Chem Factsheet

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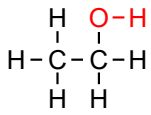
Ethanol and the Body

This Chemistry Factsheet describes:

- How ethanol interacts with the human-body, e.g. ethanol as a drug.
- Removing ethanol from the body.
- The effects of ethanol on health.

Chemistry refers to alcohol as a homogenous group of organic molecules containing a hydroxyl group, –OH. This group includes ethanol, C_2H_5OH, which is the substance commonly referred as alcohol in terms of consuming alcoholic drinks.



Ethanol

Xenobiotics are substances, classed as foods, drugs or poisons, which when taken into the body cause an effect. Ethanol can be considered as a food, a drug and as a poison. As food, ethanol has a high calorific content and the controlled metabolic oxidation of ethanol in the body is an exothermic process, releasing about 770 kJ per mole of ethanol. Ethanol is classed as a drug as it depresses the activity of the central nervous system. This is observed through reduced attentiveness and reaction-times, resulting with people under the influence of ethanol making impaired judgements. The toxic levels of ethanol are dependent on individual tolerance and usage. However, ethanol levels greater than 300 mg per 100 ml of blood can prove fatal due to respiratory depression.

The Effects of Ethanol on the Body

Note that in the United Kingdom, 8 grams of ethanol (alcohol) is measured as one unit of alcohol.

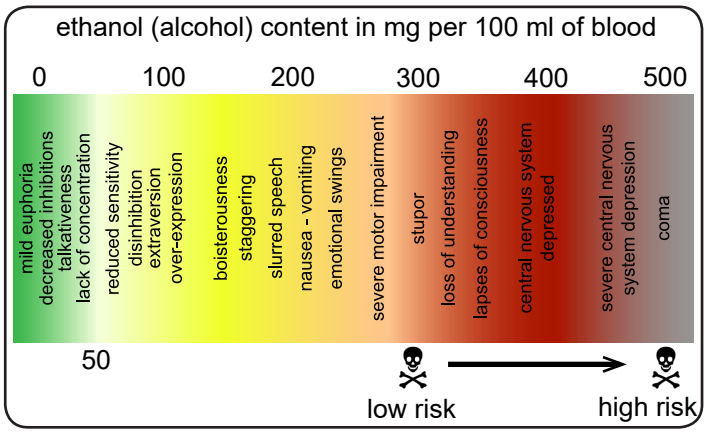
Key Points:

The units of alcohol consumed is calculated as follows:

$$\text{units of alcohol} = \frac{\text{ABV \% (alcohol by volume)} \times \text{volume of drink (ml)}}{1000}$$

The intake of ethanol through alcoholic drinks has an immediate effect on the human body due to the depression of the body's central nervous system. The severity of these effects and how rapidly they occur, depends on the size of the individual and their tolerance to alcohol, see **Figure 1**.

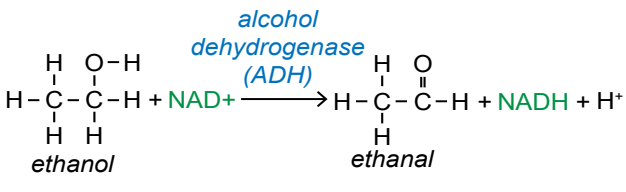
Figure 1 Effects of ethanol (alcohol) consumption



The long-term effects of consuming large amounts of ethanol include organ damage, particularly to the brain, heart, liver and pancreas. The continuous intake of ethanol increases the possible of individuals developing high blood pressure and high blood cholesterol levels. Long term alcohol abuse increases the risk of heart disease, strokes and may weaken the immune system.

The Chemistry of Ethanol in the Body

On consuming an alcoholic drink, ethanol passes through the stomach and into the bloodstream, where it is cycled around the body. Ethanol is a xenobiotic as it is not produced naturally in the body and the body cannot store it. Therefore, the body treats the ethanol as a toxin and breaks it down to remove it. This chemical process occurs in the liver, where an enzyme called alcohol dehydrogenase (ADH), converts the ethanol into ethanal (acetaldehyde), CH_3CHO. This is a redox reaction. The ethanol is oxidised by nicotinamide adenine dinucleotide (NAD+), a cofactor found in all living cells. Cofactors are molecules that assist in biochemical transformations.



Ethanal is also a toxin, but it does not display the intoxicating effects of ethanol. The ethanal formed in the liver is converted into ethanoates (acetates), a soluble anion, which is subsequently broken down into carbon dioxide and water and eliminated from the body.

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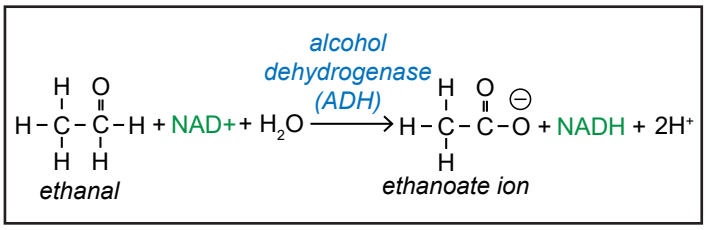


The liver is able to break down around 8 g of ethanol every hour.

The Chemistry of a Hangover

A hangover is a term used to describe an array of unpleasant symptoms that may present themselves after an individual consumes too much alcohol. Hangover symptoms may include; headache, nausea, thirst, upset stomach, a loss of appetite, and a feeling of general malaise. Hangovers are also associated with loss of productivity and poor performance leading to an economic cost running into hundreds of millions of pounds per year in the United Kingdom. The severity of a hangover depends on several factors, including; the type and amount of alcohol consumed, the rate and duration of consumption, how recently an individual ate food, gender and body weight. It appears that some people are resistant to hangovers.

There are different potential causes of hangovers:

Dehydration: The body will work to remove the ethanol consumed by decreasing the amounts of the anti-diuretic hormone (ADH) released, resulting in increased urine production. This leads to dehydration, which may contribute to a hangover. Drinking water rehydrates the body and may alleviate hangover symptoms. ADH is produced by the hypothalamus and stored in the posterior pituitary gland at the base of the brain.

Ethanal poisoning: The ethanal produced in the liver from the breakdown of ethanol is toxic and may also contribute to hangover symptoms. Fortunately, ethanal is quickly converted into ethanoates in the liver. Note that the drug *Disulfiram*, which is used in the treatment of alcoholism, inhibits the breakdown of ethanal, thus ensuring the unpleasant hangover symptoms are longer lasting.

Congeners: These additional substances are formed during the fermentation process and are present in some alcoholic drinks. Congeners include methanol, propanone, different esters, tannins and aldehydes. They add to the taste and aroma of the finished product. Different congeners or their derivatives may contribute to hangover symptoms.

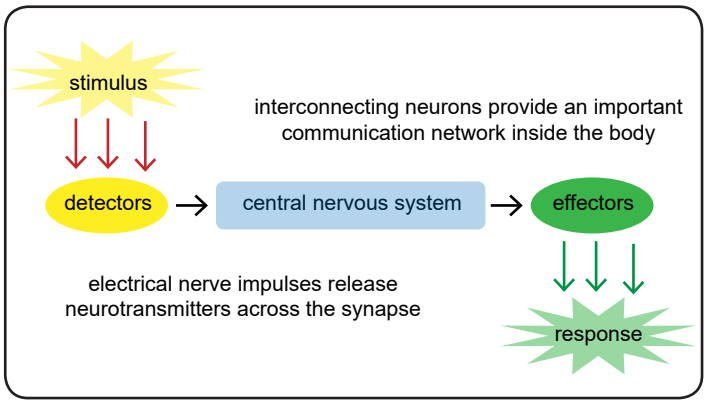
Cytokine levels: Ethanol causes changes in the cytokine concentration in the body's immune system. Cytokines are proteins released by cells and have an important role on the immune system. Some cytokines are linked to symptoms observed with hangovers.

Ethanol and the Central Nervous System

Figure 2 provides a simplified schematic of the sensory system. Changes in the environment (stimuluses) are detected, which result in electrical signals, called nerve impulses, being passed along the central nervous system via sensory nerves. Similarly, signals are sent from the central nervous system, via motor nerves, to effectors, which allow the body to respond to changes in its environment.

The nervous system consists of billions of nerve cells called

Figure 2 The Sensory System



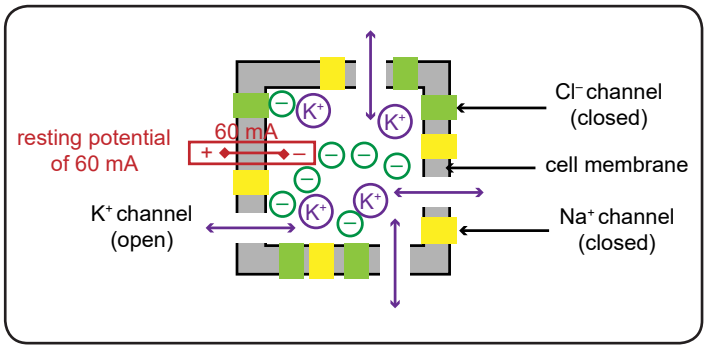
neurons that are linked together by small connections called synapses. Here the electrical signal causes the release of small molecules called neurotransmitters that carry the signal across the synapse. The neurotransmitters can either excite or inhibit the electrical behaviour of nerve calls. This is important to avoid the brain being overwhelmed with signals. The switching on (excited) and switching off (inhibited) is achieved through the movement of three different ions in and out of the nerve cell.

When nerve cells are at rest, the relative concentrations of the ions are:

Ion	Concentration	
	Inside Cell	Outside Cell
[Na^+]	LOW	HIGH
[K^+]	HIGH	LOW
[Cl^-]	LOW	HIGH

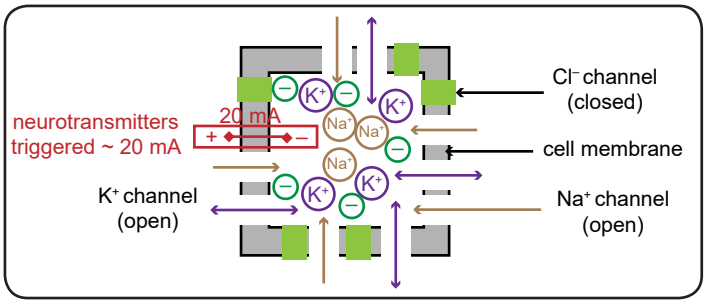
When the cell is at rest, the cell membrane is closed to Na^+ and Cl^- ions and they are unable to enter the cell. The membrane is open to K^+ ions, allowing K^+ ions to migrate freely in and out of the cell, see **Figure 3a**. There is a net migration from the region of higher concentration inside the cell to the region of lower concentration outside the cell. This results with an excess negative charge inside the nerve cell. This makes it increasingly more difficult for further K^+ ions to leave the cell. Therefore, an equilibrium is established with a negative potential of around 60 mA. This is referred to as the cell's resting potential.

Figure 3a Established potential difference across a cell at rest



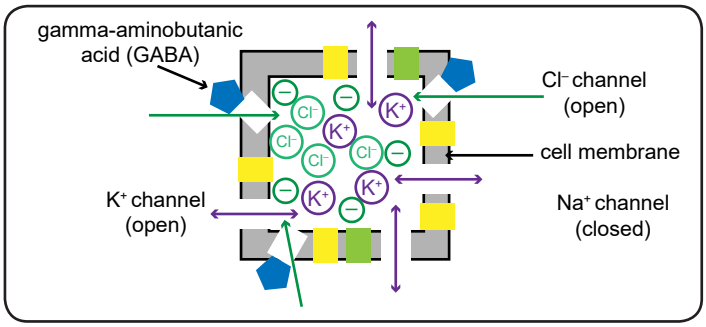
When neurotransmitters arrive from an adjacent neuron the cell membrane opens channels for the movement of Na^+ ions, allowing them to enter the cell. This results with the inside of the cell becoming more positive, to around 20 mV, see **Figure 3b**. This facilitates further movement of Na^+ and K^+ ions, thus continuing the nerve impulse.

Figure 3b Adjustment required to trigger neurotransmitters



Nerve cells are inhibited by the cell membrane opening channels for the influx of Cl^- ions, making the cell more negative. This is achieved by the neurotransmitter, gamma-aminobutanoic acid (GABA), which binds to the receptor site on protein molecules embedded in the cell membrane. This causes the protein to change shape and facilitates the opening of the Cl^- channel, see **Figure 3c**. The presence of ethanol molecules may bind nerve cells near to the GABA receptors, thus enhancing its effect on the nerve cell. This inhibits the neurons and depresses the action of the nervous system. Some medications, such as benzodiazepines, have similar effects, heightening the effects on nerve cells. Therefore, taking alcohol and benzodiazepines together is extremely hazardous as the resulting inhibition of the nervous system can prove fatal.

Figure 3c Inhibition of nerve cells by gamma-aminobutanoic acid (GABA)



Long Term Alcohol Misuse

The regular consumption of large amounts of alcohol over a period of years may cause organ damage, particularly to the brain and nervous system, the liver, heart, and pancreas. There is also a significant risk in developing high blood pressure and high blood cholesterol levels, which increase the risk of heart disease and strokes. Long term alcohol misuse may also depress the immune system making individuals more susceptible to infections.

Physical addiction: Individuals may become physically addicted to alcohol due to the chemical responses it causes in the brain. When the gamma-aminobutanoic acid (GABA) receptors interact with ethanol, they stimulate opioid receptors in the brain. This causes the release of endorphins, chemicals that cause sensations of pleasure or euphoria. GABA receptors also decrease inhibitions and promote relaxation. This may lead to individuals increasing their alcohol consumption.

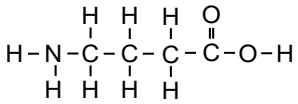
Psychological addiction: Individuals may use the consumption of alcohol as a coping mechanism when faced with stressful situations or environments. They may become dependent on alcohol to deal with psychological needs, rather than finding and using alternative coping methods.

Questions

1) A person has the choice of three alcoholic drinks. Which of the following drinks contains the most units of alcohol?
   i) One pint of lager with an ABV of 4.6%. 1 pint = 568 ml.
   ii) 250 ml glass of wine with an ABV of 13%.
   iii) A 50 ml measure of whisky with an ABV of 44%.
2) Complete equations describing the redox reactions involved in the breakdown of ethanol in the liver. Use [O] to represent the oxidising agent.
3) a) Draw the structural formula for gamma-aminobutanoic acid (GABA).
   b) Describe how the structure of this molecule differs from alpha-aminobutanoic acid.

Answers

1) The pint of lager contains the most units of alcohol:
   (i) = 2.6 units, (ii) 2.3 units, (iii) 2.2 units
2) $CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$
   $CH_3CHO + [O] \rightarrow CH_3COO^- + H^+$
3) a)



   b) In the alpha-aminobutanic acid molecule, the amino-group and carboxylic- group are both attached to the same carbon atom.

Acknowledgements: *This* ***Chemistry Factsheet*** *was researched and written by* ***Gareth RIley****, and published in* ***January 2020*** *by* ***Curriculum Press****.*