**Learning Activities 4.3: Gas Pressure and Boyle’s Gas Law**

**Summary of Learning Activities:**

* Measuring the volume of two sample materials, shaving cream and marshmallows, at atmospheric pressure and a vacuum pressure level. Using pressure and volume data to verify Boyle’s law.

# Student Learning Objectives:

1. Perform the pump-down sequence for the RVET system.
2. Collect pressure data points from the RVET system pressure gauges and volume data points for the sample materials.
3. Use scientific notation to represent numbers.
4. Apply rules of significant figures (digits) through unit conversion practice.
5. Calculate the percent difference between the initial and final PV products.
6. Verify Boyle’s law.

**Suggested Pre-lab Assignment:**

A sample of H2 has a gage pressure of -120.3 Torr and a volume of 155 ml. If the sample was transferred to a 1 L volume, what would the pressure be? Apply rules of significant figures to calculations.

**Theoretical Background:**

The relationship between the absolute pressure exerted by a constant amount of gas contained in a volume with an elastic boundary is stated in **Boyle’s law**. Mathematically, Boyle’s law can be expressed as:   
  
 *P1V1 = P2V2,*  
  
where *P1*and *V1* are the initial pressure and volume of an object with an elastic boundary and *P2*and *V2* are the final pressure and volume of that same object. Theoretically, as long as the amount of gas and temperature do not change, the product of pressure and volume should not change. In real life under these conditions, the product of pressure and volume may change slightly due to possible gas leaks from the object and/or sources of measurement error due to imperfect experiment conditions.

# Equipment and Materials:

* RVET system outfitted with pressure measurement gauge.
* Thermometer to measure the temperature within the chamber.
* Shaving cream.
* 2 each, jumbo marshmallows.
* Ruler with units in mm.
* 3 each, 200-milliliter (ml) beakers.
* Dry wipes.

**Procedure:**

**Learning Activity 4.3a: Boyle’s Law for Expanding Shaving Cream**

1. Apply power to the RVET system and the thermometer. Wait 30 minutes for electronic gauges to warm up.
2. **Record the temperature value *Ti***from the thermometer sensing the temperature inside the chamber.
3. **Record the pressure value *P1***from the capacitance diaphragm gauge **at atmospheric pressure**.
4. Add approximately 50-ml of shaving cream to the 200-ml beaker. **Record the volume value *V1* of the shaving cream in the beaker.**
5. Place the beaker with shaving cream in the vacuum chamber.
6. Shut the vent valve. Make sure the roughing valve between the pump and the chamber is closed.
7. Turn on the pump. Open the rouging valve between the pump and the chamber.
8. Close the roughing valve when the shaving cream expands to 200 ml in the beaker.
9. **Record the volume value *V2* of the expanded shaving cream**.
10. **Record the pressure value *P2*** from the capacitance diaphragm gauge.
11. Make sure the roughing valve between the pump and the chamber is closed. Turn off the pump.
12. Vent the RVET system.
13. Remove the beaker with shaving cream from the vacuum chamber.
14. Add approximately 50-ml of shaving cream to a second 200-ml beaker. **Record the volume value *V1* of the shaving cream in the beaker.**
15. Repeat steps 4-10.
16. **Record the temperature value *Tf***from the thermometer sensing the temperature inside the chamber.
17. Make sure the roughing valve between the pump and the chamber is closed. Turn off the pump.
18. Vent the RVET system.
19. Remove the second beaker with shaving cream from the vacuum chamber.
20. Rinse the shaving cream from the beakers. Dry the beakers.

**Identify measurement instruments and measurement resolution**

* 1. **Measurement Instrument (MI) 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  2. **MI 1 unit of measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  3. **MI 1 resolution \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  4. **MI 2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  5. **MI 2 unit of measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  6. **MI 2 resolution \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  7. **MI 3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  8. **MI 3 unit of measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  9. **MI 3 resolution \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  10. **MI 4 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  11. **MI 4 unit of measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  12. **MI 4 resolution \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Data Table for Learning Activity 4.3a Date data recorded:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

|  |  |
| --- | --- |
| **Data** | **Value and Unit of Measure** |
| Initial chamber temperature  (*Ti*) |  |
| Initial pressure  (*P1*) – 1st time |  |
| Initial volume of shaving cream  (*V1*) – 1st time |  |
| System pressure with shaving cream expanded (*P2*) – 1st time |  |
| Volume of expanded shaving cream (*V2*) – 1st time |  |
| Initial pressure  (*P1*) – 2nd time |  |
| Initial volume of shaving cream  (*V1*) – 2nd time |  |
| System pressure with shaving cream expanded (*P2*) – 2st time |  |
| Volume of expanded shaving cream (*V2*) – 2nd time |  |
| Final chamber temperature  (*Tf*) |  |

**Analysis: Verify Boyles’ Law using the Pressure and Volume Measurements for Expanding Shaving Cream**

Does ?

Calculate *p1V1* and *p2V2*, then say if they are the same.

Calculate percent difference between *P1V1* and *P2V2*. Are they close enough to verify Boyle’s law?

What are some reasons *P1V1* and *P2V2* might not be the same?

**Learning Activity 4.3b: Boyle’s Law for the Expanding Marshmallow**

1. **Measure** the dimensions of two jumbo marshmallow: **height and diameter.** *(Note: if using marshmallows from the previous Learning Activity, use the volumes previously calculated.)*
2. Use a beaker with 50 ml graduated markings. Allow top of marshmallow to expand to the 200 ml level.
3. Place jumbo marshmallow in the beaker with a flat side down.
4. Make sure the roughing valve between the pump and the chamber is closed.
5. Vent vacuum chamber to atmosphere if needed. Remove the chamber.
6. Place beaker in the vacuum chamber. Place the chamber over the beaker.
7. **Record the temperature value Ti** from the thermometer sensing the temperature inside the chamber.
8. **Record** **the pressure** **value P1** pressure measurement reading from the gauge.
9. Shut the vent valve. Start the rough pump.
10. Open the roughing valve to allow rough pump to remove air from the chamber.
11. Make sure the marshmallow is expanding to occupy the full volume of the beaker out to the sides of the beaker.
12. Close the roughing valve when the top of the marshmallow reaches the 200 ml marked level on the beaker.
13. **Record** **the pressure** **value P2** pressure measurement reading from the pressure gauge.
14. Vent chamber to atmosphere.
15. Remove the beaker with marshmallow from the chamber.
16. Replace the marshmallow in the beaker with the second marshmallow.
17. Repeat steps 4 through 13.
18. **Record the temperature value Tf** from the thermometer sensing the temperature inside the chamber.
19. Vent chamber to atmosphere.
20. Remove the beaker with marshmallow from the chamber.
21. After removing items from the chamber, pump system to a vacuum pressure, close the roughing valve, turn off the pump and leave the system under vacuum and unpowered.

**Data Table for Learning Activity 4.3b (6 pts) Date data recorded: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

|  |  |
| --- | --- |
| **Data** | **Value and Unit of Measure** |
| Starting height of the marshmallow  *h* – Marshmallow 1 |  |
| Starting diameter of the marshmallow  *D* – Marshmallow 1 |  |
| Initial volume of the marshmallow  (*V1*) – Marshmallow 1 |  |
| Starting height of the marshmallow  *h* – Marshmallow 2 |  |
| Starting diameter of the marshmallow  *D* – Marshmallow 2 |  |
| Initial volume of the marshmallow  (*V1*) – Marshmallow 2 |  |
| Initial chamber temperature  (*Ti*) |  |
| Starting chamber pressure – atmospheric pressure  (*p1*) – Marshmallow 1 |  |
| Chamber pressure when the marshmallow fills the beaker to the 200 ml mark level  (*p2*) – Marshmallow 1 |  |
| Pre-determined volume occupied by marshmallow  (*V2*) – Marshmallow 1 | 200 ml |
| \*Initial volume of the marshmallow  (*V1*) – Marshmallow 2 |  |
| Starting chamber pressure – atmospheric pressure  (*P1*) – Marshmallow 2 |  |
| Chamber pressure when the marshmallow fills the beaker to the 200 ml mark level  (*P2*) – Marshmallow 2 |  |
| Pre-determined volume occupied by marshmallow  (*V2*) – Marshmallow 2 | 200 ml |
| Final chamber temperature  (*Tf*) |  |

**Analysis: Verify Boyles’ Law using the Pressure and Volume Measurements for Expanding Marshmallow**

Does *P1V1* = *P2V2*?  
Calculate *P1V1* and *P2V2*. Apply rules of significant figures to the calculated results. Calculate the percent difference between *P1V1* and *P2V2*. Are the *P1V1* and *P2V2* results close enough to verify Boyle’s law?

What are some reasons *P1V1* and *P2V2* might not be the same?

Why is the temperature measurement inside the chamber taken?

Did the different material types generate similar results? Comment on the similarities and the differences in the results.

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