# Four types of Ideal Gas Problems

- Ideal gas equation problems.
- Combined gas equation problems
- Gas stoichiometry problems
- Dalton's Law of partial pressures problems

# Algebraic Approach to Problem Solving

- Write down the values you are given, assigning variables to each.
- Write the appropriate equation.
- Solve for the variable of your unknown.
- Plug in values given, including their units.
- Cancel units and if necessary, do unit conversions to get the units to cancel.
- Do the calculation and report your answer with the correct significant figures and unit.

# Unit Check

- If your units cancel to yield the correct unit or units, you know that you…
  - used the correct equation,
  - did the algebra correctly,
  - and did all the necessary unit conversions.

# Ideal Gas Equation Derivation

$$P \propto n \quad \text{if } T \text{ and } V \text{ are constant}$$

$$P \propto T \quad \text{if } n \text{ and } V \text{ are constant}$$

$$P \propto \frac{1}{V} \quad \text{if } n \text{ and } T \text{ are constant}$$

$$P \propto \frac{nT}{V}$$

$$P = (\text{a constant})\frac{nT}{V}$$

$$PV = n(\text{a constant})T$$

$$\boldsymbol{PV = nRT} \qquad R = \frac{0.082058\ \text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \text{ or } \frac{8.3145\ \text{L} \cdot \text{kPa}}{\text{K} \cdot \text{mol}}$$

# Expanded Ideal Gas Equation

$$PV = nRT \qquad R = \frac{0.082058\ \text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \text{ or } \frac{8.3145\ \text{L} \cdot \text{kPa}}{\text{K} \cdot \text{mol}}$$

$$n = \text{moles} = \text{---}\ \text{g}\left(\frac{1\ \text{mol}}{\text{---}\ \cancel{\text{g}}}\right) = \frac{\text{grams}}{\frac{\text{grams}}{\text{mole}}} = \frac{\text{mass in grams}}{\text{molar mass}} = \frac{g}{M}$$

$$PV = \frac{g}{M}RT \qquad g = \text{mass} \qquad M = \text{molar mass}$$

# Ideal Gas Equation Problems

- **Tip-off** – The usual tip-off that you can use the ideal gas equation to answer a question is that you are given three properties of a sample of gas and asked to calculate the fourth. A more general tip-off is that only one gas is mentioned, there’s not chemical reaction mentioned, and there are no changing properties.

# Ideal Gas Equation Problem Step 1

- **Step 1:** Assign variables to the values given and the value that is unknown. Use P for pressure, V for volume, n for moles, T for temperature, g for mass, and M for molar mass.

# Ideal Gas Equation Problem Step 2

- **Step 2:** Write the appropriate form of the Ideal Gas Equation.
  - If the number of particles is given or desired in moles, use the most common form of the ideal gas equation.

$$PV = nRT \quad R = \frac{0.082058 \text{ L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \text{ or } \frac{8.3145 \text{ L} \cdot \text{kPa}}{\text{K} \cdot \text{mol}}$$

  - If mass or molar mass is given or desired, use the expanded form of the ideal gas equation.

$$PV = \frac{g}{M}RT \quad g = \text{mass} \quad M = \text{molar mass}$$

# Ideal Gas Equation Problem Steps 3-6

- **Step 3:** Rearrange the equation to isolate the unknown.
- **Step 4:** Plug in the known values, including units. Be sure to use kelvin temperatures.
- **Step 5:** Make any necessary unit conversions and cancel your units.
- **Step 6:** Calculate your answer and report it to the correct significant figures and with the correct unit.

# Example

- Most incandescent light bulbs contain argon, but krypton gas does a better job than argon of slowing the evaporation of the tungsten filament in the light bulb. Because of its higher cost, however, krypton is only used when longer life is considered to be worth the extra expense. How many moles of krypton gas must be added to a 175-mL incandescent light bulb to yield a gas pressure of 117 kPa at 21.6 ºC?

# Example 1

How many moles of krypton gas must be added to a 175-mL incandescent light bulb to yield a gas pressure of 117 kPa at 21.6 ºC?

$n$ = ?   $V$ = 175 mL   P = 117 kPa

$T$ = 21.6 ºC + 273.15 = 294.8 K

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{117\ \cancel{\text{kPa}}\ (175\ \cancel{\text{mL}})}{\left(\dfrac{8.3145\ \cancel{\text{L}}\cdot\cancel{\text{kPa}}}{\cancel{\text{K}}\cdot\text{mol}}\right) 294.8\ \cancel{\text{K}}}\left(\frac{1\ \cancel{\text{L}}}{10^3\ \cancel{\text{mL}}}\right)$$

$$= \mathbf{8.35 \times 10^{-3}\ mol}$$

# Example 2

What is the volume of an incandescent light bulb that contains 1.196 g Kr at a pressure of 1.70 atm and a temperature of 97 ºC?

$V$ = ?   $g$ = 1.196 g   P = 1.70 atm

$T$ = 97 ºC + 273.15 = 370 K

$$PV = \frac{g}{M}RT \qquad g = \text{mass} \qquad M = \text{molar mass}$$

$$V = \frac{gRT}{PM} = \frac{1.196\,\cancel{\text{g}}\left(\dfrac{0.082058\ \text{L}\cdot\cancel{\text{atm}}}{\cancel{\text{K}}\cdot\cancel{\text{mol}}}\right)370\ \cancel{\text{K}}}{(1.70\ \cancel{\text{atm}})\ 83.80\,\dfrac{\cancel{\text{g}}}{\cancel{\text{mol}}}} = \mathbf{0.255\ L\ Kr}$$

# Example 3

What is the density of krypton gas at 18.2 ºC and 762 mmHg?

$$\frac{g}{V} = ? \quad T = 18.2\ ºC + 273.15 = 291.4\ K \quad P = 762\ mmHg$$

$$PV = \frac{g}{M}RT \qquad g = \text{mass} \qquad M = \text{molar mass}$$

$$\frac{g}{V} = \frac{PM}{RT} = \frac{762\ \cancel{\text{mmHg}}\left(\dfrac{83.80\ \text{g}}{1\ \cancel{\text{mol}}}\right)}{\left(\dfrac{0.082058\ \text{L} \cdot \cancel{\text{atm}}}{\cancel{\text{K}} \cdot \cancel{\text{mol}}}\right) 291.4\ \cancel{\text{K}}}\left(\frac{1\ \cancel{\text{atm}}}{760\ \cancel{\text{mmHg}}}\right)$$

$$= \mathbf{3.51\ g/L}$$

# Combined Gas Law Equation Derivation

$$PV = nRT \qquad \frac{PV}{nT} = R$$

$$P_1V_1 = n_1RT_1 \quad \text{so} \quad \frac{P_1V_1}{n_1T_1} = R$$

$$P_2V_2 = n_2RT_2 \quad \text{so} \quad \frac{P_2V_2}{n_2T_2} = R$$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

# Combined Gas Law Equation Problems

- **Tip-off –** The problem requires calculating a value for a gas property that has changed. In other words, you are asked to calculate a new pressure, temperature, moles, or volume of gas given sufficient information about the initial and final of the other properties. A more general tip-off is that only one gas is mentioned, there’s no chemical reaction mentioned, and there are changing properties.

# Combined Gas Law Equation Problem Steps 1 and 2

- **Step 1:** Assign the variables P, T, n, and V to the values you are given and to the unknown value. Use the subscripts 1 and 2 to show initial or final conditions.
- **Step 2:** Write out the combined gas law equation, and eliminate the variables for any constant properties. (You can assume that the properties not mentioned in the problem remain constant.)

# Combined Gas Law Equation Problem Steps 3-6

- **Step 3:** Rearrange the equation to isolate the unknown property.
- **Step 4:** Plug in the values for the given properties.
- **Step 5:** Make any necessary unit conversions and cancel your units.
- **Step 6:** Calculate your answer and report it with the correct units and significant figures.

# Example 4

- A helium weather balloon is filled in Monterey, California, on a day when the atmospheric pressure is 102 kPa and the temperature is 18 ºC. Its volume under these conditions is $1.6 \times 10^4$ L. Upon being released, it rises to an altitude where the temperature is -8.6 ºC, and its volume increases to $4.7 \times 10^4$ L. Assuming that the internal pressure of the balloon equals the atmospheric pressure, what is the pressure at this altitude?

# Example 4

A helium weather balloon is filled in Monterey, California, on a day when the atmospheric pressure is 102 kPa and the temperature is 18 ºC. Its volume under these conditions is $1.6 \times 10^4$ L. Upon being released, it rises to an altitude where the temperature is -8.6 ºC, and its volume increases to $4.7 \times 10^4$ L. Assuming that the internal pressure of the balloon equals the atmospheric pressure, what is the pressure at this altitude?

$P_1$ = 102 kPa   $T_1$ = 18 ºC + 273.15 = 291 K   $V_1 = 1.6 \times 10^4$ L

$P_2$ = ?   $T_2$ = -8.6 ºC + 273.15 = 264.6 K   $V_1 = 4.7 \times 10^4$ L

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2} \qquad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \qquad P_2 = \frac{P_1 V_1 T_2}{V_2 T_1}$$

$$P_2 = P_1 \left(\frac{T_2}{T_1}\right)\left(\frac{V_1}{V_2}\right) = 103\ \text{kPa}\left(\frac{264.6\ \cancel{\text{K}}}{291\ \cancel{\text{K}}}\right)\left(\frac{1.6\times10^4\ \cancel{\text{L}}}{4.7\times10^4\ \cancel{\text{L}}}\right) = \mathbf{32\ kPa}$$