THE FLAVOR OF ORGANIC CHEMISTRY

Written by Amy Rowley and Jeremy Peacock

Annotation

This three-part unit introduces students to organic chemistry through the study of flavor. The unit presents basic concepts of organic chemistry such as defining organic compounds, functional groups, naming organic compounds, and the importance of organic molecules in everyday life. Lesson One, *WHAT IS FLAVOR…AND HOW DO WE KNOW?*, introduces students to the components of flavor, taste and aroma, through interactive experiences. In Lesson Two, *MAKING SCENTS OF ESTERS*, students prepare esters through the process of esterification. In Lesson Three, *FLAVOR-"FOOL"*, students discover how the five senses affect the perception of flavor. The lessons contained in this unit may be used together as a unit or as stand-alone lessons.

Primary Learning Outcomes:

Lesson One:

Students will be able to identify taste and aroma as the components of flavor.

Students will be able to identify the four categories of taste (sweet, sour, salty, and bitter) and map where each is sensed on their tongue.

Lesson Two:

Students will be able to define the terms *organic compound* and *functional group*.

Students will be able to distinguish between alcohol, carboxylic acid, and ester compounds by identifying the functional groups characteristic to each.

Students will be able to describe the process of esterification.

Students will be able to name ester compounds.

Students will compare properties of artificial and natural flavorings.

Students will be able to describe the applications of organic chemistry to the food industry.

Lesson Three:

Students will discover how the perception of flavor is affected by the five senses.

Georgia Performance Standards:

Characteristics of Science

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

Physical Science Content
SPS2. Students will explore the nature of matter, its classifications, and its system for naming types of matter.

Chemistry Content
SC1 Students will analyze the nature of matter and its classifications.

Duration:
Lesson One – *WHAT IS FLAVOR…AND HOW DO WE KNOW?*:
Preparation: 10 minutes
Introduction: 10 minutes
Student Activities: 45 minutes
Conclusion: 10 minutes
Total Class Time: 75 minutes

Lesson Two – *MAKING SCENTS OF ESTERS*:
Preparation: 80 minutes
Introduction: 10 minutes
Pre-Lab Discussion: 20 minutes
Lab Exercise: 40 minutes
Post-Lab Discussion: 20 minutes
Total Class Time: 90 minutes

Lesson Three – *FLAVOR-"FOOL"*
Preparation: 60 minute
Introduction: 10 minutes
Student Activity: 15 minutes
Conclusion: 20 minutes
Total Class Time: 45 minutes

Lesson One – *WHAT IS FLAVOR…AND HOW DO WE KNOW?*

Materials and Equipment:
For Teacher Preparation:

1. 2 gal. water
2. Table salt
3. Sugar
4. Lemon juice
5. Tonic water
6. Jelly beans (assorted flavors)
7. Permanent markers

Per Student:

1. 5 4-oz. Paper cups
2. 4 Q-tips
3. 4 Unsalted saltine crackers

Safety:
No significant safety concerns.

Technology Connection:
Not applicable.

Procedures:
Teacher Preparation:
Sugar Solution: Add two cups sugar to one gallon drinking water and dissolve completely.
Salt Solution: Add two cups salt to one gallon drinking water and dissolve completely.

Estimated Time:
10 minutes

Introduction:
Have students complete a "one-minute paper" describing their definition of flavor. Upon completion of these initial definitions, have the students share their definitions of flavor and determine its most important component.

It is expected that students will identify taste as the most important, if not the only, component of flavor. The following exercise is based on this misconception and demonstrates that flavor is the combination of taste and aroma.

Once students have identified taste as a component of flavor, ask them to recall the four basic categories of taste, *i.e.* sweet, sour, salty, and bitter. A fifth category, Umami, is related to monosodium glutamate (MSG), a common component of Chinese and Japanese food.

Estimated Time:
10 minutes

Student Activities:
Step One:
Students should follow procedures outlined in the attached *Tongue Map* student handout to create an individualized tongue map. Upon completion of the activity, students should compare and contrast the location of taste sensations on their tongue maps.

Locations of taste sensations may differ among students. The traditional tongue map was based on the hypothesis that each basic taste was detected only at a specific location on the tongue. However, recent studies show that taste areas may overlap and may vary in location among individuals.

Estimated Time:
30 minutes

Step Two:
Provide students with jelly beans of various flavors. Ask students to close their eyes, hold their noses, eat a jelly bean, and try to determine its flavor. Students will find that they are unable to determine the jelly bean flavor while holding their nose, *i.e.* they will only taste the sweetness of the sugar in the jelly bean. Next, have students taste a jelly bean with their noses open and determine its flavor. With the addition of aroma, students should be able to identify the true flavor of the jelly bean, for example cherry or licorice.

Ask students to briefly revise their flavor definitions and again identify the most important component. Discuss these revised definitions with the class. The discussion should address the importance of aroma to flavor. The following points may be useful:

- An individual can perceive only four basic taste sensations—sweet, sour, salty, bitter—but can identify thousands of flavors. This is because your nose adds aroma to taste to create flavor.
- Fresh orange juice contains 250 aromatic chemicals that contribute to its characteristic flavor. By comparison, Tang (an artificial orange beverage) contains only six aromatic flavor chemicals.
- Coffee has more than 400 aromatic chemicals that are responsible for its flavor.
- Ask students to think about how flavor is affected when they are congested with a cold or allergies.
- It is aroma that first attracts or turns you away from a food item. For example many people find the aroma of hot pizza very attractive while the aroma of sardines is often unattractive.
- Aroma serves as a protective measure by alerting individuals to food spoilage.

Estimated Time:
15 minutes

Conclusion:
Flavor can be narrowly defined as the combination of both taste and aroma. Briefly review with students this definition of flavor, including the importance of both taste and aroma. Have students complete the following discussion questions:

1. When you constructed your tongue map, were the locations of your taste sensations similar to those of your classmates? How does this compare with what you expected?
2. You are a contestant on "Fear Factor" and have been challenged to drink a rotten egg milkshake. Based on what you learned today, what can you do to limit your perception of the shake's flavor?
3. People who are osnomic are unable to perceive aroma. Can these people taste the same things as you? Can these people perceive the same flavors as you? Why or why not?

Estimated Time:
10 minutes

Assessment:
Students should be assessed based on completion of the *Tongue Map* student handout and discussion questions.

THE TONGUE MAP *Student Handout*

Introduction

Have you ever looked at your tongue in a mirror? Do so, and you will notice that your tongue is covered with several hundred tiny bumps, called papillae. These papillae have the unique task of sensing the four basic taste sensations, sweet, sour, salty, and bitter. In addition, each of these papillae contain more than 200 taste buds, which are scattered over the surface of the tongue. Many scientists believe that each basic taste sensation is detected only at a specific location on the tongue. However, recent studies show that taste areas may overlap and may vary in location among individuals.

Purpose:

To create an individualized tongue map, identifying where on the tongue each of the four taste sensations are perceived.

Materials:

Per Class:

1. Salt solution
2. Sugar solution
3. Tonic water
4. Lemon juice

Per Individual:

1. 5 4-oz. paper cups
2. 4 Q-tips
3. 4 Unsalted saltine crackers

Procedure:

1. Obtain from the teacher 5 4-oz. paper cups, 4 Q-tips, and 4 unsalted saltine crackers.
2. Label the cups salty, sweet, sour, bitter, and water.
3. Fill each cup with roughly 5 mL of the appropriate solution.
4. Cleanse your palate by eating a cracker and rinsing your mouth with water.
5. In the space provided, draw a rough sketch of your tongue.
6. Dip a clean, dry Q-tip into the salty solution. Dab the Q-tip across all areas of your tongue, recording on your tongue map any perceived sensations.
7. Cleanse your palate by eating a cracker and rinsing your mouth with water.
8. Repeat Step 6 with each of the remaining solutions. Be sure to cleanse your palate between each new sample.

Tongue Map:

Lesson Two – *MAKING SCENTS OF ESTERS*

**This lesson was adapted from activities presented in*

- *Science Fare—Chemistry at the Table, edited by Mickey Sarquis, published by Terrific Science Press in Middletown, OH, 1999*
- *Organic Smell Identification Kit, published by Flinn Scienctific Inc., Batavia, IL, 2003*
- *Preparation of Esters Student Laboratory Kit, Flinn Scientific Inc, Batavia, IL, 2003*

Materials and Equipment:

For Teacher Preparation:

1. 2 cans Sweetened condensed milk
2. 9 cups Confectioner's sugar
3. Pure vanilla extract
4. Imitation vanilla flavor
5. 45 Beral pipets (extra large bulb)
6. Large mixing bowl
7. Wooden spoon or hand mixer
8. Measuring cup
9. Measuring spoons
10. Large beaker or Erlenmeyer flask
11. Thermometer
12. Hotplate
13. Scissors

Per Class:

1. Flinn Organic Smell Identification Kit
2. 15 Styrofoam cups (6 oz.)
3. 75 Beral pipets (thin-stem/long)
4. 45 Beral pipets (extra large bulb/modified)
5. 45 Cork stoppers (#00)
6. Spatulas
7. 15 mL Sulfuric acid 18M, H_2SO_4
8. 15 mL Acetic acid, glacial, CH_3CO_2H
9. 10 g Salicylic acid, 2-HOC_6H_4COOH
10. 15 mL Isopentyl alcohol, $(CH_3)_2\ CHCH_2CH_2OH$
11. 20 mL Methyl alcohol, CH_3OH
12. 15 mL Ethyl alcohol, C_2H_5OH
13. 1 L Hot water, 70-80^oC
14. Electronic balance
15. Pure vanilla sweets for tasting
16. Imitation vanilla sweets for tasting
17. Unsalted saltine crackers
18. Plates

19. Permanent markers
20. Safety goggles
21. Aprons

Safety:
Concentrated sulfuric acid (18M H_2SO_4) is a very dangerous chemical, which can cause severe chemical burns when in contact with skin. In addition, unknown chemicals should never be held directly under the nose when smelling; instead, the wafting procedure should be used. Carefully smell by waving a hand across the mouth of the container, pushing the vapors toward the nose.

Technology Connection:
Not applicable.

Procedures:
Teacher Preparation:
Pure and Imitation Vanilla Sweets:
Measure 2/3 cup sweetened condensed milk into a mixing bowl. Gradually add 4 ½ cups confectioner's sugar and mix. The mixture should be crumbly. Repeat the same procedures to make a second batch. Add 1½ tsp. pure vanilla extract to one batch. Mix well. This is batch A. Add 1½ tsp. imitation vanilla flavor to the other batch. Mix well. This is batch B. Shape the mixtures into small balls about the size of marbles. Keep the two batches separate. When tasting, provide students with crackers to cleanse their palates between samples.

Hot Water Bath:
Fill a large beaker or Erlenmeyer flask with water. Place on a hotplate and warm to 70-80^{o}C.

Modified Pipets:
To modify an extra large bulb pipet, cut a small portion of the stem off so that the thin-stemmed pipet can be inserted into the extra large bulb pipet stem.

Estimated Time:
60 minutes

Introduction:
Introduce students to a variety of organic compounds, including esters, by asking them to smell and describe different aromas using the Flinn *Organic Smell Identification Kit.*

Estimated Time:
10 minutes

Pre-Lab Discussion**:**
1. Review with students the definitions of organic compounds and functional groups. Organic compounds are often simplified to include those compounds that contain the element carbon. For example, aspirin, $C_9H_8O_4$, is an organic compound. Organic

compounds do contain carbon, and most organic compounds also contain hydrogen. Those compounds that consist solely of carbon and hydrogen are called hydrocarbons. Butane, C_4H_{10}, is an example of a hydrocarbon. Other organic compounds may contain oxygen, nitrogen, sulfur, phosphorus, or one of the halogens. These groups of atoms containing elements other than carbon and hydrogen constitute functional groups. Each functional group is important because it is this group of elements that provides the compound as a whole with unique chemical properties. Furthermore, organic compounds are commonly classified by the functional groups they contain.

2. Review with students the functional groups characteristic to alcohols, carboxylic acids, and esters.
   Alcohol → -OH
   Carboxylic Acid → -COOH
   Ester → -COO

3. Pass out the attached *Making Scents of Esters* student handout to allow students to follow along. Describe to students the properties of esters and the process of esterification. An ester is an organic compound that is formed, in addition to water, when a carboxylic acid reacts with an alcohol. This process is called esterification. When carboxylic acids are esterified (combined with an alcohol to form an ester), the resulting esters are liquids with fruity flavors. These synthetic esters are used in the food industry as flavorings. In many cases, the synthetic esters produced in the laboratory are nearly the same molecules that give fruits their characteristic flavors.

   General Reaction:

R-COOH	+	OH-R'	→	R-COO-R'	+	H_2O
carboxylic acid		*alcohol*		*ester*		*water*

   Specific Reaction:

CH_3COOH	+	$OH\text{-}CH_2CH_3$	→	$CH_3\text{-}COO\text{-}CH_2CH_3$	+	H_2O
acetic acid		*ethyl alcohol*		*ethyl acetate*		*water*

4. Demonstrate to students the naming of ester compounds.
   Step 1: When "alcohol" is included in the name of the alcohol, drop it
   Step 2: Remove "ic acid" from the name of the carboxylic acid, add "ate"
   Step 3: Combine the remaining names, beginning with the alcohol

   Ex. Acetic acid + ethyl alcohol → ethyl acetate

5. Describe in detail to students the laboratory exercise to be performed, stressing the safety precautions associated with the experiment. Concentrated sulfuric acid (18M H_2SO_4) is a

very dangerous chemical, which can cause severe chemical burns when in contact with skin. In addition, unknown chemicals should never be held directly under the nose when smelling; instead, the wafting procedure should be used. Carefully smell by waving a hand across the mouth of the container, pushing the vapors toward the nose.

Estimated Time:
20 minutes

Lab Exercise:
Have the students perform the *Making Scents of Esters* laboratory experiment as described in the attached student handout.

Estimated Time:
40 minutes

Post-Lab Discussion:
Present students with the prepared food samples made with pure vanilla extract and imitation vanilla flavoring. Ask students to distinguish between the two samples, citing the noted differences. Pure vanilla contains well over 100 chemicals, one of which is vanillin. Imitation vanilla is made from very few chemicals, often only vanillin and ethyl vanillin. Ethyl vanillin is not found in vanilla plants, and it has a taste similar to vanillin but about 5 times stronger. Many people can taste the difference between pure vanilla extract and imitation vanilla flavoring. This is because they notice the taste of the other chemicals in pure vanilla or because the taste of the imitation vanilla is too strong. Contrast with students artificial vs. natural flavorings (availability, preference, cost, etc.). Ask students why natural flavorings (such as chocolate) are sometimes preferable to artificial (those they prepared in today's laboratory exercise). Some artificial flavorings can be produced to taste just like natural flavors (ex. oil of wintergreen). These flavorings are comprised of a single compound (the character impact compound) or a mixture of very few chemicals. Other natural flavorings, such as chocolate, which contains over 12,000 chemicals, are such complex mixtures of chemicals that scientists have yet to make an artificial flavor that tastes just like the natural one.

Estimated Time:
20 minutes

Assessment:
Students should be assessed based on completion of the *Making Scents of Esters* student handout.

MAKING *SCENTS* OF ESTERS *Student Handout*

Introduction:
An ester is an organic compound that is formed, in addition to water, when a carboxylic acid reacts with an alcohol. This process is called esterification.

General Reaction:

Specific Reaction:

Esterification typically requires a catalyst to speed it, and for decades, concentrated sulfuric acid (18M H_2SO_4) has been used to do so. Sulfuric acid is a very dangerous chemical, which can cause severe chemical burns when in contact with skin, and therefore, the utmost care should be taken when working with sulfuric acid.

When carboxylic acids are esterified (combined with an alcohol to form an ester), the resulting esters are liquids with fruity flavors. These synthetic esters are used in the food industry as flavorings. In many cases, the synthetic esters produced in the laboratory are nearly the same molecules that give fruits their characteristic flavors.

Purpose:
To synthesize, name, and identify the structure of specific ester compounds.

Materials:
1. 1 Styrofoam cup (6 oz.)
2. 5 Beral pipets (thin-stem/long)
3. 3 Beral pipets (extra large bulb/modified)
4. 3 Cork stoppers
5. Spatula
6. Electronic balance
7. Sulfuric acid, 18M, H_2SO_4
8. Acetic acid, glacial, CH_3CO_2H
9. Salicylic acid, 2-HOC_6H_4COOH
10. Isopentyl alcohol, $(CH_3)_2$ $CHCH_2CH_2OH$
11. Methyl alcohol, CH_3OH
12. Ethyl alcohol, C_2H_5OH

13. 50 mL Hot water, 70-80^{o}C
14. Goggles
15. Apron

Procedure:
**Record all data in the attached data table.*

1. Label the three modified extra large bulb pipets “I,” “E,” and “M.”
2. Label the three thin-stemmed bulb pipets “I,” “E,” “M,” “A,” and “S.”
3. Into the large pipet labeled “I,” place 10 drops of isopentyl alcohol, 10 drops of acetic acid, and 1 drop of concentrated sulfuric acid. Stopper the pipet with a small cork and set aside.
4. Into the large pipet labeled “E,” place 10 drops of ethyl alcohol, 10 drops of acetic acid, and 1 drop of concentrated sulfuric acid. Stopper the pipet and set aside.
5. Into the large pipet labeled “M,” place 0.25 g salicylic acid, 20 drops of methyl alcohol, and 5 drops of concentrated sulfuric acid. Stopper the pipet and set aside.
6. Fill a Styrofoam cup with 50 mL of hot water. Place the pipets in the hot water bath and allow them to heat for 10 minutes.
7. After ten minutes, remove the pipets from the bath. Carefully remove each of the stoppers and cautiously smell the odor of the esters. Record the odor of each ester in the attached data table.

Table 1: Alcohol/Carboxylic Acid Pairs and Resulting Esters

Test Tube	Alcohol	Amount	Carboxylic Acid	Amount	Ester Produced	Odor of Ester
1						
2						
3						

Post-Lab Questions:
**Answers should be completed on a separate sheet of paper.*

1. Using the attached organic structures, write the chemical reaction for each of the esters produced in the above procedures. In each reaction, circle the carboxylic acid functional groups, underline the alcohol functional groups, and box the ester functional groups.

2. In addition to the ester, what compound is produced in ALL esterification reactions?
3. Isobutyl alcohol and formic acid combine to produce a raspberry odor. Predict the name of the ester.
4. Determine the alcohol and carboxylic acid used to produce octyl acetate, an ester that has an orange aroma.

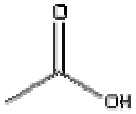
Discussion Questions:
**Answers should be completed on a separate sheet of paper.*

1. Describe the importance of esters to the food industry. Cite examples of their use?
2. In addition to food products, what other products do you suspect contain esters? Why?
3. If you could create an ester of any odor, what odor would you choose? Why?

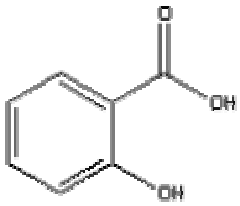
Organic Structures:

Carboxylic Acids:

Acetic acid



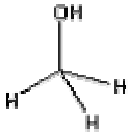
Salicylic acid



Alcohols:

Isopentyl alcohol

Methyl alcohol



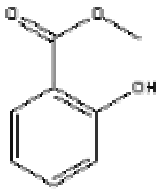
Ethyl alcohol

Esters:

Isopentyl acetate

Ethyl acetate

Methyl salicylate



Lesson Three – *FLAVOR-"FOOL"*

**This lesson was adapted from activities presented in Science Fare—Chemistry at the Table, edited by Mickey Sarquis, published by Terrific Science Press in Middletown, OH, 1999.*

Materials and Equipment:

For Teacher Preparation (per pie, one pie serves 10 students):

1. 25 Ritz crackers
2. 1 ½ cups Sugar
3. 1 ½ tsp. Cream of tartar
4. 1 tsp. Cinnamon
5. 2 cups Water
6. Pie cutter
7. 1 tsp. Butter or margarine
8. 2 9-in. Pre-made refrigerated pie crusts
9. Measuring cup
10. Measuring spoons
11. Large saucepan
12. Small saucepan
13. Wooden Spoon
14. Stove

Per Student:

1. Plate
2. Fork

Safety:

Because students will eat the product of this activity, be sure to mix and bake the pies outside of the laboratory. Emphasize to students that this activity is an exception to the rule that they should never taste or eat anything produced in the laboratory.

Technology Connection:

Not applicable.

Procedures:

Teacher Preparation:

Recipe: No-Apple Apple Pie

1. Boil 2 cups of water in the large saucepan. Once boiling, slowly add 1 ½ cups sugar and 1 ½ tsp. cream of tartar. Stir the mixture until the solids dissolve.
2. Add 25 Ritz crackers, one at a time, to the boiling water. Do not break up the crackers. Do not stir the mixture.
3. Boil the cracker mixture for 2 minutes and remove from heat.
4. Pour the cracker mixture into the crust and sprinkle with 1 tsp. of cinnamon.
5. Melt 1 tsp. of butter or margarine and drip it over the filling.

6. Carefully place the top crust on the pie and press the edges of the crust together. Cut vents in the top of the crust with a knife.
7. Bake the pie at 425°F for 25-30 minutes, or until the crust is golden brown.
8. Let the pie cool for at least 15 minutes, or until you can cut it easily.

Estimated Time:
60 minutes

Introduction:
Discuss with students the idea that flavors are chemicals. In fact, everything we put in our mouths is made up of chemicals, including pie and the fork used to eat it. The flavor of pie, as well as any other food item we eat, is the response of our bodies to the chemicals present in the food.

Estimated Time:
10 minutes

Student Activity:
Provide each student with a piece of pie. Ask them to taste the pie, as well as observe its aroma and texture, and determine the type of pie. As a class, brainstorm a list of the possible ingredients used to prepare the pie. *It is expected that students will name such ingredients as apples, applesauce, or apple juice.*

Estimated Time:
15 minutes

Conclusion:
Reveal to the students that the pie contains no apples or apple products, but rather cream of tartar and Ritz crackers are used to achieve the desired flavor and texture. The flavor of the apple pie involves our nose's and tongue's responses to the chemicals present in the pie, as well as our eye's response to the appearance of the food, and our mouth's response to the texture of the pie. Therefore, our brain can be fooled if we eat something that resembles an apple pie in flavor and texture, when in fact, it is a no-apple apple pie.

The no-apple apple pie was made with alternative ingredients that provide the flavor, appearance and texture of a real apple pie. The acidic nature of apples gives them their characteristic sour taste. In our pie, the sour taste is a result of the reaction of cream of tartar and water to form tartaric acid. In the absence of apples, Ritz crackers were used in our pie to provide the fibrous mouthfeel characteristic of apples.

Ask students to individually answer the following discussion questions:
1. What are the advantages and disadvantages of making a pie, or any food item, with alternative ingredients?
2. Would a pie made with more traditional ingredients be better for you? Why or why not?

3. How do your five senses influence your perception of flavor? Include at least one example for each of the five senses.

Estimated Time:
20 minutes

Assessment:
Students should be assessed based on completion of the discussion questions.