

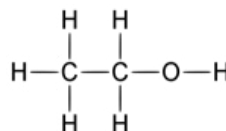
Introduction and Discussion Questions (pages 1-2)

Note: the purpose of these discussion questions is spark interest in the topic, present some background information and gauge student knowledge of the topic. Getting exactly correct answers is not essential at this stage.

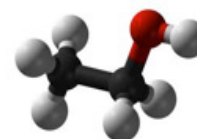
1. What is ethanol?

Answers will vary. A technical definition: A colorless, flammable liquid produced by fermentation of sugars. Ethanol is used as a transportation fuel, is the alcohol found in alcoholic beverages, is an effective antiseptic and solvent.

Chemical formula: C_2H_6O .



2-D Structure



3-D Structure

2. Describe how ethanol is made. Use words, diagrams or chemical equations to illustrate the process in as much detail as possible.

Answers will vary. The goal of this question is review the process of fermentation and how ethanol is produced at various scales.

General process: Sugars (glucose) + yeast --> ethanol + carbon dioxide

Chemical equation: $C_6H_{12}O_6 + \text{yeast} \rightarrow 2 C_2H_5OH + 2 CO_2$

At an industrial scale, students could diagram and discuss the process of growing crops, harvesting, extracting or converting biomass to sugars, fermenting the sugars to ethanol and then distilling to pure ethanol.

3. If you were to pump gas into your car that contained 10% ethanol, what plant or plant parts were used to make that ethanol?

Almost all ethanol that is in E10 gas is produced from corn grain. The starch in the corn grain is made up of polymers of glucose which can easily be broken down into glucose monomers. The glucose can then be fermented into ethanol. A very small fraction of ethanol in the U.S. comes from other plants and plant parts. Sugar cane is used to make most of the fuel ethanol in Brazil.

4. Brainstorm a list of plants and plant parts that can be used to make ethanol.

Answers will vary. Any plant part that contains sugar, starch and/or cellulose could potentially be used to make ethanol.

5. From this list, pick one plant or plant part that you think would be the best choice for making ethanol. Explain why.

Answers will vary. The goal of this question is to explore the pros and cons of various plant-based feedstocks for making ethanol.

Plants such as sugar cane are productive and produce sugars that are easy to extract, but do not grow well in temperate climates. This limits

Corn grain is easy to produce in a range of climates, but requires the additional step of converting starch to sugar, which increases the cost. Corn is also a valuable food crop and there are drawbacks to relying on food crop for fuel. Neither corn nor sugar cane can be produced in sufficient quantities to supply a large fraction of our transportation fuel needs.

Cellulosic ethanol sources such as corn stover, woody biomass, switch grass etc., are easy to grow and abundant across a range of environments. Combined cellulosic biomass sources represent a huge pool of potential chemical energy that could be converted into fuel. Unlike corn, cellulosic biomass does not have the same potential to take land and resources out of food production. Unfortunately, the technology and infrastructure does not currently exist to produce cellulosic ethanol at a large scale.

6. What are some of the benefits of using ethanol as fuel for our cars instead of gasoline?

Answers will vary. Some of the potential benefits:

- Ethanol is renewable (assuming crops are grown sustainably and converted to fuel efficiently).*
- Ethanol fuel is “carbon neutral” or “carbon negative.” This means that ethanol produced from plants does not release additional CO₂ into the atmosphere. This is because the CO₂ that is fixed in plant biomass during photosynthesis is then released when the ethanol is burned for fuel. Ethanol can be carbon negative if, in the process of growing, the crops add more carbon to the soil than is released in the process of producing and burning the fuel.*

- *Ethanol is a “local” fuel. Compared to petroleum ethanol has a greater potential to be produced locally from crops in the region. This could reduce economic dependence on foreign sources of energy.*

7. What are some of the drawbacks?

Answers will vary. Some potential drawbacks:

- *Currently there isn't the capacity to produce enough ethanol to meet our transportation fuel needs. The U.S. uses ethanol to supply approximately 10% of our transportation fuel. The U.S. Department of Energy projects that we could supply 30% of our transportation fuel needs if we could use cellulosic biomass.*
- *Ethanol is less “energy dense” than gasoline. A gallon of ethanol contains about 30% less energy than a gallon of gasoline. Another way of looking at this is that a comparable car can drive 30% farther running on a gallon of gasoline than a gallon of ethanol. Engineers hope to reduce this difference by designing future engines that more efficiently burn ethanol.*
- *Using corn grain to produce ethanol has the potential to reduce the amount of corn available for food and increase food prices.*
- *Currently, there is no efficient method to produce ethanol from cellulosic biomass at a larger scale. Hopefully research breakthroughs at GLBRC and other institutions will help to overcome this challenge.*

8. Do you think ethanol is a good option to replace gasoline used for transportation? Why or why not?

Answers will vary. The goal of this discussion is to get students to consider the context for why scientists and engineers are working to discover methods to efficiently and sustainably convert cellulosic biomass to ethanol.