**Vinegar (from Wikipedia)**

**Vinegar** is a liquid consisting mainly of [acetic acid](http://en.wikipedia.org/wiki/Acetic_acid) (CH3COOH) and [water](http://en.wikipedia.org/wiki/Water). The acetic acid is produced by the [fermentation](http://en.wikipedia.org/wiki/Ethanol_Fermentation) of [ethanol](http://en.wikipedia.org/wiki/Ethanol) by [acetic acid bacteria](http://en.wikipedia.org/wiki/Acetic_acid_bacteria). Vinegar is now mainly used as a cooking ingredient, but historically, as the most easily available mild [acid](http://en.wikipedia.org/wiki/Acid), it had a great variety of industrial, medical, and domestic uses, some of which (such as a general household cleanser) are still promoted today.

Commercial vinegar is produced either by fast or slow fermentation processes. In general, slow methods are used with traditional vinegars, and fermentation proceeds slowly over the course of months or a year. The longer fermentation period allows for the accumulation of a nontoxic slime composed of acetic acid bacteria. Fast methods add mother of vinegar (i.e., [bacterial culture](http://en.wikipedia.org/wiki/Bacterial_culture)) to the source liquid before adding air using a [venturi pump](http://en.wikipedia.org/wiki/Venturi_pump) system or a [turbine](http://en.wikipedia.org/wiki/Turbine) to promote oxygenation to obtain the fastest fermentation. In fast production processes, vinegar may be produced in a period ranging from 20 hours to three days.

**Oxidative fermentation**

For most of human history, acetic acid bacteria of the genus [*Acetobacter*](http://en.wikipedia.org/wiki/Acetobacter) have made acetic acid, in the form of vinegar. Given sufficient oxygen, these bacteria can produce vinegar from a variety of alcoholic foodstuffs. Commonly used feeds include [apple cider](http://en.wikipedia.org/wiki/Cider), [wine](http://en.wikipedia.org/wiki/Wine), and fermented [grain](http://en.wikipedia.org/wiki/Cereal), [malt](http://en.wikipedia.org/wiki/Malt), [rice](http://en.wikipedia.org/wiki/Rice), or [potato](http://en.wikipedia.org/wiki/Potato) mashes. The overall chemical reaction facilitated by these bacteria is: C2H5OH + O2 → CH3COOH + H2O

A dilute alcohol solution inoculated with *Acetobacter* and kept in a warm, airy place will become vinegar over the course of a few months. Industrial vinegar-making methods accelerate this process by improving the supply of [oxygen](http://en.wikipedia.org/wiki/Oxygen) to the bacteria. (Alcoholic solutions containing less than 18% Grain Alcohol become vinegar when airborne bacteria oxidize the alcohol into Acetic Acid.)

The first batches of vinegar produced by fermentation probably followed errors in the [winemaking](http://en.wikipedia.org/wiki/Winemaking) process. If [must](http://en.wikipedia.org/wiki/Must) is fermented at too high a temperature, acetobacter will overwhelm the [yeast](http://en.wikipedia.org/wiki/Yeast_(wine)) naturally occurring on the [grapes](http://en.wikipedia.org/wiki/Grapes). As the demand for vinegar for culinary, medical, and sanitary purposes increased, vintners quickly learned to use other organic materials to produce vinegar in the hot summer months before the grapes were ripe and ready for processing into wine. This method was slow, however, and not always successful, as the vintners did not understand the process.

One of the first modern commercial processes was the "fast method" or "German method", first practiced in Germany in 1823. In this process, fermentation takes place in a tower packed with wood shavings or [charcoal](http://en.wikipedia.org/wiki/Charcoal). The alcohol-containing feed is trickled into the top of the tower, and fresh [air](http://en.wikipedia.org/wiki/Earth%27s_atmosphere) supplied from the bottom by either natural or forced [convection](http://en.wikipedia.org/wiki/Convection). The improved air supply in this process cut the time to prepare vinegar from months to weeks.

Nowadays, most vinegar is made in submerged tank [culture](http://en.wikipedia.org/wiki/Microbiological_culture), first described in 1949 by Otto Hromatka and Heinrich Ebner. In this method, alcohol is fermented to vinegar in a continuously stirred tank, and oxygen is supplied by bubbling air through the solution. Using modern applications of this method, vinegar of 15% acetic acid can be prepared in only 24 hours in batch process, even 20% in 60-hour fed-batch process.

The oxygen supply should be kept optimum. Lack of O2 will kill the bacteria because they are extremely sensitive to overcome this problem hence we have to use efficient aeration. Efficient aeration can be achieved with the used of compressed air and proper mechanical device. Consider shear stress imparted to the fluid and the microorganisms. The efficiency depends on the ratio between the energy inputs necessary per unit weight of O2 transferred to the culture.

When there is over-oxidation, acetic acid will convert to CO2 and H2O, this will decrease acetic acid production. Keeping acetic acid concentrations above 6% of the total culture and avoiding the total depletion of ethanol will prevent overoxidization.

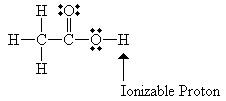
**Anaerobic fermentation**

Species of [anaerobic bacteria](http://en.wikipedia.org/wiki/Anaerobic_bacteria), including members of the genus [*Clostridium*](http://en.wikipedia.org/wiki/Clostridium) or *[Acetobacterium](http://en.wikipedia.org/wiki/Acetobacterium" \o "Acetobacterium)* can convert sugars to acetic acid directly, without using ethanol as an intermediate. The overall chemical reaction conducted by these bacteria may be represented as: C6H12O6 → 3 CH3COOH

These [acetogenic bacteria](http://en.wikipedia.org/wiki/Acetogen) produce acetic acid from one-carbon compounds, including methanol, [carbon monoxide](http://en.wikipedia.org/wiki/Carbon_monoxide), or a mixture of [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide) and [hydrogen](http://en.wikipedia.org/wiki/Hydrogen): 2 CO2 + 4 H2 → CH3COOH + 2 H2O

This ability of *Clostridium* to utilize sugars directly, or to produce acetic acid from less costly inputs, means that these bacteria could potentially produce acetic acid more efficiently than ethanol-oxidizers like *Acetobacter*. However, *Clostridium* bacteria are less acid-tolerant than *Acetobacter*. Even the most acid-tolerant *Clostridium* strains can produce vinegar of only a few per cent acetic acid, compared to *Acetobacter* strains that can produce vinegar of up to 20% acetic acid. At present, it remains more cost-effective to produce vinegar using *Acetobacter* than to produce it using *Clostridium* and then concentrate it. As a result, although acetogenic bacteria have been known since 1940, their industrial use remains confined to a few niche applications.

***% of Acetic Acid in Vinegar Inquiry Challenge***

In this challenge you will determine the molarity and percentage (by mass) of Acetic Acid (CH3CO2H) in Vinegar by titrating a sample with standardized NaOH. You will use the knowledge gained during the standardization of NaOH lab in order to titrate the vinegar. Acetic Acid (fr. Latin *acetum* for vinegar) is the main component of Vinegar. It is a carbon based compound with a single ionizable proton, making it an organic acid of the larger class of organic acids called Carboxylic Acids; organic compounds with a –COOH functional group.

***Procedure***

Record the brand/type on your data table. Use the small graduated cylinder to obtain 10.00mL of the assigned vinegar – pour the vinegar into a clean 125mL flask (rinse the cylinder with distilled and pour into the flask). Add more distilled water to the flask until you have 50 - 100mL total. Add 3 drops of phenolphthalein. Fill your buret with the standardized NaOH and record the molarity. Titrate your sample as before – complete one good trial. Calculate the molarity of acetic acid in your sample. Convert the molarity of acetic acid to mass ***percent*** of acetic acid in the vinegar “solution” – use a value of 1.01g/mL as the density of the vinegar. Obtain the known value of the mass % of acetic acid for your vinegar sample from the instructor and determine your percent error.



**Vinegar Titration Names \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

|  |  |  |
| --- | --- | --- |
|  | Trial 1 | Trial 2 |
| Initial Volume of Vinegar (mL) |  |  |
| Final Volume of Vinegar (mL) |  |  |
| *Volume of Vinegar Used (mL)* |  |  |
| Initial Volume of NaOH (mL) |  |  |
| Final Volume of NaOH (mL) |  |  |
| *Volume of NaOH Used (mL)* |  |  |

*Brand of Vinegar and/or sample #*

*\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Molarity of NaOH \_\_\_\_\_\_\_\_\_\_\_M*

*Known % acetic acid \_\_\_\_\_\_\_\_\_%*

1) Write an *equilibrium* equation to show how the acetic acid (weak electrolyte) ionizes in solution. (Make one of the equilibrium arrows large than the other to show which direction is favored.)

2) Write the molecular, complete ionic and net ionic equations to the *complete* neutralization of acetic acid with sodium hydroxide. *(Remember acetic acid is a weak acid.)*

M \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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3) What *species* (compounds or ions) will be present in the flask when the endpoint is reached. (ignoring the indicator)

4) Calculate the molarity of the of your acetic acid sample for the best trial.

*(Hint: your answer will have units of moles of acetic acid/L of vinegar sample)*

5) Convert the molarity of your sample to mass percent of acetic acid in the vinegar. Assume the vinegar has a density of 1.01g/mL. *(Hint: convert to g of acid acetic over grams of vinegar solution and multiply by 100)*

6) Calculate the percent error of your mass percent of acetic acid for your sample.

**Analysis**

1) Explain how the following errors would affect your calculation of the ***% acetic acid*** in your sample.

a) During the standardizing of the NaOH solution you forgot to remove the air bubble in the buret before titrating the KHP.

b) While titrating your vinegar sample you accidently add 2-3 more mL of NaOH after the solution reaches a light pink color.

c) You forgot to add the phenolphthalein to your vinegar sample before titrating.

d) You forgot to add distilled water to the vinegar sample before titrating.

e) ***After weighing*** the KHP during the standardization of NaOH, you spill some on to the lab bench when transferring it to the flask to titrate.