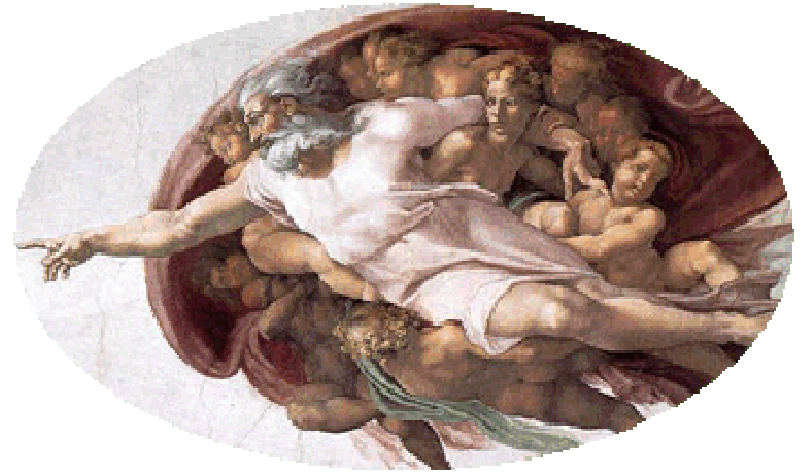


The Ideal Gas Law

$$PV = nRT$$



Ideal Gases

An “ideal” gas exhibits certain theoretical properties. Specifically, an ideal gas ...

- Obeys all of the gas laws under all conditions.
- Does not condense into a liquid when cooled.
- Shows perfectly straight lines when its V and T & P and T relationships are plotted on a graph.

In reality, there are no gases that fit this definition perfectly. We assume that gases are ideal to simplify our calculations.

We have done calculations using several gas laws (Boyle’s Law, Charles’s Law, Combined Gas Law). There is one more to know...

The Ideal Gas Law

$$PV = nRT$$

P = Pressure (in kPa) V = Volume (in L)

T = Temperature (in K) n = moles

$$R = 8.31 \frac{\text{kPa} \cdot \text{L}}{\text{K} \cdot \text{mol}}$$

R is constant. If we are given three of P, V, n, or T, we can solve for the unknown value.

Recall, From Boyle's Law:

$$P_1V_1 = P_2V_2 \quad \text{or } PV = \text{constant}$$

From combined gas law:

$$P_1V_1/T_1 = P_2V_2/T_2 \quad \text{or } PV/T = \text{constant}$$

Developing the ideal gas law equation

$PV/T = \text{constant}$. What is the constant?

At STP: $T = 273\text{K}$, $P = 101.3\text{ kPa}$, $V = 22.4\text{ L/mol}$

Because V depends on mol, $\frac{PV}{T \cdot \text{mol}} = \text{constant}$
we can change equation to:

Mol is represented by n ,
constant by R : $\frac{PV}{Tn} = R$

Rearranging, we get: $PV = nRT$

At STP: $(101.3\text{ kPa})(22.4\text{ L}) = (1\text{ mol})(R)(273\text{K})$

$$R = 8.31 \frac{\text{kPa} \cdot \text{L}}{\text{K} \cdot \text{mol}}$$

Note: always use kPa, L, K,
and mol in ideal gas law
questions (so units cancel)

Sample problems

How many moles of H₂ is in a 3.1 L sample of H₂ measured at 300 kPa and 20°C?

$$PV = nRT \quad P = 300 \text{ kPa}, V = 3.1 \text{ L}, T = 293 \text{ K}$$
$$(300 \text{ kPa})(3.1 \text{ L}) = n (8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(293 \text{ K})$$
$$\frac{(300 \text{ kPa})(3.1 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(293 \text{ K})} = n = 0.38 \text{ mol}$$

How many grams of O₂ are in a 315 mL container that has a pressure of 12 atm at 25°C?

$$PV = nRT \quad P = 1215.9 \text{ kPa}, V = 0.315 \text{ L}, T = 298 \text{ K}$$
$$\frac{(1215.9 \text{ kPa})(0.315 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(298 \text{ K})} = n = 0.1547 \text{ mol}$$
$$0.1547 \text{ mol} \times 32 \text{ g/mol} = 4.95 \text{ g}$$

Ideal Gas Law Questions

1. How many moles of $\text{CO}_2(\text{g})$ is in a 5.6 L sample of CO_2 measured at STP?
2. a) Calculate the volume of 4.50 mol of $\text{SO}_2(\text{g})$ measured at STP. b) What volume would this occupy at 25°C and 150 kPa? (solve this 2 ways)
3. How many grams of $\text{Cl}_2(\text{g})$ can be stored in a 10.0 L container at 1000 kPa and 30°C ?
4. At 150°C and 100 kPa, 1.00 L of a compound has a mass of 2.506 g. Calculate its molar mass.
5. 98 mL of an unknown gas weighs 0.087 g at SATP. Calculate the molar mass of the gas. Can you determine the identity of this unknown gas?

1. Moles of CO₂ is in a 5.6 L at STP?

P=101.325 kPa, V=5.6 L, T=273 K PV = nRT

$$(101.3 \text{ kPa})(5.6 \text{ L}) = n (8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})$$

$$\frac{(101.325 \text{ kPa})(5.6 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})} = n = 0.25 \text{ mol}$$

2. a) Volume of 4.50 mol of SO₂ at STP.

P= 101.3 kPa, n= 4.50 mol, T= 273 K PV=nRT

$$(101.3 \text{ kPa})(V)=(4.5 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})$$

$$V = \frac{(4.50 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(273 \text{ K})}{(101.3 \text{ kPa})} = 100.8 \text{ L}$$

2. b) Volume at 25°C and 150 kPa (two ways)?

Given: $P = 150 \text{ kPa}$, $n = 4.50 \text{ mol}$, $T = 298 \text{ K}$

$$V = \frac{(4.50 \text{ mol})(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(298 \text{ K})}{(150 \text{ kPa})} = 74.3 \text{ L}$$

From a): $P = 101.3 \text{ kPa}$, $V = 100.8 \text{ L}$, $T = 273 \text{ K}$

Now $P = 150 \text{ kPa}$, $V = ?$, $T = 298 \text{ K}$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$
$$\frac{(101.3 \text{ kPa})(100 \text{ L})}{(273 \text{ K})} = \frac{(150 \text{ kPa})(V_2)}{(298 \text{ K})}$$

$$(V_2) = \frac{(101.3 \text{ kPa})(100.8 \text{ L})(298 \text{ K})}{(273 \text{ K})(150 \text{ kPa})} = 74.3 \text{ L}$$

3. How many grams of $\text{Cl}_2(\text{g})$ can be stored in a 10.0 L container at 1000 kPa and 30°C ?

$$PV = nRT \quad P = 1000 \text{ kPa}, V = 10.0 \text{ L}, T = 303 \text{ K}$$

$$\frac{(1000 \text{ kPa})(10.0 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(303 \text{ K})} = n = 3.97 \text{ mol}$$
$$3.97 \text{ mol} \times 70.9 \text{ g/mol} = 282 \text{ g}$$

4. At 150°C and 100 kPa, 1.00 L of a compound has a mass of 2.506 g. Calculate molar mass.

$$PV = nRT \quad P = 100 \text{ kPa}, V = 1.00 \text{ L}, T = 423 \text{ K}$$

$$\frac{(100 \text{ kPa})(1.00 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(423 \text{ K})} = n = 0.02845 \text{ mol}$$

$$\text{g/mol} = 2.506 \text{ g} / 0.02845 \text{ mol} = 88.1 \text{ g/mol}$$

5. 98 mL of an unknown gas weighs 0.081 g at SATP. Calculate the molar mass.

$$PV = nRT \quad P = 100 \text{ kPa}, V = 0.098 \text{ L}, T = 298 \text{ K}$$

$$\frac{(100 \text{ kPa})(0.098 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L}/\text{K}\cdot\text{mol})(298 \text{ K})} = n = 0.00396 \text{ mol}$$

$$\text{g/mol} = 0.081 \text{ g} / 0.00396 \text{ mol} = 20.47 \text{ g/mol}$$

It's probably neon

(neon has a molar mass of 20.18 g/mol)

Determining the molar mass of butane

Using a butane lighter, balance, and graduated cylinder determine the molar mass of butane.

- Determine the mass of butane used by weighing the lighter before and after use.
- The biggest source of error is the mass of H₂O remaining on the lighter. As a precaution, dunk the lighter & dry well before measuring initial mass. After use, dry well before taking final mass. (Be careful not to lose mass when drying).
- When you collect the gas, ensure no gas escapes & that the volume is 90 – 100 mL.
- Place used butane directly into fume hood.
- Submit values for mass, volume, & g/mol.



Molar Mass of Butane: Data & Calculations

Atmospheric pressure:

Temperature: