Lab-09:
March 25th

Objectives:
Measure the pressure in the room and measure the molar density of air.

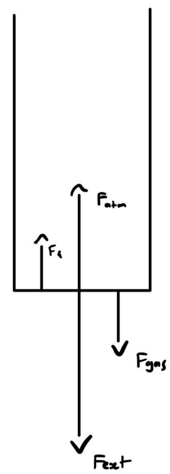
Revised Procedure:
1. Use a vernier caliper to measure the syringe's diameter.
2. Adjust the syringe to a 3 ml volume before inserting the stopper.
3. Place the syringe on the holder.
4. For each mass (500g, 1000g, 1400g, and 1500g), attach it to the syringe and record the resultant volume.
5. Calculate frictional force by creating a new line that accounts for pressure compression so by taking the midline we can calculate the intercepts without friction (Edit 1. Add frictional force to make overall calculations much more accurate)
6. Plot a graph of the force versus the inverse volume.
7. Draw a straight line that best fits the data points.
8. Determine the y-intercept and adjust this intercept to compensate for the friction force (Edit 2. makes calculations much more accurate as we integrate all forces) (edit 3. Determine the average of the two y intercepts in order to calculator the kPa without frictional force for a more accurate result)
9. Calculate the atmospheric pressure (Patm) in Pascals (PA) by dividing the average y-intercept by the syringe's cross-sectional area.
10. Find the amount of gas (in moles) by taking the graph's slope, dividing it by the product of the syringe's cross-sectional area, the gas constant, and the temperature (in Kelvin).
11. Calculate the molar volume by dividing the total moles of gas by the initial volume.

Frictional Force:
In our initial equation

$$F_{external} = -F_{gas} + F_{atmosphere} + F_{friction}$$

The adding of the terms $F_{atmosphere} + F_{friction}$ accounts for expansion. We can now change this to $F_{atmosphere} - F_{friction}$ to account for friction on compression. We can take the average between these two lines to get the y-intercept where there is no friction.

Figure 1. Free body diagram

Free body diagram


Constants:

Table 1. Area of Syringe

Area of syringe in m^2
$2.00 \cdot 10^{-4} \pm 1.00 \cdot 10^{-6}$

Table 2. Gas constant

Gas constant in $L \cdot Kpa \cdot K^{-1} \cdot mol^{-1}$
8.314472

Table 3. Room temperature

Room temperature in kelvin
293.15

Table 4. Vancouver P_{atm}

Atmospheric pressure at YVR in kPa
101.0

Table 5. Molar Density of Air

Molar density of air in moles per liter
0.04159

Equations:

$$F_{friction} + F_{atmosphere} = F_{gas} + F_{external}$$

$$F_{external} = -F_{gas} + F_{atmosphere} + F_{friction}$$

$$mg = -\frac{(AnRT)}{V} + AP_{atm} + F_{friction}$$

And

$$mg = -\frac{(AnRT)}{V} + AP_{atm} - F_{friction}$$

Data:

Table 6. Volume as a function of mass with an initial volume of 3mL

Mass in grams (g) $\pm$ 0.5g	Volume in liters (L) $\pm$ 0.00005L
0	0.0030
500	0.0036
600	0.0043
700	0.00501
800	0.00572
900	0.00643
1000	0.00713

1100	0.00784
1200	0.00855
1300	0.00925
1400	0.00996
1500	0.01067

Table 7. Force as a function of the inverse of volume with an initial volume of 3mL

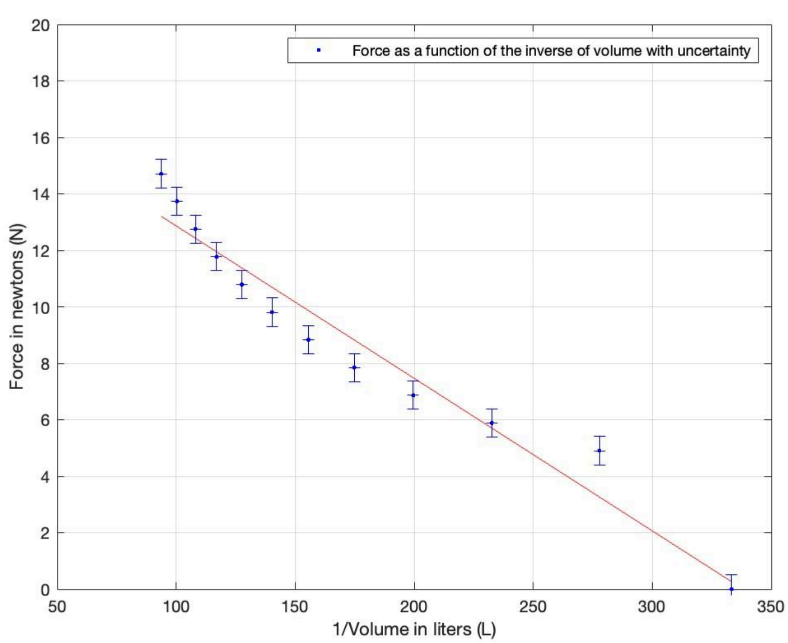
Force in newtons (N) ± 0.5N	1/Volume in liters (L) ± 0.00005L
0	333.3333333
4.905	277.7777778
5.886	232.5581395
6.867	199.6007984
7.848	174.8251748
8.829	155.5209953
9.81	140.2524544
10.791	127.5510204
11.772	116.9590643
12.753	108.1081081
13.734	100.4016064
14.715	93.72071228

Table 8. Force as a function of the inverse of volume with an initial volume of 3mL for compression

Force in newtons (N) ± 0.5N	1/Volume in liters (L) ± 0.00005L
0	327.2091436

4.905	271.653588
5.886	226.4339498
6.867	193.4766087
7.848	168.7009851
8.829	149.3968056
9.81	134.1282647
10.791	121.4268307
11.772	110.8348746
12.753	101.9839184
13.734	94.27741668
14.715	87.59652254

Figure 2. Force as a function of the inverse of volume with an initial volume of 3mL



```
m=result(1,2)
```

m = -0.0540

with uncertainity

```
del_m=abs(m-ci(2,2))/gof.rmse
```

del_m = 0.0021

y-intercept is

```
b=result(1,1)
```

b = 22.2125

with uncertainity

```
del_b=abs(b-ci(1,1))/gof.rmse
```

del_b = 0.4138

Calculations and Uncertainty:

Figure 3. Image of calculations

$F_{external} = -F_{gas} + F_{atm} + F_{friction}$

$mg = -\frac{AnRT}{V} + AP_{atm} + mg_{friction}$

$m = -0.0540$

del m

0.0021

$m_{slope} = -AnRT$

$-0.0540 = -AnRT$

$0.0540 = (2.00\times10^{-4})\,n\,(8.314472)(293.15)$

$\frac{n}{V}$ = molar density

and accounting for units we get

$0.0369247816 \text{ mol}/$

$b_{average} = 20.129$

$b_{average} = \frac{18.0455 + 22.2125}{2}$

$b = AP_{atm}$

$20.129 = (2\cdot10^{-4})P_{atm}$

$P_{atm} = 100645$

$= 100.645 \text{ kPa}$

Figure 4. Uncertainty calculations

$$\frac{\partial P_{atm}}{P_{atm}} = \sqrt{\left(\frac{2\partial r}{r}\right)^2 + \left(\frac{\partial b}{b}\right)^2 + \left(\frac{\partial F_f}{F_f}\right)^2}$$

$$\partial n = \sqrt{\left(\frac{\partial n}{\partial T}\right)^2 \partial T^2 + \left(\frac{\partial n}{\partial m}\right)^2 \partial m^2 + \left(\frac{\partial n}{\partial A}\right)^2 \partial A^2}$$

$$\partial_{density} = \sqrt{\left(\frac{\partial den}{\partial n}\right)^2 \partial n^2 + \left(\frac{\partial den}{\partial v}\right)^2 \partial v^2}$$

Final Values:

$P_{atm} = 100.645 kPa \pm 0.7 kPa$

$Molar\ density = 0.0369 mol/L \pm 0.002 mol/L$

Reflection:

This experiment aimed to derive precise values for the atmospheric pressure and the molar density of air by accounting for various factors such as the syringe's diameter, the volume of air under different masses, and the application of corrections for frictional forces. The final measurements yielded an atmospheric pressure of 100.645 kPa, slightly below the standard atmospheric pressure of 101.0 kPa expected in Vancouver, and a molar density of air at 0.0369 mol/L, lower than the standard value of 0.04159 mol/L. These differences, albeit modest, hint at potential areas of improvement and sources of error in the experimental setup.

The methodology of reading volumes with the human eye, although practical, introduces a subjective element prone to errors, potentially skewing measurements. The precision of instruments used, such as the vernier caliper for measuring the syringe's diameter, may also contribute to the overall uncertainty. Moreover, the experiment's foundation on the assumption that air behaves ideally might not hold entirely under laboratory conditions, affecting the accuracy of the derived values. The effort to correct for frictional forces, though useful, might not capture the complete impact of these forces on the experiment's outcomes.

To enhance the reliability and accuracy of future experiments, several improvements can be implemented. Adopting digital measurement tools could significantly reduce subjective errors in volume readings. Refining the experimental design to account for non-ideal gas behaviors, possibly through the application of more complex gas laws, could provide results that align more closely with standard values. Additionally, a detailed investigation into the effects of frictional forces and their accurate quantification could refine the corrections applied and improve the experiment's precision. All in all, I think it is safe to say this experiment was carried out fairly well given the constraints of this lab