



Website: contoureducation.com.au | Phone: 1800 888 300

Email: hello@contoureducation.com.au

VCE Chemistry $\frac{3}{4}$
AOS 1 (Fuels & Energy) [1.0]
Media Analysis SAC Solutions

40 Marks. 15 Minutes Reading. 50 Minutes Writing.

Section A: Article



Article: Fuel Ethanol: Hero or Villain?

- This article provides the advantages and disadvantages of using fuel ethanol to help give engine owners a balanced view and make the most of their fuel.

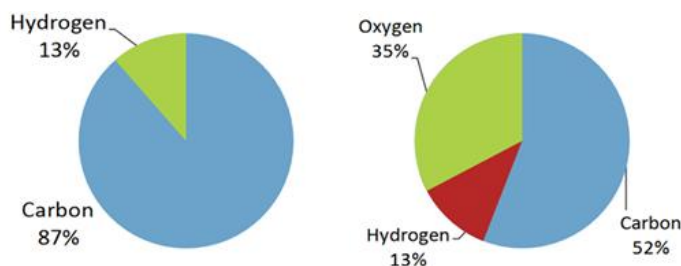


Figure 1. Atomic composition by mass of gasoline (left) and ethanol (right).

➤ Introduction

- Ⓢ In recent years, fuel ethanol has become a popular controversy in America. For some people, it seems to be the worst thing since disco music. For others, it seems to be the answer to all of life's problems. The truth of the matter is probably less extreme and includes a bit of each side—ethanol as a fuel does have some challenges, but it also has some benefits. Since ethanol is firmly established as a part of our fuel supply, it is worthwhile to try to keep a balanced view and make effective use of this biofuel.
- Ⓢ Ethanol is blended with petroleum gasoline in America in order to meet a federal government mandate known as the Renewable Fuel Standard (RFS) and its updated version, RFS2. The reasons for this standard include the desire to support U.S. agriculture, improve fuel security for the nation, and reduce the imbalance between exports and imports. The RFS currently requires that about 10 percent of all gas-engine fuel sold in the United States be ethanol. A few gas stations do sell what they call "ethanol-free gasoline," but these are relatively uncommon, and most gasoline sold today is gasoline with 10 percent ethanol (called "E10"). Higher-concentration ethanol blends, such as 15 percent ("E15") and 85 percent ("E85"), are also available in some locations. By comparison, Brazil's gasoline blend is between 20 and 25 percent ethanol.
- Ⓢ At the atomic level, gasoline is mostly carbon, with some hydrogen. Ethanol is lower in carbon but includes oxygen. (See Figure 1)
- Ⓢ When you look at the chemical composition of ethanol and gasoline, you find that ethanol is a single molecule, C_2H_6O , whereas gasoline is a complex mix of hundreds of different hydrocarbons (including pentane, benzene, xylene, butane, toluene, and hexane, plus a variety of additives). The chemical composition of gasoline can vary depending on the source of the petroleum, the manner in which it is refined, and the way that it is blended.
- Ⓢ Because of these differences, it is not surprising that gasoline and ethanol do not perform identically, and that blending ethanol with gasoline can affect the performance of the fuel.

➤ Problems with Ethanol

➤ Many people have noticed problems when using ethanol-blended gasoline. The more common issues attributed to ethanol include the following:

➤ Fuel Energy

- Ethanol contains about 30 percent less energy per unit volume than gasoline. As a result, a 10 percent ethanol-gasoline blend will have 97 percent as much energy as gasoline. In reality, that's not a very big difference. If you notice a difference in performance when running on E10, it is likely due to other factors, such as those that follow:

➤ Fuel Contaminants

- Gasoline is not water soluble, but ethanol is. Therefore, ethanol can pick up contaminants that gasoline doesn't and may deposit those contaminants inside your engine, leading to fouled filters or injectors. This can cause noticeable decreases in engine performance if not dealt with. Engines that are rarely or seasonally used, such as lawnmowers or chainsaws, are especially prone to difficulties, although the reasons are not all clearly understood. Proper formulation and care of ethanol blends is something that fuel transporters and resellers are getting the hang of, so hopefully this will be less of a problem in the future.

➤ Seals and Hoses

- On old machinery, seals and hoses on engines and fuel systems tend to be weak and susceptible to degradation. Ethanol in gasoline can cause them to deteriorate, shrink, or swell, resulting in leaks.

➤ Fuel-Air Ratio

- Ethanol molecules include oxygen atoms, whereas gasoline molecules don't. That's part of the reason why ethanol has less energy than gasoline. Another effect of the oxygen from ethanol is that ethanol blends tend to run "leaner" than pure gasoline because there is more oxygen available in the fuel-air mixture. If your engine is not able to compensate by reducing the incoming airflow, the resulting combustion conditions in the engine cylinder may be less than ideal. Newer vehicles are generally designed to take care of this automatically, but older engines may need a bit of manual adjustment to get the air-fuel mixture just right.
- Some people have reported engines overheating when ethanol blends are used, suggesting that ethanol burns "hotter." This is a bit mysterious since ethanol contains less energy per unit volume than gasoline, and the flame temperature of ethanol is more than 40°C cooler than gasoline. The most likely explanation is related to the air/fuel ratio. Most engines are designed to run with an excess of fuel relative to the amount of air (a "rich" mixture); experience has shown that this leads to higher power output and cooler engine temperatures. When ethanol blends are used, newer engines are equipped with sensors to adjust the air/fuel ratio automatically. Older vehicles and small engines may not be equipped to do this, resulting in a "leaner" burn that may increase engine temperatures and/or reduce engine power. A simple adjustment to the fuel system to "richen" the mixture can often fix this problem.

Increased Competition for Crops

- The ethanol industry uses about 40 percent of America's corn crop. That's a lot, even when you take into account that a great deal of the corn for ethanol becomes "distiller's dried grains," a high-protein animal feed. In a poor year (such as the drought of 2012), the presence of the ethanol market can drive up the price of feed corn and other crops that could be grown on those fields, leading to higher feed and food prices. One research study concluded that over half of recent increases in commodity corn prices can be attributed to increased demand (by the ethanol and animal feed sectors), and about 19 percent of increased retail food prices are due to higher commodity prices.
- It is interesting to note that food prices worldwide are more closely correlated to petroleum prices than to ethanol production. The following graph shows that as petroleum prices go up, food prices go up. By the same token, as petroleum prices go down, food prices go down. If we care about keeping food affordable, it follows that we need to find ways to keep fuel affordable.

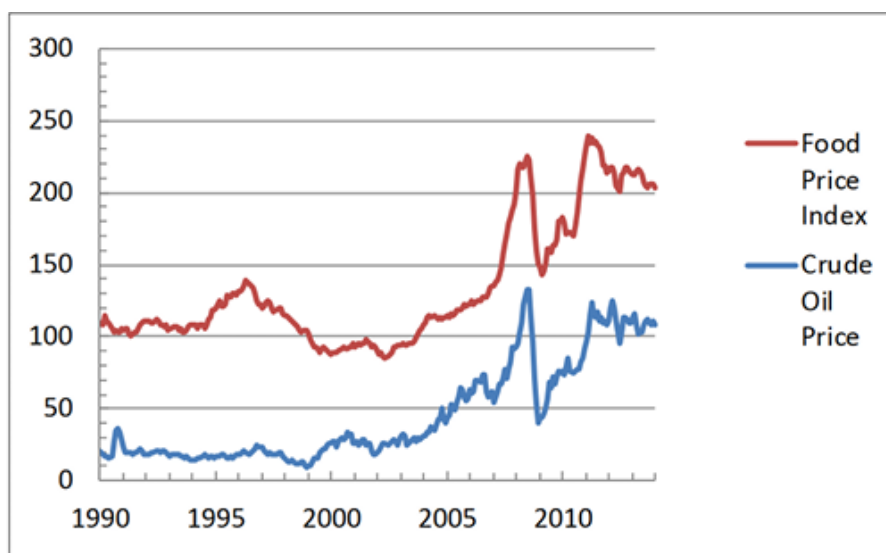


Figure 2. Food Price Index and Brent crude oil price (\$/barrel), 1990 to present.

Benefits of Ethanol

- While challenges from fuel ethanol are certainly real, they are not the entire story. Ethanol also provides benefits that should be taken into consideration. The most significant benefits include the following:

Oxygenation

- Before ethanol was blended with gasoline, the United States used a fuel additive called MTBE to oxygenate the fuel, which improves combustion efficiency and reduces air emissions. The problem with MTBE is that it is extremely toxic and can pollute groundwater if spilled. Ethanol oxygenates the fuel and is much safer for the water supply.

Boosts Octane

- Ethanol boosts the octane number of fuels, which helps prevent pre-ignition knock. Incidentally, the octane rating system for fuels was originally developed by Penn State chemist Russell Marker in the 1920s. The octane rating (Anti-Knock Index, AKI) of normal unleaded gasoline in the United States is 87. The octane rating of pure ethanol is 100. What's interesting is that when ethanol is blended with gasoline, it performs as if its octane rating is 112, making ethanol a very effective octane booster when used in gasoline. High octane is one reason why NASCAR uses ethanol for their high-compression racing engines. Engines that are designed and optimised for ethanol fuel have the potential to run at higher efficiencies than engines designed for and using gasoline.

Price

- One of the toughest benefits to get a handle on is the impact of ethanol on fuel prices, and economists enjoy debating this issue. However, it is reasonable to say that having an extra 10 percent of our gasoline provided by ethanol is increasing the total amount of fuel available while eliminating the need for other oxygenates and octane boosters, thus exerting a downward pressure on petroleum prices.

Ethanol is Renewable

- Ethanol from corn or other crops can be grown and produced year after year after year. The same cannot be said of gasoline.

Supports Domestic Agriculture

- The U.S. farm economy has benefited from ethanol to the tune of billions of dollars per year. This includes as much as an estimated 70,000 direct jobs and 330,000 indirect jobs, usually in rural areas and small towns. In years when the corn yield is high and commodity prices dip, ethanol can be a farm saver for thousands of farmers each year. In Pennsylvania, farmers who supply the local ethanol plant have received a premium above commodity rates for their corn.

➤ What Should Engine Owners Do?

-  Unless the technology, economics, and politics of fuel change dramatically, we can expect ethanol to be a part of the fuel supply for the foreseeable future. With that in mind, what should engine owners do to make the most of their fuel?

Check and Maintain Your Engine

- Find out if your equipment is suitable for ethanol-blended fuel. If not, you should find out from the manufacturer if modifications can be made to your engine or additives can be used to make the fuel compatible.

Maintain Your Infrequently Used Equipment

- Lawnmowers, boats, hobby cars, and the like should receive extra attention when not in use. Add fuel stabiliser if the equipment will be idle for more than a few weeks, and avoid keeping stored fuel for long periods of time. Some small engine manufacturers recommend using fuel stabiliser mixed with gasoline at all times, not only when storing equipment.

Don't Let Ethanol Be an Excuse

- Often, ethanol is blamed for the malfunctions of poorly maintained equipment. Don't let that happen to you. Keep your engine clean and your cooling system in good shape, and perform regular maintenance as appropriate. There is truth to the saying, "If you take care of your equipment, it will take care of you."

Try a Comparison

- If you are convinced that ethanol is causing problems with your engine, track down a seller of ethanol-free gasoline (the Internet is a good starting point for a search), and try a tankful to see if it makes a difference. If it does, you may need to "go the extra mile" to get your fuel from a specialised ethanol-free fuel supplier. Antique car owners and small engine operators are the most likely people to need this approach. Fortunately, most of us won't have to go to that extreme.

Have a Glass of Water

- The clean, pure water that most of us enjoy is being protected by ethanol's replacement of MTBE. Let's keep that in mind and be thankful that future generations have better prospects for pure water due to the use of fuel ethanol.
- In the end analysis, is ethanol a net benefit or a step in the wrong direction? It may be fun to debate various opinions on that, but the bottom line is that it is a matter of personal opinion as to whether the positives or negatives are more compelling. For most of us, ethanol blends do not affect the performance of our engines. However, if you own older equipment or devices that sit idle for long periods of time, a few common-sense precautions can help minimise problems and maximise performance for your machinery.

➤ Reference

-  Energy Information Administration, United States Department of Energy. "Monthly Spot Prices for Crude Oil." Washington, D.C.: United States Department of Energy, Energy Information Administration, 2014.
-  Ferris, J. "Analysing the Influence of Energy Policy." Ethanol Producer Magazine (October 2013): 50-52.
-  Food and Agriculture Organisation of the United Nations. "Food Price Index." Rome: United Nations Food and Agricultural Organisation, 2014.
-  Morvay, Z., and D. D. Gvozdenac. Applied Industrial Energy and Environmental Management. Part III: Fundamentals for Analysis and Calculation of Energy and Environmental Performance. John Wiley & Sons, 2008.
-  Urbanchuck, J. Contribution of the Ethanol Industry to the Economy of the United States: Report to the Renewable Fuels Association. New Castle, Del.: Cardno Entrix Corp., 2011.
-  Prepared by Daniel Ciolkosz, Penn State Department of Agricultural and Biological Engineering. Reviewed by Andre Boehman, University of Michigan, and Douglas Schaufler, Penn State Department of Agricultural and Biological Engineering.

➤ Authors

Daniel Ciolkosz,
P.E. Assistant Professor and Research Associate
dec109@psu.edu
814-863-3484.

Space for Personal Notes

Section B: SAC Questions (40 Marks)



- The questions that follow are based on the article written by PennState Extension, entitled, "Fuel Ethanol: Hero or Villain".

Question 1 (10 marks)

In America, ethanol is blended with petroleum gasoline to meet the Renewable Fuel Standard.

- a. According to the article, list **two** reasons why this standard exists. (2 marks)

Desire to support U. S. agriculture/improve fuel security for the nation/reduce the imbalance between imports and exports.

- b. Describe what "E85" fuel is. (1 mark)

Gasoline with 85% of the blend being ethanol.

- c. Verify the percentage composition of oxygen in ethanol, by mass, as shown in **Figure 1**, with an appropriate calculation. (1 mark)

$$\%(\text{O}) = 16 / (16 + 6 + 2 \times 12) \times 100 = 34.8 \% = 35\%$$

- d. "Ethanol has less energy than gasoline". Explain why this is the case, with reference to ethanol's structure in relation to combustion as an oxidation reaction. Is this an advantage or a disadvantage of ethanol as a fuel source? (3 marks)

Ethanol contains an oxygen in its structure due to the hydroxyl group. (1)

In an engine, since ethanol is being combusted – which is an oxidation reaction - ethanol has less oxidation remaining to be undergone compared to gasoline, as it is partially oxidised. (2)

As such, it cannot release as much energy compared to gasoline, which is one of the disadvantages associated with ethanol. (3)

- e. With regards to its structure and intermolecular bonding, explain why “ethanol can pick up contaminants that gasoline doesn’t. Outline how this property influences engine owners’ decision-making regarding fuel selection. Ensure to reference relevant statements from the article. (3 marks)

— Ethanol contains a polar hydroxyl group. As such, it can undergo hydrogen bonding with water (1), deeming it “water soluble” (2).
 — This is a disadvantage for engines (3), as it can absorb and deposit contaminants, “leading to fouled filters or injectors”.

Question 2 (16 marks)

Ethanol also presents an array of advantages, which is why its use has gained tremendous popularity in recent times.

- a. List and briefly describe the five major benefits associated with ethanol, as presented in the piece. (5 marks)

— Oxygenation – safer for water supply as toxic MTBE is no longer used (1).
 — Boosts octane number – preventing pre-ignition knock (2).
 — Price – leaves more fuel available and less need for oxygenators and octane boosters, hence leading to a downward pressure on petroleum prices (3).
 — Renewable – can be produced via bioethanol. (4)
 — Supports domestic agriculture – created jobs for farmers and boosted farming economy (5).

- b. State **one** Green chemistry principle and list **two** United Nations Sustainable Development Goals relevant to ethanol replacing MTBE as an oxygenator. (3 marks)

Goal 6: Clean water and sanitation.

Goal 7/9/11/12 are all valid as the second option.

Designing safer chemicals is the most relevant Green chemistry principle.

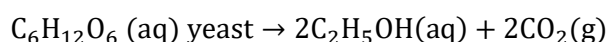
c.

- i. With reference to both the definition of renewability, and the article, explain why ethanol can be classified as a renewable fuel source. Justify with reference to an appropriate type of economy, **and** a Green chemistry principle. (4 marks)

It can be replenished by natural processes (fermentation of glucose in the presence of yeast) within a relatively short period of time. ("Ethanol from corn or other crops can be grown and produced year after year after year.") Ethanol made in this way is referred to as bioethanol, and upholds a circular economy, and aligns with the "Use of renewable feedstocks."

(1 mark for definition; 1 for reference to article; 1 for mentioning circular economy; 1 for Green chem principle)

- ii. Write the balanced chemical equation for the production of bioethanol. (2 marks)



- iii. Outline a process which is typically performed following the production of bioethanol. Explain why this process is regarded as being essential for ethanol use as a fuel. (2 marks)

Simple/fractional distillation. (1)

This is done to purify the ethanol and get rid of the water, so as to make the ethanol produced more effective as a fuel and increase its efficiency upon combustion. (2)

Space for Personal Notes

Question 3 (14 marks)

Whilst ethanol is renewable, its production is not without its flaws.

a.

- i.** According to the first paragraph under “Increased Competition for Crops” on **Page 4**, explain what a major drawback of the ethanol industry is. Justify your answer by referring to a relevant United Nations Sustainable Development Goal. (2 marks)

Using a lot of crops means there's less for actual food and agriculture, which can drive up commodity prices, and consequently, retail food prices. (1)

This reality goes against United Nations Goals 7/9/11/12/15, as *insert relevant justification*. (2)

- ii.** The second paragraph under “Increased Competition for Crops” on **Page 4**, however, suggests an alternative view. Explain what **Figure 2** is suggesting, and outline what relationship “crude oil” - the blue curve – has with petroleum. (2 marks)

This paragraph explains how food prices are actually correlated with petroleum prices, rather than ethanol/corn prices. (1)

Figure 2 highlights this trend, and it shows crude oil rather than petroleum as crude oil is the raw material from which petroleum is obtained (2) (via fractional distillation).

- b.** From **part a.**, it is evident that using crops to produce ethanol has its downsides. The article, however, later presents one major benefit regarding this process. Identify what benefit this is, and briefly describe it. (1 mark)

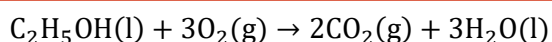
Supports domestic agriculture. Creates jobs and boost farmers economy.

c. Some experts argue that the production and usage of bioethanol is carbon neutral, whereas others disagree.

i. Outline what is meant by the term 'carbon neutral'. (1 mark)

CO₂ released upon combustion is 'offset' by CO₂ absorbed during production
– no net carbon emissions overall.

ii. Write the balanced equation for the complete combustion of ethanol at SLC. (2 marks)



iii. Hence or otherwise, **discuss** the carbon neutrality of bioethanol. You may use chemical equations to justify your reasoning. (3 marks)

For: the CO₂(g) released upon combustion is offset by CO₂(g) absorbed during photosynthesis (1).



Against: However, the farming equipment and transportation vehicles used for the process release carbon emissions, making the overall process NOT carbon neutral. (3)

Both sides must be argued in a discuss question.

d. Based on the concluding remarks of the article, evaluate whether the authors would contend that ethanol is ultimately beneficial as a fuel source, or that it is detrimental and not sustainable for future technologies and generations. Quote excerpts from the article to justify your response. (3 marks)

They would contend that it is beneficial. (1)

Almost all of the final statements are about how the issues lie with engine and equipment quality, not with ethanol itself. (2)

They also mention how ethanol being an issue will only be the case "antique car owners and small engine operators". (3)

Even the closing paragraph praising the cleanliness of our water encourages the reader to be thankful for ethanol.

VCE Chemistry $\frac{3}{4}$

Free 1-on-1 Support



Be Sure to Make The Most of These (Free) Services!

- Experienced Contour tutors (45+ raw scores, 99+ ATARs).
- For fully enrolled Contour students with up-to-date fees.
- After school weekdays and all-day weekends.

<u>1-on-1 Video Consults</u>	<u>Text-Based Support</u>
➤ Book via bit.ly/contour-chemistry-consult-2025 (or QR code below). ➤ One active booking at a time (must attend before booking the next).	➤ Message +61 440 137 304 with questions. ➤ Save the contact as "Contour Chemistry".

Booking Link for Consults

bit.ly/contour-chemistry-consult-2025



Number for Text-Based Support

[+61 440 137 304](tel:+61440137304)