

Ideal Gas Law

You can relate Pressure (P), Volume (V), Temperature (T), and moles (n) under the following assumptions that define "Ideal" behavior:

1. Molecules of an ideal gas don't interact with each other.
2. Molecules of an ideal gas have no volume.

$$PV=nRT$$

*Always use absolute temperature

*Always choose R to be consistent with P, V, T.

Nonideal Gases

The closer that a gas is to the liquid state, the more it will deviate from ideal behavior.

High temperature and pressure (gas volume is no longer negligible)

Strong intermolecular forces (intermolecular attraction is no longer negligible)

The **van der Waals equation** is an equation of state which may be used to account for deviations from ideality.

$$\left(P + a \cdot \frac{n^2}{V^2}\right)(V - nb) = nRT$$

Take a look, if the van der Waals constants a and b are zero, the equation reduces to the ideal gas law.

The **van der Waals constant a** accounts for deviations caused by the attractive forces between particles.

The **van der Waals constant b** accounts for deviations caused by particle volume.

Know how to solve the van der Waals equation for pressure:

$$P = \frac{nRT}{V - nb} - a \cdot \frac{n^2}{V^2}$$

Here are some van der Waals constants for some typical gases

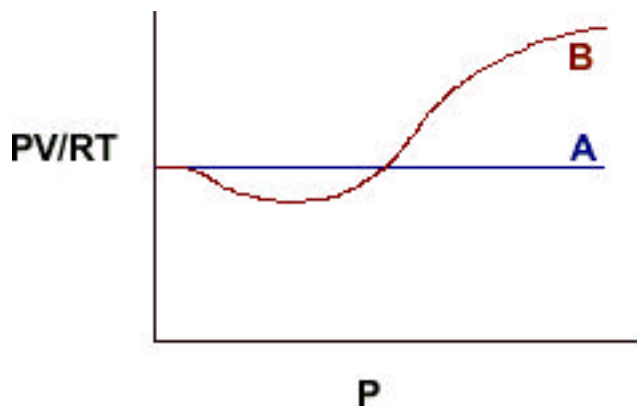
Gas	a (L ² •atm)/(mol ²)	b (L/mol)
H ₂	0.244	0.027
O ₂	1.360	0.032
N ₂	1.390	0.039
CH ₄	2.253	0.043
CO ₂	3.592	0.043
SO ₂	6.714	0.056
Cl ₂	6.493	0.056
H ₂ O	5.464	0.030

Student Packet: 3.2: Non-Ideal Gases: AssessMe questions

- 1) A hydrogen gas thermometer has a volume of 100 ml at 0°C. When immersed in a low temperature liquid the volume of the gas fell to 87.2 ml. What was the temperature of the liquid? ($R = 0.0821 \text{ L}\cdot\text{atm} / \text{K}\cdot\text{mole}$)
- A) -35°C B) 13°C C) 35 K D) 0.0872°C E) I'm clueless
- 2) A 22.4 liter sample of gas at STP weighs 16.0 grams. What is the molecular weight of the gas?
- A) 22.4 g/mol B) 16.0 g/mol C) 29.4 g/mol D) 12.0 g/mol E) I'm clueless
- 3) Which of the following would have the largest second ionization energy?
- A) K B) Ne C) Cl D) Na E) I'm clueless
- 4) Which gaseous atom has the highest second ionization energy?
- A) C B) Li C) F D) Ne E) I'm clueless
- 5) In any one period of the periodic table, the element in Group I, as compared to the element in Group VII, has a
- A) larger number of valence electrons.
B) lower electron affinity.
C) smaller radius.
D) higher ionization energy.
E) I'm clueless
- 6) Which of the following ions is largest in size?
- A) O^{2-} B) Al^{3+} C) Na^+ D) F^- E) I'm clueless

Student Packet: 3.2: Non-Ideal Gases: ShowMe questions

- 1) Of the following plots of PV/RT vs. P , which corresponds to a real gas, and which corresponds to an ideal gas?



- 2) The van der Waals equation of state is an empirical equation designed to correct for the deviation from ideality of real gases. According to the van der Waals equation,

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

- a) Which of the following gases has a larger value of a ?

H_2O or H_2

- b) Which of the following gases has a larger value of b ?

He or Cl_2

- 3) Calculate the pressure exerted by 1.00 mol of $He_{(g)}$ in a 3.00 L steel cylinder at 300 K assuming that the gas behaves ideally.

Calculate the pressure of $He_{(g)}$ under the same conditions using the van der Waals equation.

$$(a \text{ He} = 0.034 \text{ atm}\cdot\text{L}^2/\text{mol}^2; \text{ } b \text{ He} = 0.0237 \text{ L/mol})$$

- 4) Calculate the pressure exerted by 1.00 mol of $He_{(g)}$ in a 0.300 L steel cylinder at 800 K, assuming that the gas behaves ideally.

Calculate the pressure of $He_{(g)}$ under the same constant using the van der Waals equation.

$$(a \text{ He} = 0.034 \text{ atm}\cdot\text{L}^2/\text{mol}^2; \text{ } b \text{ He} = 0.0237 \text{ L/mol})$$

Student Packet: 3.2: Non-Ideal Gases: TestMe questions

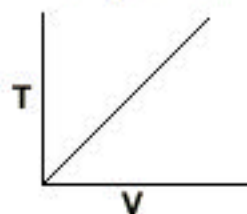
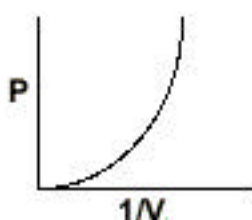
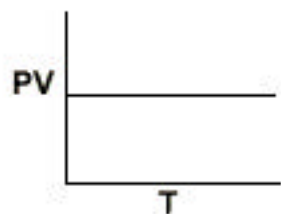
- 1) Match the following gases with their van der Waals b constants:

Gases: (Ne, N₂, Cl₂) b (L/mol): (0.0391, 0.0171, 0.0562)

- A) b Ne = 0.0391, b N₂ = 0.0171, b Cl₂ = 0.0562
 B) b Ne = 0.0391, b N₂ = 0.0562, b Cl₂ = 0.0171
 C) b Ne = 0.0171, b N₂ = 0.0391, b Cl₂ = 0.0562
 D) b Ne = 0.0171, b N₂ = 0.0562, b Cl₂ = 0.0391
 E) b Ne = 0.0562, b N₂ = 0.0171, b Cl₂ = 0.0391

- 2) Which of the following plots for 1 mol of gas represent(s) a non-ideal gas?

I. PV vs. V , constant T II. P vs. $1/V$, constant T III. T vs. V , constant P



- A) I, II, III B) I and III C) I only D) II only E) III only

- 3) Match the following gases with their van der Waals a constants:

Gases: (CO₂, H₂O, Ne) a (atm L²/mol²): (0.211, 3.59, 5.46)

- A) a CO₂ = 0.211, a H₂O = 3.59, a Ne = 5.46
 B) a CO₂ = 3.59, a H₂O = 0.211, a Ne = 5.46
 C) a Ne = 0.211, a H₂O = 5.46, a Ne = 0.211
 D) a CO₂ = 5.46, a H₂O = 3.59, a Ne = 0.211
 E) a CO₂ = 5.46, a H₂O = 0.211, a Ne = 3.59

- 4) A steel cylinder with a radius of 10.0 cm and a height of 25.0 cm is filled with 500.0 g of argon gas at 27°C. What is the observed pressure of argon according to the ideal gas equation?

- A) 3.53 atm B) 38.0 atm C) 39.2 atm D) 123 atm E) 1570 atm

- 5) Calculate the pressure of argon under the conditions of the previous problem ($V = 7.85$ L, $n = 12.52$ moles and $T = 300$ K) using the van der Waals gas equation:

$$\left[P + a \left(\frac{n}{V} \right)^2 \right] (V - nb) = nRT$$

where: a Argon = $1.35 \frac{\text{atm L}^2}{\text{mol}^2}$, b Argon = 0.0322 L/mol

- A) 3.53 atm B) 38.0 atm C) 39.2 atm D) 123 atm E) 1570 atm