

Tutorial Four

Ideal gas (Perfect gas) vs. non-ideal gas (Real gas)

Q1)

Calculate the pressure exerted by the gas CO₂ which has the following properties;

$$V = 22.4 \text{ liter; } n = 1.0 \text{ mole; } T = 0^\circ \text{C}$$

$$a = 3.592 \text{ L}^2 \text{ atm/mol}^2$$

$$b = 0.04267 \text{ L/mol}$$

1. Assume ideal gas behavior
2. Assume non-ideal gas behavior (use Van der Waals equation)

Solution

Part one: (ideal gas behavior)

$$PV = nRT : R = 0.08206 \text{ L atm/mol K}$$

$$P = nRT/V = (1.0 \text{ mol})(0.08206 \text{ L atm/mol K}) (0+273)/(22.4 \text{ L})$$

$$P = 1.0 \text{ atm}$$

Part two: (non-ideal gas behavior)

$$[P + a(n/V)^2] (V - nb) = nRT$$

$$[P + (3.592 \text{ L}^2 \text{ atm/mol}^2) (1.0 \text{ mol})^2 / (22.4 \text{ L})^2] [22.4 \text{ L} - (1.0 \text{ mol})(0.04267 \text{ L/mol})] = (1.0 \text{ mol})(0.08206 \text{ L atm/mol K})(0+273 \text{ K})$$

$$P_{\text{ideal}} = 1 \text{ atm} : P_{\text{real}} = 0.995 \text{ atm}$$

$$V_{\text{ideal}} = 22.4 \text{ L} : V_{\text{real}} = 22.4 - 1 \times 0.04267 = 22.35733 \text{ L}$$

$$V_{\text{real}} / V_{\text{ideal}} = 22.35733/22.4 = 0.9981 = 1.0$$

Q2)

Calculate the pressure exerted by the gas CO₂ which has the following properties;

$$V = 0.2 \text{ liter; } n = 1.0 \text{ mole; } T = 0 \text{ }^{\circ}\text{C}$$

$$a = 3.592 \text{ L}^2 \text{ atm/mol}^2$$

$$b = 0.04267 \text{ L/mol}$$

1. Assume ideal gas behavior
2. Assume non-ideal gas behavior (use Van der Waals equation)

Solution

Part one: (ideal gas behavior)

$$PV = nRT$$

$$P = nRT/V = (1.0 \text{ mol})(0.08206 \text{ L atm/mol K}) (0+273)/(0.2 \text{ L})$$

$$P = 112 \text{ atm}$$

Part two: (non-ideal gas behavior)

$$[P + a(n/V)^2] (V - nb) = nRT$$

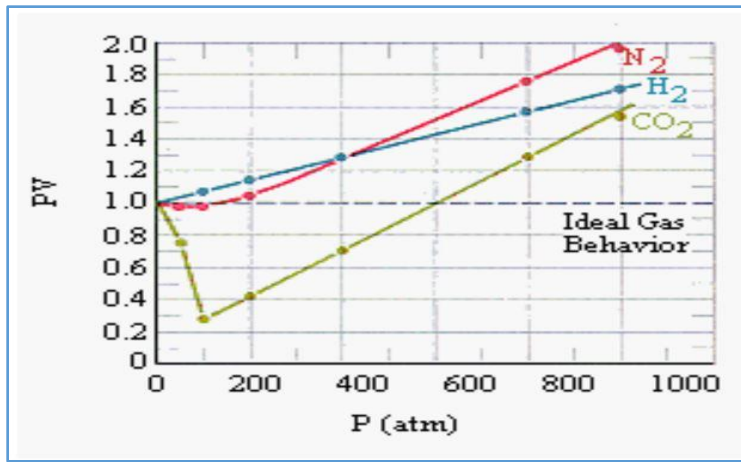
$$[P + (3.592 \text{ L}^2 \text{ atm/mol}^2) (1.0 \text{ mol})^2 / (0.2 \text{ L})^2] [0.2 \text{ L} - (1.0 \text{ mol})(0.04267 \text{ L/mol})] = (1.0 \text{ mol})(0.08206 \text{ L atm/mol K})(0+273 \text{ K})$$

$$P_{\text{ideal}} = 112 \text{ atm} : P_{\text{real}} = 52.6 \text{ atm}$$

$$V_{\text{ideal}} = 0.2 \text{ L} : V_{\text{real}} = 0.2 - 1 \times 0.04267 = 0.15733 \text{ L}$$

$$V_{\text{real}} / V_{\text{ideal}} = 0.15733/0.2 = 0.787$$

As the pressure of CO₂ increases the van der Waals equation initially gives pressures that are *smaller* than the ideal gas equation, as shown in the figure below, because of the strong force of attraction between CO₂ molecules.



Q3)

Calculate the pressure exerted by the gas CO₂ which has the following properties;

$V = 0.05$ liter; $n = 1.0$ mole; $T = 0\text{ }^{\circ}\text{C}$

$a = 3.592\text{ L}^2\text{ atm/mol}^2$

$b = 0.04267\text{ L/mol}$

1. Assume ideal gas behavior
2. Assume non-ideal gas behavior (use Van der Waals equation)

Solution

Part one: (ideal gas behavior)

$$PV = nRT$$

$$P = nRT/V = (1.0\text{ mol})(0.08206\text{ L atm/mol K})(0+273)/(0.05\text{ L})$$

$$P = 448\text{ atm}$$

Part two: (non-ideal gas behavior)

$$[P + a(n/V)^2] (V - nb) = nRT$$

$$[P + (3.592\text{ L}^2\text{ atm/mol}^2)(1.0\text{ mol})^2 / (0.05\text{ L})^2] [0.05\text{ L} - (1.0\text{ mol})(0.04267\text{ L/mol})] = (1.0\text{ mol})(0.08206\text{ L atm/mol K})(0+273\text{ K})$$

$$P = 1620\text{ atm}$$

$$P_{\text{ideal}} = 448\text{ atm} : P_{\text{real}} = 1620\text{ atm}$$

$$V_{\text{ideal}} = 0.05\text{ L} : V_{\text{real}} = 0.05 - 1 \times 0.04267 = 0.00733\text{ L}$$

$$V_{\text{real}} / V_{\text{ideal}} = 0.00733/0.05 = 0.1466$$

The van der Waals equation gives results that are *larger* than the ideal gas equation at very high pressures, as shown in the figure above, because of the volume occupied by the CO₂ molecules.