# Module

# 2

# Chemical and Physical Characteristics of Ethanol and Hydrocarbon Fuels

## Terminal Objective

Upon the successful completion of this module, participants will be able to describe the chemical and physical differences between pure gasoline and gasoline/ethanol blends.

## Enabling Objectives

1. Compare the chemistry of gasoline and ethanol.
2. Describe the characteristics of ethanol-blended fuels.

**Instructor Note:**

***Module Time:*** *1 hour*

***Materials:***

- *Worksheet 2.1*
- *Table 2.1*
- *LCD Projector*
- *Paper chart, dry erase board*

# Introduction

In order to understand the nature of ethanol-blended fuels, emergency responders will need to understand the characteristics of polar solvents and hydrocarbons, their differences, and how these types of products interact. Under some conditions, ethanol-blended fuels will retain certain characteristics as a gasoline-type fuel, and under others it will exhibit polar solvent-type characteristics. Understanding these conditions will help emergency responders mitigate the various incidents according to the conditions found.

**Instructor Note:**

*Guide participants through a matching activity in which they match the definitions and terms they will need to effectively discuss the uses of and responses to ethanol as it appears in incidents. After participants have successfully matched the terms with the definitions, discuss them to be sure that everyone understands all the terms.*

# Activity 2.1—Definitions

## *Purpose*

To allow participants to identify the definitions related to ethanol.

**Instructor Note:**

***Time:*** *15 minutes*

***Materials:*** *Worksheet 2.1*

**Instructor Directions:**

1. *Tell participants that the definition for ethanol has been given. Ask them to take 5 minutes and see if they can fill in the terms for each of the definitions provided in Worksheet 2.1.*
2. *Give participants 5–10 minutes to write in the terms for each of the definitions below. Point out that #1 has been completed for them.*
3. *After you call time, call on participants to provide an answer for each definition. Make sure everyone understands each definition before moving to the next.*

## *Participant Directions*

1. A list of definitions is provided in Worksheet 2.1.
2. Write in the appropriate definition for each in the space provided.
3. You will have approximately 5–10 minutes to complete the activity.

# Characteristics of Gasoline (A Hydrocarbon)

Hydrocarbon fuels (gasoline, diesel fuel, kerosene, jet fuel, etc.) generally have similar characteristics whether they are flammable liquids or combustible liquids. In this program we will specifically identify the characteristics of gasoline as they relate to ethanol and gasoline blends.

Gasoline is a hydrocarbon produced from crude oil by fractional distillation. It is non-water miscible (which makes it hydrophobic) and has a flash point of approximately -45°F, varying with octane rating. Gasoline has a vapor density between 3 and 4. Therefore, as with all products with a vapor density greater than 1.0, gasoline vapors will seek low levels or remain close to ground level. Gasoline has a specific gravity of 0.72–0.76 which indicates it will float on top of water since it is non-water miscible or insoluble. Its auto-ignition temperature is between 536°F and 853°F, and it has a boiling point between 100°F and 400°F depending on fuel composition. Gasoline is not considered a poison but does have harmful effects after long-term and high-level exposure that can lead to respiratory failure. Smoke from burning gasoline is black and has toxic components. Gasoline's greatest hazard is its flammability even though it has a fairly narrow flammability range (LEL is 1.4 percent and UEL is 7.6 percent).

# Characteristics of Ethanol (A Polar Solvent)

Emergency responders are generally not going to encounter pure ethanol unless they respond to an event at an ethanol production facility. Ethanol for use in motor fuel blends will generally be denatured with up to 5 percent gasoline or a similar hydrocarbon (E-95) for any style of transport. Nevertheless, the following discussion of the characteristics of ethanol will be based on pure rather than denatured product, for in actuality the denaturant will have minimal effects on product characteristics.

**Instructor Note:**

*Ask participants the difference between renewable and non-renewable resources.*

***Answer:***

- *A non-renewable resource is a natural resource that cannot be remade, regrown, or regenerated.*
- *A renewable resource is one that can be replenished.*

*Ask participants for examples of non-renewable and renewable resources.*

***Answer:***

- *Non-renewable resources would be fossil fuels such as coal, petroleum, and natural gas.*
- *Renewable resources would be things like water, oxygen, timber, fruits, and vegetables.*

Ethanol is a renewable fuel source that is produced by a fermentation and distillation process. The most common source of ethanol in the United States in 2008 is corn. However, it can be produced from other products such as sugar cane, saw grass, and other natural products that will be conducive to the fermentation/distillation process.

Pure Ethanol is a polar solvent that is water-soluble and has a 55°F flash point. Ethanol has a vapor density of 1.59, which indicates that it is heavier than air. Consequently, ethanol vapors do not rise, similar to vapors from gasoline, which seek lower altitudes. Ethanol's specific gravity is 0.79, which indicates it is lighter than water but since it is water-soluble (it be considered hydrophilic). it will thoroughly mix with water. Ethanol has an auto-ignition temperature of 793°F and a boiling point of 173°F. Ethanol is less toxic than gasoline or methanol. Carcinogenic compounds are not present in pure ethanol.

Like gasoline, ethanol's greatest hazard as a motor fuel component is its flammability. It has a wider flammable range than gasoline (LEL is 3.3 percent and UEL is 19 percent). In a pure form, ethanol does not produce visible smoke and has a hard-to-see blue flame. In a denatured form there is little to no smoke, but a slight orange flame may be visible **(**http://www.fsi.illinois.edu/content/courses/programs/ethanol/**).** Interestingly, ethanol and some ethanol blends can conduct electricity while gasoline does not and is considered an electrical insulator.

**Instructor Note:**

*Show slide number 11:*

- *Figure 1 shows a solution of ethanol and water. You can see how the two are completely miscible. The foam is just a result of the agitation.*
- *Figure 2 is a close-up of oil and water showing how the two do not mix.*
- *Figure 3 shows an oil and water mixture. Upon agitation the oil will often separate out and appear as if it will completely mix but will reform and separate.*

The most striking difference between these two fuels is that unlike gasoline, ethanol mixes easily with water. While it is possible to dilute ethanol to a condition where it no longer supports combustion, this is not practical in the field as it requires copious amounts of water. Even at 5 parts water to 1 part ethanol, it will still burn.

# Activity 2.1—Comparison of Gasoline and Ethanol

## *Purpose:*

To allow participants to discuss the differences and similarities in the chemical and physical properties of ethanol and gasoline.

**Instructor Note:**

***Time:*** *15 minutes*

***Materials:*** *Table 2.1*

**Instructor Directions:**

1. *Have participants take a few minutes to review the prior information and fill in Table 2.1.*
2. *In the participant manual the chart is left blank. The answers (the italicized text in Table 2.1) are only in your instructor's guide.*
3. *Based on this information, lead into a discussion in which you have the participants predict how the differences in the fuels, particularly when combined, might lead to different outcomes during emergencies by asking the following questions:*
   - *Which product is more flammable?*
     - ***Answer:*** *Ethanol, but only slightly*
   - *Why is it more flammable?*
     - ***Answer:*** *It has a wider flammable range than gasoline, but only slightly.*
   - *What types of issues does the conductivity of ethanol present in emergency situations?*
     - ***Answer:*** *The danger of a scene can increase if water is present together with charged or downed power lines.*
   - *With a specific gravity of 0.79, how would you expect the mixed blend to react if released into a water source such as a creek or pond?*
     - ***Answer:*** *Since the product is miscible and will mix readily in the water and travel with any current.*

## *Participant Directions*

1. Review the information in module 2.
2. Fill in Table 2.1.
3. Use the NIOSH Pocket Guide to Hazardous Chemicals as a reference or MSDS

**Table 2.1: Gasoline and Fuel Grade Ethanol**

| | **Gasoline** | **Fuel Ethanol** |
|---|---|---|
| Flash Point | *-45°F* | *-5°F* |
| Ignition Temperature | *530–853°F* | *793°F* |
| Specific Gravity | *0.72–0.76* | *0.79* |
| Vapor Density | *3–4* | *1.49* |
| Vapor Pressure | *38–300 mmHg* | *44 mmHg* |
| Boiling Point | *100–400°F* | *173°F* |
| Flammable Range (LEL–UEL) | *1.4%–7.6%* | *3.3%–19%* |
| Conductivity | *None* | *Yes* |
| Smoke Character | *Black* | *Slight to none* |
| Toxicity | | *Lower than gasoline* |
| Water Solubility | *None* | *Completely* |
| **Reference:** *The National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards* | | |

# Characteristics of Ethanol-Blended Fuels

Blending ethanol with gasoline has multiple effects. Ethanol increases the heat output of the unleaded gasoline, which produces more complete combustion resulting in slightly lower emissions from unburned hydrocarbons. The higher the concentrations of ethanol, the more the fuel has polar solvent-type characteristics with corresponding effects on conducting fire suppression operations. However, even at high concentrations of ethanol, minimal amounts of water will draw the ethanol out of the blend away from the gasoline. Ethanol and gasoline are very similar in specific gravity. The two differing fuels mix readily with minimal agitation, but the blend is more of a suspension than a true solution.

Ethanol has a greater affinity for water than it does for gasoline. Over time, without agitation, gasoline will be found floating on a layer of an ethanol/water solution. The resulting ethanol/water solution is still flammable since the concentration of ethanol is still fairly rich. Phase separation can occur in fuel storage systems where water is known to be present.

Blending these fuels together alters the physical and chemical characteristics of the original fuels. However, the resulting changes may be unnoticeable to emergency responders however, because gasoline is used in the blend, E-85 is considered potentially carcinogenic. One of the noticeable differences in the blended fuel versus unblended gasoline is the visual difference of the smoke and flame characteristics. Higher concentrations of ethanol produce less black smoke and decreased visible flame color. These characteristics may be masked by other substrates that may also be burning such as vehicle tires. Another noticeable difference of ethanol-blended fuels under fire conditions is that when foam or water has been flowed on the burning product, the gasoline will tend to burn off first, eventually leaving the less volatile ethanol/water solution which may have no visible flame or smoke.

# Summary

**Instructor Note:**

*Ask participants:*

- *Are you surprised by any of the differences between gasoline and ethanol?*
- *Which differences are going to be of most concern to first responders?*
- *Mixed blends of fuel present interesting situations for emergency responders. Water is a readily available fire fighting agent, and we have discussed how the fuel mixtures react with water. What other hazards are associated with ethanol and ethanol blends, and what can be done to minimize these hazards?*
  - ***Answers:***
    - *Flammability, respiratory, and contact hazards. Also the issue of conductivity which demands that grounding and bonding be part of the tactical plan for transfers.*
    - *The proper use of protective equipment such as eye protection, Self-Contained Breathing Apparatus (SCBA), flame resistant clothing, and appropriate gloves*

Ethanol is a polar solvent that is simultaneously water-soluble and flammable. Creating a blend of gasoline and ethanol results in a chemical change that can easily go unnoticed by emergency responders. Knowing that the ethanol will be the last fuel to burn and that it may burn without visible smoke or flame is important in determining an approach to take in dealing with ethanol-involved incidents.

## Worksheet 2.1: Definitions

Match the definition to the words below:

| | |
|---|---|
| Polar solvent | Hydrophilic (water miscible) |
| Auto-ignition temperature | Flash point |
| Toxicity | Combustible liquid |
| Ethanol | Flammable liquid |
| Hydrocarbon | Hydrophobic (non-water miscible) |
| Specific gravity | Boiling point |
| Vapor density | Flammable range (Upper Explosive Limit [UEL]–Lower Explosive Limit [LEL]) |

## Worksheet 2.1:

1. _____: It is a clear colorless, flammable solvent with a boiling point of 173°F/ 78.5°C; also known as ethyl alcohol, grain spirits, or alcohol. Unlike other alcohols of similar molecular weight, is considered non-toxic or a drinking alcohol, found in transportation fuels has been denatured, generally by the addition of up to 5 percent gasoline, rendering it unfit for drinking and thereby avoiding the tax burden imposed on liquor by the Alcohol and Tobacco Tax and Trade Bureau, formerly known as the Alcohol Tobacco and Firearms (ATF).

**Answer:**

*Ethanol*

2. _____: A compound such as alcohol, acid, or ammonia with a separation of charge in the chemical bonds. These have an affinity for water and will readily go into solution.

**Answer:**

*Polar solvent*

3. _____: A compound composed of only carbon and hydrogen and commonly obtained through the refining of crude oil; these are the primary constituent parts of both gasoline and diesel fuel.

**Answer:**

*Hydrocarbon*

4. _____: Has an affinity to water; “water-loving”

**Answer:**

*Hydrophilic (water miscible)*

5. _____: Repels water; “water-fearing”; apparent when oil and water separate or when a drop of water beads on a coat of wax

**Answer:**

*Hydrophobic (non-water miscible)*

6. _____: The lowest temperature at which a flammable liquid can form an ignitable mixture in air near the surface of the liquid; the lower the value is, the easier it is to ignite. This is the minimum temperature at which a liquid gives off vapor in sufficient concentrations to allow the substance to ignite.

**Answer:**

*Flash point*

*The flash point of gasoline is -45°F; the flash point of ethanol is -5°F.*

7. _____: The minimum temperature required to ignite a gas or vapor to spontaneously combust in air without a spark or flame being present

**Answer:**

*Auto-ignition temperature*

8. _____: The ratio of the density of a substance to the density of water

**Answer:**

*Specific gravity*

9. _____: Relative weight of a gas or vapor in comparison to air

**Answer:**

*Vapor density*

10. _____: The temperature at which the vapor pressure of a liquid equals the environmental pressure surrounding the liquid

**Answer:**

*Boiling point*

11. _____: Concentration range for a gas or vapor within which a fire may result if an ignition source is introduced; includes an upper and a lower limit between which the danger lies.

**Answer:** _____

*Flammable range (Upper Explosive Limit [UEL]–Lower Explosive Limit [LEL])*

12. _____: The degree to which a substance can harm humans or animals.

**Answer:** _____

*Toxicity*

13. _____: Any liquid with a flash point under 100°F; referred to as Class I liquids; examples are gasoline and ethanol.

**Answer:** _____

*Flammable liquid*

14. _____: Any liquid with a flash point above 100°F but below 200°F; examples include diesel fuel and kerosene

**Answer:** _____

*Combustible liquid*