Using the MicroLab pressure sensor to determine the moles of CO_2 produced in the reaction between $NaHCO_3$ and acetic acid

The Ideal Gas Law, PV=nRT, is used to find the moles of gas produced in the acid-base reaction:

$$CH_3COOH\ (aq) + NaHCO_3\ (s) \rightarrow H_2O + CH_3COONa\ (aq) + CO_2\ (g)$$

P_{CO2} and T are found using the MicroLab FS522 and software. The volume of the gas produced is measured by finding the mass of water required to fill the flask-stopper-hose assembly used in this experiment. R is the gas constant in units of L atm mol^{-1} K^{-1}. Students compare the number of moles produced in the reaction as calculated by PV = nRT with the number of moles expected based on the stoichiometry of the reaction and mass of $NaHCO_3$ used. Students complete the calculations by demonstrating that $NaHCO_3$ is the limiting reagent based on the stoichiometry of the reaction.

Apparatus:

A dry 250 mL flask is fitted with 2-hole rubber stopper. In one hole of the stopper is placed an on/off Luer Lock stopcock, to be fitted later into a 3 mL plastic syringe. A A snug-fitting hose is placed into and through the second hole, the other end of which attaches directly to the MicroLab pressure sensor input. This should be tested for leaks to make sure that all seals are air tight. **The Luer Lock fittings, tubing, and syringes are available from MicroLab or** or from various suppliers**.** The volume of the gas formed is the same as the volume of the flask assembly and hose to the pressure sensor connector on the MicroLAB unit, which must be measured when the reaction is complete.

The MicroLab FS522 Role:

To build this experiment in the MicroLab software, three sensors are used: pressure, thermistor temperature, and time. The pressure (torr) sensor set up on the y-axis as well as in the spreadsheet and in the digital display. Time (seconds) is placed on the x-axis. A thermistor is used to get the air temperature, which is a good approximation of the system temperature. Alternatively, the entire flask assembly can be placed in a large beaker of water to maintain a constant temperature.

Procedure:

Approximately 1 mmol of $NaHCO_3$ (1 mmol = 0.0840 grams), weighed precisely, is placed into one side of the bottom of the flask as shown in the photo, and the stopper attached. Next, 3 mL of white vinegar (5% CH_3COOH) is loaded into the syringe and, with the Luer Lock stopcock closed, the syringe is twisted tightly onto the stopcock. The “Start Experiment” button is pressed on MicroLAB screen. Once a baseline pressure is confirmed, the stopcock is opened and the vinegar is ***injected into side of the flask opposite the*** $\boldsymbol{NaHCO_3}$***,*** and the stopcock closed. (We like to tilt the flask to be certain the vinegar ends up on the opposite side of the flask than the baking soda). This allows the system to adjust for any pressure change due to the injection and to the vapor pressure of the water in the vinegar solution. A new baseline pressure is confirmed. Next, the flask is gently swirled to allow the reagents to mix completely. Data are collected until the MicroLab pressure vs. time graph levels off (see the Figure). The experiment is stopped, and data are analyzed. P_{CO2} is taken as the difference between the maximum, constant final pressure and the baseline pressure after injection of vinegar. The software can be used to get the average temperature.

Sample calculations from an actual trial:

Mass of $NaHCO_3$ = 0.0840 g = 1.00 mmol
Volume of vinegar added: 3.0 mL (*ca*. 2.5 mmol)
PV=nRT and so n=PV/RT
P_{CO2} = P(final) − P(new baseline after Injection)

= (800.79-735.95) torr/760torr/atm = .0853 atm
V_{CO2} = V(flask assembly) = 292.3 mL=.2923 L

R= 0.0821 L*atm/K*mol
T= 23.783 ^{o}C = 296.933 K
n = (0.0853 atm)(0.2923 L)/(0.082144 L*atm/K*mol)(296.933 K)

= 0.00102 mol CO_2 formed
moles CO_2/moles $NaHCO_3$ = 0.00102/0.00100 = 1.02/1

Conclusions:

This experiment is a safe, easy to use, and easy to understand application of pressure measurements to get accurate information about a chemical reaction involving a gas. There is time in lab to do multiple runs. Thus there is plenty of time in lab for doing calculations and discussing results in the context of limiting reagents, balanced equations, and sources of error. It is also possible to extend this lab by varying the amount of vinegar and/or the amount of $NaHCO_3$ to prepare a plot of P_{CO2} vs. mole ratio of $NHCO_3/CH_3COOH$ to determine reaction stoichiometry. This experiment is a great example of how MicroLAab has changed how students learn in lab.

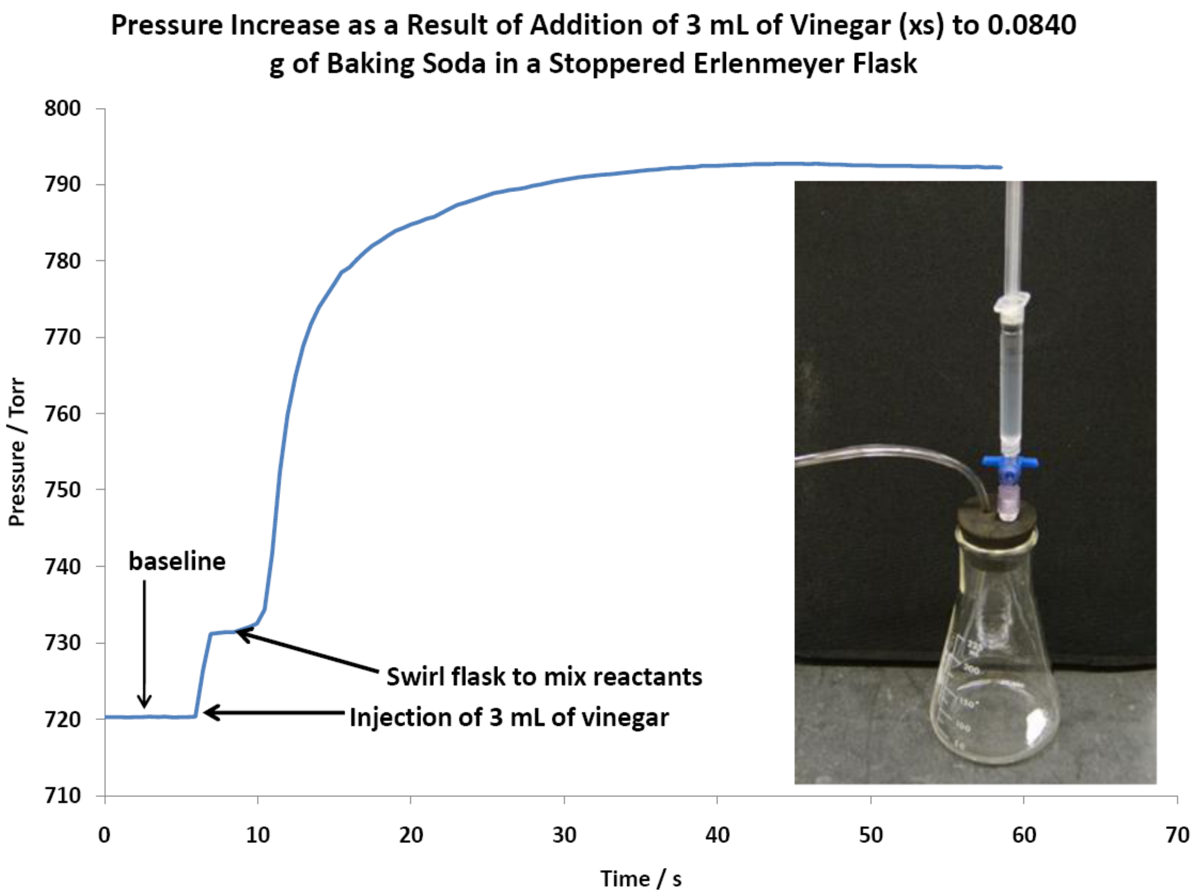

Figure: The plot shows a 7 sec baseline after which the vinegar was injected, but not allowed to come in contact with the sodium bicarbonate. The pressure rise between 7-8 sec is due to the vapor pressure change and the ~1% decrease in air volume from adding the solution. At the 10 sec mark, the flask was swirled to initiate the reaction. The reaction was complete one minute later.