

**C125 Laboratory Experiment #5**  
**Gas Laws**  
**Example Calculations**

Complete the following calculations to assist you with calculating the molecular weight of butane, the molecular weight of the unknown gas, the estimate of the uncertainty based upon random (equipment) error, and the relationship between pressure and volume of a gas.

**Part I.**

Use the following sample data (the gas in the data is X – NOT butane):

Mass of gas delivered = 0.1089 g  
 Temperature of water = 23.8° C = 296.95 K  
 Volume of gas = 0.0940 L  
 Atmospheric pressure on day of experiment = 30.25 in Hg = 1.011 atm\*  
 Vapor pressure of water from *CRC Handbook* = 2.92008 kPa = 0.02911 atm\*

\*Use the unit conversions on pg. 36 of the Lab Manual.

1. Calculate the partial pressure of the gas in the graduated cylinder.

Make sure the water level in the grad cylinder is the same as the water level in the trough. Then, the gas in the cylinder has the same pressure as the atmospheric pressure.

$$P_{\text{atm}} = P_{\text{X}} + P_{\text{H}_2\text{O}}$$

Example:

$$P_{\text{X}} = P_{\text{atm}} - P_{\text{H}_2\text{O}} = 1.011 \text{ atm} - 0.02911 \text{ atm} = 0.9819 \text{ atm}$$

2. Calculate the molecular weight of the gas.

$$\text{MW} = gRT/PV$$

Example:

$$\text{MW}_{\text{X}} = \frac{(0.1089 \text{ g}) (0.08206 \text{ L atm/mol K}) (296.95 \text{ K})}{(0.9819 \text{ atm}) (0.0940 \text{ L})}$$

$$\text{MW}_{\text{X}} = 28.751 \text{ g/mol} = \text{MW}_{\text{exp}}$$

3. Estimate the uncertainty of the devices used to measure mass, temperature, and volume. These values help determine the precision and the random error of the experimental data based upon the instrumentation.

Example: Estimate uncertainties of each instrument first:

(balance) An analytical balance reads a mass  $\pm 0.0001$  g. An object which has a recorded mass of 2.4987 g in the laboratory could actually be

$$+ 0.0001 \text{ g} \rightarrow 2.4988 \text{ g}$$

or

$$- 0.0001 \text{ g} \rightarrow 2.4986 \text{ g}$$

(barometer) The pressure is recorded  $\pm 1$  mm Hg. Convert 1 mm Hg to atm\* to determine the variance in the pressure in atm.

$$P = \pm 1 \text{ mm Hg} = \pm 0.001315 \text{ atm}$$

(thermometer) Typically, a human is able to read a thermometer to the nearest half degree.

$$T = \pm 0.5 \text{ }^\circ\text{C} = \pm 0.5 \text{ K}$$

(graduated cylinder) Typically, a human is able to read a graduated cylinder to the nearest two tenths of a milliliter:

$$V = \pm 0.2 \text{ mL} = \pm 0.0002 \text{ L}$$

6. Calculate the uncertainty of the experimental molecular weight:

You will calculate an upper limit and a lower limit for the range of experimental values according to the uncertainty (random error) from the instrumentation.

$$MW = gRT/PV$$

UPPER LIMIT: Calculate the largest possible numerator and the smallest possible denominator.

$$MW_{max} \rightarrow \text{large numerator} \rightarrow \begin{aligned} g &= 0.1089 + 0.0001 \text{ g} = 0.1090 \text{ g} \\ T &= 296.95 + 0.5 \text{ K} = 297.45 \text{ K} \\ R &\text{ is a constant} \end{aligned}$$

$$\rightarrow \text{small denominator} \rightarrow \begin{aligned} P &= 0.9819 - 0.0013 \text{ atm} = 0.9806 \text{ atm} \\ V &= 0.0940 - 0.0002 \text{ L} = 0.0938 \text{ L} \end{aligned}$$

$$MW_{max} = \frac{(0.1090 \text{ g}) (0.08206 \text{ L atm/mol K}) (297.45 \text{ K})}{(0.9806 \text{ atm}) (0.0938 \text{ L})} = 28.925 \text{ g/mol}$$

LOWER LIMIT: Calculate the smallest possible numerator and the largest possible denominator

$$MW_{min} \rightarrow \text{small numerator} \rightarrow \begin{aligned} g &= 0.1089 - 0.0001 \text{ g} = 0.1088 \text{ g} \\ T &= 296.95 - 0.5 \text{ K} = 296.45 \text{ K} \\ R &\text{ is a constant} \end{aligned}$$

$$\rightarrow \text{large denominator} \rightarrow \begin{aligned} P &= 0.9819 + 0.0013 \text{ atm} = 0.9832 \text{ atm} \\ V &= 0.0940 + 0.0002 \text{ L} = 0.0942 \text{ L} \end{aligned}$$

$$MW_{min} = \frac{(0.1088 \text{ g}) (0.08206 \text{ L atm/mol K}) (296.45 \text{ K})}{(0.9832 \text{ atm}) (0.0942 \text{ L})} = 28.577 \text{ g/mol}$$

NOTE: The maximum value calculated for the MW should be greater than the experimental value and the minimum molecular weight should be lower than the experimental value.

The range based upon the uncertainty is:

$$MW_{\max} = 28.925 \text{ g/mol}$$

$$MW_{\text{exp}} = 28.751 \text{ g/mol}$$

$$MW_{\min} = 28.577 \text{ g/mol}$$

The max should be about the same amount above the experimental value as the min is below it:

$$MW_{\max} - MW_{\text{exp}} = 28.925 - 28.751 \text{ g/mol} = +0.174 \text{ g/mol}$$

$$MW_{\min} - MW_{\text{exp}} = 28.577 - 28.751 \text{ g/mol} = -0.174 \text{ g/mol}$$

The uncertainty limits the number of significant digits. (Use the first non-zero digit. The variance is in tenths place).

Report your answer:

$$MW_x = 28.8 \pm 0.2 \text{ g/mol}$$

(FYI: How does the uncertainty compare with the standard deviation calculated in step #4 of the calculations, pg 34 of experiment #5?)

## Part II.

1. The lowest reading on the pressure gauge is 0 psi (pounds per square inch). This value corresponds to atmospheric pressure. You must add the atmospheric pressure given in class ( $P_{\text{atm}}$ ) to the gauge reading (psig) to obtain the actual pressure (psia) in the syringe.

$$\text{psia} = \text{psig} + P_{\text{atm}}$$

Example:

$$\text{psig} = 0 \text{ psi}$$

$$P_{\text{atm}} = 14.61 \text{ psi}$$

$$\text{psia} = \text{psig} + P_{\text{atm}} = 0 + 14.61 \text{ psi} = 14.61 \text{ psi}$$

2. You will make two EXCEL plots, P vs V and P vs 1/V). Plot V on the x-axis and P on the y-axis. The gas constant, R, has units of [L atm/mol K]. Make sure the values you enter for P have units of atm and the volume units are in L. Which plot is LINEAR?
3. Rearrange the ideal gas equation to solve for P (on the y axis):

$$PV = nRT \rightarrow P = nRT (1/V)$$

What does the slope equal, algebraically? slope = m = ?

Substitute the value calculated for the slope (linear EXCEL plot) into this equation, use R and the temperature of the room in K. Determine the number of moles of air (n) in the syringe.