3.16

What is the relative (%) change in P if we double the absolute temperature of an ideal gas keeping mass and volume constant? Repeat if we double V having m, T constant.

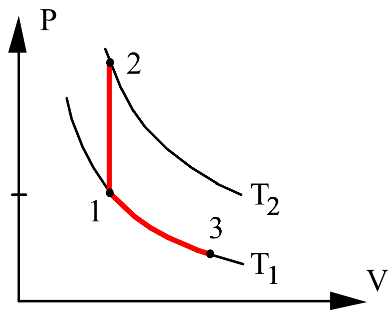
Ideal gas law: $PV = mRT$

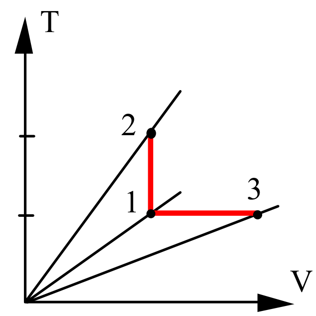
State 2: $P_2V = mRT_2 = mR2T_1 = 2P_1V \Rightarrow P_2 = 2P_1$

Relative change = $\Delta P/P_1 = P_1/P_1 = 1 =$ **100%**

State 3: $P_3V_3 = mRT_1 = P_1V_1 \Rightarrow P_3 = P_1V_1/V_3 = P_1/2$

Relative change = $\Delta P/P_1 = -P_1/2P_1 = -0.5 =$ **-50%**





3.17

Calculate the ideal gas constant for argon and hydrogen based on table A.2 and verify the value with Table A.5

The gas constant for a substance can be found from the universal gas constant from the front inside cover and the molecular weight from Table A.2

Argon: $R = \frac{\bar{R}}{M} = \frac{8.3145}{39.948}$ **= 0.2081 kJ/kg K**

Hydrogen: $R = \frac{\bar{R}}{M} = \frac{8.3145}{2.016}$ **= 4.1243 kJ/kg K**

3.18

How close to ideal gas behavior (find Z) is ammonia at saturated vapor, 100 kPa? How about saturated vapor at 2000 kPa?

Table B.2.2: $v_1 = 1.1381\ m^3/kg$, $T_1 = -33.6^oC$, $P_1 = 100\ kPa$

$v_2 = 0.06444\ m^3/kg$, $T_2 = 49.37^oC$, $P_2 = 2000\ kPa$

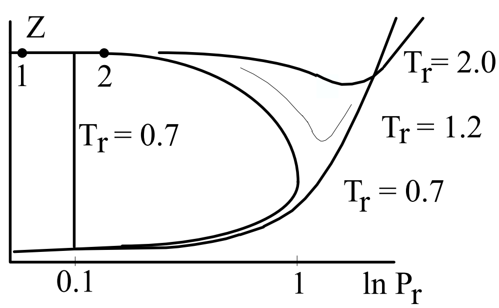
Table A.5: $R = 0.4882\ kJ/kg\ K$

Extended gas law: $Pv = ZRT$ so we can calculate Z from this

$$Z_1 = \frac{P_1v_1}{RT_1} = \frac{100 \times 1.1381}{0.4882 \times (273.15 - 33.6)} = 0.973$$

$$Z_2 = \frac{P_2v_2}{RT_2} = \frac{2000 \times 0.06444}{0.4882 \times (273.15 + 49.37)} = 0.8185$$

So state 1 is close to ideal gas and state 2 is not so close.



3.52

Saturated water vapor at 200 kPa is in a constant pressure piston cylinder. At this state the piston is 0.1 m from the cylinder bottom. How much is this distance and the temperature if the water is heated to occupy twice the original volume?

Solution:

From B.1.2, $v_1 = 0.8857\ m^3/kg$

2: From B.1.3., $P_2 = P_1$, $v_2 = 2v_1 = 2 \times 0.8857 = 1.7714\ m^3/kg$

Since the cross sectional area is constant the height is proportional to volume

$$h_2 = h_1\ v_2/v_1 = 2h_1 = \mathbf{0.2\ m}$$

Interpolate for the temperature

$$T_2 = 400 + 100\ \frac{1.7714 - 1.5493}{1.78139 - 1.5493} \approx \mathbf{496°C}$$

3.65

A spherical helium balloon of 10 m in diameter is at ambient T and P, 15^{o}C and 100 kPa. How much helium does it contain? It can lift a total mass that equals the mass of displaced atmospheric air. How much mass of the balloon fabric and cage can then be lifted?

$$V = \frac{\pi}{6} D^3 = \frac{\pi}{6} 10^3 = 523.6 \text{ m}^3$$

$$m_{He} = \rho V = \frac{V}{v} = \frac{PV}{RT}$$

$$= \frac{100 \times 523.6}{2.0771 \times 288} = 87.5 \text{ kg}$$

$$m_{air} = \frac{PV}{RT} = \frac{100 \times 523.6}{0.287 \times 288} = 633 \text{ kg}$$

$$m_{lift} = m_{air} - m_{He} = 633\text{-}87.5 = \mathbf{545.5\ kg}$$

3.68

A rigid tank of 1 m^3 contains nitrogen gas at 600 kPa, 400 K. By mistake someone lets 0.5 kg flow out. If the final temperature is 375 K what is then the final pressure?

Solution:

$$m = \frac{PV}{RT} = \frac{600 \times 1}{0.2968 \times 400} = 5.054 \text{ kg}$$

$$m_2 = m - 0.5 = 4.554 \text{ kg}$$

$$P_2 = \frac{m_2 R T_2}{V} = \frac{4.554 \times 0.2968 \times 375}{1} = \mathbf{506.9\ kPa}$$

3.71

A hollow metal sphere of 150-mm inside diameter is weighed on a precision beam balance when evacuated and again after being filled to 875 kPa with an unknown gas. The difference in mass is 0.0025 kg, and the temperature is 25°C. What is the gas, assuming it is a pure substance listed in Table A.5 ?

Solution:

Assume an ideal gas with total volume: $V = \frac{\pi}{6}(0.15)^3 = 0.001767 \text{ m}^3$

$$M = \frac{m\bar{R}T}{PV} = \frac{0.0025 \times 8.3145 \times 298.2}{875 \times 0.001767} = \mathbf{4.009} \approx M_{He}$$

=> **Helium Gas**