, which is composed of nucleotide monomers. Plastics like those we find in squeeze bottles and types are polymers of different simple chemicals.

Milk contains a specific molecule called casein. In milk, casein forms a *micelle*, or a small sphere. Although casein micelles are extremely stable, when you add heat and acid, it causes casein and another milk protein, whey, to bind to each other in a long chain.

The combination of the heat and acid create a chemical change where you can watch the bonds being broken and reformed in a new way. While the experiment is occurring, students will immediately see a change in the milk once they start stirring after the acid is added. The milk will separate and curd will form as the denaturing and reforming process that is taking place.

WANT MORE INFORMATION?

Check out some of these resources:

American Chemistry – Polymer Basics

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Properties of Polymers

Intro to Bonding

Structures and Bonding

What can we do with milk polymers?

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Purpose

The goal of this activity is to learn how to make casein plastic from milk and explore the properties of plastic.

Skills: This activity will help you practice these skills:

- Describe the differences between starting and final ingredients
- Observation skills

Knowledge: This activity will also help you to become familiar with the knowledge that is needed in fields like chemistry or chemical engineering:

- Plastic polymers
- Protein bonding and denaturing

Task

- Today you will:
  - Listen to an introduction about bonds between molecules
  - Mix ingredients together to form a polymer
  - Make observations about the reaction that forms the polymer.
  - Brainstorm why different ingredients might lead to different observations.
  - Share your ideas!
- As you are completing the experiment consider these questions:
  - Have you ever seen milk separate into thick chunks and liquid? Why did that happen?
  - Why does the milk form curd when the acid is added? What do you think the curds are made of?
  - What aspects of the acid cause the changes in the milk?
  - Why does the kneaded polymer look and feel different from the unkneaded polymer?

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- Discussion questions to consider after the experiment:
    - What would happen if room temperature or cold milk is used instead of heated milk?
    - How would increasing or decreasing the amount of acid affect how much polymer you get?
    - What are other household acids that you could use for this experiment?

Tips for Success:

- Focus on vivid descriptions of the reaction and the final product.
    - Use descriptive words such as “cloudy,” “opaque,” “shiny,” etc.
    - Compare what you see to common things such as the thickness of syrup, oil, or melted butter.
    - Feel free to draw pictures to capture what is happening.
    - Focus your descriptions in a way that someone who has not conducted the experiment can visualize what you saw.
- Some good descriptions you can use:
    - Texture: rough, smooth, bumpy, sticky, tacky
    - Color: white, gray, clear, shadowy, uneven
    - Odor: sour, sharp, floral, yeasty
    - Size: “grain of sand”, “size of a dime”
    - Shape: uneven, round, oblong, stringy
    - Example: “the curds formed after the reaction were small about the size of rice, not see through, and white. The liquid looked like chicken broth, but it smelled sour like vinegar. The polymer was bumpy and sticky at first but after kneading it wasn’t sticky, but it was still bumpy.”
- Excellent work includes writing down your observations at all points of the reaction:
    - What everything looks like before you mix it
    - What happens immediately when you add them together
    - What (and how long) the reaction happens
    - What it looks like when it is done
    - What changes happen as you knead the polymer

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Instructions

1. Read all the directions first.

_____1.1. Read the directions through to the end.

_____1.2. Get the observation table out and ready.

2. Obtain materials.

_____2.1. Get 1 cup of hot milk and 4 teaspoons of your assigned acid. Everyone will get a different acid, so be sure to take good notes so you can share your observations later!

_____2.2. Prepare cheesecloth by folding 4 layers on top of itself or fold about 4-5 paper towels in a stack for later use.

_____2.3. Write down your observations about your starting ingredients.

3. Combine liquids to create a reaction.

_____3.1. Pour the 4 teaspoons of acid into the milk and begin mixing with a spoon.

_____3.2. Observe the changes happening in the liquid and record them on your worksheet. Pay attention to the color, texture, odor, size, and shape of the milk/curds as well as the speed of the changes.

_____3.3. Mix the solution for about 30 seconds until you see no more curds forming.

_____3.4. Let the mixture sit for about 1 minute to let the curds settle to the bottom (this makes it easier to remove them).

_____3.5. What do the curds look like? How many are there? Record your observations in your worksheet.

4. Remove and dry curds.

_____4.1. Use the cheesecloth or gauze to filter the curds from the liquid. Find a partner to help by holding the cloth above an empty cup. Take your cup and pour the liquid into the cup through the cloth. Finally take all sides of the cloth and squeeze the extra liquid out into the cup.

_____4.2. Place the curds in a pile on a paper towel and pat dry if needed.

_____4.3. What do the dry curds look like? What do they feel like?

5. Knead polymer.

_____5.1. Begin to massage and squeeze the polymer slowly. This is called “kneading”. Some of the polymer will stick to your hands but as you keep kneading it, the polymer will come off.

_____5.2. Keep kneading for 2-4 minutes or until it is a smooth, solid mass.

_____5.3. How did the curds feel? Did that change as you kneaded them? How did their appearance change? Record your observations in your table.

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6. Clean up

_____6.1. Set polymer aside to dry for 24-48 hours

_____6.2. Throw cup with leftover milk, cheesecloth/gauze, and paper towels in the trash (NOT down the drain)

_____6.3. Wipe down area with a clean cloth and wash your hands.

7. Think-Pair-Share

_____7.1. Brainstorm different ways to do this experiment. Think about how you could change the milk, the acid, or the amount of plastic you get. Hold on to these ideas for the class discussion.

_____7.2. Find a partner who used a different acid and compare observations of your polymers. Write down similarities and differences of your plastics on your worksheet

_____7.3. Come up with an explanation of why your polymers are the same or different and write it down in your table.

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Worksheet

The goal of this activity is to learn how to make casein plastic from milk and explore the properties of plastic. This worksheet is where you will record all your observations.

Description of starting ingredients:

Texture	Color	Odor	Size	Shape	Other Observations
Milk	Milk	Milk	Milk	Milk	Milk
Acid	Acid	Acid	Acid	Acid	Acid

Description of reaction: *Describe what you see as you add the acid into the milk; focus on texture, color, odor, size, and shape descriptions. Note the speed of the reaction.*

Texture	Color	Odor	Size	Shape	Speed

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Description of final product:

Texture	Color	Odor	Size	Shape	Other Observations
Polymer	Polymer	Polymer	Polymer	Polymer	Polymer
Liquid	Liquid	Liquid	Liquid	Liquid	Liquid

Think-Pair-Share: Describe similarities and differences between your polymer and your partner's polymer.

Similarities	Differences

Final explanations and observations: *Any comments or explanations of the experiment.*