Charles law

2294 words

Research Question: To use Charles law to investigate whether gases such as air, oxygen and hydrogen obey the volume-temperature ratio and give an accurate determination of absolute zero.

Introduction:

This phenomenon is seen often in real life, for example in balloons where the balloons will crumble if taken out in the cold or put in cold surroundings and will expand again of put in the warm. This occurs due to change in volume of the gas due to change in pressure. The same applies for a hot air balloon. The air expands when heated and thus helps to the balloon slowly into the air. Also when a ping pong ball get dented, placing it in a container with warm water will restore its shape as the air in the ball will expand and hence bring the ball back to its original shape[1]. Thus, to test these phenomena and to calculate absolute zero I conducted this experiment with three gases which are air, hydrogen and oxygen gases to determine whether the research question can be proven or not. Till date absolute zero has never been obtained and the closest value reached by scientists to absolute is 0.0001K for helium gas[2]

Background Information:

Charles Law states that the volume of a gas is directly proportional to the temperature, provided the amount of gas and the pressure of the gas remain constant. It says that as the temperature of the gas increases, the volume of the gas increases and thus the gas expands and vice versa for when a gas is cooled, it compresses and the gas molecules

[1] Edulab. 2016. Charles' Law - Real Life Application 1st Edition. United Kingdomhttps://edulab.com/charles-law-real-life-applications

[2] National Science Foundation. 2002. What is the closest to absolute zero that has ever been reached?. What would happen to a substance if it were cooled to absolute zero?. 1st edition. http://scienceline.ucsb.edu/getkey.php?key=225

reduce their activity and eventually all activity will stop. The temperature at which the gas can get no colder and enthalpy and entropy of the gas reaches its minimum value. This temperature is known as absolute zero.

Method/Procedure of the experiment:

1. Five beakers filled with water of different temperatures were taken. One contained ice with salt, which had the least temperature, next a mixture of ice and water, a beaker with water at regular temperature of the water in the tap, a beaker with water heated up, and a beaker containing water with the highest temperature, that is, water heated on Bunsen burner.
2. A particular volume of air was sucked into the syringe and then the syringe was covered with a rubber cap to prevent any water getting into it when it was placed in the beaker.
3. The syringe was placed in each of the 5 beakers containing water for 3 minutes and 15 seconds. The syringe was placed in the coldest beaker first and finally in the hottest beaker.
4. At the end of the time the volume of air in the syringe was measured for each of the temperature of water in the beaker to calculate the absolute zero.
5. This was repeated 2 more times to get an average of the absolute zero to improve the accuracy of the results.
6. Next hydrogen and oxygen gases were collected from the Hoffman's Apparatus in the lab by passing electricity through 0.75 mol of sulfuric acid to form hydrogen at the anode and oxygen at the cathode.
7. The gas was then passed through a rubber tube into the syringe to calculate absolute zero for the 2 gases as well.
8. The syringe was immediately covered with a rubber cap to prevent the gas escaping the syringe and also water entering it.
9. The syringe with these 2 gases was placed in each of the 5 beakers with different temperatures of water for 3 and a quarter minute to calculate change in volume,

to calculate absolute zero for the gases. The syringe was placed in the coldest beaker first and finally in the hottest beaker.

10. This was repeated 2 more times to get an average of the absolute zero of the gas to improve the accuracy of the results.

Hypothesis:

A certain volume of a gas will be taken in the syringe initially. The hypothesis of the experiment is that when the syringe with gas is kept in cold water beaker the volume of the gas inside the syringe will decrease, and as it is kept in warmer surroundings the volume of the air will expand. When the graph of volume vs temperature is obtained and extrapolated the value of absolute zero of the gas is expected to be -273.15 °C or 0 K.

Apparatus and Materials:

The equipment used for the experiment was:

- Glass Syringes of $100cm^3$ capacity
- Beakers of 600ml each
- Bunsen Burner and retort stand
- Hoffman's Apparatus
- Stopper and rubber tubes
- Ice and salt
- Water
- 75ml (0.75 mol) of H_2SO_4 solution

Variables:

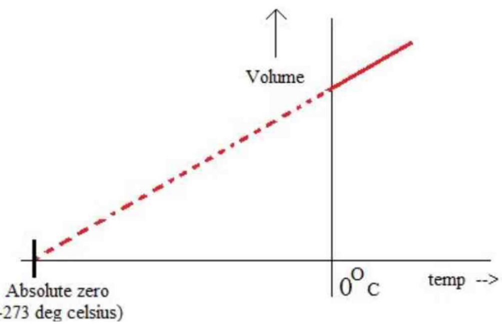
The 2 variables measured in the experiment were:

- Independent Variable: The temperature of the water in the beaker.
- Dependent Variable: The volume of the gas.
- Control Variables: The volume of water in each beaker in which beaker was placed, and the surrounding pressure and temperature.

Safety Concerns:

Precautions for safety were taken as per the IBO safety and it was made sure that there was proper first aid was present in case there was any injury. The safety measures taken while conducting the experiment were:

- A lab coat was put on in case the concentrated sulfuric acid would squirt out of the Hoffman's Apparatus.
- Safety glasses were also put on in case the acid was to squirt out.
- Thick gloves were put on when holding a beaker with extremely hot water to avoid burns
- There were no ethical or environmental considerations to be taken into account.



[3]

This graph shows how the temperature volume changes with temperature and at -273.15°C or 0 K all activity of the gas stops thus the point of absolute zero. The perfect graph for absolute zero looks like the one above.

Weakness and Limitation: A possible weakness to the experiment could be that the experiment does not calculate the absolute zero of the gas based on the change of

[3] 'https://www_meritnation.com/ask-answer/question/explain-graph-of-absolute-zero-dont-copy-ncert-portion-e/thermal-properties-of-matter/8695145

volume with change in surrounding pressure of the gas. This could improve the experiment by giving a better average of the absolute zero for air, hydrogen and oxygen in the experiment.

Raw Data: The data collected while the experiment was being conducted was tabulated for each of the 3 replicates for air, oxygen and hydrogen. The following are the tables of raw data collected in the experiment.

Table 1: Shows the volume and temperature for each replicate for Air

Replicate 1		Replicate 2		Replicate 3	
Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)
-1	43	2	45	2	43.5
3	47	5	48	6	48
18	50	18	52.5	18	51
49	55	58	57	54	56
68	57	70	59	79	58.5

Table 2: Shows the volume and temperature for each replicate of oxygen gas

Replicate 1		Replicate 2		Replicate 3	
Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)
3	36	3	36	1	36
6	38	6	38	6	39
18	40.5	18	41.5	19	42.5
55	44	55	44.5	59	45
68	48	67	48	66	48.5

Table 3: Shows the volume and temperature of each replicate of hydrogen gas

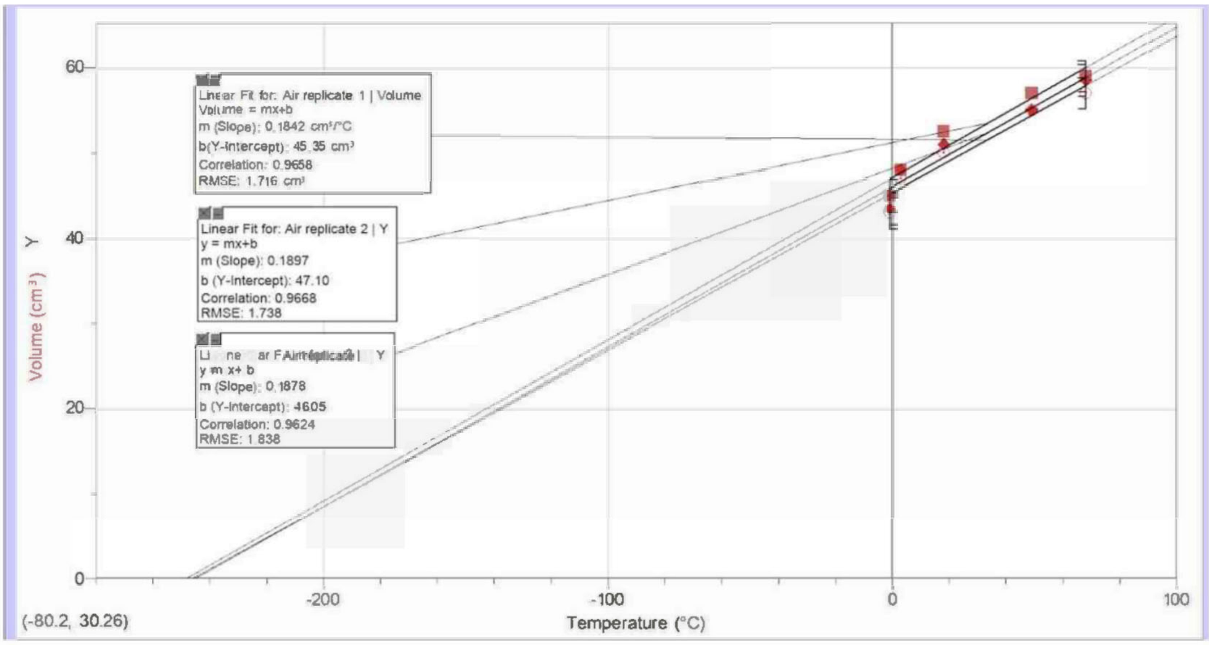
Replicate 1		Replicate 2		Replicate 3	
Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)	Temperature in °C (±1°C)	Volume in cm^3 (±1cm^3)
2	39	2	40	3	40
5	42	6	42.5	6	43
18	43.5	18	45.5	18	46.5
56	47.5	53	49	53	50
72	53	70	53.5	66	53.5

Qualitative Observations:

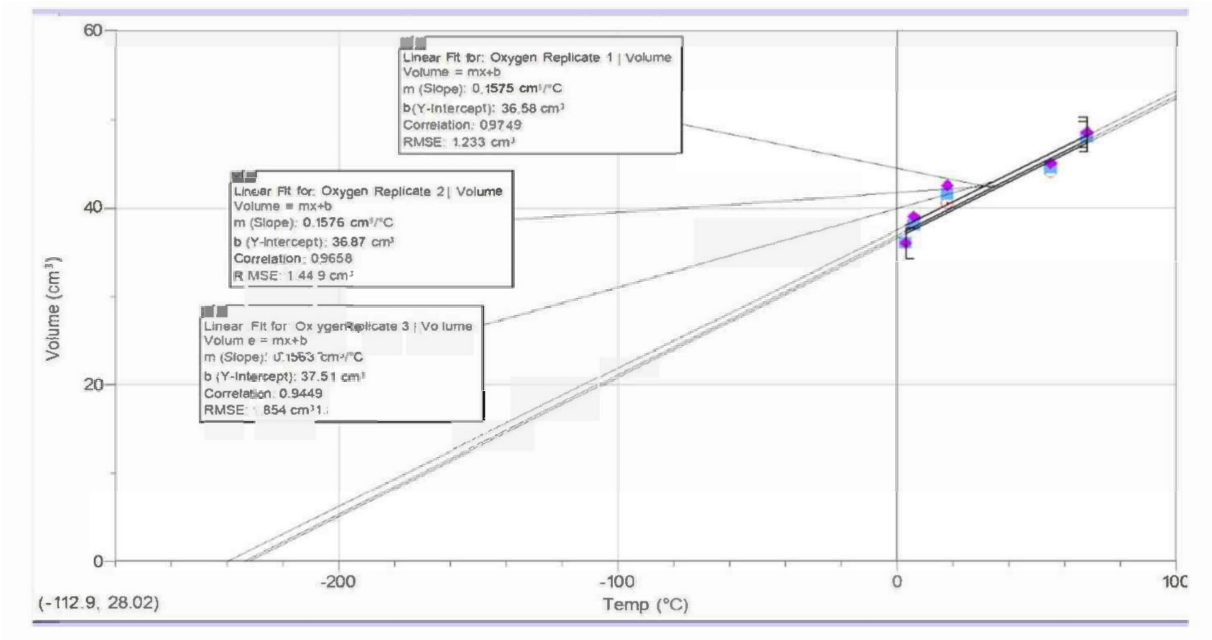
The observations seen when the raw data was being collected was agreeing with the hypothesis of the experiment. When the syringe was kept in a beaker with surrounding colder than the room temperature, the plunger moved downwards and as the surrounding temperature of syringe in the beaker kept increasing the plunger kept moving upwards slowly.

Data Processing and Analysis: Using the data from the raw tables the graph was plotted on Logger Pro. The graph from logger pro was extrapolated to obtain the relationship between volume and temperature and the value for absolute zero.

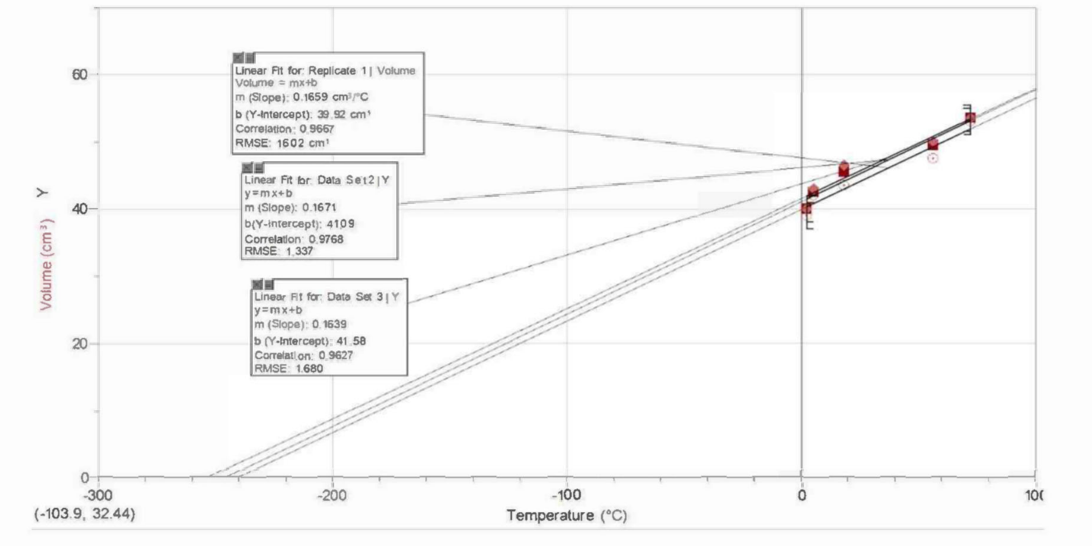
Graph 1: The graph obtained for value of absolute zero for each replicate of air



Graph 2: The graph obtained for values of absolute zero for each replicate of oxygen gas is shown below



Graph 3: The graph obtained for values of absolute zero for each replicate of hydrogen is shown below.



The graphs above which show the values for absolute zero for air, oxygen and hydrogen when the graph was extrapolated using logger pro along with the relationship between volume and temperature of the gases. The lines were extrapolated till the lines reached their value for absolute zero. From the extrapolated lines the slope and the y intercept were taken and an equation was formed in the terms: y=mx+b, where m is the slope (the rate at which the volume decreases with decrease in temperature) of the line and c is the y intercept (the point where x is zero on the graph). Hence from the graph, the point where the extrapolated line touches the x-axis is the value of absolute zero obtained from each of the trials for each gas. Using this equation the value for absolute zero for all three gases was found along with the replicates. The values of absolute zero were tabulated and an average absolute zero value for all three replicates of each gas was then found. The table below shows the values for absolute zero obtained from the experiment.

Table 4: Absolute zero values

	Air	Oxygen	Hydrogen
Absolute zero rep 1	-246.19°C	-232.25°C	-240.62°C
Absolute zero rep 2	-259.62°C	-233.94°C	-245.90°C
Absolute zero rep 3	245.02°C	-239.99°C	-253.69°C
Average Absolute zero	**-250.29**°C	**-235.39**°C	**-246.73**°C

Error Analysis: The literature value for absolute zero is -273.15°C. The values obtained from the experiment for air is -250.29C, hydrogen is -246.73C and for oxygen is -235.39.

The error analysis for the gases are:
Air: [(-250.29+273.15)/273.15] x 100
The percentage error obtained for air is 8,37%
Oxygen: [(-235.39+273.15)/273.15] x 100
The percentage error obtained for oxygen is 13.82%

Hydrogen: [(-246.73+273.15)/273.15] x 100
The percentage error obtained for hydrogen is 9,67%

When the percentage error values are incorporated into the values for absolute zero found from the experiment, the range of temperature values obtained for each of the gases are:

- Air: -229.34°C to -273.15°C
- Oxygen: -202.85°C to -273.15°C
- Hydrogen; -222.87°C to -273.15°C

Conclusion:

Thus from the processed data in the experiment we can prove that the volume and temperature of a gas are directly proportional to each other when the pressure of the gas is kept constant. As the gases are cooled down, their volumes also begin to decrease. This is an attempt to calculate absolute zero for the gases because when gases are heated, the molecules will begin to expand due to gain of energy and the molecules of the gas move at a faster speed, whereas when a gas is cooled it gets compressed due to loss of energy and the particles begin to slow down. Finally at a temperature of -273.15°C or 0 K the molecules of the gas stop their motion and become still. In the experiment values were obtained for absolute zero of air, hydrogen and oxygen, which were close to the actual value of -273.15C but yet not the exact value of absolute zero. Till today absolute zero has never been obtained by scientists despite reaching very close to the value. This is mainly because a temperature cold enough as -273.15 degrees can never be obtained. Even if the experiment is conducted and the value of absolute zero is obtained by extrapolation of various volumes and temperatures, it can never be fully accurate as it is only a prediction of what the data could be. According to the New Scientist Magazine, "the work needed to remove heat from a gas increases the colder you get, and an infinite amount of work would be needed to cool something to absolute zero. In quantum terms, you can blame Heisenberg's uncertainty principle, which says the more precisely we know a particle's speed, the less we know about its position, and vice versa. If you know your atoms are inside your experiment, there must be some uncertainty in their momentum keeping them above absolute zero -- unless your experiment is the size of the whole universe. [4]
Also to obtain the value for absolute zero we will need a temperature colder than -273.15C Thus in conclusion, the research question can be answered that the volume of a gas is directly proportional to the temperature, but to find out the exact value for absolute zero of a gas is very rare. The values obtained from the experiment conducted and the processing done to obtain the value for absolute zero is only a predicted value for absolute zero. The percentage error for the values of absolute zero obtained for air, hydrogen and oxygen are also quite significant with relation to the actual value. Hence, from the experiment the value for absolute zero is only a predicted value and not actual

[4] Hazel Muir. 2010. What happens at Absolute Zero. 1st Edition. United Kingdom
https ://www.newscientist.com/arti cl e/d n 18541-what-happens-at -absolute- zero/

and some weaknesses in the method of the experiment may have prevented the value for absolute zero coming to -273.15°C.

Evaluation: The experiment being conducted extremely carefully whilst taking into account the possibility of errors. The experiment was conducted personally after testing the equipment before doing the experiment. This methodology helps the data to become more reliable and accurate. Despite this there may have been some limitations in the experiment. Along with this there may have been some errors that may have crept into the method while conducting the experiment. Some of the difficulties faced while conducting the experiment are listed along with the possible improvement for it:

Difficulties	Solutions
The time for which the syringe was placed in the beaker of water was only 3 and a quarter minutes.	The syringe could be placed in the beaker for 5 minutes to allow the gas to come to the temperature of the water in beaker.
Only three trials were conducted to obtain an average to calculate the value for absolute zero.	More number of trials could be conducted to improve the accuracy of the value for absolute zero obtained.
The temperature of water in beaker could change with time due to the difference between its own and the temperature of the room.	The water in the beaker could be put just before placing the syringe in the beaker with water.
4. Some water may have entered the syringe despite covering its mouth with a rubber cap.	Use a tighter stopper to cover the mouth of the syringe or calculate the amount of water went into the syringe and add it to the volume of the replicate.
5. The temperature of the syringe could affect the temperature of the water in the beaker	The syringe could be left out of one beaker for some time before placing it into the next beaker.

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