Determination of %Alcohol in Wine using Simple Distillation & Hydrometry

The specific gravity of distilled water is, by definition, equal to one. "Pure" ethanol has a specific gravity of 0.79. It follows, therefore, that a mixture of water and ethanol must have a specific gravity that is less than one: the more alcohol, the lower the specific gravity. The exact nature of this relationship is depicted in Table D-1 and Figure D-2 (see below). However, since wine consists of many other compounds in addition to water and ethanol, the percent alcohol level of wine cannot be accurately estimated by simply measuring its specific gravity.

Fortunately, one can use the process of distillation to extract virtually all of the alcohol (and much of the water) contained in a sample of wine and separate it from its other less volatile constituents. Distillation involves evaporating a liquid into a gaseous vapor and then condensing this vapor back to a liquid state and collecting the resulting "distillate" into a separate receiving vessel. Substances that have a higher boiling point than the desired compound being extracted via distillation (at a given operating temperature) will remain behind in the boiling flask. When wine is boiled, the ethanol begins to vaporize before the water. If boiled for a sufficient length of time, all of the alcohol will be vaporized and extracted from the wine sample prior to the volatilization of most of its other components. The condensed "distillate" collected at this point now contains virtually all of the ethanol from the original sample – but at a lesser volume. If pure water is added to the distillate to bring it back to the same volume as the original wine sample, this reconstituted distillate will have the same percent alcohol (by volume) as the original wine. As such, the distillate can be considered to consist of a simple solution of water plus ethanol. Since the specific gravity of a simple water + ethanol mixtures varies in a lawful way, the percent alcohol in the reconstituted distillate can be accurately estimated by measuring its specific gravity using a short-range hydrometer. The specific gravity measurement can then be easily converted to percent alcohol using either a lookup table or a simple polynomial equation (see Eq. D-1).

Procedure

1. Add exactly 150 mL of room temperature wine to a 250 mL graduated cylinder.
2. Transfer contents of the graduated cylinder to the 250 mL boiling flask.
3. Rinse down walls of the graduated cylinder with approximately 50 mL of distilled water and add this rinse water to the boiling flask (This will capture virtually all of the alcohol still remaining in the graduated cylinder. The extra volume of water will also prevent the flask from boiling dry).
4. Add a few boiling stones to the boiling flask (to prevent violent "bumping" while boiling). Optional: Add a few drops of "anti foam" solution as well.
5. Join the boiling flask to the foam trap (see Figure D-1).
6. Turn-on the cold water intake to keep the condenser cool.
7. Place the 250 mL graduated cylinder under the condenser's output to collect the distillate.
8. Light the Bunsen burner, set to a low flame and bring the wine sample to a slow boil.

9 Keep boiling the wine sample until approximately 140 mL of clear distillate has collected in the graduated cylinder (This takes approximately 30 min depending upon the boiling rate). Make sure that you do NOT allow more than 150 mL of distillate to collect or you will invalidate the procedure.
10 Remove the graduated cylinder from the apparatus and allow its contents to cool to room temperature (A cold water bath can be used to accelerate the cooling process).
11 Once cool, carefully add distilled water to the distillate until the volume reaches 150 mL (The same volume as the original wine sample).
12 Use your short-range hydrometer to measure the specific gravity (SG) of the room temperature distillate. Next, use Table D-1 to convert the specific gravity measure to %Alcohol by volume. Alternatively, you can use a special alcohol hydrometer that's calibrated to read %Alcohol directly (thereby eliminating the need to use the lookup table). Finally, if you're using a SG hydrometer you can use the following equation to convert SG to %Alcohol (very handy for using a computer program to automate this process):

$$\%\text{Alcohol (v/v)} = 8610.6 - (16584 * SG) + (7973.3 * SG^2) \qquad \text{[Eq. D-1]}$$

where **SG** = specific gravity of the distillate returned to the original 150 mL volume

Note:
SO_2 levels exceeding 200 PPM or volatile acidity levels exceeding 0.1 g/L can result in a slight underestimation of the real %alcohol value via hydrometric analysis of the distillate. These artifacts can be minimized by adding 2 drops of 10% NaOH to the sample prior to beginning the distillation process.

Equipment

Hydrometer sample jar (200 mL)
Specific Gravity Hydrometer (short range: 0.970-1.000) or Alcohol Hydrometer (0-20 %Alc (v/v))
Boiling stones; Anti-foam solution
Apparatus depicted in Figure D-1

All glassware with 24/40 joints in MoundTop MicroVinification lab.
Lab stand and various mounting clamps not shown.
Rubber hoses and cold water source required for condenser.
Hose and gas source required for Bunsen burner.
Digital thermometer useful for monitoring distillation progress is optional.

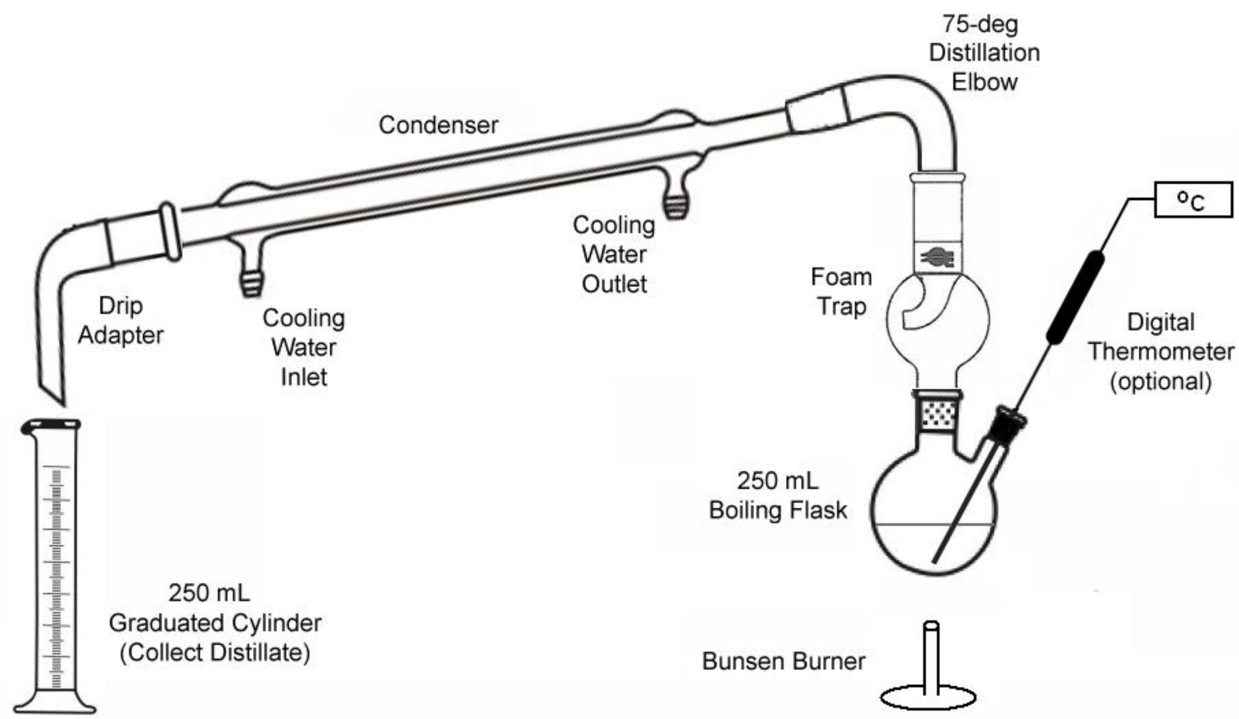

Figure D-1.
Apparatus used for distilling alcohol from a 150 mL sample of wine. Wine sample in boiling flask is vaporized by the heat of the Bunsen burner. Any liquid "bubbling over" from the boiling wine is prevented from entering the condenser by the foam trap. Alcohol and water vapor released from the boiling wine enters the water-cooled condenser where it reverts back to the liquid state. This condensed distillate is an aqueous ethanol solution which is gravity feed into the graduated cylinder receiving vessel.

Table D-1.

Specific Gravity of Aqueous Ethanol Solutions as a function of %Alcohol (v/v)

(Data derived from Amerine & Ough (1974), page 38)

Specific Gravity	%Alcohol (v/v)	Specific Gravity	%Alcohol (v/v)
1.00000	0.0	0.98485	11.5
0.99925	0.5	0.98427	12.0
0.99850	1.0	0.98372	12.5
0.99777	1.5	0.98316	13.0
0.99703	2.0	0.98262	13.5
0.99630	2.5	0.98208	14.0
0.99558	3.0	0.98155	14.5
0.99488	3.5	0.98102	15.0
0.99418	4.0	0.98049	15.5
0.99350	4.5	0.97994	16.0
0.99281	5.0	0.97946	16.5
0.99215	5.5	0.97892	17.0
0.99148	6.0	0.97841	17.5
0.99085	6.5	0.97791	18.0
0.99021	7.0	0.97741	18.5
0.98960	7.5	0.97691	19.0
0.98898	8.0	0.97642	19.5
0.98838	8.5	0.97593	20.0
0.98778	9.0	0.97543	20.5
0.98719	9.5	0.97493	21.0
0.98659	10.0	0.97442	21.5
0.98600	10.5	0.97393	22.0
0.98542	11.0		

This data is graphically presented in Figure D-2 (see next page).

Note:

The specific gravity of aqueous ethanol solutions changes very little as the percent alcohol increases from 0 to 22%. Since the hydrometers typically used to monitor fermentation might cover the range between 0.98 and 1.18, it would be very difficult to collect precise measurements across the 0.97 to 1.0 range expected in distillates collected from table wines and fortified wines. Instead, a “short-range” hydrometer with a range between 0.96-1.00 is preferable for accurate %alcohol estimation using the distillation procedure. Special hydrometers calibrated in %alcohol (from 0-20%) are also available (but tend to be somewhat expensive).

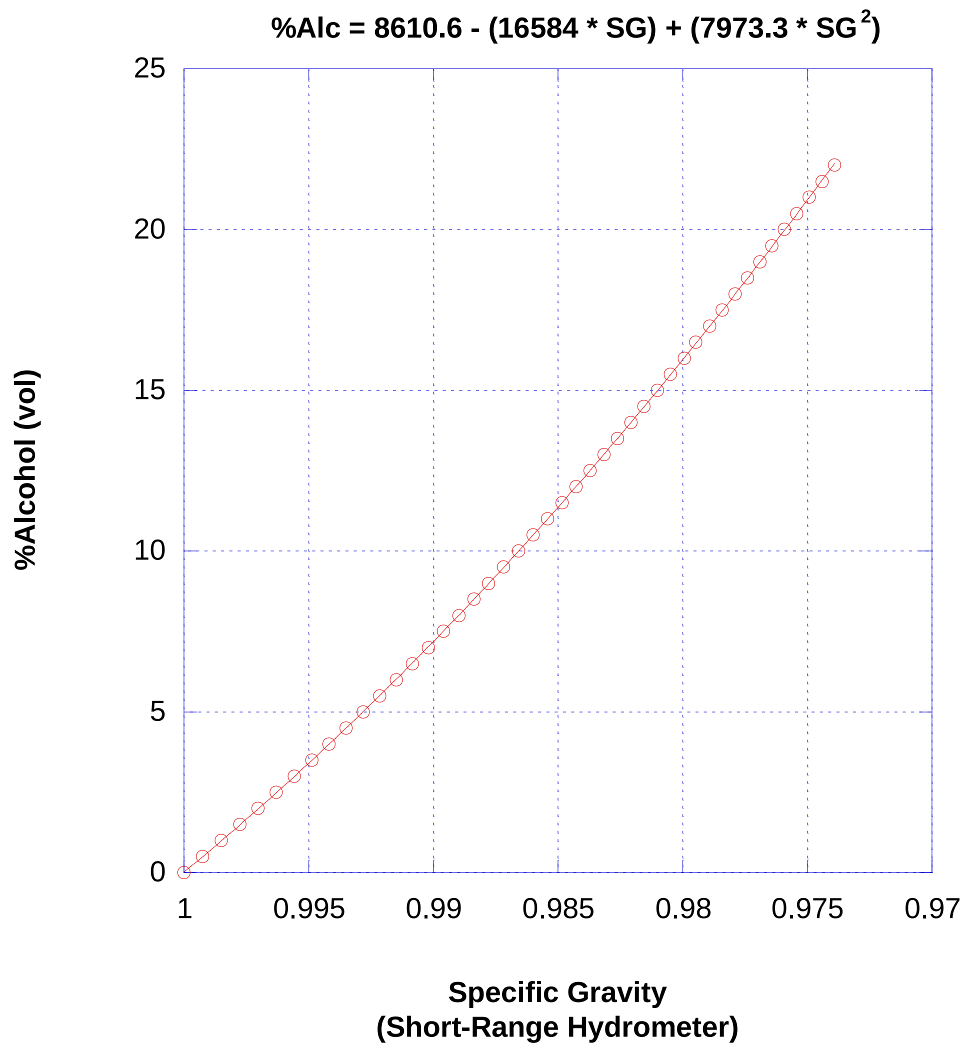

Figure D-2.

Relationship between specific gravity and the %Alcohol (by volume) in an aqueous solution of ethanol plus distilled water.

Reference

Amerine, M.A. & Ough, C.S. (1974). *Wine and must analysis*. New York: John Wiley & Sons.