The Ethanol Production Process

Unit 2 Lesson 3

Precepts

A. Action
A1. Work independently and in group settings to get things done.
C. Vision
C2. Conceptualize ideas.

National Standards

NL-ENG.K-12.6. Applying knowledge.

Student Learning Objectives

As a result of this lesson, the student will …
1. Identify the types of fermentation that can produce ethanol.
2. Identify how starch and cellulose differ in the fermentation process.

Time

Instruction time for this lesson: 50 minutes.

Resources

www.harvestcleanenergy.org
www.ethanolrfa.org

Tools, Equipment, Supplies

Writing surface
Projector
Crayons
8 ½ x 11 or larger paper
Markers
AS.A – one per student
TM.A
Assess.A

Key Terms

The following terms are presented in this lesson and appear in ***bold italics***:
Cellulose
Cellulosic
Conventional
Ethanol
Fermentation
Starch

INTEREST APPROACH

*Recall with students that **ethanol** is a product of **fermentation**, highlight the following points:*

- *__Ethanol__ is a product of __fermentation__.*
- *Define __fermentation__ as a sequence reaction which releases energy from organic molecules in the absence of oxygen.*
- *Sugar -> __Ethanol__ + Carbon Dioxide*

 We've learned that ***ethanol*** is a product of the ***fermentation*** process. Looking back to your notes, who can share with us the definition, we created for ***fermentation****?*

Great! We even created an equation to help us remember that sugar, through the ***fermentation*** process, yields what two products? *(**Ethanol** and carbon dioxide)*

Great work! Keep this information in mind; we will build on it today!

*Explain to students that all beverage **ethanol** and industrial **ethanol** is made in this process. Lead students to this understanding by making comparisons of other items that are similar, but carry differences. Go on to explain that all **ethanol** is not made through the same process. In objective 1, students will write down the **fermentation** equation and explain the two methods used in the production of **ethanol**.*

 Think about some things you know of that are similar but have slight differences. Think about apples and oranges. They're both fruits right? Think about how they were grown. They both came from a tree and are sold in the grocery store as a fruit. Both apples and oranges can be eaten with little preparation. But when you think of pies, which fruit do you think of? Apples, right? Apples are used to make pies, cakes, breads, sauces, and other foods much more often than oranges are.

Now think about raw milk. What is raw milk used to make? *Elicit student responses.*

Raw milk is used to make a number of different products including the milk we drink, cream, cottage cheese, yogurt, ice cream, buttermilk, and is processed a number of different ways to be used in hundreds of foods. ***Ethanol*** also has similarities and differences.

We are mostly concerned with industrial ***ethanol***, or ***ethanol*** that is made for use as a fuel. There is also ***ethanol*** that is made in certain food making processes. While the outcome is a little different and the products are used for different reasons, the process of ***fermentation*** is virtually the same. Sugars are broken down to make ***ethanol*** and a by-product of carbon dioxide. There are; however, a couple of different ***fermentation*** processes depending on what the raw material is. Today we will examine the ***fermentation*** equation in-depth. We will be able to identify and describe two different ***fermentation*** processes.

OBJECTIVE 1. Identify the types of fermentation that can produce ethanol.

A. ***Fermentation*** Equation: Raw Material + Yeast= ***Ethanol*** (Energy) + by-product of carbon dioxide. C6H12O6 -> 2 CH3CH2OH + 2 CO2.

*In this objective, the instructor will present the **fermentation** equation to students and guide them to understand the types of **fermentation** processes that result in different types of **ethanol**. Use the Crayon Moment when presenting the **fermentation** equation. The Hieroglyphic Moment can be used to present the different types of **fermentation** processes.*


We know that the ***fermentation*** processes yields two products. Who can tell us what those two products are? *Elicit responses.*

Great, those two products are ***ethanol*** and carbon dioxide. Who can tell us what the input is in the ***fermentation*** process? *Elicit responses.*

Awesome, the input is a sugar or carbohydrate. Let's put the ***fermentation*** process into a chemical equation. Take out a piece of paper for notes and a writing utensil.

Crayon Moment
*The Crayon Moment is used to help students' associate different parts of the **fermentation** equation. Identify the compounds in the equation, raw material, **ethanol**, etc., then assign a color for each component, or let students choose their own colors. The instructor should record the equation on the board while students record it in their notes. If possible, the instructor can use colored writing utensils to match the suggestions in the lesson.*


While we are writing this equation we will be using crayons to help us make associations between each of the components of the equation. Choose any color crayon and write "***Fermentation*** Equation" as a heading in your notes. Then locate brown, red, and blue crayons. Also, choose another color you can use. This color will be used to write some numbers and symbols. We know that sugar is an input to the ***fermentation*** equation. Since this sugar or simple carbohydrate hasn't been processed yet, let's call it a "Raw Material" for our equation. The brown crayon will represent the inputs to our equation. Use the brown crayon to write "Raw Material" on the far left side of the equation.

Fermentation Process

Raw Material

We also need yeast in this equation on the left side of the equation. Using the number/symbol crayon you chose, make a plus sign to the right of raw material. Now, write "Yeast" to the right of the plus sign using the brown crayon.

Fermentation Process

Raw Material + Yeast

These two components yield, or equal two outputs, ***ethanol*** and carbon dioxide. Use your number/symbol crayon and draw an equal sign in the equation to the right of yeast.

Fermentation Process

Raw Material + Yeast =

Locate the red and blue crayons. These represent the outputs of our equation. Use the red crayon to write ***ethanol*** and the blue crayon to write carbon dioxide, so our equation should look like what I have on the writing surface.

Raw Material + Yeast = ***Ethanol*** + Carbon dioxide

*Now guide students through the process of writing the chemical equation for the **fermentation** process using elemental symbols. Using the corresponding colors for the elements, write the equation, and then explain how the equation is similar to the equation above that is written out in words.*

We can take this equation a step further by writing it using elemental symbols from the periodic table. There will be three elements in our equation that will make up the components we wrote above. They are C – carbon, H – hydrogen, and O – oxygen. We'll continue using crayons to write our equation. We'll use the same colors to match up with our previous equation. Let's create our equations; do this in your notes below the equation we wrote out in words.

The first part of our equation is $C_6H_{12}O_6$. This represents the raw material, or sugar and yeast. What color did we use before to represent the inputs? We will use brown again to write out this compound. On the far left hand side of the paper, write out $C_6H_{12}O_6$.

$C_6H_{12}O_6$

Next we need to draw a symbol that leads us to the right side of the equation, or the products. For this we will use an arrow, this arrow means "equals" or "yields". Using the crayon you chose for numbers and symbols draw an arrow left to right from the chemical compound we just drew.

$C_6H_{12}O_6$ →

Since we used the elements carbon, hydrogen and oxygen on the left side of the equation, we need to see those same elements on the right side of the equation. Who can tell us what we can expect to see on the right side of the equation, or what are the products of this process? *Elicit student responses.*

That is correct; we should see the results of ***ethanol*** and carbon dioxide. Our next task is to write these compounds in a chemical equation. Leave some space between the arrow and the placement of your next letter, we'll need to come back to fill in some information later.

The compound we really want to get out of this process is ***ethanol***, so let's look at that first. Remind me again, what color did we use above for ***ethanol***? Great, find your red crayon and draw the compound for ***ethanol***:

$C_6H_{12}O_6 \rightarrow CH_3CH_2OH$

The second product of the ***fermentation*** process or a by-product is carbon dioxide. Who will tell us the two elements that we will use to represent carbon dioxide? Great answer, carbon and oxygen are correct. We need one atom of carbon and two atoms of oxygen to represent carbon dioxide. Let's record a plus sign next to ***ethanol***, leaving some space to come back to record more information later. Use blue to represent carbon dioxide and record that compound.

$C_6H_{12}O_6 \rightarrow CH_3CH_2OH + CO_2$

In order to balance this equation, we need to make sure there is the same number of atoms of each element on each side of the equation. To balance the equation, we must add a 2 before ***ethanol*** and carbon dioxide to get the same amount of atoms on the right side. Let's do that now. *(Instructors may wish to go in-depth into teaching balancing equations; this is suggested below as an extended classroom activity.)*

$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$

As we look at the two equations we wrote, we can immediately see the similarities because of the color coding. Brown represents the inputs sugar and yeast. What does red represent? ***(ethanol)*** And blue represents oxygen. As you think back to the ***fermentation*** process, you can make associations with the colors and the compounds involved.

*Now that students have identified the compounds involved in the **fermentation** process and the chemical equation, identify the two types of **ethanol**. Use the Motion Moment to help students visually and kinesthetically remember these two types of **ethanol**.*

Motion Moment
*The two types of **ethanol**, **conventional** and **cellulosic ethanol** are developed from different products. Creating motions will help students recall the differences learned in objective 2. First, present the content on the writing surface, while students record it in their notes. Then guide students through making each motion. The instructor will need to model what each motion looks like.*

B. There are different types of ***fermentation*** processes that result in different types of ***ethanol***.
1. ***Conventional Ethanol- ethanol*** that is derived from grains such as corn and wheat.
2. ***Cellulosic Ethanol- ethanol*** that is exactly the same as grain-based ***ethanol***, but it is made from agricultural residues.

Conventional*: using both hands, make the motion of putting a pan of cookies in the oven*
Cellulosic*: using both hands, make the motion of sweeping the floor with a broom*

 There are two types of ***ethanol*** that can be made through the ***fermentation*** process, ***conventional ethanol*** and ***cellulosic ethanol***. Let's take a moment to capture some information about these two types of ***ethanol***.

Conventional ethanol – ***Ethanol*** that is derived from grains such as corn and wheat

Cellulosic ethanol – ***Ethanol*** that is exactly the same as grain-based ***ethanol***, but it is made from agricultural residues.

 Let's think about what this means. ***Conventional*** means usual or typical. The word ***conventional*** is used to describe the type of oven that we see in many homes. For us to remember that ***conventional ethanol*** is the "usual" or "standard" type of ***ethanol***, let's make a motion like we are putting a pan of cookies in the oven. So, when I say "***conventional***", put the cookies in the oven.

*"**Conventional**" The instructor and students will make motion for **conventional.***

Great job! Now, let's look at ***cellulosic***. ***Cellulosic ethanol*** is made from plant residues, or the leftovers. To represent ***cellulosic ethanol*** we can make the motion of sweeping the floor, like we are cleaning up after a project. Let's practice this. Stand up! When I say "***cellulosic***" pretend like you are sweeping the floor.

Okay, now that we have our two motions, "***Conventional***" *(make motion)* and "***Cellulosic***" *(make motion)* we can find out more information about each.

OBJECTIVE 2. Identify how starch and cellulose differ in the fermentation process.

II. The ***starch*** and ***cellulose fermentation*** process each have unique steps.

A. ***Starch*** Process

1. ***Starch*** must first be broken down into simple sugars before ***fermentation*** can even occur.
    a. In early times this was done by chewing of the corn in which enzymes were broken down.
    b. Today the cooking of corn and the addition of enzymes, alpha amylase and gluco amylase, are added as catalyst.
2. Yeast is added and feeds on the sugar beginning the ***fermentation*** process.
3. Production of ***ethanol*** results with the byproduct of carbon dioxide.

B. ***Cellulose*** Production Process

1. Made from ***cellulosic*** biomass materials that are composed of ***cellulose***, hemi***cellulose***, and lignin.
    a. Plant wastes- corn stover, cereal straws, sugarcane and bagasse
    b. Plant wastes from industrial processes- sawdust, paper pulp
    c. Energy crops- switch grass.
2. Aim is to extract fermentable sugars from the feedstock, in which they are locked in complex carbohydrates called polysaccharides.
3. Separating complex structures is essential to the efficient and economic production of ***cellulosic ethanol***.
4. There are two major processes in ***cellulosic ethanol*** production
    a. Acid hydrolysis- this is the break-down of complex carbohydrates to simple sugars.
    b. Enzymatic hydrolysis- this process utilizes pre-treatment process to reduce the size of the material to make it accessible for hydrolysis. Enzymes than are added back in to break corn material for ***fermentation***.

The purpose of this objective is to help students understand the differences between how ***conventional*** *and* ***cellulosic ethanol*** *are made. This can be accomplished by using the Cartographer Moment. This moment allows students to conceptualize the information in a map. Provide students with the content in AS.A, split students into groups of 2-3, guide them through the process of creating a map (examples included below), have groups share maps with the class, and summarize the content of the objective.*


These two types of ***ethanol*** are made through two different processes. The process for ***conventional ethanol*** is the ***starch*** process while we call the process for ***cellulosic ethanol*** the ***cellulose*** production process.

Cartographer Moment


When you're traveling somewhere, like to the national FFA convention, it is useful to have a map to get you there. Since we don't have an aerial view of the roads, we need a guide to get us there. Since we can't see everything that is different about the ***starch*** and ***cellulose***

processes, we can create a map to help us. Let's take a look at the information we have about these two processes.

Provide students with copies of AS.A.


Take a moment to pick out the important points of the content. Circle, highlight or underline those important points.

These important points will help us create our maps. Our maps should represent the content of each process so that we can describe it to someone else. We'll make our maps in groups.

The instructor can determine how to group students. Counting off, alphabetical grouping, or clusters of students who sit near each other are a few ideas for grouping students.


Make sure you have your handout and a writing utensil and let's get into groups. Each of us came up with important information for each process. Now, let's take some time to think in our groups about the important information we want to include in our maps. Share with your group your ideas and come to a consensus on what your group will use for the map.

Guide students through the first aspect of the map using TM.A before they continue in groups. Finally, have groups share their maps with the class.


We will create two mini-maps, one for the ***starch*** process and one for the ***cellulose*** process. We'll need paper and markers to do this. Send one person from each group to the front of the room to get materials for your group.

Let's start with the ***starch*** process. What was the first important piece of information you found about this process? *Elicit student responses.* Great thoughts! One of the first important points I found was that ***starch*** first has to be broken down before ***fermentation*** can occur. This will make up the first part of my map. If you would like to use my example as the starting point for your map feel free, or use this example to create your own starting point. We identified earlier that these starches come from grains like corn. So, I am using Kernel Corn as the traveler in my map. Kernel Corn starts his journey by taking a box of ***starch*** and breaking it down into smaller pieces using a hammer.

Show students this aspect of TM.A to provide an example of how they will create their maps. Instructors may choose to share another aspect of the sample map on TM.A depending on the students' ability to come up with ideas for each component of their map.


From here, Kernel Corn will travel to another location on the map. Our task is to continue this journey for Kernel Corn and then to create a mini-map for the ***cellulose*** process. Let's take 8-10 minutes to complete our maps. When we're finished we'll share with the class. What questions are there?

Okay, let's create our maps!

The instructor should circulate through the room to be sure groups are including essential elements in their maps and to assist groups in creating points on the maps. The samples in TM.A can be used to guide students through the process. Once finished, allow groups to share maps.


Great job creating maps! Awesome job at working in groups and coming up with new ways to communicate the information! Let's take a moment to share our creations with the class.

Groups present maps. Show appreciation to each group through applause, snaps, etc.


These maps really reflect the content from the handout. With our maps and the content from the handout, we have a great understanding of the differences between the ***starch*** and ***cellulose*** processes for making ***ethanol***.

REVIEW/SUMMARY

*Review with students the equation for the **fermentation** process, the motions for the two types of **ethanol**, and ask students to select components from their maps to review objective 2.*


We have learned some great information about the ***ethanol*** production process today! Be sure to have your notes and your maps in front of you. Let's review the ***fermentation*** equation. Think about the left side of the equation. What are our inputs? *Elicit student responses.* Yes, raw material and yeast. Picture in your mind what that chemical compound looks like from our second equation. Who can tell us the major product of the ***fermentation*** process? That's right, it's ***ethanol***. Picture in your mind the letter and number combinations that represent ***ethanol***. Last, a by-product of the ***fermentation*** process is carbon dioxide. Who can tell us the letters and numbers that make up carbon dioxide? Amazing, CO_2 is correct.

The second thing we discussed was the difference between ***conventional*** and ***cellulosic ethanol***. Let's practice our motions. Stand up! Make the motions when I say the words. We learned that "***conventional***" *(putting cookies in the oven)* ***ethanol*** is the standard type of ***ethanol*** using grains like corn and wheat. We also learned that "***cellulosic***" *(sweeping motion)* ***ethanol*** is made from plant residues or leftovers.

Finally, we looked at the two processes of ***fermentation*** that make these types of ***ethanol***, ***starch*** and ***cellulose***. Within your group, take one minute to pick out one important part of your map you can share with the class.

Let's share these important points.

Have groups share one important point.


Great job! What questions are there about the ***fermentation*** equation, the two types of ***ethanol***, and the two ***fermentation*** processes?
Let's show what we know about today's lesson by taking the evaluation.

APPLICATION

Extended classroom activity: *Instructors can teach a "lesson within the lesson" on balancing chemical equations and go in depth on why twos were placed before* ***ethanol*** *and carbon dioxide in the chemical equation for* ***fermentation****. Additionally, instructors can obtain chemical equations for other reactionary processes to allow students to practice balancing chemical equations.*

FFA activity: *Invite a chemist (preferably involved in the* ***ethanol/fermentation*** *process) to serve as guest speaker at an FFA meeting for career exploration opportunities.*

SAE activity: *Students with a grain production SAE project can give a short talk on the production process from planting to harvest so students can see where the raw material in the* ***fermentation*** *process originates.*

EVALUATION

Assess.A

Answers to Assessment:

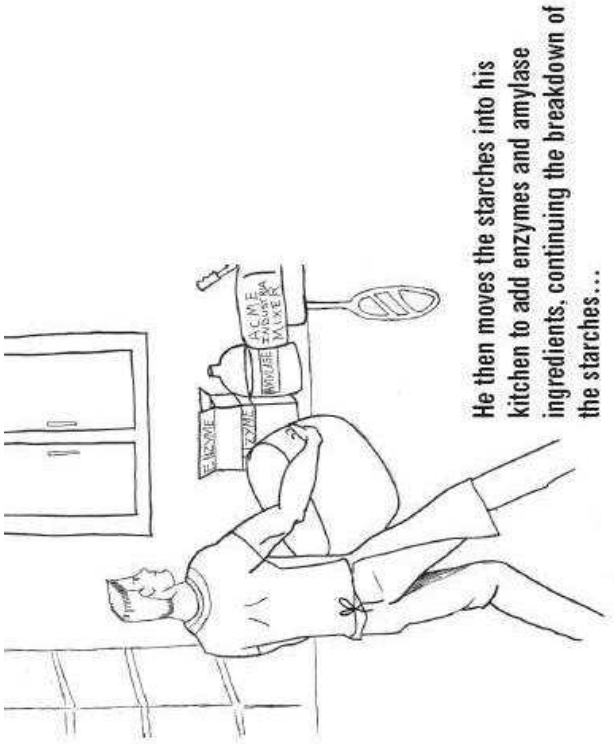
A. Matching:
1. Acid hydrolysis
2. Starch
3. Cellulosic
4. Enzymatic Hydrolysis
5. Fermentation
6. Conventional

B. Short Answer:

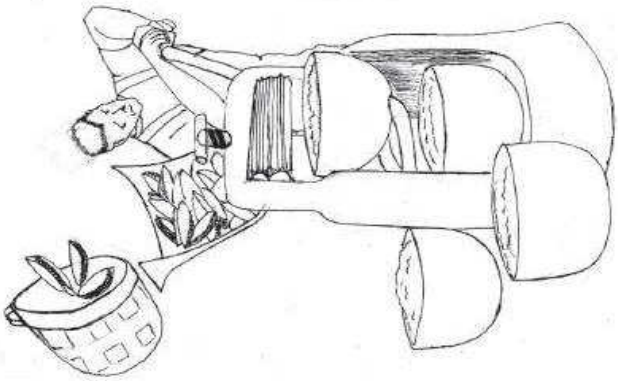
1. $C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$.

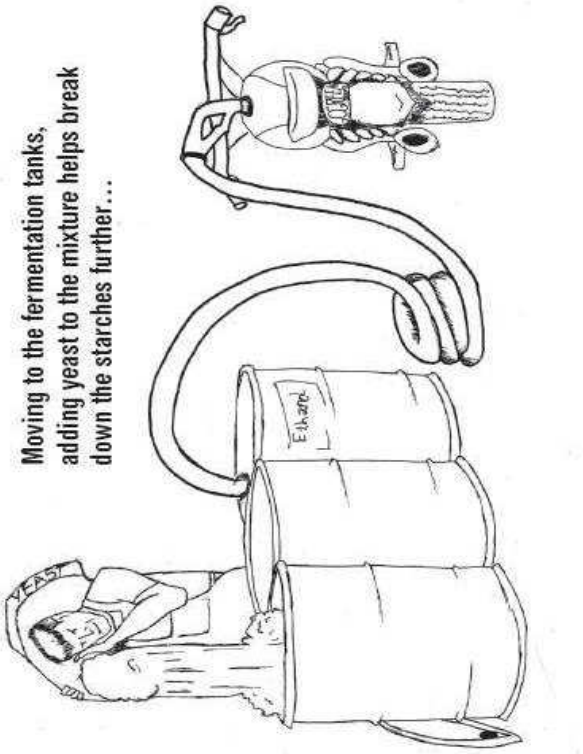
2. The starch process breaks down carbohydrates at a more rapid pace than cellulosic fermentation. Starch fermentation is cheaper and more economical than cellulosic.

TM.A


He then moves the starches into his kitchen to add enzymes and amylase ingredients, continuing the breakdown of the starches…


When the fermentation process is over, Kernel Corn uses the Ethanol in the corn mobile for fuel. Carbon Dioxide, CO_2 is a by-product of fermentation.


Kernel Corn starts the Ethanol process by breaking down starches in his garage…


Moving to the fermentation tanks, adding yeast to the mixture helps break down the starches further…
YEAST
Ethanol

AS.A

II. The ***starch*** and ***cellulose fermentation*** process each have unique steps.

A. ***Starch*** Process

1. ***Starch*** must first be broken down into simple sugars before ***fermentation*** can even occur.

a. In early times this was done by chewing of the corn in which enzymes were broken down.

b. Today the cooking of corn and the addition of enzymes, alpha amylase and gluco amylase, are added as catalyst.

2. Yeast is added and feeds on the sugar beginning the ***fermentation*** process.

3. Production of ***ethanol*** results with the byproduct of carbon dioxide.

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a. Plant wastes- corn stover, cereal straws, sugarcane and bagasse

b. Plant wastes from industrial processes- sawdust, paper pulp

c. Energy crops- switch grass.

2. Aim is to extract fermentable sugars from the feedstock, in which they are locked in complex carbohydrates called polysaccharides.

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4. There are two major processes in ***cellulosic ethanol*** production

a. Acid hydrolysis- this is the break-down of complex carbohydrates to simple sugars.

b. Enzymatic hydrolysis- this process utilizes pre-treatment process to reduce the size of the material to make it accessible for hydrolysis. Enzymes than are added back in to break corn material for ***fermentation***.

Assess.A

A. Matching:

Conventional	Cellulose	Fermentation
Starch	Acid hydrolysis	Enzymatic hydrolysis

1. _____ is the break-down of complex carbohydrates to simple sugars.

2. _____ is a complex carbohydrate.

3. _____ ***ethanol*** that is exactly the same as grain-based ***ethanol***, but it is made from agricultural residues.

4. _____ utilizes pre-treatment process to reduce the size of the material to make it accessible for hydrolysis. Enzymes than are added back in to break corn material for ***fermentation***.

5._____ results in ***ethanol*** and carbon dioxide.

6. _____ ***ethanol*** is derived from grains such as corn and wheat.

B. Short Answer:

1. Write out the ***fermentation*** equation with the by-products in the correct chemical formula.

2. Explain the difference in the ***starch*** process and ***cellulosic*** process of ***fermentation***?