Determination of the Molar Mass of Ethanol

Abstract: The molar mass of ethanol was determined by using the ideal gas law. The gas was volatilized in a fixed volume at atmospheric pressure in a 99.3 °C water bath. The molar mass was determined to be 45.2 ± 0.3 g/mol.

Equation summary:

PV=nRT $\quad PV = \frac{m}{M}RT \quad MolarMass = M = \frac{m}{n}\left[\frac{g}{mole}\right] \quad M = \frac{mRT}{PV}$

Data

m(empty flask) = 82.36g
m(flask with ethanol) = 82.76, 82.77, 82.76g
T=99.8 °C
V= 272.27 mL
P=752 mm Hg

Results

$m_{ethanol}$(average)= 0.403g ethanol
$n_{ethanol}$(average)= 8.80E-3mol ethanol
$MM_{ethanol}$= 45.8±0.7g/mol

Discussion

Using the procedure outlined above, an average molar mass of 45.8±0.7g/mole was determined for ethanol. The molar mass obtained from the periodic table for ethanol is 46.069g/mole. This value is well within the limits of the precision of this method. The primary source of error is in the mass measurement, which had a standard deviation of 1.5%.

The method could be improved by using a more precise balance to decrease the error in the mass measurements. It is also interesting to note that the molar mass was found to be slightly smaller than the literature value. This might be the result if the mass of gas is less than the amount that would truly fill that volume at that temperature and pressure. Using this procedure, this type of deviations is likely because some air may remain or re-enter the flask, making the volume accessible to ethanol smaller. Therefore, less ethanol would be present and the measured mass would be smaller than that required to actually fill the true volume. This will appear as a low molecular weight as was determined in this experiment.

Another source of error might be the pressure reading. The pressure in the flask is likely near that of the surroundings, but if may be slightly larger as long as more gas is leaving the vessel as is entering. Thus a pressure meter in the flask would give the best results for the molar mass determination.

Conclusion

The molar mass of a volatile solvent was determined to be 45.8±0.7g/mole. This is a surprisingly precise result given the lack of precision of the pan balances. It should be noted that the ideal gas law appears to be accurate to at least 1% (relative to actual molar mass) with ethanol at 1 atm and 100 °C.

Sample Calculations

Mass by difference: $m_{ethanol} = m_{flask\ with\ ethanol} - m_{flask\ without\ ethanol}$ = 82.76g - 82.36g = 0.40g

Average: $m_{average}$(ethanol)=(0.40g+0.41g+0.40g)/3=0.403g

$$\text{Standard Deviation}: \left(\frac{(0.40g-0.403g)^2+(0.41g-0.403g)^2+(0.40g-0.403g)^2}{2}\right)^{\frac{1}{2}} = 0.006g$$

T(K)=99.8 °C + 273.15K=372.95K

$$\mathrm{V(L)} = 272.27\mathrm{mL}\left(\frac{1\mathrm{L}}{1000\,\mathrm{mL}}\right) = 0.27227L \qquad \mathrm{P(atm)} = 752\ \mathrm{mm\ Hg}\left(\frac{1\,\mathrm{atm}}{760\ \mathrm{mm\ Hg}}\right) = 0.989atm$$

$$MM_{ave} = \frac{m_{ave}RT}{PV} = \frac{(0.403g)\left(0.08206\frac{Latm}{moleK}\right)(372.95K)}{(0.989atm)(0.27227L)} = 45.80\frac{g}{mole} \qquad Error\,\mathrm{Pr}opagation: MM_{ave}\left(\frac{\Delta m}{m}\right) = 45.80\frac{g}{mole}\left(\frac{0.006g}{0.403g}\right) = 0.7\frac{g}{mole}$$