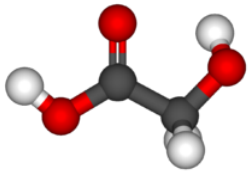
# 18.1: The Danger of Antifreeze

An antifreeze is an additive which lowers the freezing point of a water-based liquid. An antifreeze mixture is used to achieve freezing-point depression for cold environments and also achieves boiling-point elevation to allow higher coolant temperature. Freezing and boiling points are colligative properties of a solution, which depend on the concentration of the dissolved substance. Because water has good properties as a coolant, water plus antifreeze is used in internal combustion engines and other heat transfer applications. The purpose of antifreeze is to prevent a rigid enclosure from bursting due to expansion when water freezes. Commercially, both the additive (pure concentrate) and the mixture (diluted solution) are called antifreeze, depending on the context. Careful selection of an antifreeze can enable a wide temperature range in which the mixture remains in the liquid phase, which is critical to efficient heat transfer and the proper functioning of heat exchangers.

Fluorescent green-dyed antifreeze is visible in the radiator header tank when car radiator cap is removed. (CC BY-SA 2.0; EvelynGiggles)

Ethylene glycol solutions became available in 1926 and were marketed as "permanent antifreeze" since the higher boiling points provided advantages for summertime use as well as during cold weather. They are used today for a variety of applications, including automobiles, but gradually being replaced by propylene glycol due to its lower toxicity.

When ethylene glycol is used in a system, it may become oxidized to five organic acids (formic, oxalic, glycolic, glyoxalic and acetic acid). Inhibited ethylene glycol antifreeze mixes are available, with additives that buffer the pH and reserve alkalinity of the solution to prevent oxidation of ethylene glycol and formation of these acids. Nitrites, silicates, theodin, borates and azoles may also be used to prevent corrosive attack on metal.



Glycolic acid is the major metabolite of ethylene glycol responsible for toxicity. (Public Domain).

Ethylene glycol is poisonous to humans and other animals,[4][5] and should be handled carefully and disposed of properly. Its sweet taste can lead to accidental ingestion or allow its deliberate use as a murder weapon.[6][7][8] Ethylene glycol is difficult to detect in the body, and causes symptoms—including intoxication, severe diarrhea, and vomiting—that can be confused with other illnesses or diseases.[4][8] Its metabolism produces calcium oxalate, which crystallizes in the brain, heart, lungs, and kidneys, damaging them; depending on the level of exposure, accumulation of the poison in the body can last weeks or months before causing death, but death by acute kidney failure can result within 72 hours if the individual does not receive appropriate medical treatment for the poisoning.[4] Some ethylene glycol antifreeze mixtures contain an embittering agent, such as denatonium, to discourage accidental or deliberate consumption.

The toxic mechanism of ethylene glycol poisoning is mainly due to the metabolites of ethylene glycol. Initially it is metabolized by alcohol dehydrogenase to glycolaldehyde, which is then oxidized to glycolic acid.[7] The increase in metabolites may cause encephalopathy or cerebral edema.[13] The metabolic effects occur 12 to 36 hours post ingestion, causing primarily metabolic acidosis which is due mainly to accumulated glycolic acid. Additionally, as a side effect of the first two steps of metabolism, an increase in the blood concentration of lactic acid occurs contributing to lactic acidosis. The formation of acid metabolites also causes inhibition of other metabolic pathways, such as oxidative phosphorylation.[7]

The kidney toxicity of ethylene glycol occurs 24 to 72 hours post ingestion and is caused by a direct cytotoxic effect of glycolic acid. The glycolic acid is then metabolized to glyoxylic acid and finally to oxalic acid. Oxalic acid binds with calcium to form

calcium oxalate crystals which may deposit and cause damage to many areas of the body including the brain, heart, kidneys, and lungs.[7] The most significant effect is accumulation of calcium oxalate crystals in the kidneys which causes kidney damage leading to oliguric or anuric acute kidney failure.[7] The rate-limiting step in this cascade is the conversion of glycolic to glyoxylic acid.[14] Accumulation of glycolic acid in the body is mainly responsible for toxicity.[15]

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