Experiment 1 - Verification of Gas Laws
CHM 1311 General Chemistry Laboratory

Experiment Title: Verification of Gas Laws

Author(s) Name(s): Samuel Moses and Stanley Senathipathy

Submitting Author's Partner:

TA (Demonstrator)'s Name: Eliza-Jayne Boisvert

Date Experiment Performed: 09/10/2019

Date Experiment Submitted: 09/17/2019

uOttawa

Procedure – Charles' Law:

- As outlined in "Experiment 1 Theory and Instructions" on CHM 1311 General Chemistry Laboratory website on Brightspace.

- Step 1: Remove 125mL Erlenmeyer Flask from the oven.

- Step 2: Place rubber stopper (with hole) on the opening of the flask and mark the bottom of the stopper with a piece of tape.

- Step 3: Fill a 600 mL beaker with two-thirds of it being water.
- Step 4: Place the beaker on the hot plate.

- Step 5: Use an extension clamp to clamp and place Erlenmeyer Flask in the beaker of water. Make sure that the flask is fully submerged and that no water is entering the beaker.

- Step 6: Turn the hot plate on and heat the water to boiling. As soon as the water begins boiling, let the flask stay in the boiling water for 6 to 7 minutes.

- Step 7: While you are waiting, prepare a large ice bath and make sure its temperature is below 6°C.

- Step 8: As you wait, work with your partner to write a step-by-step for the Boyle's Law experiment which is the second part of the lab. You should define your variables, identify the dependent and independent variables, determine starting and ending values, and plan how many measurements and at what intervals you will take them. Use the Assessment Criteria to help you plan the procedure.

- Step 9: Place your finger over the hole in the stopper and remove the Erlenmeyer Flask from hot water by disconnecting the extension clamp.

- Step 10: Keep your finger on the hole and lower the Erlenmeyer Flask facing downwards into the ice bath. Once submerged, remove your finger from the stopper and now the water will enter the flask.

- Step 11: Keep the erlenmeyer submerged in the ice bath for approximately 5 to 6 minutes.

- Step 12: Record the temperature of the ice bath.

- Step 13: While keeping the stopper underwater, lower or raise the flask so that the water inside the flask matches the water level inside the ice bath.

- Step 14: Once the water levels match, place a finger on the stopper's hole and remove the flask.

- Step 15: Transfer the water from the Erlenmeyer Flask into a graduated cylinder and record its volume. Label this volume as Vcw which corresponds to T2 (the temperature of the ice bath).

- Step 16: Fill the Erlenmeyer flask to the mark of the stopper's bottom. Transfer this volume of water to a graduated cylinder. Record this volume as V1 as it corresponds to T1 (Temperature of boiling water.
- Step 17: Repeat the entire experiment once more. Make sure a new Erlenmeyer flask is used.

Procedure – Boyle's Law:

- Step 1: Connect gas pressure sensor to 20mL syringe and LabQuest 2.
- Step 2: Take measurements using the same mark of plunger (bottom line) of 20mL syringe at chosen intervals: 20mL, 18mL, 15mL, 12mL, 10mL, 8mL and 20mL. Ensure that measurements are taken right after each other without refilling the syringe so as not to change the amount of air.
- Step 3: Add 0.8mL (space in gas pressure sensor) to each measurement and enter KEEP into LabQuest at each point to collect data.
- Step 4: Plot points in graph to observe the relationship between volume and pressure in gases.
- Step 5: Omit one of the two measurements taken at 20mL based on which measurement fits better with the recorded data.

Discussion:

Charles' Law

Table 1 - Trial 1 Results for Volume and Temperature

Temperature (T)	Volume (V)
T1 = 100°C	V1 = 159 mL
T2 = 4.0°C	V2 = 120.5 mL

Graph 1 - Temperature vs Volume for Trial 1

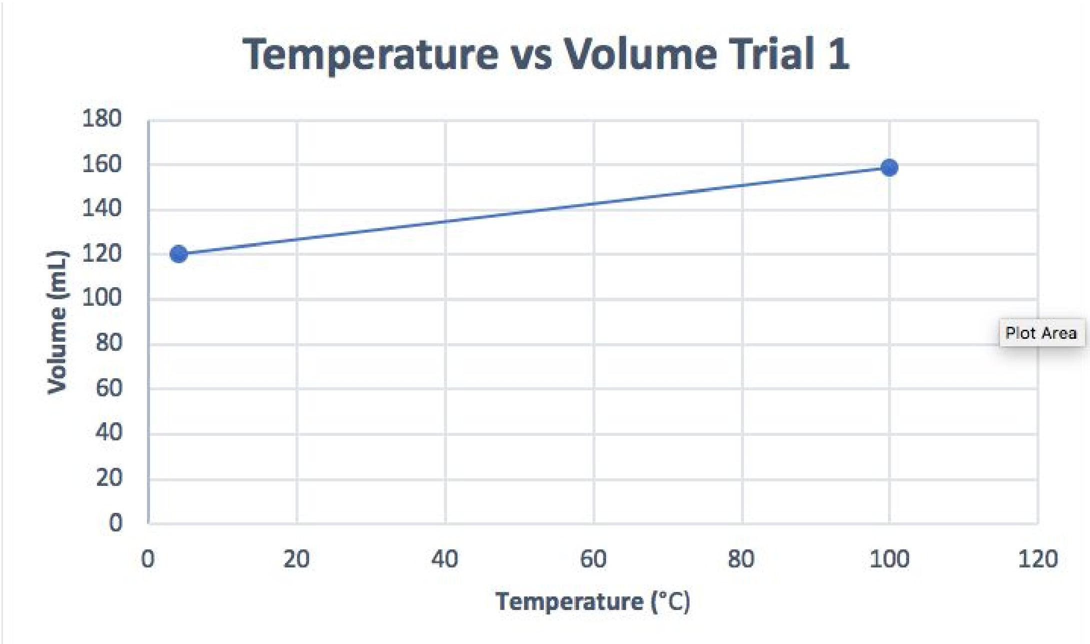
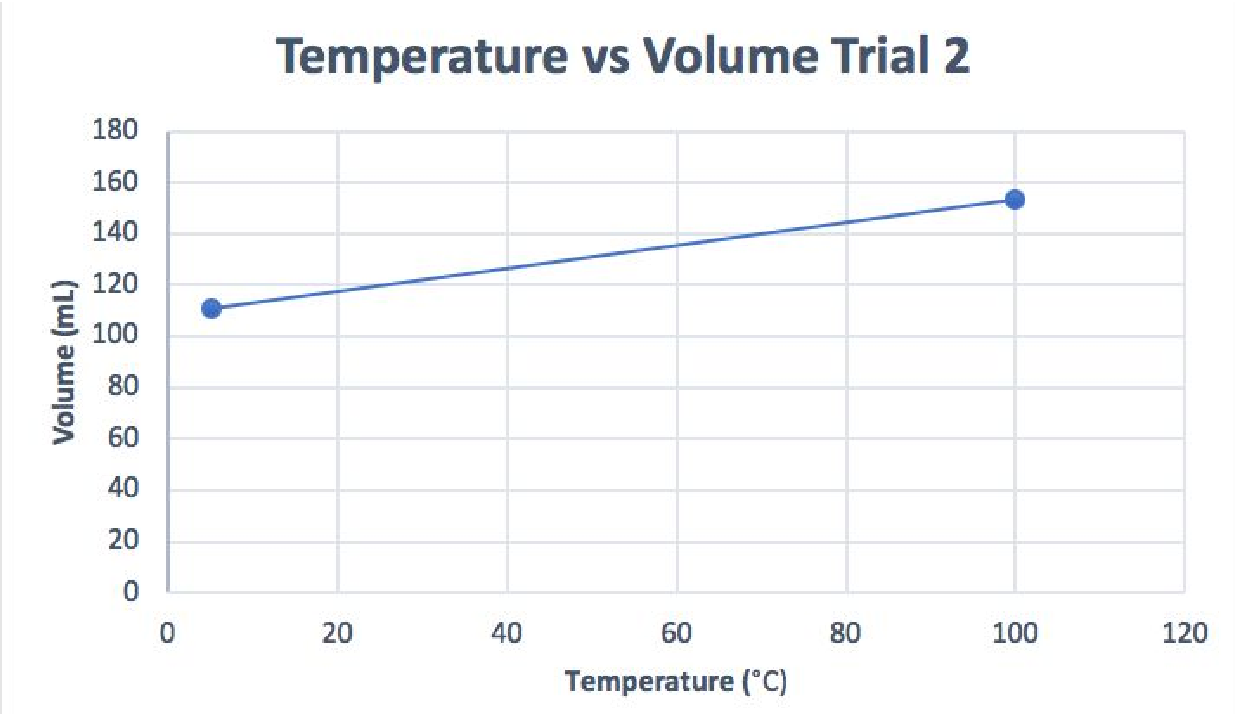


Table 2 - Trial 2 Results for Temperature and Volume

Temperature (T)	Volume (V)
T1 = 100°C	V1 = 153.5 mL
T2 = 5.2°C	V2 = 110.5 mL

Graph 2 - Temperature vs Volume for Trial 2



As can be clearly seen in Table 1 and Graph 1, the volume and temperature pair from step 15:

- V1 = 159mL
- T1 = 100°C

Date

To calculate V_2 at T_2, use Trial 1 as an example.

$V_{cw} = 38.5 mL$

$V_1 = 159 mL$

Therefore since V_2 equals V_1 minus V_{cw}

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

substitute the values

$V_{cw} = 38.5 mL$

$V_1 = 159 mL$

$$V_2 = 159 mL - 38.5 mL$$
$$= 110.5 mL$$

Therefore V_2 at Trial 1 at T_2 is 110.5 mL.

To verify Charles Law with the current data, divide volume by temperature using V1 and T1 and V2 and T2 and compare the values. Converting temperature from degrees celsius (°C) to Kelvin (K) is necessary. Do this for both trials.

Trial 1

$$T_1 = 100°C + 273.15 = 373.15\,K$$
$$T_2 = 4.0°C + 273.15 = 277.15\,K$$

$$\frac{V_2}{T_2} = \frac{120.5\,mL}{277.15\,K} \doteq 0.435\,\frac{mL}{K}$$

$$\frac{V_1}{T_1} = \frac{159\,mL}{373.15\,K} \doteq 0.426\,\frac{mL}{K}$$

Trial 2

$$T_1 = 100°C + 273.15 = 373.15\,K$$
$$T_2 = 5.2°C + 273.15 = 278.35\,K$$

$$\frac{V_2}{T_2} = \frac{110.5\,mL}{278.35\,K} \doteq 0.397\,\frac{mL}{K}$$

$$\frac{V_1}{T_1} = \frac{153.5\,mL}{373.15\,K} \doteq 0.411\,\frac{mL}{K}$$

The units, mL (millilitres) / K (Kelvin), shows that every time the temperature rose by 1 Kelvin, the volume rose by 0.411 mL. Charles Law states that the volume of a gas rises as the temperature rises (John Olmsted III, Greg Williams, Robert Burk; Chemistry Third Canadian Edition, Chapter 2, Wiley, Page 63, January 2016). The minimal differences between the calculated values shows minimal experimental error. The experimental error could be a result of not emptying out the entire erlenmeyer flask when transferring it to the graduated cylinder. This means remaining water droplets sticking to the side and the bottom of the flask.

The calculated average value will be the average slope of the trial 1 and trial 2 graphs.

Date

Trial 1 Graph Slope

$y_2 = 120.5\,mL$

$y_1 = 159\,mL$

$x_2 = 277.15\,K$

$x_1 = 373.15\,K$

$$slope = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(120.5 - 159)\,mL}{(277.15 - 373.15)\,K} \doteq 0.401\,\frac{mL}{K}$$

Trial 2 Graph Slope

$y_2 = 110.5\,mL$

$y_1 = 153.5\,mL$

$x_2 = 278.35\,K$

$x_1 = 373.15\,K$

$$slope = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(110.5 - 153.5)\,mL}{(278.35 - 373.15)\,K} \doteq 0.453\,\frac{mL}{K}$$

Since there is a small difference between both calculated slopes, it clearly shows that there was minimal experimental error. A positive slope also shows the proportionality between temperature and volume. As Charles Law states that as volume increases, temperature increases.

Both percent errors for trial 1 and trial 2 are very small, indicating that the experimental error was minimal. Sources of experimental error as mentioned are the remaining water droplets along the flask that hasn't exited when transferring from the flask to the graduated cylinder.

Boyle's Law

The volume (mL) of air in the 20mL syringe acts as the independent variable and the air pressure (kPa) collected by the air pressure sensor acts as the dependent variable because a change in volume consequently changes the air pressure reading.

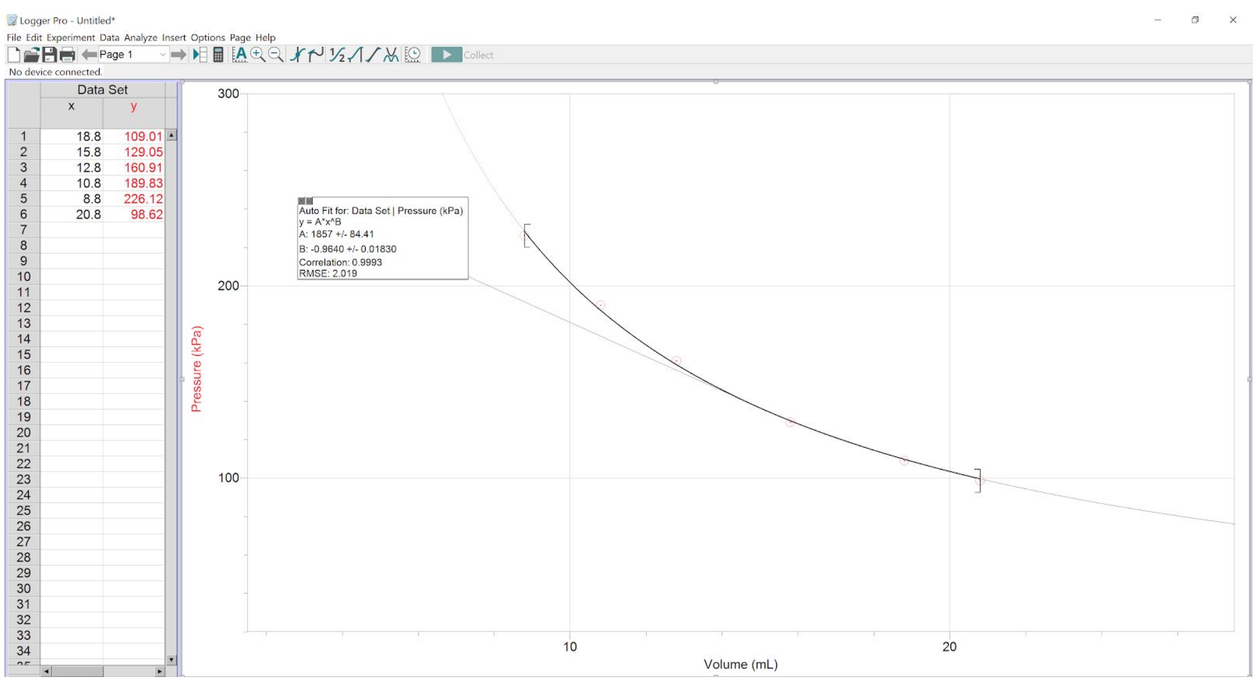
Table 1 - Trial Results for Boyle's Law Volume and Pressure

Volume (mL)	Pressure (kPa)
~~20.8~~	~~98.04~~
18.8	109.01
15.8	129.05
12.8	160.91
10.8	189.83
8.8	226.12
20.8	98.62

The first set of data collected at 20.8mL can be omitted because the second reading at 20.8mL is closer to the data set.

Graph 1 - Boyle's Law Volume and Pressure

Volume vs. Pressure



The Boyle's law constant can be calculated using the formula PV=k, with P being pressure in kPa, V being volume in mL, and k representing the constant. Once a constant (k) is found for all values in the collected data, an average of the six values can be taken to find the constant (k). The Boyle's law constant in this experiment is approximately k= 2,056.23.

Boyle's law states that the volume of a gas and its pressure are inversely proportional. As volume decreases, pressure increases at a constant, and vice versa. The plotted graph shows that the relationship can be plotted in a power function, meaning the relationship is exponential. The constant, Boyle's law constant, is the product of the volume and pressure. The constant in this experiment can help develop the equation $P = 2{,}056.23 \times V^{-1}$ that defines the relationship of pressure and volume in this experiment.

Multiple readings are taken to ensure the experiment is as precise as possible. Human error plays a part in this experiment and multiple readings would minimize human error.

Boyle's law requires that the temperature and mass of gas remain constant. These variables were taken into consideration as the measurements were taken without refilling the 20mL syringe so as to not change the mass of the gas. The temperature of the syringe was assumed constant as the temperature in the room was relatively constant. The precautions we took ensured that our results were as accurate as possible according to the limitations of Boyle's law.

<u>Conclusion:</u>

Charles' Law: As seen through calculations of percent error, slope of the graphs and the table of values, the relationship between temperature and volume is directly proportional just as it says in Charles Law; as the volume of a gas increases so does its temperature.

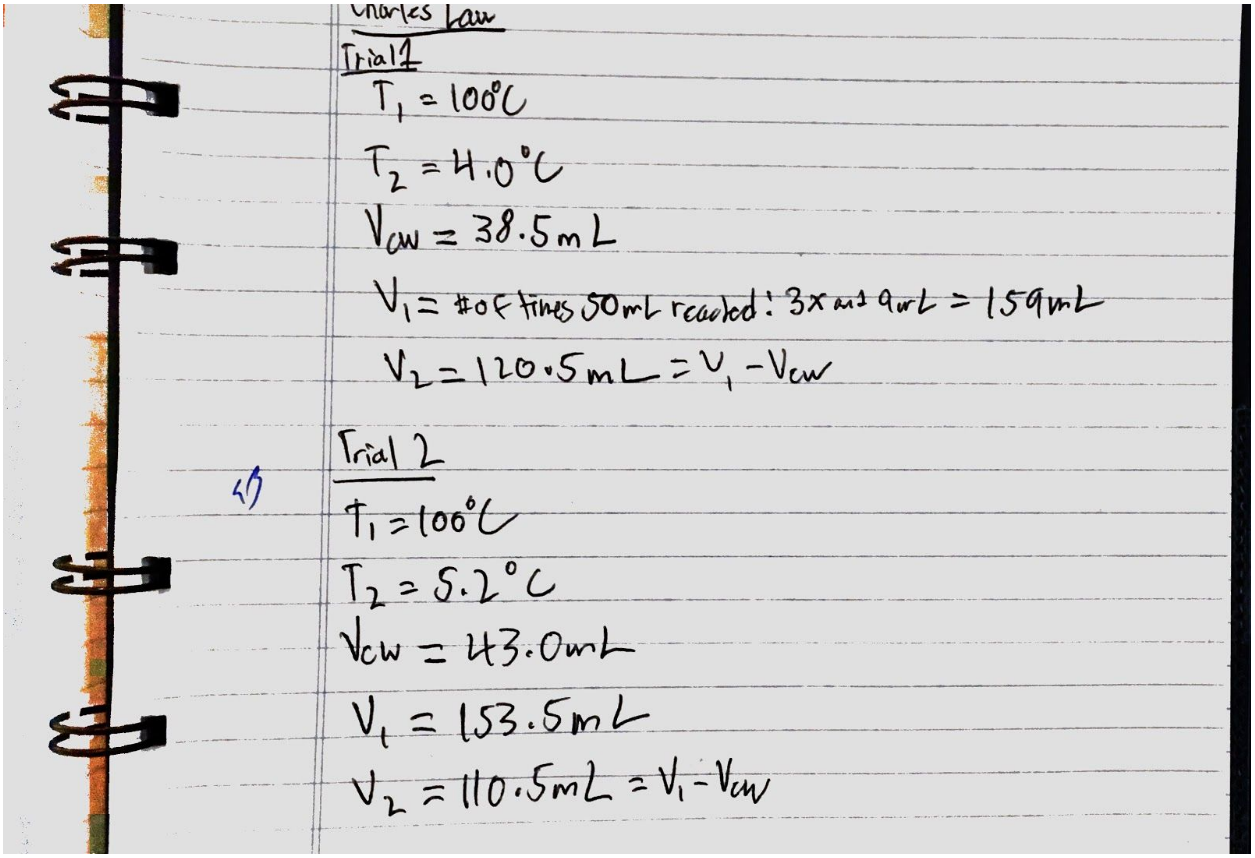
Boyle's Law: As seen through the data collected, the relationship between volume and pressure of a gas is inversely proportional to each other when the temperature and mass of a gas are kept constant.

<u>Reference(s):</u>

- John Olmsted III, Greg Williams, Robert Burk; Chemistry Third Canadian Edition, Chapter 2, Wiley, Page 63, January 2016

Appendix:

Raw Data:


Charles Law

Trial 1

$T_1 = 100°C$

$T_2 = 4.0°C$

$V_{cw} = 38.5 mL$

V_1 = # of times 50mL reached: 3x and 9mL = 159mL

$V_2 = 120.5 mL = V_1 - V_{cw}$

Trial 2

$T_1 = 100°C$

$T_2 = 5.2°C$

$V_{cw} = 43.0 mL$

$V_1 = 153.5 mL$

$V_2 = 110.5 mL = V_1 - V_{cw}$

LabQuest2 Data

Vernier Format 2

untitled.txt 0/1/2019 10:41:38

Run 1

volume	pressure	Pressure
v	p	P
ml	kPa	kPa
20.8		98.04
18.8		109.01
15.8		129.05
12.8		160.91
10.8		189.83
8.8		226.12
20.8		98.62

Sample Calculations, Charles' Law

Date

To calculate V_2 at T_2, use Trial 1 as an example.

$V_{cw} = 38.5\,mL$
$V_1 = 159\,mL$

Therefore since V_2 equals V_1 minus V_{cw}

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

substitute the values

$V_{cw} = 38.5\,mL$
$V_1 = 159\,mL$

$$V_2 = 159\,mL - 38.5\,mL$$
$$= 110.5\,mL$$

Therefore V_2 at Trial 1 at T_2 is $110.5\,mL$.

Date

Trial 1 % Error

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

$$= \frac{\frac{159\,mL}{373.15\,K} - \frac{120.5\,mL}{277.15\,K}}{\frac{159\,mL}{373.15\,K}} \times 100\%$$

$$\doteq 2.11\ \%\ error$$

Trial 2 % Error

$$\%\ Error = \frac{\frac{153.5\,mL}{373.15\,K} - \frac{110.5\,mL}{278.35\,K}}{\frac{153.5\,mL}{373.15\,K}} \times 100\%$$

$$\doteq 3.53\ \%\ error$$

Page

Additional Data, Boyle's Law

Boyle's law:

procedure:

1. Connect gas pressure sensor to lab quest
2. take measurements on syringe using first mark 20 mL at 20, 18, 15, 12, 10, 8, 20 mL
   * add 0.8 mL to each measurement
3. Enter KEEP into LabQuest at each measurement
4. Plot points in graph

	Independent Volume (mL)	Dependent Pressure (kPa)
1.	208	98.04
2.	18.8	109.01
3.	15.8	129.05
4.	12.8	160.91
5.	10.8	189.83
6.	8.8	226.12
7.	20.8	98.62

Sample Calculations, Boyle's Law

Boyle's law constant:

$PV = k$ (constant)

~~1) (98.04 kPa)(20.8 mL) = 2,039.232~~ omitted value

2) (18.8 mL)(109.01 kPa) = 2,049.388

3) (15.8 mL)(129.05 kPa) = 2,038.99

4) (12.8 mL)(160.91 kPa) = 2,059.648

5) (10.8 mL)(189.83 kPa) = 2,050.164

6) (8.8 mL)(226.12 kPa) = 1,989.856

7) (20.8 mL)(98.62 kPa) = 2,051.296

$$k = \frac{(2{,}049.388) + (2{,}038.99) + (2{,}059.648) + (2{,}050.164) + (1989.856) + (2{,}051.2\ldots}{6}$$

$k \doteq 2{,}056.23$

Equation:

$PV = k$

$P = k/V$

$P = k \cdot V^{-1}$

$P = 2{,}056.23 \cdot V^{-1}$

Assessment Criteria Sheet

Assessment Criteria for Planning the Boyle's Law Investigation

TA Name:	Eliza-jayne Boisvert	Names of Students in Group:	a. Samuel Moses b. Stanley Senathipathy
		Date:	Sept 10, 2019
Criteria:	**Marks Possible**	**Assessment**	
		Self	**TA**
1. Plan to vary only one independent variable at a time.	1	1	
2. Controls on other variables are clearly stated.	1	1	
3. Measurement errors are minimized by appropriate procedures or apparatus.	1	1	
4. The methods are clear enough to be followed by other students.	1	1	
5. Trials and replicas are stated.	1	1	
6. Limitations of the experimental design are described.	1	1	
TOTAL:	6	6	