Derivation of the Ideal Gas Law

An ideal gas is a hypothetical gas whose pressure, volume, and temperature follow the relationship $PV = nRT$. Ideal gases do not actually exist, although all real gases can behave like an ideal gas at certain temperatures and pressures. All gases can be described to some extent using the Ideal Gas Law, and it is important in our understanding of how all gases behave. In this assignment, you will derive the Ideal Gas Law from experimental observations.

The state of any gas can be described using the four variables: pressure ($P$), volume ($V$), temperature ($T$), and the number of moles of gas ($n$). Each experiment in Virtual ChemLab: Gases allows three of these variables (the independent variables) to be manipulated or changed and shows the effect on the remaining variable (the dependent variable).

1. Start Virtual ChemLab and select Ideal Gas Law from the list of assignments. The lab will open in the Gases laboratory.

2. Use the balloon experiment already setup in the laboratory to describe the relationship between pressure ($P$) and volume ($V$). Increase and decrease the pressure using the lever on the Pressure LCD controller to determine the effect on volume.

   What can you conclude about the effect of pressure on volume? Write a mathematical relationship using the proportionality symbol ($\propto$).

3. Use this same experiment to describe the relationship between temperature ($T$) and volume by increasing and decreasing the temperature.

   What can you conclude about the effect of temperature on volume? Write a mathematical relationship using the proportionality symbol ($\propto$).

4. Use this same experiment to describe the relationship between moles of gas and volume by increasing and decreasing the number of moles ($n$).

   What can you conclude about the effect of moles on volume? Write a mathematical relationship using the proportionality symbol ($\propto$).

5. Since volume is inversely proportional to pressure and directly proportional to temperature and moles, we can combine these three relationships into a single proportionality by showing how $V$ is proportional to $1/P$, $T$, and $n$. 
Write one combined proportion to show the relationship of volume to pressure, temperature and moles.

6. This proportional relationship can be converted into a mathematical equation by inserting a proportionality constant \((R)\) into the numerator on the right side.

Write this mathematical equation and rearrange with \(P\) on the left side with \(V\).

7. This equation is known as the Ideal Gas Law.

Using data for volume, temperature, pressure and moles from one of the gas experiments, calculate the value for \(R\) with units of \(L\cdot\text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}\). (Show all work and round to three significant digits).

8. Using the conversion between atmospheres and mm Hg \((1 \text{ atm} = 760 \text{ mm Hg})\), calculate the value for \(R\) with units of \(L \cdot \text{mm Hg} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}\). (Show all work and round to three significant digits).

9. Using the conversion between atmospheres and kPa \((1 \text{ atm} = 101.3 \text{ kPa})\), calculate the value for \(R\) with units of \(L \cdot \text{kPa} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}\). (Show all work and round to three significant digits).