Real Gases: Deviations From Ideal Behavior

Advanced Chemistry

Introduction

- The extent to which a real gas departs from ideal behavior can be seen by rearranging the ideal-gas equation to solve for n.

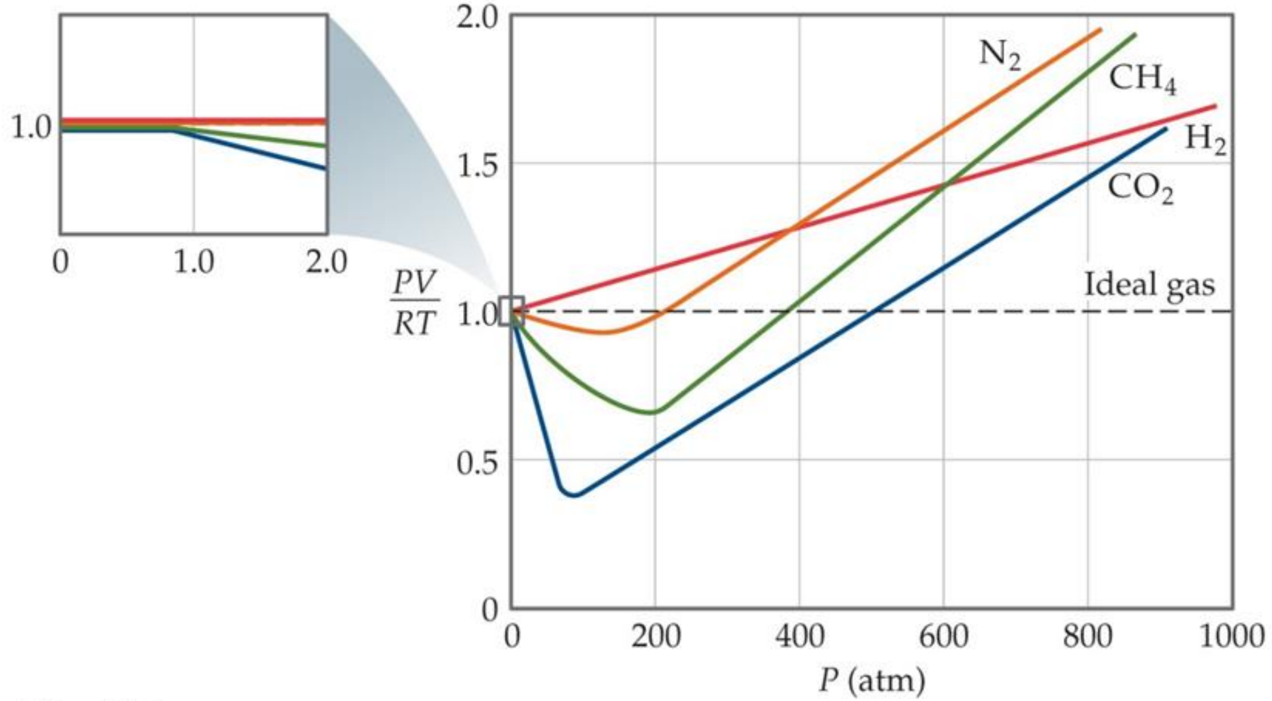
$$\frac{PV}{RT} = n$$

- The equation tells us that for 1 mol of ideal gas, the quantity PV/RT equals 1 at all pressures.

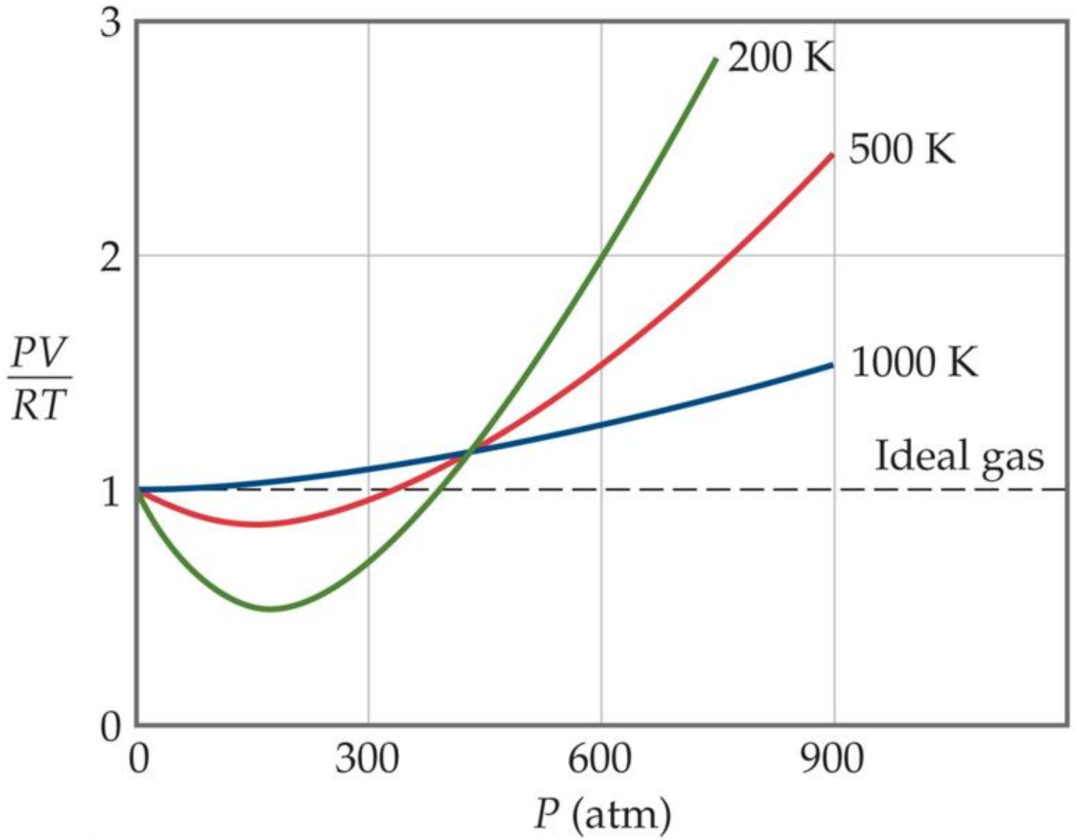
Ideal-Gas Law Deviation

- At high pressures (above 10atm), the deviation from ideal behavior is large and different for each gas.
- At lower pressures (below 10atm), the deviation from ideal behavior is small.
- At high temperatures, the deviation is small
- At low temperatures, the deviation is large

- The behavior of real gases only conforms to the ideal-gas equation at relatively high temperatures and low pressure.



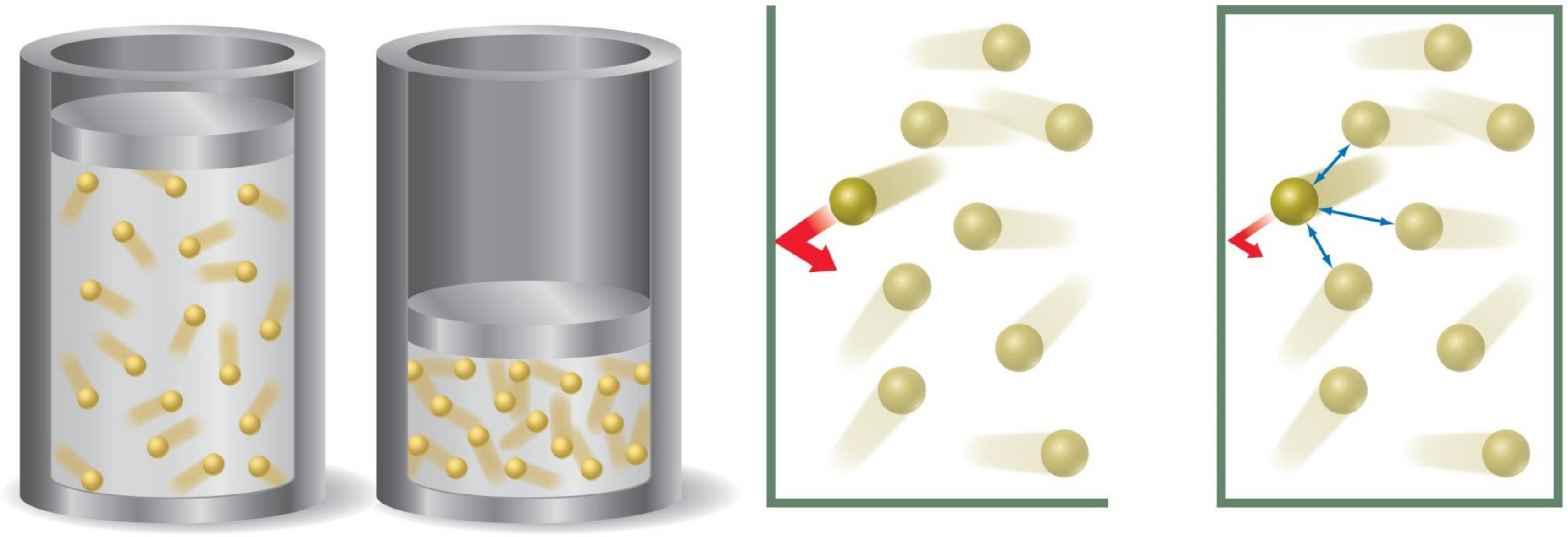
- Even the same gas will show wildly different behavior under high pressure at different temperatures.



Knowledge Check

- Under which conditions do you expect helium gas to deviate most from ideal behavior?
  - 100 K and 1 atm
  - 100 K and 5 atm
  - 300 K and 2 atm

Deviations from Ideal Behavior



The assumptions made in the kinetic-molecular model (negligible volume of gas molecules themselves, no attractive forces between gas molecules, etc.) break down at high pressure and/or low temperature.

Corrections for Nonideal Behavior

- The ideal-gas equation can be adjusted to take these deviations from ideal behavior into account.
- The corrected ideal-gas equation is known as van der Waals equation.

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

Van der Waals

- $(P + \frac{n^2 a}{V^2})(v - nb) = nRT$
  - a = a measure of how strongly the gas molecules attract one another
  - b = measure of the finite volume occupied by the molecules
- a and b are constants determined through experiments.
- R = 0.08206 L-atm/mol-K

TABLE 10.3 • Van der Waals Constants for Gas Molecules

Substance	a (L^2-atm/mol^2)	b (L/mol)
He	0.0341	0.02370
Ne	0.211	0.0171
Ar	1.34	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0510
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
H_2O	5.46	0.0305
CH_4	2.25	0.0428
CO_2	3.59	0.0427
CCl_4	20.4	0.1383

Using Van der Waals Equation

- Use the Van der Waals equation to estimate the pressure exerted by 1.00 mol of $Cl_2(g)$ in 22.41 L at 273.15 K

Comparing Van der Waals to Ideal Gas Law

- Use ideal gas equation to determine the pressure exerted by 1.00 mol of $Cl_2(g)$ in 22.41 L at 273.15 K

HOMEWORK

- A sample of 1.00 mol of CO_2(g) is confined to a 3.00 L container at 273.15 K. Calculate the pressure of the gas
  - (a) the ideal gas law

HOMEWORK

- A sample of 1.00 mol of CO_2(g) is confined to a 3.00 L container at 273.15 K. Calculate the pressure of the gas
  - (b) the van der Waals equation

More Practice

- Using the van der Waals equation, the pressure in a 22.41 L vessel containing 1.00 mol of neon gas at 100.0°C is ___________ atm. (*a* = 0.211 L2-atm/mol2, *b* = 0.0171 L/mol)

HOMEWORK

- Using the van der Waals equation, the pressure in a 22.41 L vessel containing 1.50 mol of xenon gas at 100.0°C is ___________ atm. (*a* = 4.19 L2-atm/mol2, *b* = 0.0510 L/mol)