***BETTER BUTTER BEATING***

**discussion of colligative properties and emulsions**

**Background:**

An **emulsion** is a mixture of two liquids containing droplets that don’t normally blend together: they are **immiscible** (which means they don’t blend together naturally)**.** There are two basic types of emulsions: **Oil-in-Water** **(O/W)** and **Water-in-Oil (W/O)**. It depends which molecule is the solute and which molecule is the solvent. The number of solute molecules and the number of solvent molecules is a **colligative property.** In chemistry a colligative property is the ratio, or proportion, of the different molecules in a solution. Basically, the colligative property of Reduced Fat 2% Milk would be 2 molecules of fat spread throughout 98 molecules of the milk (2:98 or 1:49--ie, one molecule of fat for every 49 molecules of the liquid). The fat is the solute, the liquid is the solvent.

In a solution, the solute disperses--spreads out--throughout the solvent. The solute is said to be in the **dispersed phase** while the solvent particles cling together, surrounding and separating the solutes. The solvent is said to be in the **continuous phase**. Most food emulsions are Oil-in-Water, meaning the oil (fat) droplets are the solute spread throughout the water, which is the solvent. Mayonnaise is an example of an Oil-in-Water solution (Note: “solution” doesn’t necessarily mean it pours). Butter and margarine are the main Water-in-Oil emulsions, with water as the solute dispersed throughout the oil solvent.

In order to mix two liquids that don’t naturally mix together, like oil and water, they need to have an **emulsifier.** **Proteins**, like those found in milk and cream, are natural emulsifiers. An emulsifier coats the solute particles to keep them dispersed, blending the emulsion so it doesn’t separate into oil and water again—stabilizing it. Temperature, salt, or agitation affects the emulsifier coating, making the emulsion less stable—more likely to separate back into oil and water.

Butter is made of cream that has separated from non-homogenized milk. Cream is a natural Oil-in-Water emulsion. When the cream is shaken or beaten, it breaks the emulsion layer around the fat droplets and fats begin to **coalesce,** or stick together, becoming larger droplets of fat. With molecules, “like attracts like,” so the oil (fat) molecules unite with other oil molecules and the water molecules unite with water molecules.

This creates a change in the dispersion phases of what makes up the solution, so the solute is now the water dispersed within the fat (oil) solvent. It is also changing the number of particles of the solute: the oil (fat) droplets are sticking together and forming large clumps, forcing the water out of the emulsion. There are fewer individual fat molecules, and the water that used to surround the fat now can be drained off, no longer part of the emulsion. The only solvent left in the original emulsion is the water that got trapped within the large clumps of fat. This is the new Water-in-Oil emulsion.

The ratio has now changed between solute and solvent, creating a change in the **colligative property** of the emulsion because it is a change in the number of the solute particles to the number of the solvent particles—the ratio of one to the other. The water that was forced out and drained off (buttermilk) has very little fat left in it, and becomes its own emulsion of oil-in-water.

The **physical state** of the emulsion has also changed, turning two immiscible liquids into a liquid and a solid.

**Vocabulary:**

*Coalesce* –a recombining of two like particles. For example, when two small fat

molecules that join together to make a larger fat droplets, they coalesce.

*Colligative properties* –The ratio of solute particles to solvent particles in a solution.

*Colloidal dispersion—*A mixture with microscopic particles that spread evenly

throughout other microscopic particles in a solution. Colloids are big enough to

be seen in a microscope, but not visible to the naked eye. In a colloidal

dispersion the particles do not settle to the bottom of the container.

*Continuous phase –*The phase, or condition, in an emulsion that surrounds the solute

particles by the solvent.

*Dispersed phase—*The phase, or condition, in an emulsion where solutes are distributed

throughout the continuous phase.

*Emulsifiers—*A substance that coats the emulsion droplets to prevent them from

recombining with each other, so the oil and water droplets stay blended. It is a

molecule that has both hydrophobic (water-hating) and hydrophilic (water-

loving) areas so that the hydrophobic part is attracted to the oils (fats) and the

hydrophilic is attracted to the water in an oil-in-water or water-in-oil solutions,

these joint attractions give structure to an emulsion solution.

*Emulsions—*Any food that involves blending two liquids that usually do not blend:

typically oil and water.

*Fats—*The most efficient storage form of energy from food. Along with storing excess

energy from food that has been eaten, fats help foods taste good; they also carry

the fat-soluble vitamins A, D,E and K, which are all essential to good health. Fats

appear solid at room temperature. Chemically, fats are in the class of nutrients

known as **Lipids.**

*Immiscible*—Something that does not naturally mix together—like oil and water.

*Oils—*A fat that is liquid at room temperature. Also in the class of nutrients known as

**Lipids**. Many times “Oil” and “Fat” are used interchangeably.

*Oil-in-Water emulsion--*A solution where an emulsifier has blended oil and water

together and the oil (or fat) is dispersed through the liquid. The oil is the solute

in the dispersed phase of an emulsion, and the water is the solvent the oil

droplets and is in the continuous phase of the emulsion.

*Physical properties*—A characteristic that can be seen or measured without changing

the substance into something else. Examples of physical traits would be color,

odor, hardness, boiling point or melting point. One physical trait would be the

state something can be in: solid, liquid or gas.

*Protein—*Molecule groups made of carbon, hydrogen, oxygen and nitrogen that are

arranged in coils and strands of amino acids, which make proteins extremely

useful in a number of ways in food and in the body. Because proteins are large

molecule groups that have hydrophobic and hydrophilic areas on them, proteins

are natural emulsifiers, bonding with both the oil and the water to blend them

into one product.

*Ratio*—Something that compares the number of times one thing is contained in

something else. For example: If there are 2 molecules of hydrogen for every one

molecule of oxygen, the ratio of hydrogen to oxygen is 2 to 1, or 2:1. A ratio can

also be called a **proportion** of something.

*Solutions--* A homogenous (all the same) mixture in which one substance is dissolved

into another substance.

*Water-in-Oil emulsion—*A colloidal dispersion where the solute is water particles which

are spread throughout the oil solvent.

**This lesson addresses the following USOE Core Standards:**

**Foods & Nutrition 1:**

Standard 4: Students will identify the sources and functions of proteins and lipids (fats and oils) and apply appropriate food preparation techniques.

**Chemistry:**

Standard 6, Objective 2a: Identify the colligative properties of a solution

Standard 6, Object 2c: Describe how colligative properties affect the behavior of solutions in everyday applications

**Materials:**

Heavy Whipping Cream (1.5 oz. per container)

Plastic 2 oz. containers with lids (1 container per 4-5 students)

Salt (1/4 teaspoon for half of the containers)

*One marble per container for a third group (optional: there can be three groups rather than two: one cream, one cream and salt, one cream and a marble to help agitate the cream)*

Paper towels

Instructions: *(With teacher notes)(Note: Before starting students need to thoroughly wash their hands.)*

***NOTE: Students need to answer some discussion questions BEFORE doing the experiment.***

1. Divide students into groups of 4-5. Each group will need a 2 oz. container with a tight sealing lid, 1.5 oz. of heavy cream, and a paper towel.
2. Students should pour 1.5 oz. of heavy whipping cream into the 2 oz. container. Make sure there is air space in the container and then seal with lid tightly.
3. To add variability to the experiment, have half of the students add 1/4 teaspoon of salt to the cream in their container. *If it is a large class, divide it into thirds and have the third group use marbles to help agitate the cream.*
4. Wrap the container with a paper towel to catch any leaks. Have students begin to shake the sealed containers of cream. Have different groups shake at different speeds and forces based on their earlier hypotheses.
5. Compare the salted butter to the unsalted butter. *(And the marble group as well if the class is using the marbles)* How does it look? Taste?
6. List similarity and differences and compare to earlier hypotheses. Record findings in the Discussion section.

What You Should See:

* *After approximately 10 minutes of vigorous shaking, a lump of butter will form. There will also be some liquid (buttermilk). Pour the buttermilk off and keep shaking until no more liquid separates. Marbles and salt additions take slightly longer to turn to butter, but seem to do a better job of separating the liquid out.*
* *Add a math element to the lesson by having students measure how much buttermilk comes off each container. Compare this to earlier measures of the cream to determine percentage of buttermilk and butter (fat solids). Traditionally, when people made their own butter, they would collect the buttermilk in a jar and cool it for drinking or baking.*

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**Discussion points/questions:**

***Before students begin shaking the container***, have them hypothesize about what they think will happen. Consider these questions:

1. How much time will they need to shake the container before butter is formed? What was the actual time for your container?

**Actual time: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. Does the force and speed of the shaking make a difference?
2. Will the salt affect the butter making process? *Does the marble affect the butter making process?*

*Yes. It slows down the process. The salt does make the butter taste better. The marble seems to separate the liquid from the butter fat better.*

1. Does temperature matter?

*Warm emulsions are less stable because the oil droplets become more fluid and likely to coalesce, separating the parts of the emulsion. Cooling the emulsion to refrigerator temperatures could solidify the fats, so the emulsion would be more stable.*

**5.** Compare the salted and unsalted butter. What are the similarities? What are the

differences? Record your findings.

Hypothesis:

Actual:

***6.*** *Compare the cream turned to butter with the marble and the cream turned to*

*butter without the marble. What are the similarities? What are the differences?*

*Record your findings.*

*Hypothesis:*

*Actual:*

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Hypothesis:

Actual:

4. Does temperature matter?

Hypothesis:

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