The Story of Milk

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Topic

Procedures for laboratory analysis

Time

1½ hours

Safety

Please click on the safety icon to view the safety precautions. Adult supervision is required. Sodium hydroxide (lye) is a dangerous chemical that can cause burns. Wear goggles and gloves. Be extremely careful when handling sodium hydroxide to avoid any contact with skin. Avoid spilling, and wash all utensils, apparatus, and work area thoroughly when through. Dispose of all liquids properly by flushing them down the toilet. Make sure you have adequate ventilation throughout the experiment.

Materials

- 1 qt skim milk
- 50-mL burette with ring stand and clamp
- sour skim milk (Leave milk carton open in the refrigerator for 10–30 days to obtain sour milk.)
- 100-mL graduate
- 100-mL beaker
- two 250-mL Erlenmeyer flasks
- ½ pt heavy cream
- 1-L volumetric flask
- 100 mL white vinegar
- stirring rod
- phenolphthalein indicator solution (see Part E)
- pipette or glass tube
- hot plate
- ethyl alcohol or vodka
- beam balance scale
- 0.25 *M* sodium hydroxide solution (or Red Devil™ 100% lye drain opener; see Part E)
- evaporating dish
- funnel
- filter paper
- two 10-mL graduates
- heat source

Procedure

Part A: Density

Density of a given object is the ratio of mass to volume. If two objects of the same size are weighed, the one with the lower mass has the lower density. In this procedure, we will test the density of skim milk and the density of heavy cream. Raw milk (unprocessed after milking) contains a layer of cream on top of the milk. When milk is taken to the dairy, it is homogenized, which means that the cream is broken up into smaller particles and dispersed throughout the milk. Removing the cream leaves skim milk.

1. Pour out separate quantities of cream and skim milk into glasses, and observe them. Record your observations as to how they are similar and how they are different. Draw a hypothesis about which is the denser of the two liquids.
2. Find the mass of the 10-mL graduate. Record its mass on data table 1.

DATA TABLE 1		
Density		
Item	Cream	Skim milk
Weight of graduate (g)		
Weight of graduate and liquid (g)		
Weight of liquid (g)		
Volume of liquid (mL)	10	10
Density (g/mL)		

3. Fill the graduate with 10 mL heavy cream, and find the new mass. Record this mass on data table 1.
4. Subtract the mass of the graduate from the combined mass. Divide this number by 10. This is the density in grams per mililiter. Record this amount.
5. Repeat steps 2 and 3 with the skim milk.

PART B: EVAPORATION

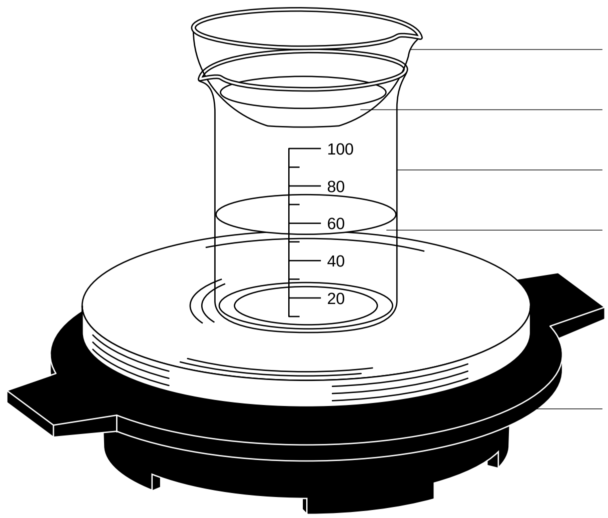
Most common substances contain water. When this water is evaporated out of a substance, a certain amount of solid matter that was dissolved in the water will usually be left behind. The following procedure determines what percentage of the compound (the milk) is water and what percentage is made up of other substances. These solids can then be quantified and further identified.

1. Find the mass of the evaporating dish. Record the mass on data table 2.
2. Add 10 mL skim milk to the evaporating dish, and find the new mass. Record the mass.

DATA TABLE 2	
Evaporation	
Weight of dish (g)	
Weight of dish and milk (g)	
Weight of milk (g)	
Weight of dish and milk solids (g)	
Weight of milk solids (g)	
Weight of water (g)	
Percentage of milk solids	
Percentage of water	

3. Fill the 100-mL beaker half full with water. Place the evaporating dish on top of this (see figure 1), and heat together on the hot plate until you are left with a solid mass in the dish. You may have to break the skin that forms on top of the milk a few times during evaporation; be careful not to remove any of the sample when you do this.

Figure 1



4. After the dish has cooled, determine its mass again. Repeat step 3 if necessary until you have a constant mass. Record this mass.
5. After you have determined the mass of the milk solids and the mass of the evaporated water, compute the percentage of milk solids by dividing the mass of the milk solids by the original mass of the milk and multiplying this amount by a factor of 100.
6. The above percentage subtracted from 100 will provide you with the percentage of water originally contained in your milk sample.

PART C: PRECIPITATION

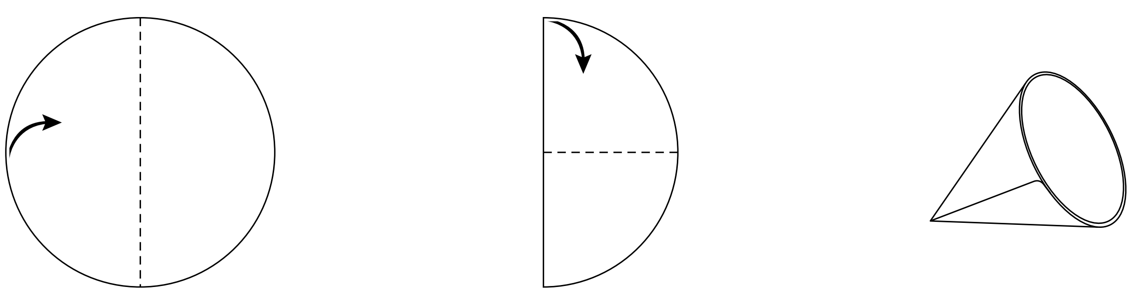
A precipitate is an insoluble (undissolvable) substance formed as a result of a chemical reaction. In some cases, it is a new compound, and in others it is an already existing compound that was in solution. By adding a specific chemical to a solution, in this case acetic acid (vinegar) to milk, it is possible to form a precipitate of a known substance (in this case milk protein) and quantify it.

1. Determine the mass of the 100-mL beaker. Record the mass on data table 3.
2. Add 10 mL skim milk to the beaker, and find its mass; again record these data.
3. Measure out 3 mL white vinegar, using a pipette or glass tube and graduate, and add this to the milk. Allow this mixture to sit 10 min. This will precipitate the protein contained in the milk.

DATA TABLE 3	
Precipitation	
Weight of beaker (g)	
Weight of beaker and milk (g)	
Weight of milk (g)	
Weight of filter paper (g)	
Weight of filter paper and protein (g)	
Weight of protein (g)	
Percentage of proteins	
Percentage of carbohydrates	

4. Determine the mass of a piece of filter paper. Fold the piece of filter paper in half, and then in half again, as shown in figure 2. Place the paper cone in the funnel and set this in an Erlenmeyer flask. Filter the precipitate by pouring it into the filter paper in the funnel and allowing it to drain. Fill the 100-mL beaker with fresh water. Pour 25 mL water into the filter to wash the precipitate. Repeat this washing two more times. Let the filter paper dry overnight.

Figure 2



Fold filter paper in half twice to form a cone.

5. After the filter paper and protein precipitate have dried completely, find their mass and record the combined mass. Subtract the mass of the filter paper from the total mass. Determine the percentage of proteins in the milk by dividing the mass of the precipitated proteins by the mass of the milk sample you used, and multiplying the result by a factor of 100.
6. Determine the percentage of carbohydrates in your milk sample by subtracting the percentage of proteins from the percentage of milk solids you obtained in the previous test. You can do this because the milk solids are the combined product of the proteins and carbohydrates contained in the skim milk.

PART D: CALORIC VALUE

To determine the caloric value of an 8-oz glass of skim milk, do the following calculations:

1. Take the percentage of milk solids found in Part B of this experiment and multiply it by 224, which is the number of grams contained in 8 oz. After determining this value, divide it by a factor of 100. This will convert the number from a percentage to a gram amount. Record the result below.
2. Since the caloric value of 1 g of carbohydrate or protein is approximately 4 Cal (or 4,000 calories or 4 kcal), multiply the amount determined above by 4. This is the caloric value of 8 oz skim milk.

   a. Grams of proteins and carbohydrates in skim milk ___________ g

   b. Caloric value of 8 oz skim milk ___________ Cal

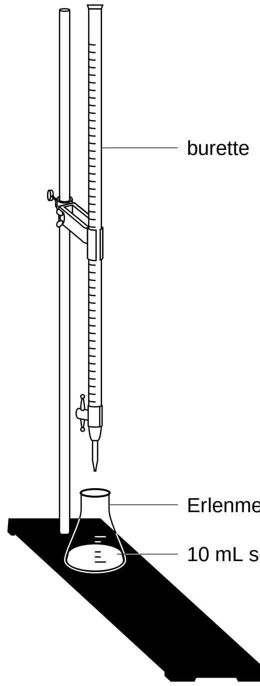
PART E: TITRATION

Titration is a procedure by which it is possible to quantify the amount present of an unknown acid or base by slowly adding a known concentration of its opposite until a neutralization reaction occurs. To know when this reaction is complete, add a small amount of an indicator to the solution containing the unknown. The point at which the indicator changes color is the moment when the reaction is complete. This is called the *end point*. In the following procedure you will use titration to calculate the percentage of lactic acid contained in a sample of sour skim milk. Lactic acid is formed by bacterial action on lactose (milk sugar) as milk sours.

1. Preparation (if the following solutions are available from the school lab, use them):
   a. Prepare a 0.25 *M* solution of sodium hydroxide (lye) as follows: Weigh out 10 g sodium hydroxide pellets (or drain opener) onto a piece of filter paper (this must be done quickly because the lye absorbs water from the air). Place this in a 1-L volumetric flask, and fill the flask to the 1-L mark with water. Mix using a stirring rod. Stopper the container, label it, and put it in a safe place.
   b. Prepare the indicator solution as follows:

      Weigh out 0.05 g phenolphthalein onto a piece of filter paper. Place this in a 250-mL flask. Add to this 50-mL ethyl alcohol (vodka will substitute) and 50 mL distilled water. Mix using a stirring rod. Stopper the container, label it, and put it in a safe place.
2. Carefully fill the 50-mL burette with the 0.25 *M* solution of sodium hydroxide.
3. Determine the mass of a 250-mL Erlenmeyer flask. Record its mass on data table 4. Add 10 mL sour skim milk to the flask, and determine the mass again. Record this mass.
4. Add 2 to 3 drops of phenolphthalein solution to the sour skim milk. Place the flask containing the milk on the ring stand base under the tip of the burette (see figure 3).

Figure 3



5. Open the stopcock (valve) on the burette slowly until you observe a steady dripping. Make sure that you don't open the valve any further. Continue titration until the milk shows a light pink color throughout. This is the end point. Close the stopcock.
6. Enter the final reading from the burette on data table 4 as the volume of base used.

DATA TABLE 4	
Titration	
Weight of flask (g)	
Weight of flask and milk (g)	
Weight of milk (g)	
Volume of base (mL)	
Molarity of base	.0025
Moles of base	
Moles of acid	
Molar mass of lactic acid	90.049
Weight of lactic acid (g)	
Percentage of lactic acid	

7. Calculate the moles of base used by multiplying the volume of the base by the molar concentration of sodium hydroxide solution (.0025 or whatever concentration your teacher gives you). Since .25 *M* means that there are .25 moles of base in 1 L of solution, and the volume of the base you have used is in milliliters, you need to divide .25 by 1,000 to standardize units. This is why you multiply by .0025.
8. In a titration, the amount of moles of the titrant (in this case the base, sodium hydroxide) added to neutralize the solution being titrated (in this case, the lactic acid in sour skim milk) is equal to the amount of moles of acid present in the solution.
9. Given that the atomic (formula) mass of lactic acid is 90.049, calculate the mass of lactic acid in the milk by multiplying the moles of acid by the atomic mass of lactic acid. The formula mass is the combined atomic mass of the chemical composition of a substance, determined by adding the relative atomic mass of the component elements together. A quantity equal in mass to a substance's formula mass is 1 mole; 90.049 grams of lactic acid would be 1 gram-mole (1 g-mol) of lactic acid.
10. Divide the mass of lactic acid by the mass of milk tested, and multiply it by a factor of 100. This is the percentage of lactic acid contained in your sample.
11. Were the procedures performed quantitative or qualitative analyses?
12. Which is denser, skim milk or heavy cream? Did your findings support or contradict your hypothesis?
13. Does skim milk contain more protein or carbohydrates?
14. How many grams of protein are there in an 8-oz glass of skim milk? (Remember: There are 224 g in 8 oz.)

What's Going On

Since all the test procedures aim to answer questions about how much substance is present, they are clearly quantitative analysis. While heavy cream is much thicker (more viscous) than skim milk, it is less dense. Cream has a much higher percentage of fat in it. The attractive forces between molecules of fat are stronger than those between molecules of the water in skim milk. The stronger the attraction between the molecules of a liquid, the greater its viscosity. This does not determine its density, which is a measure of the mass of a substance relative to the volume being measured. The density of cream is .99 g/mL; the density of skim milk is 1.01 g/mL. Your results may be a few hundredths of a gram off, but the relative densities should appear.

Skim milk contains more carbohydrate (about 4% to 5%) than protein (about 3.5%). Your findings may be slightly larger than this because of a very small amount of fat that is mixed in the milk. There are 8 g protein in an 8-oz glass of skim milk. Multiply the percentage of protein (3.5) by the number of grams (224) and divide by 100.

Connections

Scientists use a number of standard test procedures to learn about substances and their components. Tests carried out on a substance to answer the question "What is it?" or "What does it contain?" are called *qualitative analysis*; those carried out on a substance to answer the question "How much of a given component does it contain?" are called *quantitative analysis*. In this experiment you performed several different tests on skim milk in order to analyze its contents.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say "be careful with hot liquids" or "don't cut yourself with the knife" does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don't use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES