

Unit 6 Phases of Matter

- Real gases

Real gases

- The ideal gas model assumes molecules do not interact. Real molecules **do** have interactions.
- At low densities (low pressure), molecules in the gas spend little time close together so the effect of any interactions is negligible and the ideal gas equation can be quite accurate.
- At high densities (high pressure), interactions start to have an effect and more accurate gas equations are needed, such as the virial equation or the van der Waals equation.

Van der Waals' Equation

1. **Repulsive interaction** (Size effect): The repulsive interaction between molecules implies that they cannot come closer than a certain distance. The actual volume in which the molecules can move is thus reduced compared with the volume of the container V . Therefore, we replace V in the ideal gas law by $(V - nb)$, where b is a constant specific to each gas.
2. **Attractive forces**: The attractive forces reduce the pressure that the gas exerts. Thus, the observed pressure p will be less than the ideal gas pressure P_{ideal} . Therefore, P_{ideal} in the ideal gas law is replaced by $(P + an^2/V^2)$ where a is a constant specific to each gas.

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

attraction repulsion

van der Waals Constants for Gas Molecules

Substance	a (L²-atm/mol²)	B (L/mol)
He	0.0341	0.02370
Ne	0.211	0.0171
Ar	1.34	0.0322
Kr	2.32	0.0398
H ₂	0.244	0.0266
Cl ₂	6.49	0.0562
H ₂ O	5.46	0.0305
NH ₃	4.17	0.0371
CH ₄	2.25	0.0428
CO ₂	3.59	0.0427
CH ₃ OH	9.65	0.0670
C ₃ H ₈	8.78	0.0844
NO ₂	5.354	0.0442
SO ₂	6.803	0.0563

Virial Equation

- Compressibility factor: $z \equiv PV / (nRT)$; ideal gas: $z = 1$

$$z \equiv \frac{PV}{nRT} = 1 + \frac{B_{2P}}{RT} \cdot P + \frac{B_{3P}}{RT} \cdot P^2 + \frac{B_{4P}}{RT} \cdot P^3 + \dots$$

$B_{2P}, B_{2p}, B_{2p}, \dots$ are virial coefficients

- Experimental observations:

