Making Ethanol (Lesson Plan)

(Investigation and Analysis of an Alternative Fuel)

Suggested Grade Level 7-9

Standard Statements (Pennsylvania)

3.2.7 A	Explain and apply scientific and technological knowledge
3.2.7 B	Apply process knowledge to make and interpret observations
3.2.10 B	Describe and explain the chemical and structural basis of living organisms
3.4.7 A	Describe concepts about the structure and properties of matter
3.4.10 A	Explain concepts about the structure and properties of matter
3.6.7 A	Explain biotechnologies that relate to related technologies of propagating, growing, maintaining, adapting, treating, and converting

Content Objectives

Students will know that

1. There are reasons why our society needs to consider the use and implementation of alternative fuels.
2. When yeast cells ferment simple sugars (such as glucose), ethanol and carbon dioxide are produced.
3. Ethanol is a renewable fuel and is considered to be "CO_2 neutral."
4. Using ethanol as a fuel is not a new development in our society; it has been used since the late 1800's on and off throughout history as certain situations have dictated.

Process Objectives

Students will be able to

1. Provide evidence that a chemical reaction is occurring.
2. Conclude that the inflation of a balloon is evidence that ethanol is being produced.
3. Draw diagrams that show how ethanol is considered to be "CO_2 neutral" and why fossil fuels are not.
4. Make and test predictions about whether or not certain substances are fermentable by yeast.

Assessment Strategies

1. Evaluation of completed student handout.
2. Class discussion of key ideas throughout the activity.

Materials

- Empty (1/2 liter) soda bottles with their caps
- Balloons
- Yeast
- Glucose Tablets
- Funnels
- Water
- Corn syrup
- Corn starch
- Cane (table) sugar
- Honey
- An apple
- Equipment to project the overheads included in the Teacher Notes

Procedures

Part 1 *(Hmwk Assignment & 25-min class discussion)*

1. Have the students complete the readings and questions in Part 1 as a homework assignment. If desired, go over the answers as a class.
2. Solicit student thoughts about why we need to consider using alternative fuels. During this class discussion, emphasize that fossil fuels are a finite resource, that it is not ideal to depend so heavily on foreign countries for such a large portion of our fuel, and that burning fossil fuels produces harmful emissions.
3. Introduce ethanol as one type of alternative fuel. Tell the students this is the alternative fuel they will be investigating during this lesson.

Part 2 *(1, 45-min class period)*

1. Distribute the materials for the preliminary investigation with sugar and yeast. In this investigation, students will combine dissolved glucose tablets with yeast in a soda bottle and watch what happens to a deflated balloon placed over the mouth of the bottle. Have the students follow the directions in their handout for this investigation.
2. While students are observing the balloon over the course of 30-40 minutes, have them complete the reading on fermentation in their handout.
3. Have the students answer the questions in their handout to help them make sense of what they observed with their balloon. Students are asked to provide evidence of the chemical reaction and fermentation that occurred, and they decide whether or not ethanol was produced. These questions also guide the student in concluding that glucose is a simple sugar.

Part 3 *(1, 45-min class period)*

1. Write the five substances the class will test for ethanol production on the board: corn syrup, corn starch, table sugar, apples, and honey.
2. Have students think about what they expect to see by answering the questions in their handout. Refer them to the table in the *Additional Resources* section of their handout to help them make predictions about which substances yeast will be able to use to produce ethanol.
3. Divide the students up into five groups, and assign each group one of the substances to test. Have them rinse out and re-use their soda bottles from Part 2. For the students testing apples, give them about ¼ of an apple, sliced into small, thin pieces.

4. After students have tested their assigned substances, have them share their observations with the rest of the class. Have the students record one another's findings in the table provided in their handout.
5. Point out to students that complex sugars can still be used in ethanol production, as long as they are broken down by enzymes first. At the conclusion of this part, point out that corn syrup was once corn starch. The same enzymes used in human digestion were added to the starch, and the starch became a syrupy liquid of simple sugars (corn syrup).

Part 4 *(30 min)*

1. Have the students reach their own conclusion about the production of CO_2 produced during the production of ethanol by answering questions in their handout.
2. Explain why ethanol is considered to be "CO_2 neutral" (refer to Teacher Notes for this explanation). Use the overheads provided.
3. Have the students make sense of this by completing the illustrations in their handout.

Part 5 *(Hmwk Assignment)*

1. Assign the questions in Part 5 for homework. If desired, go over the answers.
2. Be sure that the students have made the connection between the substances they tested and the actual crops they came from (corn, sugar cane, etc.), as this should help them understand why ethanol is a renewable resource. Also emphasize that fossil fuels are considered nonrenewable because they take millions of years to replace.

Part 6 *(Variable)*

1. Have the students complete the questions in Part 6 as an in-class or homework assignment. Make sure students understand that ethanol has been used as a fuel for many years, and is not merely a passing fad.

Making Ethanol (Teacher Notes)

(Investigation and Analysis of an Alternative Fuel)

General Lesson Notes

- **Ethanol.** Ethanol is a clear, colorless liquid. Other names for ethanol include ethyl alcohol, grain alcohol, or simply "EtOH." Like gasoline, ethanol is an organic compound, which means that it consists mainly of carbon atoms. Unlike gasoline, however, ethanol contains one oxygen atom for every two carbon atoms. By weight, ethanol is 35% oxygen. This feature enhances combustion (because oxygen is needed in combustion) and helps reduce carbon monoxide emissions. Ethanol is often added to gasoline in various amounts. "E10," "E85," and "E95" are all gasoline-ethanol blends, with the number signifying the percentage of ethanol added to the gasoline. E85, for example, is the most commonly used blend that consist of 85% ethanol and 15% gasoline. E85 and E95 are considered alternative fuels, but E10 is NOT.
- **Clarification of terms used in this activity.** The list of terms with definitions included in the *Additional Resources* of the Student Handout is provided to assist students with terms that may be unfamiliar to them as they are working through the activity (i.e. "alternative fuel," "nonrenewable," etc.) and also to clarify basic terms used in the activity (i.e. "fuel," "sugar," "gasoline"). It is also a good reference for the instructor. Encourage students to use this terms list as they work through the activity.

Part 1 Notes

- **Why we need alternative fuels.** ***(This explanation pertains to Question #5 in the Student Handout)*** Hold a discussion at the end of Part 1 to emphasize why our society needs to consider developing and using alternative fuels. Some key reasons are:
    - **Fossil fuels are a finite resource.** ***(This explanation also pertains to Question #2 a) and b) in the Student Handout)*** While there is debate about whether or not we will ever actually run out, there are two key issues to emphasize here. One is that because fossil fuels take millions of years to create, they *are* considered a nonrenewable resource. The second point is that *the most accessible* oil (cheapest and easiest to drill; the stuff that we enjoy now) *will* eventually run out. When this occurs, oil will become *much* too expensive to use because there will be an extreme cost in drilling and finding new, less accessible sources. For more information on this, check out www.howstuffworks.
    - **Dependence on foreign countries.** ***(This explanation also pertains to Question #2 e), f), g), and h) in the Student Handout)*** Because OPEC controls the majority of the world oil production, they have the power to reduce production and send gas prices soaring for Americans. Students will observe the increase in oil prices over four years by analyzing a graph from the U.S. Department of Energy. Students should observe that prices are highest today than they ever have been. High gas prices affect not only the cost of commuting to work and school, but also food prices and other consumer goods that require transportation from factories to stores. Events in our society's history point to the dangers of heavily relying upon foreign countries for fuel. If students inquire about what the OPEC "Basket" means on the chart title, you can either refer them to the website listed with the attribution or explain that "basket" refers to the 7 different types of crude oils that the OPEC countries produce. The "basket" price is an average of the 7 types.

- **Emissions.** ***(This explanation also pertains to Question #3 in the Student Handout)*** Combustion in a car engine is imperfect because the gasoline fuel is burned so quickly and is not given sufficient time to burn with enough oxygen. Products of perfect combustion are carbon dioxide and water. Products of imperfect combustion also include pollutants such as unburned hydrocarbons (VOC's, volatile organic compounds), nitrogen oxides, and carbon monoxide. Finding fuels that have an increased oxygen content, such as ethanol, can help the fuel burn more cleanly in an engine. Gasoline consists of long chains of hydrocarbons (no oxygen atoms); where as ethanol consists of one oxygen atom for every 2 carbons.

Part 2 Notes

- **How ethanol is made.** ***(This explanation pertains to Questions #12, #13, & #14 in the Student)*** The two things required to produce ethanol are yeast cells and a source of sugar (or starch). The process of making ethanol from sugar is called fermentation and also yields carbon dioxide gas. (Refer to the *Additional Resources* section of the Student Handout for more in-depth explanation of fermentation and yeast).

Part 3 Notes

- **Sugars and ethanol production.** ***(This explanation pertains to Questions #20, #21, and #26 in the Student Handout)*** If the starting material contains starch (a sugar too complex for yeast to ferment), enzymes must be added to break down the starch into simple sugars before fermentation can begin. These enzymes are the same enzymes used in the human digestive system to break down starches other carbohydrates. The process of making fuel ethanol is similar to the one used to make beer, only fuel ethanol is "denatured" by adding poisons so people do not drink it.
- **Substances to test** for ethanol production. Write or post the substances for the students to test in Part 3, and assign each group of students a substance. These substances are: **corn syrup, corn starch, table sugar, apple, and honey**. The corn starch should not cause the balloon to inflate because the sugars it contains are too complex for the yeast to break down. Enzymes must be added if the starch in field corn is to be fermented by yeast into ethanol. A good extension for this part of the activity would be to purchase the two enzymes alpha amylase and glucoamylase (many times available in kits through science suppliers, such as Carolina Biological) and have students use these enzymes to break down the starch in corn starch. The procedure is simple and relatively straightforward. Students could then re-test the enzyme-treated starch and notice that the yeast is able to ferment it. If this is carried out, emphasize to the students that the enzymes they used are the same ones manufacturers use to break down the starch in corn to prior to ethanol production.

Part 4 Notes

- **Fossil fuels, CO2, and global warming.** The use of fossil fuel removes carbon that has been buried deep in the earth for millions of years and dumps it into the air, thus increasing the total amount of atmospheric carbon dioxide in circulation. In burning fossil fuels, there is a net flow of CO_2 INTO the atmosphere. Make sure students understand this. Atmospheric carbon dioxide is a greenhouse gas and traps heat like the windows of a car on a warm, summer day.[1]

[1] Drive Clean Across Texas. "Fossil Fuels and Climate Change: Our Cars and CO_2." Unit 1, Lesson 1. http://www.drivecleanacrosstexas.org, accessed May 3, 2005.

The issue of whether or not this is causing global warming continues to be debated. Some sources state that there is no question it is occurring, while others purport it is not. Climate change on earth is complicated and continues to be studied by scientists. Because the main focus of this activity is not on global warming, mentioning only some key points briefly should suffice. It makes more sense to instead place greater emphasis on how ethanol differs from fossil fuels when it is burned (see the next bulleted note).

- **Understanding ethanol as "CO2 neutral."** ***(This explanation pertains to Question #28 and #29 in the Student Handout)*** Because ethanol contains carbon, it will also produce carbon dioxide when it is burned just as gasoline does. However, instead of taking carbon from deep underground and adding to the total amount of CO_2 in the atmosphere, burning ethanol produces CO_2 that was *removed* from the atmosphere only months before by the plants that were harvested to produce ethanol. These plants (mainly corn in the United States) used CO_2 during photosynthesis to produce sugars. When ethanol is burned, that CO_2 can then be used again by more crops that are being grown to produce ethanol fuel. Thus, we have come full circle and reasoned how ethanol can be "CO_2 neutral."[2] The attached illustrations should be used as overheads to assist the students as they are completing the corresponding section of their handout.
- **Accounting for CO_2 during fermentation to produce EtOH**. In light of these things, the production of CO_2 that is produced during fermentation to *produce* ethanol will surely (or should) be confusing to students. What about *this* CO_2? There are several points that could be emphasized here. First, no alternative fuel is a perfect alternative and there are hidden side effects of which many not be obvious to the common consumer. Second, because CO_2 is being generated in a purposeful and controlled manner, it can either be: a) sequestered (collected and placed back into a strategic location of the environment where it will be utilized effectively by vegetation, soil, or phytoplankton); or b) used to prepare dry-ice for use in other industrial applications. For more information on carbon sequestration, visit the U.S. Department of Energy's website or go to the URL: http://cdiac2.esd.ornl.gov/ (accessed March 24, 2005).

Part 5 Notes

- **Feedstocks.** ***(This explanation pertains to Questions #30 & #33)*** A feedstock is any raw material that is converted into another product through mechanical, chemical, or biological processes. For example, corn is a feedstock for ethanol fuel production. In the United States, most all of the fuel ethanol is made by fermenting corn. In Brazil, sugar cane is the primary feedstock for ethanol production. Other feedstocks containing fermentable sugars could theoretically be used, but many are cost prohibitive or are needed to feed people. This is the reason why ethanol fuel is typically not made by using apples or honey. Students should be helped to understand this.

Part 6 Notes

- **History of fuel ethanol in this country.** Using ethanol as a fuel is not new. Refer to *Additional Resources* section of the Student Handout for a brief history of ethanol.

Notes on Materials

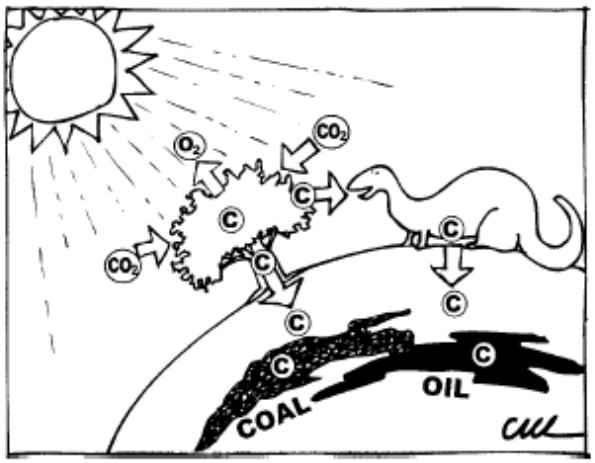
- **Yeast**. Fleishmann's Highly Active Dry Yeast Packets are recommended.

[2] KCPC Education Resource Webstie: 9.2.3 Potential of Ethanol as Fuel: Chemistry. http://www.kcpc.usyd.edu.au accessed April 5, 2005.

- **Glucose Tablets**. These can be found in the diabetic supply aisle of most stores. The label may say “dextrose” or “blood sugar” tablets.

FOSSIL FUELS & CLIMATE CHANGE

Carbon Moves Into the Ground

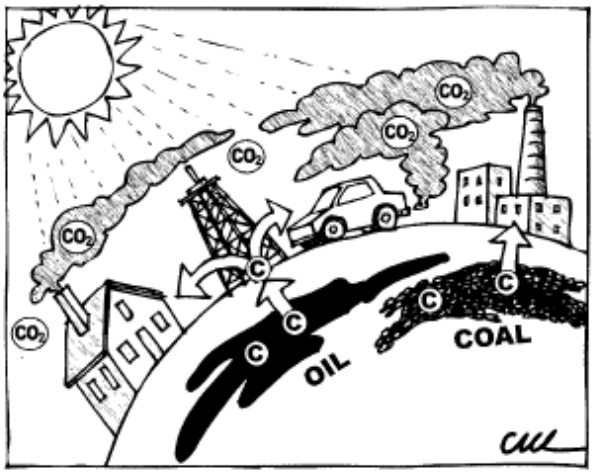


Through photosynthesis, plants use energy from the sun (sunlight) and carbon dioxide from the air to grow. This changes sunlight into chemical energy and moves carbon from the air into plants.

Through the food chain, carbon and the stored chemical energy moves into all other living things.

As living things die and decompose, the carbon and chemical energy moves into the ground. Over millions of years, this becomes *fossil fuels* such as coal and oil.

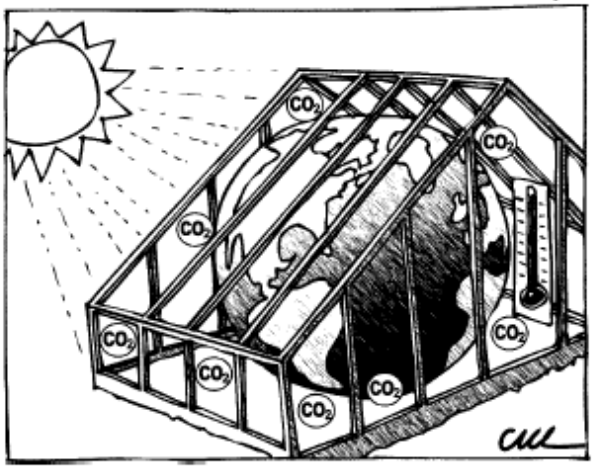
Carbon Moves Into the Atmosphere



Millions of years of accumulated carbon, in the form of oil and coal, is released back to the atmosphere when we burn these fuels to heat our homes, make electricity, run factories, and drive vehicles.

For the average American, driving produces sizably more CO_2 that any other consumer behavior. Other significant contributors include home heating or cooling and running appliances and lighting.

Carbon Dioxide Traps Heat Like a Greenhouse



CO_2 and other gases in the atmosphere trap the sun's energy like a greenhouse.

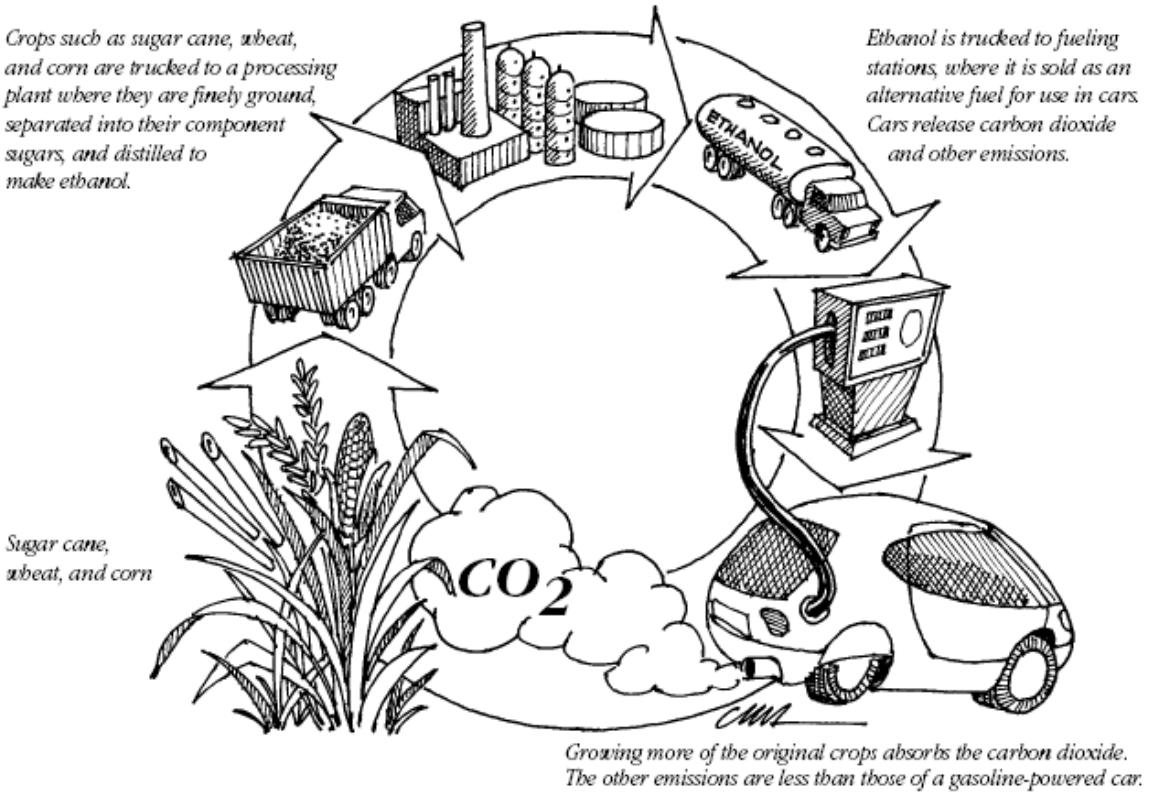
The right amount of CO_2 and other greenhouse gases protects us and keeps us warm, especially at night.

In the last 100 years we have been increasing greenhouse gas levels, in part, by burning fossil fuels. This appears to be increasing the temperature of the earth.

Source: Drive Clean Across Texas. "Fossil Fuels and Climate Change: Our Cars and CO2." Unit 1, Lesson 1. http://www.drivecleanacrosstexas.org

Overhead Transparency

ETHANOL IN THE CARBON CYCLE



Source: North East Sustainable Energy Association (NESEA), Cars of Tomorrow and the American Community: High School Curriculum on Alternative Fuels, p. 74, 2002. www.nesea.org

Name:_____

Making Ethanol

(Investigation and Analysis of an Alternative Fuel)

Overview

In this activity, you will learn about one type of alternative fuel – ethanol. You will learn what an alternative fuel is and why we should consider using them. You will also experiment with how ethanol is synthesized.

Part 1 (What's Wrong With Gasoline?)

1) Read Reading #1 in the "What's Wrong With Gasoline" section of *Additional Resources*. Answer the following questions:

a) How many miles do Americans drive per year? _____

b) How many gallons of gasoline does one barrel of oil produce? _____

c) How much gasoline does the United States consume per day? _____

2) Read Reading #2 in the "What's Wrong With Gasoline" section of *Additional Resources*. Answer the following questions:

a) Why is gasoline considered a fossil fuel? (You may need to consult the definitions in *Additional Resources*)

_____

_____

b) What does it mean to say that gasoline is a ***finite*** resource?

_____

_____

_____

c) Is production of oil *within* the United States (***domestic*** oil production) increasing or decreasing? _____

d) Is the United States becoming more or less dependent on other countries for oil?

_____

_____

e) Consult *Additional Resources* to define **OPEC**:

_____

_____

_____

f) Who controls the prices of oil (and therefore gasoline)?

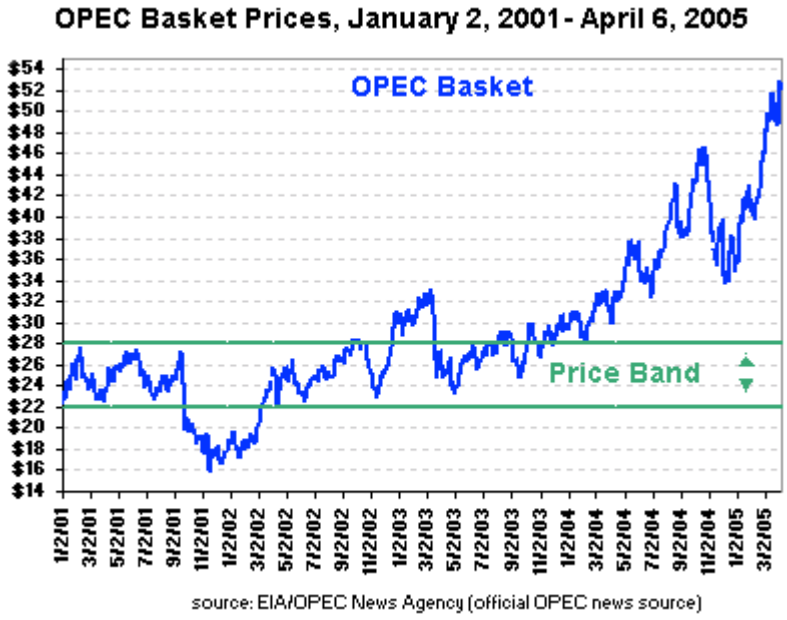
_____

g) Graph 1 shows the trend in the price of oil over approximately four years. Are oil prices increasing or decreasing over time?

_____

_____

Graph 1. Trend in price for a barrel of oil for January 2, 2001 to April 6, 2005. Source: Energy Information Administration, Official Energy Statistics from the U.S. Government (http://www.eia.doe.gov/emeu/cabs/opec.html).



h) Cite some specific historical examples from Reading #2 that indicate why your answer to 2d) could cause problems for Americans.

_____

_____

_____

_____

_____

3) Read Reading #3, and then complete the following task:

On the left hand side of the box provided, draw a picture or diagram illustrating perfect combustion. On the right side, draw a picture or diagram that illustrates the type of combustion that actually occurs when gasoline is burned inside a car engine (imperfect combustion). Be sure to label your pictures.

Perfect Combustion	Car engine (imperfect) combustion

4) Consult *Additional Resources* to define **Alternative Fuel**:

_____

_____

_____

5) Using what you read from the three readings, brainstorm about why it is important for our society to consider using alternative fuels. Share these ideas in a class discussion.

Why do we need alternative fuels?

6) After your teacher introduces the alternative fuel you will be studying in the remainder of this activity, go on to *Part 2*.

Part 2 (Preliminary exercise with sugar and yeast)

7) Obtain the following materials from your teacher:

1 Empty soda bottle (1/2 liter) with cap
1 balloon
1 package of yeast
2 glucose tablets
1 funnel
Water (1 cup)

8) Place 1 cup of water in your empty bottle. Break the glucose tablets into several pieces small enough so that they can fit through the mouth of the bottle, and then drop them in the water. Screw the cap of the bottle on and shake to dissolve the tablets.

9) Using a funnel, carefully transfer the package of yeast into the bottle. Place the lid back on the bottle and gently swirl or swish the contents so that all of the yeast becomes immersed in the solution. Place a ***completely deflated*** balloon over the mouth of the bottle.

10) Observe what happens over the course of 30-40 minutes. Note your observations in Box #1.

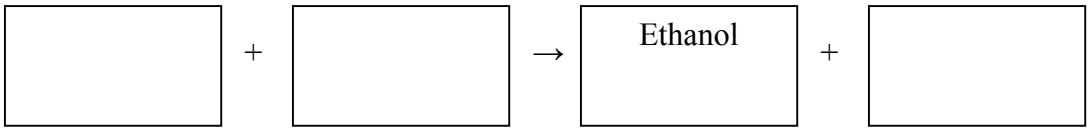
Box #1. Observations for *Part 2*.

Observations

11) Read "Fermentation & Yeast" in *Additional Resources* and then answer questions 12), 13), and 14).

12) The process of yeast making ethanol from sugar is called: _____

13) What two things are required to produce ethanol? Write these things in Boxes #2 and #3 below. What else is produced during this process? Write this in Box #4.

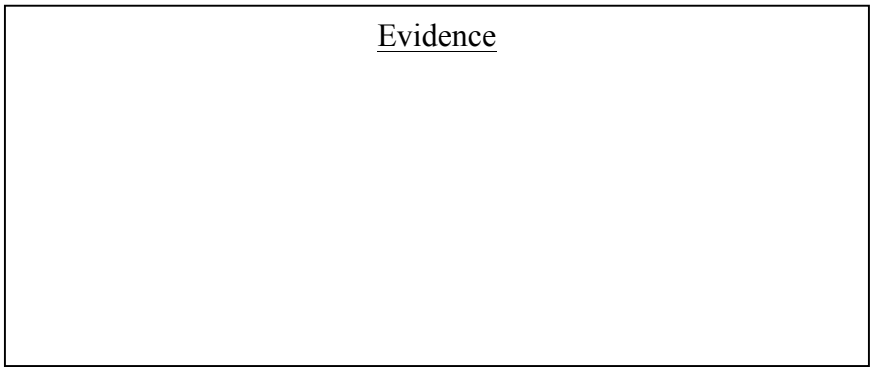


Box #2 Box #3 Box #4

14) What is the state of matter of the substance in Box #4? (SOLID LIQUID GAS)

15) You dissolved glucose tablets in water and then added yeast. Glucose is a type of sugar. Do you think **ethanol** was produced in Part 1? (YES or NO). Describe the evidence you have to support whatever answer you chose. Write this evidence in Box #5.

Box #5. Evidence for or against the production of ethanol.



16) Now discuss your evidence with other members of the class. Is there agreement or disagreement? If there is disagreement, ask one another questions to see whether or not you can determine why you disagree.

17) It turns out that yeast can only use certain types of sugars in the fermentation process. Some sugars are too large and complex for yeast enzymes to break down and use as food in the fermentation process.

Based upon what you observed, do you think glucose is…
simple enough for yeast to ferment *OR* too complex for yeast to ferment?

18) Justify your reasoning for whatever answer you chose, and write your reasoning in Box #6

Box #6. Justification for glucose being either a simple or complex sugar.

Is glucose simple or complex and WHY?

19) Now discuss your thoughts and reasoning about whether glucose is a simple or complex sugar with your classmates. Do you agree?

Part 3 (A closer look at sugars and yeast in ethanol production)

In this part of the activity, you and your classmates will add yeast to several substances in an attempt to make ethanol. Not all sources have the same type of sugar – some are simple and some are complex. Therefore, the yeast will not be able to use the sugars in all of the substances.

Answer the following questions before proceeding to the experiment:

20) What would you expect to see if the substance contains simple sugars?

_____

_____

21) What would you expect to see if the substance consisted only of complex sugars (called starch)?

_____

_____

22) Your teacher will write a list of substances on the board. Write these in Box #7, and then predict which ones you think that the yeast will be able to use to produce ethanol. Use any information given in *Additional Resources* to make informed predictions.

Box #7. Substances to test and your predictions.

Substance	Predictions: Can the yeast use it in fermentation?

23) Circle the substance in Box #7 that your teacher assigns to your group. Repeat the directions you followed in Part 2 for your assigned substance, substituting the glucose tablets with ¼ cup of your assigned substance. Record your observations in Box #8.

Box #8. Observations for *Part 3*.

Observations of your assigned substance

24) Was your substance fermented by yeast to produce ethanol? YES or NO

25) Share your findings with the rest of your class, and record what other students discovered about their substances. Use the table provided.

Substance	What happened to the balloon?	Did fermentation occur?	Was ethanol produced?	Type of sugar in the substance (simple or complex?)

26) Complex sugars (called starch) can still be used to produce ethanol as long as they are broken down for the yeast first. What must manufacturers do to starches before they can be fermented into ethanol by yeast?

_____

_____

Part 4 (The "CO_2 neutral" argument)

27) What gas filled the balloons during fermentation? _____

28) Recall that you read the following in Reading #3 as you completed Part 1:

"Carbon *di*oxide and nitrous oxide are considered to be greenhouse gases. Greenhouse gases in the earth's atmosphere trap the sun's energy. Many scientists say that this is increasing the overall temperature of the earth and causing global warming."

What problem or inconsistency do you see about producing ethanol as an alternative fuel?

_____

_____

_____

29) After your teacher has explained how this inconsistency is accounted for AND why ethanol is considered to be "CO_2 neutral," explain what this means in your own words by drawing two pictures in the boxes provided. Follow these instructions:

One picture should illustrate the origin and destination of CO_2 when fossil fuels are burned.

The other picture should illustrate the origin and destination of carbon and CO_2 when ethanol is burned.

Use arrows in your pictures to demonstrate where things end up. Be sure to label what you draw.

If you need to, review what photosynthesis is in the *Additional Resources* section before beginning.

Origin and Destination of CO_2: Fossil Fuels

Origin and Destination of CO_2: Ethanol

Part 5 (Ethanol Feedstocks)

30) Consult *Additional Resources* to define **feedstock**:

_____

_____

31) What feedstocks did you and your classmates use to produce ethanol in this activity?_____

_____

_____

32) Corn syrup and corn starch are things you may find in your kitchen at home. Corn syrup is used as an ingredient in many foods we buy at the grocery store. Perhaps you have seen someone thicken gravy by adding corn starch. What crop do these substances come from?_____

33) Why are apples and honey typically NOT used as feedstocks for fuel ethanol production?

_____

_____

_____

_____

34) Explain why ethanol is considered a **renewable** resource, but fossil fuels are **nonrenewable**? (Consult Additional Resources for the definition of renewable / nonrenewable resources).

_____

_____

_____

_____

_____

Part 6 (Ethanol's History)

35) Ethanol is considered to be an alternative fuel, but is definitely not a new fuel. People have used ethanol for fuel at various times and for various reasons through out history. List some of the events in ethanol's history as a fuel in Box #10.

Box #10. Ethanol's history as a fuel.

Ethanol's history as a fuel

Additional Resources

Fuel – substance containing energy

Alternative Fuel – a fuel that is made from something *other than* fossil fuels; vehicle fuels that are *not* made from petroleum (crude oil).[3]

Fossil Fuel – a fuel (coal, crude oil, natural gas) formed a long time ago from the remains of dead plants or animals.[4]

Crude Oil – a black, sticky goo that has little use unless it is refined into products such as gasoline.

Gasoline – a vehicle fuel produced from chemically changing and separating refined crude oil.[5]

OPEC – Organization of Petroleum Exporting Countries; a powerful grouping of oil producing countries which has received a lot of criticism for the way in which it seeks to influence world oil prices; the current member nations are: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.[6]

Barrels – volumes of crude oil are measured in barrels. One barrel equals 42 US gallons, or 159 liters. OPEC's Members currently produce around 28 million barrels of oil per day. This is around 40 percent of the world total output, which stands at about 75 million barrels per day.[7]

Sugars – substances made of carbon, hydrogen, and oxygen; also called carbohydrates. There are several types of sugars; some are simple and some are complex

Glucose – a simple sugar; also known as "blood sugar" or "dextrose"; the simplest carbohydrate.

Fructose – a simple sugar; has the same chemical formula as glucose, only the atoms are arranged slightly differently.

Sucrose – consists of a glucose unit and fructose unit bonded together; commonly called "table sugar;" you can think of sucrose as a 50/50 mixture of glucose and fructose.

Maltose – consists of two glucose units bonded together

Starch – complex sugars; made up of chains of thousands of glucose units.

Nonrenewable Sources of Energy – energy sources that cannot be replaced once they have been used up.

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[3] HowStuffWorks. www.howstuffworks.com
[4] No Fossils in This Fuel: Your PlanET (GM Environmental Science Club). http://www.gm.com/company/gmability/edu_k-12/teachers/plans/ethanol.pdf ; accessed May 2, 2005.
[5] No Fossils in This Fuel: Your PlanET (GM Environmental Science Club).
[6] KCPC Education Resource Website: Fossil Fuel Reserves. http://www.kcpc.usyd.edu.au/discovery/9.2.2/9.2.2_OilReserves.html; accessed April 6, 2005.
[7] KCPC Education Resource Website: Fossil Fuel Reserves.

Renewable Sources of Energy – energy sources that can be replaced and used over and over again.

Feedstock – any raw material that is converted into another product through mechanical, chemical, or biological processes.

Octane Rating – tells you how much the fuel can be compressed in the fuel cylinder of an engine before it spontaneously ignites; spontaneous ignition due to compression is called "knocking" and is undesirable; a high-octane fuel means that it handles compression very well and will not spontaneously ignite or "knock"; a low-octane fuel means that it handles compression poorly and will ignite when it is compressed only slightly; high octane fuels allow cars to run more smoothly.

Compression – squeezing gas to make it fit into a smaller space.

Ignition – fuel explodes and creates fire.

Photosynthesis – using water, CO_2, and sunlight to make sugars.

Substance	**Type of sugars**
Corn syrup	Glucose, maltose
Corn starch	Starch
Table sugar	Sucrose
Apples	Fructose
Honey	Fructose, glucose

Readings: What's Wrong With Gasoline?

Reading #1

Excerpts from: *Guzzling Gas in America* and *How much gasoline does the United States consume in one year?* www.howstuffworks.com (accessed May 2, 2005)

Americans have an [unquenchable] thirst for gasoline…Just look at the roads and highways and you'll see that a severe gas shortage would practically cripple the country. Americans drive more than 2.5 trillion miles per year in automobiles, light trucks and SUVs.

[To fuel this lifestyle], the United States consumes about 18 million barrels of oil each day. [One] barrel of oil will yield…[about] 19 or 20 gallons of gasoline. [Therefore, about] 360 million gallons of gasoline gets consumed every day. In a year…the U.S. consumes about 131 billion gallons (almost 500 billion liters) of gasoline!

Reading #2

Excerpts from "Cars of Tomorrow and the American Community: High School Curriculum on Alternative Fuels." Northeast Sustainable Energy Association (www.nesea.org) June 2002.

Fossil fuels, which are the source of gasoline used in most automobiles, are a finite resource. We don't know exactly how much fossil fuel is present in the earth, since new supplies are continually being located; but with more and more people around the world using gasoline-powered cars and other vehicles, the supplies are being used faster than ever before.

In the United States, oil production has been steadily declining since the 1970s. The decline is expected to continue as we use up our domestic supplies of oil. America now imports over 54% of its oil. By 2010, we'll import more than 60 percent. With a growing number of cars on the road and the popularity of driving large vehicles, the amount of fuel we need to import keeps rising. This means that the United States is becoming less self-sufficient and more dependent on other countries to meet our transportation needs.

Keeping enough fuel available to drivers in America is a challenge. Americans have experienced shortages in the past. In the early 1970s, supplies of gasoline were so limited that gas was rationed. In some areas of the country, gas stations were closed on certain days of the week. In other places, an even or odd number on one's license plate determined which days of the week one was entitled to buy gas. Long lines at gas pumps and signs reading "out of gas" were common.

In the early '90s, conflicts in the Middle East threatened the supplies of oil that we import from that region and led us to war to assure that supplies would continue.

In the year 2000, gasoline prices rose as the group of oil-producing and –exporting countries limited the amount of oil it processed and distributed at the time. Limited supplies of oil raised prices not just in the United States but throughout the world. In the

United States, where food and other goods are delivered by oil-dependent trucks…the rising price of [oil] is often noticed in increased prices of food.

Reading #3

Gasoline is a hydrocarbon, which means that it contains only the elements carbon and hydrogen. When gasoline is burned to fuel an automobile engine, it combines with air (nitrogen and oxygen) and produces several by-products (called "emissions"). If there is plenty of oxygen (O_2) and all of the gasoline fuel has time to burn completely, all of the hydrogen in gasoline combines with the oxygen to give water (H_2O) and all of the carbon in gasoline combines with oxygen to give carbon dioxide (CO_2). This is called "perfect combustion." In this ideal case, the nitrogen in air remains unaffected in the process.

Unfortunately, perfect combustion never occurs in gasoline-powered automobiles because the gasoline is burned so quickly and does not have sufficient oxygen in enough time (there is more nitrogen in the air than oxygen). Therefore, along with carbon dioxide and water, carbon monoxide and unburned fuel vapors (called volatile organic compounds, VOC's) are produced.

Because of the compression that occurs in the engine while gasoline is burned, the nitrogen and oxygen in the air combine in various undesirable ways, giving rise to nitrogen-oxygen pollutants (called nitrogen oxides).

Carbon *mon*oxide, unburned hydrocarbons, and nitrogen-oxides are all considered to be harmful emissions produced when you drive a car.

Carbon *mon*oxide is an extremely poisonous gas, and is fatal to humans. Carbon *di*oxide and nitrous oxide are considered to be greenhouse gases. Greenhouse gases in the earth's atmosphere trap the sun's energy. Many scientists say that this is increasing the overall temperature of the earth and causing global warming.

Fermentation & Yeast

Many years ago, before fermentation was understood completely, it was simply defined as *any reaction that produced effervescence, or bubbles*. We now know much more about fermentation.

For fermentation to occur, you need a source of sugar and yeast cells. This source of sugar must be simple enough that the yeast enzymes can break it down. The products you obtain are ethanol and carbon dioxide gas.

Yeast cells are living organisms that need energy. They are microscopic, single-celled fungi.

Yeast cells produce enzymes. These enzymes allow the yeast cells to break down simple sugars for energy use. When these simple sugars are broken down, ethanol and carbon dioxide are the by-products. The entire process is called fermentation.

Said differently, fermentation is when sugars are converted into ethanol by yeast cells. It is this fermentation process upon which we depend for producing ethanol as an alternative fuel.

Brief History of Ethanol As A Fuel

Excerpt from: "Cars of Tomorrow and the American Community: High School Curriculum on Alternative Fuels," p. 73. Northeast Sustainable Energy Association (www.nesea.org) June 2002.

Ethanol has been used as a transportation fuel since Henry Ford and other transportation pioneers began developing automobiles.

In [1896], Ford used ethanol to fuel one of his first automobiles, the quadricycle. In 1908, the Ford Model T was designed with a carburetor adjustment that could allow the vehicle to run on ethanol fuel produced by American farmers. Ford's vision was to "build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy."

During the 1930s, more than 2,000 service stations in the Midwest sold ethanol made from corn, but the ethanol industry closed down in the '40s with the coming of low-priced petroleum.

During World War I and II in both the United States and in Europe, alcohol fuels supplemented supplies of oil-based fuels. During World War II, the government even commandeered whiskey distilleries for alcohol fuel production.

In recent history, public interest in alcohol as a transportation fuel has changed with periods of war and the fluctuating supply and price of oil. The oil crisis in the 1970s raised the price of oil and gas and gave birth to the gasohol era, when gasoline was extended with the addition of 10 percent ethanol. (Gasohol is not considered an alternative fuel.)