

Monohydroxy Alkanes or Alcohols

Student Learning Outcomes

After studying this chapter, students will be able to:

- Describe the manufacture of ethanol
(This can be done by discussing fermentation of aqueous glucose at 25-35 °C in the presence of yeast and in the absence of oxygen catalytic addition of steam to ethene at 300°C and 6000kPa /6 atm in the presence of an acid catalyst including a comparison of the advantages and disadvantages of the two methods)
- Describe the combustion of alcohols
- Discuss the applications of alcohols as fuels, including their advantages and disadvantages over fossil fuels.
- Explain the role of alcohols in various industries such as pharmaceuticals, cosmetics, and fuel production.
- Discuss the impact of alcohols on daily life, including their use as solvents and disinfectants.





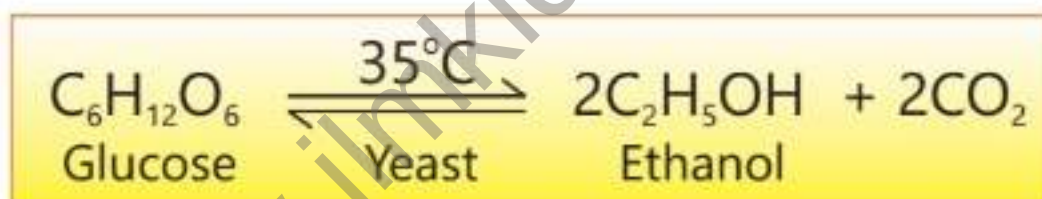
Monohydroxy alkanes or alcohols are an important class of organic compounds. Some of these alcohols can be obtained by the reactions in which living organisms are used as catalysts. They can also be synthesized in the laboratory.

Ethyl alcohol or ethanol is a very important member of this homologous series. It is manufactured on large scale by the following processes:

23.1 Manufacture of Ethyl Alcohol ($\text{CH}_3\text{-CH}_2\text{-OH}$)

Fermentation of Glucose by Yeast

Fermentation is a reaction in which a substance breaks down into simpler substances in the presence of enzymes present in yeast. Preparation of yogurt, bread and ethyl alcohol are some examples of the fermentation reactions. Glucose can be converted to ethyl alcohol in the presence of yeast at around 35°C and in a neutral or acidic solution. This fermentation reaction must be carried out in the absence of air (anaerobic conditions) to obtain ethanol. Yeast contains an enzyme which acts as a catalyst in this reaction. The balanced chemical equation for the fermentation of glucose is as follows:



Carbon dioxide gas comes out of the reaction mixture leaving behind a mixture of ethanol and water.

The temperature of the process must be kept around 35°C to get the maximum yield of the product. A lower temperature decreases the rate of the reaction whereas the higher temperature makes the enzyme inactive in anaerobic conditions. Oxygen is excluded from the reaction because it converts the resulting ethanol into ethanoic acid. Since ethanol is toxic to yeast in high concentration, yeast is made inactive when the concentration of ethanol in the reaction mixture exceeds 15%.



23.1 Quick Check!

- What is the role of yeast in fermentation reaction?
- At which temperature enzymes present in yeast get inactive?

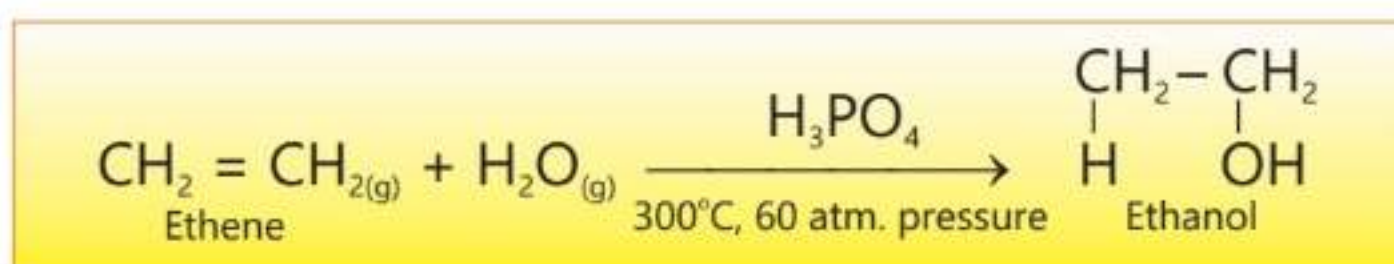




Hydration of Ethene or Ethylene

Hydration of ethene is an addition reaction. In this reaction water is added across the double bond of the ethene. The reaction is carried out by passing a mixture of ethene and steam over hot phosphoric acid (H_3PO_4), which acts as a catalyst.

Hydrogen atom of H_2O attaches itself to one carbon atom of ethene and the hydroxyl group to other atom. During this addition the double bond breaks down to give a saturated compound, ethanol.



Gaseous ethanol obtained is then condensed into its liquid form. Hydration of ethene is an important industrial process because ethanol is a versatile compound. It has a wide range of applications from alcoholic drinks to fuels and as a solvent.

A comparison of methods of production of ethanol is given in the following table 23.1.

Table 23.1 Comparison of methods of production of ethanol

Hydration of Ethene	Fermentation
Reaction is performed at high temperature and at high pressure.	It takes place at around 35°C and at atmospheric pressure.
Starting material for the process is obtained from crude oil, which is a non-renewable source.	Starting material for this method is a renewable source, such as cane-sugar.
Rate of reaction is high.	Rate of reaction is low. It may take days to complete.
The reaction produces relatively pure alcohol.	The reaction produces 15% alcohol which needs further distillation to increase the concentration. Distillation requires energy.
Ethanol produced in this method is expensive.	Ethanol produced in this process is cheap.



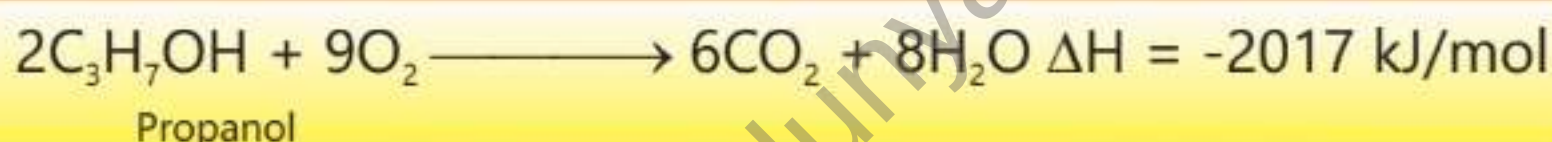
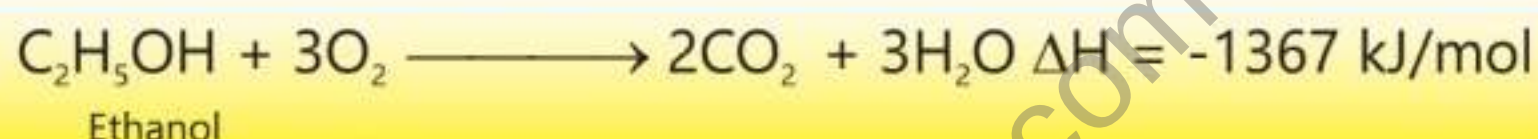
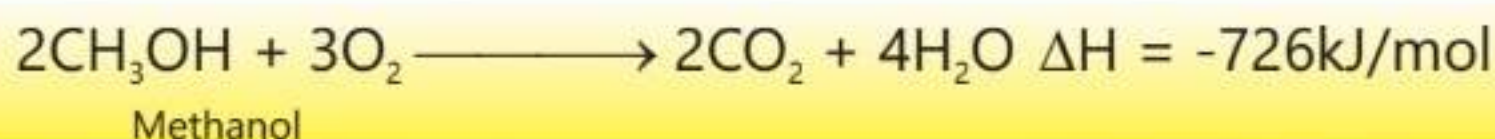


23.2 Quick Check!

1. Why oxygen is excluded when the fermentation reaction is carried out?
2. Which method for the preparation of ethene involves renewable source?

23.2 Combustion of Alcohols

Alcohols are flammable, therefore, burn in air to produce CO_2 and H_2O evolving a large amount of heat. Methanol, ethanol and 1-propanol, all burn completely in excess of air because they contain a hydrocarbon chain. The balanced equations for the combustion of alcohols are given below:



During combustion of alcohols the weaker C-H bonds in $-\text{CH}_2$ groups break and the stronger C=O and O-H bonds are formed in CO_2 and H_2O respectively. This explains why the amount of heat evolved increases with the addition of a $-\text{CH}_2$ group in the alcohol homologous series.

23.3 Quick Check!

Why does butanol evolve a higher amount of heat than propanol when burnt in oxygen?

23.3 Applications of Alcohols as Fuels

Alcohols are also used as fuels instead of petrol and diesel to run an automobile. The first four aliphatic alcohols namely methanol, ethanol, propanol and butanol have such properties which make them suitable to be used in internal combustion engines.



Advantages of Alcohols as Fuels

1. Alcohols are obtained from renewable sources.
2. Burning of alcohols does not produce oxides of sulphur which makes them environmental friendly as compared to fossil fuels.
3. Alcohols have higher fuel efficiency as compared to petrol or diesel fuels.

Interesting Information!

Alcohols are produced from plant materials which, in turn, are the result of the photosynthesis process using CO_2 of the atmosphere. The same CO_2 is generated when these bioalcohols are burnt in internal combustion engine. The overall process is considered to be carbon neutral because it does not increase the concentration of carbon dioxide gas in the atmosphere.

Disadvantages of Alcohols as Fuels

1. Alcohols have less energy per volume than gasoline. It means more fuel is needed to travel the same distance.
2. Alcohols can increase wear and tear on engine components.
3. Land is utilized to grow crops which then yield alcohols. This fact affects the cultivation of food crops.



23.4 Quick Check!

1. Why does the amount of heat evolved during burning of alcohols go on increasing from lower to higher alcohols?
2. Why burning of alcohols does not produce oxides of sulphur unlike fossil fuels?

23.4 Role of Ethanol in Industries

Pharmaceutical Industry

Ethyl alcohol serves as a very common ingredient in a variety of manufacturing processes in pharmaceutical industry. It possesses bactericidal activity and it is often used as a disinfectant in hand sanitizer and methylated spirit. It is also commonly used as a solvent and preservative in many pharmaceutical preparations including vaccines.

Ethanol and isopropanol are found as an active ingredient in certain oral and topical drug products. They help solubilize many drugs.

Interesting Information!

Ethanol as a fuel reduces greenhouse gas emissions by 44 to 52% as compared to petrol. Besides this, ethanol also cuts down on other harmful pollutants like CO_x , NO_x and particulate matter.





Cosmetic Industry

Ethyl alcohol plays an important role in cosmetic industry because of its following properties:

1. Being highly volatile it evaporates in a very short time.
2. Deodorizing and anti-inflammatory properties.
3. Refreshing and antimicrobial properties.

Ethanol is an important part of such cosmetic and hygiene products as hair styling products, foundation creams, perfumes, deodorants and after shave lotions.

23.5 Impact of Alcohols on Daily life

Ethyl alcohol is an essential part of first aid kit in every home in the form of methylated spirit. Methylated spirit is used as an antiseptic, for dressing of wounds and as an antidote for snake bites. In many parts of the world, ethanol is used as high efficiency fuel to drive vehicles. Ethanol is widely used as a solvent in perfumes. It is relatively safe and can be used to dissolve many organic compounds which are insoluble in water.

Do You Know?

Ethyl alcohol as a drink can cause hangover, alcohol poisoning, accidents and risky behaviour. Long-term use of alcohol is known to cause more than 200 different diseases.

EXERCISE

A Multiple Choice Questions

Choose and tick the correct answer from the given choices.

1. Which conditions are considered best for the fermentation of glucose?
 - (a) 35 °C, fresh yeast, absence of oxygen
 - (b) 45 °C, yeast
 - (c) 45 °C, absence of oxygen
 - (d) 35 °C, fresh yeast





2. Which catalyst other than H_3PO_4 can also be used for hydration of alkenes?
- (a) NaOH (b) H_2SO_4
(c) CH_3COOH (d) Ni
3. Alcohol which has the maximum heat of combustion is:
- (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ (b) $\text{CH}_3\text{CH}_2\text{OH}$
(c) CH_3OH (d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
4. The most environment friendly fuel is:
- (a) coal (b) kerosene oil
(c) ethanol (d) wood
5. Which property or properties of ethanol make it suitable to be used in cosmetic industry?
- (a) Easily Flammable
(b) Highly volatile and deodorizing
(c) Antipyretic
(d) Sedative
6. Which is the correct name of the following alcohol:
- $$\begin{array}{ccccccc} \text{CH}_3 & - & \text{CH} & - & \text{CH}_2 & - & \text{CH} & - & \text{CH}_3 \\ & & | & & & & | & & \\ & & \text{OH} & & & & \text{CH}_3 & & \end{array}$$
- (a) 2-Methylpentan-4-ol (b) 4-Methylpentan-2-ol
(c) Hexan-2-ol (d) Hexan-4-ol
7. Which property of ethanol makes it suitable for cleaning wounds?
- (a) Good solvent (b) Volatility
(c) Antiseptic (d) Deodorizing
8. Which alcohol is used to accomplish all the following tasks:
It is added in petrol to improve combustion. It serves as a feed stock to prepare vinegar and many other organic compounds.
- (a) Propanol (b) Propan-2-ol
(c) Ethanol (d) Methanol





B Short Answer Questions

- 23.1 Give two advantages of burning of alcohols over the burning of fossil fuel?
- 23.2 Which properties of ethyl alcohol make it useful for cosmetic industry?
- 23.3 How is ethyl alcohol important for pharmaceutical industry?
- 23.4 Give any two disadvantages of fermentation reactions.
- 23.5 Write the conditions involved in the hydration of ethene.

C Constructed Response Questions

- 23.1 How ethanol is obtained as a by-product in sugar industry?
- 23.2 Why do we get relatively impure alcohol in the fermentation process?
- 23.3 How do properties of ethyl alcohol help us to utilize it as fuel?

D Descriptive Questions

- 23.1 Give a comparison of fermentation reaction and catalytic hydration of ethene for the preparation of ethanol.
- 23.2 Describe the preparation of ethanol by fermentation process.
- 23.3 Describe the applications of ethanol in pharmaceutical and cosmetic industries?

