Ethanol: From Grains to Gas

Ethanol is a simple molecule containing only 9 atoms and known to humans long before the arrival of modern chemistry. It has been used for many purposes such as solvents, cleaning products, fuel for table top cookery, industrial applications and even medical uses. Ethanol even finds its way into thermometers where it is colored red. However, ethanol found in the psychoactive drugs such in alcoholic drinks such as beers, wines and spirits.

[Chemical structure of ethanol]

Ethanol is also called ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol. Ethanol is a volatile, flammable, colorless liquid with the structural formula (CH₃CH₂OH), often abbreviated as (C₂H₅OH) or (C₂H₆O). Ethanol can cause alcohol intoxication if consumed. The intoxicating effects of ethanol consumption have been known since ancient times. However, it is best known as the type of alcohol found in alcoholic beverages. However, the fermentation of sugar into ethanol is one of the earliest techniques employed by humans. In addition, ethanol burns with a smokeless blue flame that is not always visible in normal light. The physical properties of ethanol stem primarily from the presence of its hydroxyl group which is able to participate in hydrogen bonding, and the shortness of its carbon chain. Ethanol hydroxyl group allow the molecule to be more viscous and less volatile than less polar organic compounds of similar molecular weight, such as propane.

During ethanol fermentation, glucose and other sugars in the corn (or sugarcane or other crops) are converted into ethanol and carbon dioxide. However, ethanol fermentation is not 100% selective due to the other side products such acetic acid, glycols and many other products that are formed to a considerable extent and need to be removed during the purification of the ethanol. The fermentation takes place in aqueous solution and the resulting solution after fermentation has an ethanol content of around 15%. The ethanol is subsequently isolated and purified by a combination of adsorption and distillation techniques. During combustion ethanol
reacts with oxygen to produce carbon dioxide, water, and heat. Ethanol fermentation also known as alcoholic fermentation is a biological process that is performed by yeasts in the absence of oxygen and considered an anaerobic process.

\[ \text{C6H12O6} \rightarrow 2 \text{C2H5OH} + 2 \text{CO2} + \text{heat} \]

\[ \text{C2H5OH} + 3 \text{O2} \rightarrow 2 \text{CO2} + 3 \text{H2O} + \text{heat} \]

The synthesis of ethanol was one of the first biotechnologies in human history. Aforementioned, ethanol was consumed as an alcohol during ancient times. Proof of distilling alcohol was discovered when scientists analyzed dried residue from 9,000-year old pots from China. There are two widely used methods to make ethanol. One method is for making ethanol for use as an industrial feedstock or solvent and the second method is for use in alcoholic beverages and fuel. The first method is ethylene hydration where ethanol is made by the acid-catalyzed hydration of ethylene. This reaction is illustrated below.

An acid like sulfuric acid can catalyze the above reaction. In the second method, ethanol is produced by fermentation of yeast. In short, fermentation is the culturing of yeast under specific thermal conditions so that alcohol is produced. An example of this is the reaction of certain species of yeast with sugar. The sugar is metabolized in reduced-oxygen conditions, which yields ethanol and carbon dioxide products. This particular reaction is shown below.
Ethanol can also be produced out of cellulosic materials such as starch and cellulose. However, it is necessary to do pretreatment in order to split the cellulose into glucose molecules and other sugars which subsequently can be fermented to generate the result product cellulosic ethanol. Ethanol may also be produced industrially from ethene (ethylene) by hydrolysis of the double bond in the presence of catalysts and high temperature. $C_2H_4 + H_2O \rightarrow C_2H_5OH$

For the ethanol to be usable as a fuel, the majority of the water must be removed by distillation. However, the purity is limited to 95–96% due to the formation of a low-boiling water-ethanol azeotrope. This mixture is called (hydrous ethanol) and can be used as a fuel alone. But unlike anhydrous ethanol, hydrous ethanol is not miscible in all ratios with gasoline. Therefore, the water fraction is typically removed in further treatment in order to burn in combination with gasoline in gasoline engines.

There are three dehydration processes to remove the water from an azeotropic ethanol/water mixture. The first process, used in many early fuel ethanol plants called azeotropic distillation and consists of adding benzene or cyclohexane to the mixture. When these components are added to the mixture, it forms a heterogeneous azeotropic mixture in vapor-liquid-liquid equilibrium. However, when distilled, it will produce anhydrous ethanol in the column bottom, and a vapor mixture of water, ethanol, and cyclohexane/benzene. When condensed, this becomes a two-phase liquid mixture. The heavier phase which is poor in benzene or cyclohexane is recycled to the feed, while the lighter phase together with condensate from the stripping is recycled to the second column. Another early method, called extractive distillation, consists of adding a ternary component which will increase ethanol's relative volatility. When the ternary mixture is distilled, it will produce anhydrous ethanol on the top stream of the column.

In addition, there are many methods that help save energy have been proposed to avoid distillation altogether for dehydration. One of those methods was the third method that has emerged and has been adopted by the vast majority of modern ethanol plants. This new process uses molecular sieves to remove water from fuel ethanol. In this process, ethanol vapor under pressure passes through a bed of molecular sieve beads. The bead's pores are sized to allow absorption of water while excluding ethanol. After a period of time, the bed is regenerated under
vacuum or in the flow of inert atmosphere (e.g. N₂) to remove the absorbed water. This dehydration technology can account for energy saving of \((840 \text{ kJ/L})\) compared to earlier azeotropic distillation.

Ethanol is most commonly used to power automobiles, farm tractors, boats and airplanes. Ethanol consumption in an engine is approximately 51% higher than for gasoline since the energy per unit volume of ethanol is 34% lower than for gasoline. The higher compression ratios in an ethanol-only engine allow for increased power output and better fuel economy than could be obtained with lower compression ratios.

Vehicles that use E85 have to meet similar requirement such as tailpipe emission standards as other light duty vehicles. However, when using E85, these flex-fuel vehicles may have lower emissions of some pollutants than conventional gasoline-fueled vehicles.

Ethanol contains soluble and insoluble contaminants. These soluble contaminants, halide ions such as chloride ions, have a large effect on the gradual destruction of alcohol fuels. Halide ions increase corrosion in two ways; they chemically attack oxide films on several metals causing pitting corrosion, and they increase the conductivity of the fuel. Increased electrical conductivity promotes electric, galvanic, and ordinary corrosion in the fuel system. Soluble contaminants, such as aluminum hydroxide, itself a product of corrosion by halide ions, clog the fuel system over time.

Ethanol is hygroscopic, which has the ability to absorb water vapor directly from the atmosphere. However, because absorbed water dilutes the fuel value of the ethanol and may cause phase separation of ethanol-gasoline blends, containers of ethanol fuels must be kept tightly sealed. This high ability to be mixed with water indicates that ethanol cannot be efficiently shipped through modern pipelines over long distances. Mechanics also have encountered increased cases of damage to small engines in particular the carburetor due to the increased water retention by ethanol in fuel.

Furthermore, ethanol is considered to be better and less harmful for the environment than gasoline. Ethanol-fueled vehicles produce lower carbon monoxide and carbon dioxide emissions, and the same or lower levels of hydrocarbon and oxides of nitrogen emissions. Also, ethanol production supports farmers and creates domestic jobs. Also, because ethanol is produced domestically, from domestically grown crops, it reduces U.S. dependence on foreign oil and increases the nation’s energy independence.
The electronegativity of the oxygen atom that polarizes hydroxyl groups is what makes ethanol such a good polar solvent - and this is a major use for ethanol in chemistry. It can be mixed with water in all proportions forming hydrogen bonds between the hydroxyl groups of the alcohol with those in the water. Ethanol can also be used in fuel cells where it can react with the oxygen in the air over a platinum catalyst. This does not produce heat and light, but converts the ethanol's chemical energy directly into electrical energy.

Moreover, during burning ethanol, ethanol can also be partially oxidized to both an aldehyde (called ethanal or acetaldehyde) and carboxylic acid (called ethanoic or acetic acid). When alcoholic beverages turn to vinegar - which is essentially ethanoic acid - it is *acetobacter* bacteria in the air that bring about the oxidation. An oxidation process is also how the body gets rid of ethanol from our systems, and partially oxidized ethanal is thought to be contributing to the symptoms of the hangover that follows excessive drinking.

One of the advantages of ethanol is that it can burn cleaner than gasoline. Ethanol creates fewer toxic emissions and does not contain significant amounts of toxic materials such as lead and benzene. However, by lowering the amount of greenhouse gases and ozone created by car exhaust, the use of ethanol is believed to be a much better alternative to gasoline. Another one of the advantages of ethanol fuel is the reduced dependence on imported oil. While ethanol may never fully replace petroleum oil as the United States main source of energy, it can reduce the total amount of oil the country would need to import.

So why hasn’t the US pushed for the use of ethanol as a primary fuel source? Firstly, the amount of ethanol needed to satisfy the amount of drivers there are in the US would be in the hundreds of billions of gallons. In 2013 alone, the US consumed roughly 133 billion gallons of fuel, which averages to 366 million gallons of fuel a day. Secondly, the majority of cars in the US are not made for ethanol fuel so the demand for high-ethanol based fuels is low. However, ethanol is the main fuel source in the Midwest US where there is an abundance of corn crops. Another significant factor in ethanol production is land use. Ethanol fuel critics contend that producing ethanol as a primary fuel source will drive world food prices up and cause drastic shortages in corn crops for food. However, ethanol fuel advocates counter this contention by stating that more than 93% of all corn grown in the US is never fed to people, but is used as livestock feed and ethanol production. In addition, American farmers grow more corn than people can purchase; there is generally an annual surplus of corn in the US. In regards to the environment, the
expansion of acreage for ethanol would cause new carbon emissions, habitat loss, and water-
quality degradation.

In conclusion, ethanol is the best way to fight air pollution from vehicles. Also, there is
no fuel available at scale today that is similar to ethanol's ability in improving the overall
environmental quality compared to gasoline. However, from its biodegradable nature to
reductions in greenhouse gas and tailpipe emissions, ethanol provides a tool that considers all the
environmental concerns without requiring an entirely new way for goods and people to get from
one place to another.
Work cited


