Unit-09 Ideal Gas Experiment

Objective：

Clarify ideal gas formula through Ideal Gas Law Syringe, and derive gas molecular mole number n.

Apparatus：

Gas law syringe, pressure sensor, temperature sensor, digital device, analogy device, digital-analogy adapter

Principle：

A. Ideal gas formula

During 17th century, R. Boyle found the following relationship between pressure P and volumn V at constant temperature.

$$PV = const. \quad \text{(constant temperature)} \tag{1}$$

Result is called Boyle's law. In an isothermal process, the gas pressure P is inversely proportional to the gas volume V.

Charlie (J. Charles) and Lussac (J. Gay-Lussac) found that at a fixed pressure P, the density of the gas volume V and the Celsius temperature t have the following relationship

$$V = V_0\left(1 + \frac{t}{273.15}\right) \tag{2}$$

Where t is the Celsius temperature, and V_0 is the volume of gas at 0℃. That is, when the gas pressure P is constant, the increase in gas volume is $\frac{1}{273.15}$ times the amount of V_0 per Celsius.

From the gas temperature and the gas volume relationship can introduce a new temperature scale called the absolute temperature (absolute temperature):

$$T = 273.15 + t \tag{3}$$

From the above, 0℃ corresponds to 273.15 K ; Celsius temperature t = -273.15℃ equals the absolute temperature of 0 K, also known as absolute zero degree.

Assume T_0 = 273.15 K,(2) can be rewritten as

$$\frac{V}{T} = \frac{V_0}{T_0} = const. \tag{3}$$

When the gas pressure is constant, the gas volume of P and T is proportional to the absolute zero. That you combine (1) and (3) can find gas molecules must satisfy the following relationship:

$$\frac{PV}{T} = const. \tag{4}$$

This equation is called the ideal gas formula. The conditions were there is no volume, attractive ,and no interaction of gases between molecular.

B. Gas moleculars mole number

From the ideal gas equation, the gas temperature under the standard condition is around T_0 = 273.15 K, the gas pressure of about P_0=1 atm, and the gas volume of about V = 22.4 L ,which contribute to the equation (4) and get the gas constant R:

$$\begin{aligned} R &= \frac{P_0 V_0}{nT_0} = \frac{(1atm)(22.4L)}{(1mol)(273.15K)} \\ &= 0.082\frac{atm \cdot L}{mol \cdot K} \\ &= 8.31\frac{N \cdot m}{mol \cdot K} = 8.31\frac{J}{mol \cdot K} \end{aligned}$$

Gas equation includes n moles gas can be written as

$$\begin{aligned} PV &= nRT \\ \Rightarrow \frac{P}{T} &= nR\frac{1}{V} \end{aligned}$$

From the ideal gas equation, we can derive the gas volume V, temperature T and gas pressure P combine with following relation. Plot the figure between gas volume V(mL) and the gas temperature / gas pressure (K / kPa), and its slope equals nR. The number of moles of gas molecules can be expressed as:

$$n = \frac{slope}{8.31} \times 10^{-3}\,(mol)$$

Remarks：

1. When the time place piston barrel to the bottom of Gas Law Syringe, keep holding syringe by one hand and push piston barrel properly to the bottom by the other hand.

Procedure：

A. Clarify ideal gas formula

1. Press the piston down to the bottom of the sensor before the gas law syringe connected to any sensor. Recorded at this time the air column volume V_2, in other words, the lower edge of the piston (black rubber band) corresponding to the scale.
2. Pull up the piston from syringe, and record the volume inside V_1 (35.0 mL 40.0 mL),in other words, the lower edge of the piston (black rubber band) corresponding to the scale.
3. Open the software and set the related parameters by instruction book.

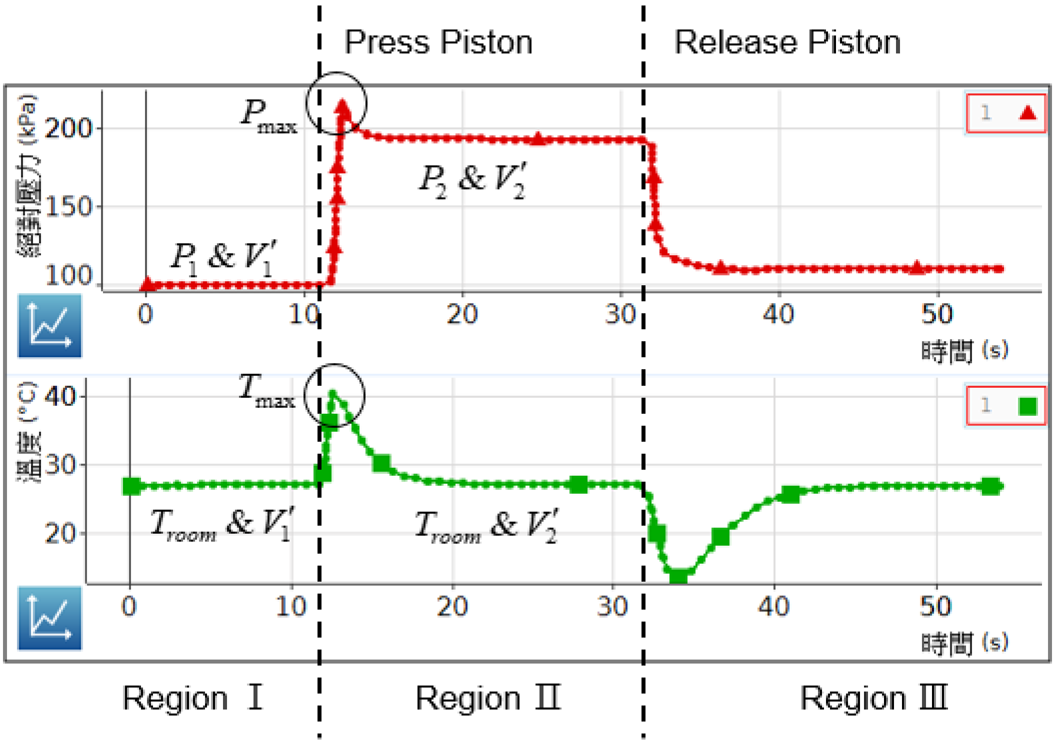

Figure 1. 『Pressure - Time』 and 『Temperature - Time』 diagram I

4. Press start button to start acquiring data, and observe the 『Pressure - Time』 and 『Temperature - Time』 diagram for about 10 seconds. (Figure 1, region I)
5. Hold the gas law syringe, and use the other hand to press the pistol to the bottom and keep it.

   [Note] The mark that was corresponded to the lower edge of the piston is V_2.

6. Observe『Pressure - Time』 diagram, the air pressure will rise from P_1 to a certain maximum pressure P_{max}, and then down to the steady pressure P_2. (Figure 1, region II)
7. Observe『Temperature - Time』diagram, the air temperature will rise rapidly from room temperature T_{room} to a maximum temperature T_{max}, and then down to room temperature T_{room}. (Figure 1, region II)
8. When the 『Pressure - Time』 and 『Temperature - Time』 diagram don't change for about 10 seconds, please release piston. (Figure 1, region III)
9. After release piston, observe the 『Pressure - Time』 and 『Temperature - Time』 diagram don't change for about 10 seconds, please stop catching data.

(a) Measure volume of the transparent plastic tube V_0 in constant temperature

1. Record『Pressure - Time』 and 『Temperature - Time』 diagram before pressing the pistol (Figure 1, region I) which means air pressure P_1 and air volume V_1' (including volume V_1 and plastic pipe volume V_0).
2. Record『Pressure - Time』and 『Temperature - Time』 after pressing the pistol and the temperature back to room temperature T_{room} (Figure 1, region II) which means air pressure P_2 and air volume V_2' (including the volumes of air column V_2 and plastic pipe V_0).

   [Note] $V_1' = V_1 + V_0$ 、 $V_2' = V_2 + V_0$

(b) Verify the ideal gas formula

1. As shown in Fig.1. Record the air pressure P_1, air temperature T_{room} and air volume V_1' (including the volumes of air column V_1 and plastic pipe volume V_0).
2. Record the maximum of air temperature T_{nax} and air pressure P_{nax} during the time pressing pistol.
3. Calculate $\frac{P_1 V_1'}{T_{room}}$ and $\frac{P_{max} V_2'}{T_{max}}$ from the equation.

B. Verify molecular mole number *n*

1. Pull up the pistol and make gas column inside mark to 60.0 mL scale.
2. Open the software and set the related parameters by instruction book.
3. Press start button to start acquiring data, and observe the『Pressure - Time』 and 『Temperature - Time』 diagram for about 10 seconds.
4. Hold the gas law syringe, and use the other hand to press the lower edge of pistol (black rubber band) to mark 55.0 mL, and keep it.
5. Observe『Pressure - Time』 diagram, the air pressure will rise from P_1 to a certain maximum pressure P_{max}, and then down to the steady pressure.
6. Observe『Temperature - Time』 diagram, the air temperature will rise rapidly from room temperature T_{room} to a maximum temperature T_{max}, and then down to room temperature T_{room}.

7. Record gas pressure value and gas temperature value of mark 60.0 ml, 55.0 mL, 50.0 mL, 45.0 mL, 40.0 mL, and 35.0 mL of 『Pressure - Time』and 『Temperature - Time』 diagram.
8. Observe the 『Pressure - Time』 and 『Temperature - Time』 diagram don't change for about 10 seconds, please stop catching data.
9. Plot $\frac{P}{T} - \frac{1}{V}$ diagram, and get the slope from Linear regression line.
10. Calculate molecular mole number of gas $n = \frac{slope}{8.31} \times 10^{-3}$ (mol).

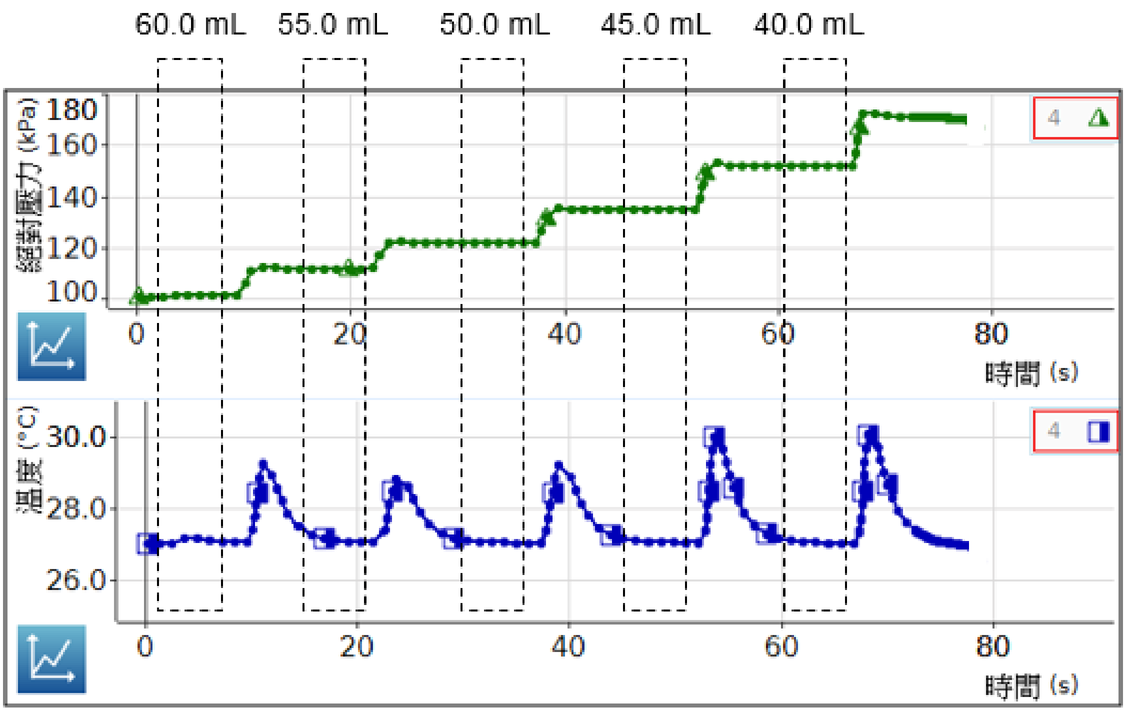

Figure 2. 『Pressure - Time』 and 『Temperature - Time』 diagram II

Questions：

1. Please compare $\frac{P_1 V_1'}{T_{room}}$ to $\frac{P_{\max} V_2'}{T_{\max}}$.
2. From the figure 1, under the condition of pressing the pistol for a while, give the reasons why will gas temperature back to room temperature slowly but gas pressure is larger than before. Please explain.
3. From the figure 1, temperature will decrease first and return to room temperature after releasing the pistol, why? Please explain.
4. Please compare gas moleculars mole number between experimental value real value.