

Experiment 1. Verification of Charles' Law and Boyle's Law

Written by:

Justin Kearney, 300086610

and

Jong Hyun (James) Kim, 300082080

TA: Jacky Deng

Date: September 21st, 2018

Introduction:

Gases take up more space when they have a higher temperature. Charles' law describes the relationship between the volume of a gas and its temperature. It states that the volume occupied by a certain amount of gas is proportional to its temperature in Kelvin at a constant pressure.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

If there is a gas trapped inside of a container and then the volume of the container changes, the pressure is also changed. Assuming that before and after the change temperature and the amount of gas stays constant, the pressure will change inversely proportional to the volume of the container. That is Boyle's law.

$$P_1V_1 = P_2V_2$$

An ideal gas is a theoretical gas where the particles are so small and far apart that they are negligible meaning they don't have a considerable volume or attraction to one another. An ideal gas always satisfies the equation $PV = nRT$. In reality though, the particles in gases do exert forces on one another and their volumes are not negligible. The deviations from the expectations of the equation become increasingly noticeable as the gas changes from low pressure and high temperature to high pressure and low temperature. (Olmstead, Williams, Burk)

Procedure:

Experiment 1: Verification of Charles' Law

As written in lab manual (Venkateswaran)

Experiment 2: Verification of Boyle's Law

1. Acquire: Gas pressure sensor, plastic syringe
2. Turn on LabQuest and plug in the gas pressure sensor
3. Move plunger to volume chosen by the group
4. Attach syringe to gas pressure sensor by putting in and rotating 180°
5. Record initial volume
6. Move the plunger in the syringe to different volumes
7. Give the labquest a second to stabilize after moving the plunger.
8. After pressure stabilizes record data and repeat steps 6 and 7 as many times as necessary
9. After recording sufficient data return the plunger to its original pressure and record the volume again
10. Choose either the first or last measurement and cross out the over
11. Export data onto USB drive

12. Return equipment and clean work space

Observations/Data:

Table 1. Data From Testing Charles' Law

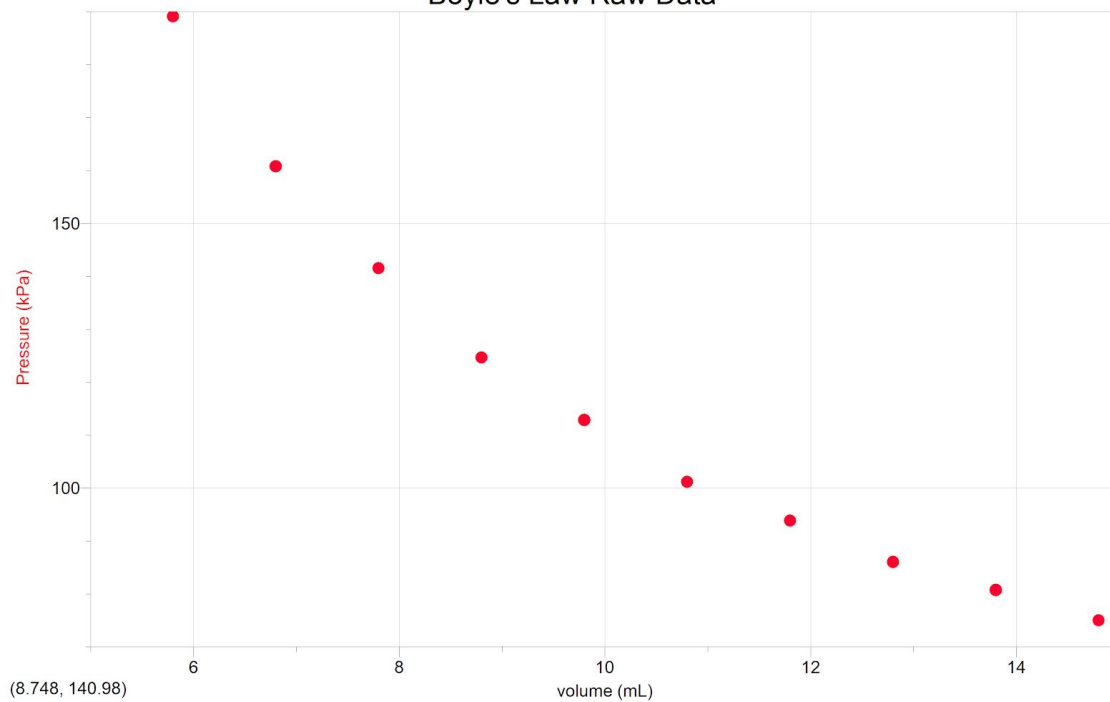
	T_1 (°C)	V_1 (mL)	T_2 (°C)	V_{cw} (mL)	V_2 (mL)	V_1/T_1 (mL/K)	V_2/T_2 (mL/K)
Trial 1	101.0	152	4.0	33.5	119	0.406	0.429
Trial 2	98.5	155	6.0	32.5	123	0.417	0.441

Table 2. Data/Results From Testing Boyle's Law

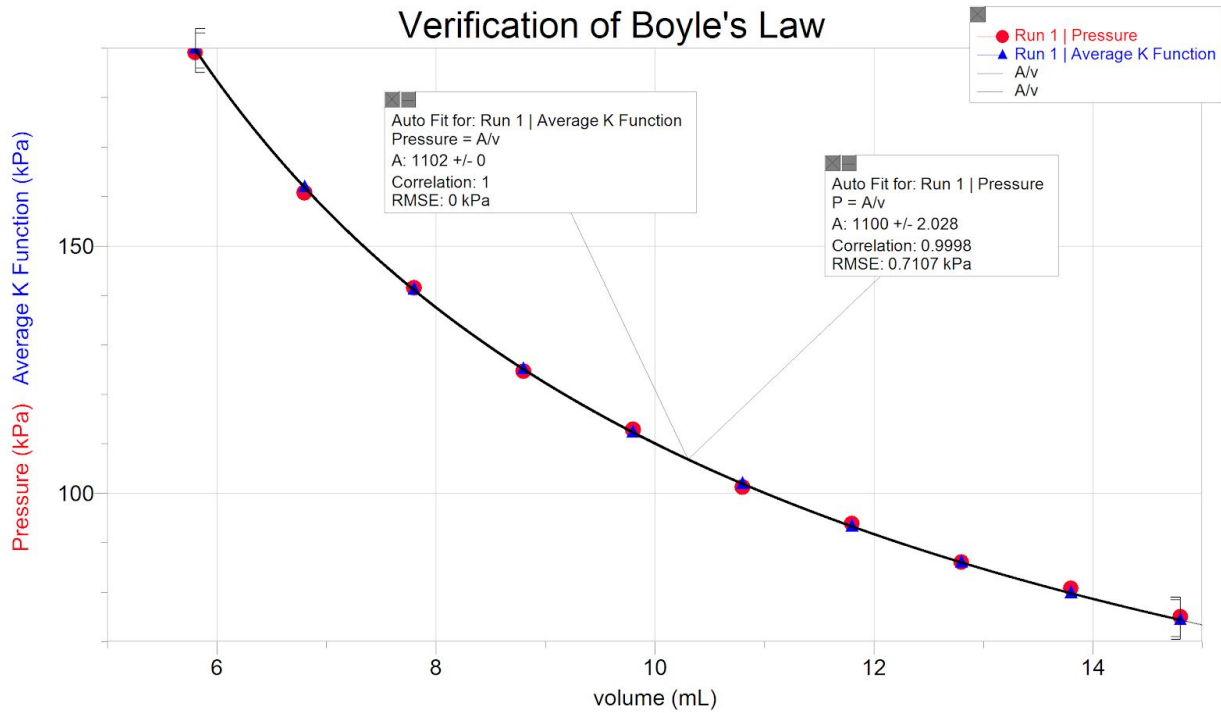
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Trial 11
V (ml)	10.8	9.8	8.8	7.8	6.8	5.8	11.8	12.8	13.8	14.8	10.8
P (kPa)	101.21	112.87	124.67	141.56	160.77	189.10	93.86	86.06	80.76	75.05	103.70
k (kPa·mL)	1090	1106	1097	1104	1093	1097	1108	1102	1114	1111	

Graph no. 1

Boyle's Law Raw Data



Graph no. 2



From the data k_{avg} was determined to be 1102 kPa·mL so the P-V curve on a graph should be $P=1102/V$. Plotting the points by plugging the experimental volumes into the function gives us the graph above.

- There was difficulty pushing syringe past 5mL
- There was difficulty pulling syringe back past 15mL

Calculations:

Finding V_2 from V_{cw}

$$V_2 = V_1 - V_{\text{cw}}$$

$$V_2 = 152\text{mL} - 33.5\text{mL}$$

$$V_2 = 119\text{mL}$$

Conversion to Kelvin from $^{\circ}\text{C}$

$$K = ^{\circ}\text{C} + 273.15$$

$$K = 101.0 + 273.15$$

$$K = 374.2\text{K}$$

Charles' Law Constant

$$k = \frac{V}{T}$$

$$k = \frac{152\text{mL}}{374.2\text{K}}$$

$$k = 0.406\text{mL/K}$$

$$k_{avg} = \frac{(k_1+k_2+k_3+k_4)}{4}$$

$$k_{avg} = \frac{(0.406+0.429+0.417+0.441)}{4} \text{ mL/K}$$

$$k_{avg} = 0.423\text{mL/K}$$

Boyle's law constant

$$k = PV$$

$$k = (101.21 \text{ kPa})(10.8 \text{ mL})$$

$$k = 1090 \text{ kPa} \cdot \text{mL}$$

$$k_{avg} = \frac{(k_1+k_2+k_3+\dots+k_{10})}{10}$$

$$k_{avg} = \frac{(1090+1106+1097+1104+1093+1097+1108+1102+1114+1111)}{10} \text{ kPa} \cdot \text{mL}$$

$$k_{avg} = 1102 \text{ kPa} \cdot \text{mL}$$

% Error calculation for Charles' law

$$\%error = \frac{\frac{V_1 - V_2}{T_1 - T_2}}{\frac{V_1}{T_1}} \times 100\%$$

$$\%error = \frac{0.406 - 0.429}{0.406} \times 100\%$$

$$\%error = -5.66\%$$

%Deviation from k_{avg} for Boyle's law

$$\%dev = \frac{k_1 - k_{avg}}{k_{avg}} \times 100\%$$

$$\%dev = \frac{1090 - 1102}{1102} \times 100\%$$

$$\%dev = -1.1\%$$

Discussion:

In the experiment for the verification of Boyle's law a syringe was attached to a pressure sensor. The results showed an inverse relationship ($P \propto 1/V$) between pressure and volume as stated in Boyle's law. An average "k" value of $1102 \text{ kPa} \cdot \text{mL}$ was determined by multiplying the pressures with their respective volumes then taking the average. The greatest outliers had a percent deviation of $\pm 1.1\%$ from the average value.

Using the value k_{avg} an inverse function that shows the pressure vs. volume was made. The function $P = 1102/V$ was graphed on top of the plotted raw data values in Graph no. 2. The two graphs are nearly identical with little deviation due to limitations of the markings on the syringe, and the ability for a person to push the syringe to the exact volume. Furthermore after the syringe was pushed or pulled to the correct volume, the pressure on the pressure reader fluctuated due to the slight movements of the experimenter's hand. The striking resemblance between the plotted data and the function proves that the data from the lab follows the inverse relationship that is stated in Boyle's law.

The results were as expected with little deviation because of the precision of the air pressure sensor and the simplicity of the experiment with the most uncertain factor being the experimenter using the syringe. However, a wider range of volumes could not be tested because the more extreme values for volume (i.e. 1.8 or 19.8 mL) are past the limitations of the syringe and the strength and stability of the experimenter's hand. For example, if a volume of 1.8 mL was used the pressure inside the sensor and the syringe would be around 610 kPa according to the function. This is an unreasonable amount of pressure for the equipment and the experimenter to control. This limitation prevented the use of a wider range of usable data, leaving a narrower range of volumes and pressure to work with. Because we cannot reach the incredibly high and low pressures there is no way to determine if Boyle's law applies in these extremes using this experiment setup. Therefore, Boyle's law was only verified for the small range of pressures and not extreme ones.

The starting volume of the experiment was recorded twice during the experiment, once at the beginning and once at the end. The last measurement was 2.49 kPa higher than the first. This could be due to 3 factors, if we look at the ideal gas law $PV = nRT$ there are 3 variables (V, n and T) that can impact the pressure. $P \propto 1/V$ and $P \propto n$ and T. Therefore, a rise in temperature, a

rise in the amount of air and a decrease in volume could have caused the change. The experiment was done in a stable environment, away from any sources of heat or cold objects. Furthermore, the miniscule amount of heat from the experimenter's hand would not change the temperature of the air through the plastic. The volume was lined up perfectly to the 10mL mark both times but could be due to the volume because of the miniscule hand movements fluctuating the pressure. The amount of air is most likely the cause of this difference in pressure. The volume used prior to the last measurement was 15.8mL which was the greatest volume used. Because of the low pressure inside the syringe it is possible that the air in the atmosphere leaked into the low pressure environment inside the syringe. This could have happened through the connection between the syringe and the pressure reader or through the rubber on the plunger.

As an increase in the amount of air was likely the cause of this difference the final value was crossed out, as the most air would have seeped in on the 2nd last (15.8mL) measurement. This renders the final (10.8mL) measurement less reliable than the first 10.8mL measurement. Because the air likely seeped into the syringe after the majority of measurements were made the final measurement for 10.8mL was cut from the data table.

From the theory of Charles' law, the value of the ratio between the volume and the temperature of the gas should be constant for the 2 distinct moments where the temperature and volume were measured in each of the trials. This should be true because every gas of defined pressure and amount has its own constant. We can not compare the constants from the resulting from the trials directly because there is not a constant number of moles of gas.

When comparing the the values of V_1/T_1 and V_2/T_2 in both trials, it is evident that the values are not identical but are near each other. The percent error for the first trial is -5.66% and for the second trial it is -5.76%. These results are precise because they are very similar but are lacking in accuracy because the second trial is always higher. This could be due to two things; limitations in the procedure and/or the fact that real gases don't behave exactly like ideal gases.

One limitation in the procedure is that the temperature readings of the gases were not taken from the gases directly but by the environment that was transferring thermal energy to the gases (boiling water) or absorbing the thermal energy from the gases (ice bath). The gases were most likely not exactly in thermal equilibrium with their environments because the glass containing the gas was an insulator meaning that thermal energy does not pass through it easily. For this reason, T_1 will be lower in actuality than what was measured and T_2 will be higher in reality than what was measured. Consequently, the actual value for V_1/T_1 is greater than the result in this lab and the actual value for V_2/T_2 is lower than the result in this lab. This, in turn, would decrease the difference between the two calculated values of the Charles' law constant.

The theory of Charles' law assumes that the gas undergoing the change in temperature and pressure is an ideal gas. Experimentally, this theory is accurate for gases with low pressure and high temperature but as pressure increases and/or temperature decreases, deviations are expected. Since this lab was conducted with real gases, our results are not expected to be exactly accurate to the theory but should relate closely to the theory.

Conclusion:

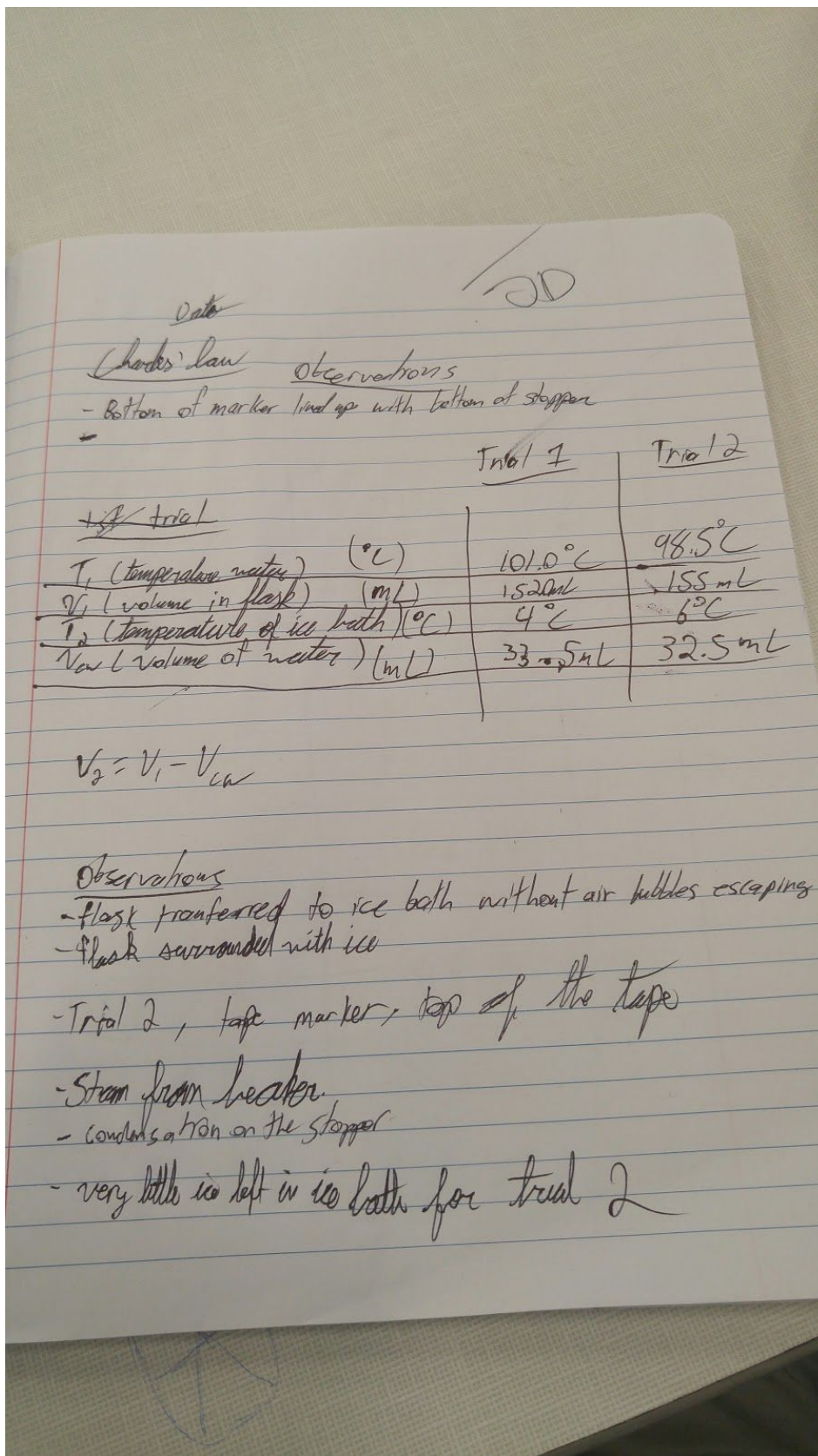
A consistent k value was achieved in the experiment to verify Boyle's law. With the k_{avg} being $1102 \text{ kPa} \cdot \text{mL}$ with the most outer values having a % deviation of $\pm 1.1\%$. This proves the validity of Boyle's law within the limitations of the experiment, i.e. extreme pressures could not be achieved with the lab setup. ∴ the validity of Boyle's law under these extreme conditions remains unverified. In the experiment to verify Charles' law, the T/V ratios were similar, coming in at $0.406, 0.429 \text{ mL/K}$ for trial 1 and $0.417, 0.441 \text{ mL/K}$ for trial 2 with a % error of -5.66% and -5.76% respectively. Similarly to Boyle's experiment extreme temperatures could not be reached and the law could not be verified for said extreme temperatures.

References

Dr. Rashmi Venkateswaran, What in the World isn't Chemistry?, Experiment 1, 2018

John A. Olmsted, Gregory Williams, Robert Burk, Chemistry, Canadian Edition, 3rd Edition, chapter 2, John Wiley & Sons (Canada), 2016-01-15.

Justin Kearney's raw data



Boyle's Law

$$P_1 V_1 = P_2 V_2$$

or

	V (ml)	P (kPa)
1	10.8	101.23 kPa
2	9.8	112.87 kPa
3	8.8	124.54 kPa
4	7.8	141.59 kPa
5	13.8	80.75
6	11.8	93.44 kPa
7	12.8	86.10
8	10.8	103.70
9	14.8	75.00
10	5.8	160.78

Data

Trial 1

Lined up bottom of stopper w/ bottom of marker

Flask submerged a few mm above 125 mL mark

T_1 = temperature of boiling water
 V_1 = Volume of air inside the flask

T_2 = Temperature of ice bath
 V_2 = Volume of water inside flask

Allowed water to boil for 6 min

- flask successfully transferred to ice bath
 - water is rising up the flask

Volume of water in eudiometer = 33.5 mL
 (measured with graduated cylinder)

	T_1 (°C)	V_1 (mL)	T_2 (°C)	V_2 (mL)
Trial 1	101.0°C	152.0 mL	4.0°C	118.5 mL
Trial 2	98.5°C	155.0 mL	6.0°C	122.5 mL

total volume (V_1) $50 \pm 5.0 \pm 5.0 \pm 2.0 = 152$ mL (graduated flask)

Trial 2

Lined up top of marker w/ bottom of stopper

- Allowed to boil for 6 min
- very little ice left in ice bath

Volume of water inside = 32.5 mL
 (used grad cylinder)

$150 \pm 5\%$ + 5 ± 0.5 mL

150
~~150~~ + 5
 (grad cylinder & beaker)

Boyle's Law

$$P_1 V_1 = P_2 V_2$$

	V	P
1	10.8ml	101.23
2	9.8	112.87
3	8.8	124.54
4	7.8	141.59
5	6.8	160.78
6	11.8	93.99
7	12.8	86.10
8	13.8	80.75
9	14.8	75.00
10	15.8	70.14
11	10.8	103.72
12	5.8	160.78

COURSE: CHM1311 Z09 TA Name: Jacky Deng

YOUR NAME (PRINT): Jong Hyun Kim SIGNATURE: JK

CONFIDENTIAL PEER EVALUATION FORM FOR EXPERIMENT

Verification of Charles' and Boyle's Laws

Each team member must submit one assessment form evaluating each **other** member of the team.

Teams may consist of 2-3 members for reports and up to 18 for planning sessions.

You may edit this form.

Do not share or discuss the contents or possible contents of this assessment with others.


In assessing the work of your fellow team members, consider the following aspects:

- Quality of work others
- Contribution to the work as a whole correct
- Ability to get along with others
- Improvements when asked to

Team member name	Comments	Grade
Justin Kearney	Was cooperative and helpful during the lab and did quality work on his part of the lab report. He was also very accepting of my feedback on the lab report and was willing to give me his own feedback.	A

A – Excellent (5) B: Great (4) C: Good (3) D: Fair(2) F: Poor (1)

Note: Do not evaluate yourself on this form

COURSE: CHM 1311 TA Name: Jacky Deng
 YOUR NAME (PRINT): Justin Kearney SIGNATURE: 

CONFIDENTIAL PEER EVALUATION FORM FOR EXPERIMENT 1

Each team member must submit one assessment form evaluating each **other** member of the team.
 Teams may consist of 2-3 members for reports and up to 18 for planning sessions.

You may edit this form.

Do not share or discuss the contents or possible contents of this assessment with others.

In assessing the work of your fellow team members, consider the following aspects:

- Quality of work
- Contribution to the work as a whole
- Ability to get along with others
- Improvements when asked to correct

Team member name	Comments	Grade
Jong Hyun (James) Kim	Great work ethic, contributed a lot to work load and thought process. Worked well as a teammate and produced high quality material. Was open to constructive criticism.	A

A – Excellent (5) B: Great (4) C: Good (3) D: Fair(2) F: Poor (1)

Note: Do not evaluate yourself on this form

Assessment Criteria for Planning the Boyle's Law Investigation
(to be completed BEFORE lab and given to TA)

TA Name:	Jacky Deng	Names of Students in Group:	a. Jong Hyun Kim
			b. Justin Kearney
		Date:	14/09/2013
Criteria:	Marks Possible	Assessment	
		Self	TA
1. Identify the problem and state it clearly in a way that can be tested.	1	0.5	0.5
2. Use proper apparatus, techniques and safety precautions.	1	1	1
3. Materials are easily available.	1	1	1
4. Plan to vary only one independent variable at a time.	1	1	1
5. Controls on other variables are clearly stated.	1	1	1
6. Measurement errors are minimized by appropriate procedures or apparatus.	1	1	1
7. The methods are clear enough to be followed by other students.	1	1	1
8. No invalid assumptions are made.	1	1	1
9. Reagents that need accurate measurement are identified.	1	1	1
10. Lab trials are stated.	1	1	1
11. Repeats are stated.	1	1	1
12. Chemistry vocabulary is used correctly.	1	1	1
13. Limitations of the experimental design are described.	1	1	0.5
TOTAL:	13	12.5	12