3.50
Is it reasonable to assume that at the given states the substance behaves as an ideal gas?

Solution:

a) Oxygen, O$_2$ at 30°C, 3 MPa Ideal Gas (T $>$ $T_c = 155$ K from A.2)

b) Methane, CH$_4$ at 30°C, 3 MPa Ideal Gas (T $>$ $T_c = 190$ K from A.2)

c) Water, H$_2$O at 30°C, 3 MPa NO compressed liquid $P > P_{sat}$ (B.1.1)

d) R-134a at 30°C, 3 MPa NO compressed liquid $P > P_{sat}$ (B.5.1)

e) R-134a at 30°C, 100 kPa Ideal Gas $P$ is low $< P_{sat}$ (B.5.1)

3.53
A 1 m$^3$ rigid tank has propane at 100 kPa, 300 K and connected by a valve to another tank of 0.5 m$^3$ with propane at 250 kPa, 400 K. The valve is opened and the two tanks come to a uniform state at 325 K. What is the final pressure?

Solution:
Propane is an ideal gas ($P << P_c$) with $R = 0.1886$ kJ/kgK from Tbl. A.5

\[ m_A = \frac{P_A V_A}{RT_A} = \frac{100 \times 1}{0.1886 \times 300} = 1.7674 \text{ kg} \]

\[ m_B = \frac{P_B V_B}{RT_B} = \frac{250 \times 0.5}{0.1886 \times 400} = 1.6564 \text{ kg} \]

\[ V_2 = V_A + V_B = 1.5 \text{ m}^3 \]

\[ m_2 = m_A + m_B = 3.4243 \text{ kg} \]

\[ P_2 = \frac{m_2 RT_2}{V_2} = \frac{3.4243 \times 0.1886 \times 325}{1.5} = 139.9 \text{ kPa} \]
3.54

A glass is cleaned in 45°C hot water and placed on the table bottom up. The room air at 20°C that was trapped in the glass gets heated up to 40°C and some of it leaks out so the net resulting pressure inside is 2 kPa above ambient pressure of 101 kPa. Now the glass and the air inside cools down to room temperature. What is the pressure inside the glass?

Solution:

\[
\begin{align*}
1 \text{ air: } & \quad 40^\circ\text{C, } 103 \text{ kPa} \\
2 \text{ air: } & \quad 20^\circ\text{C, } \ ? \\
\text{Constant Volume: } V_1 &= V_2,
\end{align*}
\]

\[
\begin{align*}
\text{Constant Mass } m_1 &= m_2 \\
\text{Ideal Gas } & \quad P_1V_1 = m_1RT_1 \quad \text{ and } \quad P_2V_2 = m_1RT_2 \\
\text{Take Ratio } & \quad \frac{P_2}{P_1} = \frac{T_1}{T_2} = 103 \times \frac{29 + 273}{40 + 273} = 96.4 \text{ kPa}
\end{align*}
\]

3.59

Verify the accuracy of the ideal gas model when it is used to calculate specific volume for saturated water vapor as shown in Fig. 3.9. Do the calculation for 10 kPa and 1 MPa.

Solution:

Look at the two states assuming ideal gas and then the steam tables.

\text{Ideal gas:}

\[
v = \frac{RT}{P} \\
v_1 = \frac{0.46152 \text{ kJ/kgK} \times (45.81 + 273.15) \text{ K}}{10 \text{ kPa}} = 14.72 \text{ m}^3/\text{kg}
\]

\[
v_2 = \frac{0.46152 \text{ kJ/kgK} \times (179.91 + 273.15) \text{ K}}{1000 \text{ kPa}} = 0.209 \text{ m}^3/\text{kg}
\]

\text{Real gas:}

\text{Table B.1.2:} \quad v_1 = 14.647 \text{ m}^3/\text{kg} \quad \text{so error} = 0.3 \%

\text{v}_2 = 0.19444 \text{ m}^3/\text{kg} \quad \text{so error} = 7.49 \%
3.68

Argon is kept in a rigid 5 m³ tank at -30°C, 3 MPa. Determine the mass using the compressibility factor. What is the error (%) if the ideal gas model is used?

Solution:

No Argon table, so we use generalized chart Fig. D.1

\[ T_r = \frac{T}{T_c} = \frac{243.15}{150.8} = 1.612, \quad P_r = \frac{P}{P_c} = \frac{3000}{4870} = 0.616 \quad \Rightarrow \quad Z \approx 0.96 \]

\[ m = \frac{PV}{ZRT} = \frac{3000 \times 5}{0.96 \times 0.2081 \times 243.2} = 308.75 \text{ kg} \]

Ideal gas \( Z = 1 \)

\[ m = \frac{PV}{RT} = 296.4 \text{ kg} \quad 4\% \text{ error} \]

3.73

Carbon dioxide at 330 K is pumped at a very high pressure, 10 MPa, into an oil-well. As it penetrates the rock/oil the oil viscosity is lowered so it flows out easily. For this process we need to know the density of the carbon dioxide being pumped.

Solution:

There is not a B section table so use compressibility chart

Table A.2  \( \text{CO}_2: \quad T_c = 304.1 \text{ K}, \quad P_c = 7.38 \text{ MPa} \)

\[ T_r = \frac{T}{T_c} = \frac{330}{304.1} = 1.085 \]

\[ P_r = \frac{P}{P_c} = 10/7.38 = 1.355 \]

From Figure D.1: \( Z \approx 0.45 \)

\[ \rho = \frac{1}{\nu} = \frac{P}{ZRT} = \frac{10000/(0.45 \times 0.1889 \times 330)}{356 \text{ kg/m}^3} \]

\[ \begin{align*}
T_r &= 2.0 \\
T_r &= 0.7 \\
T_r &= 1.1 \\
\ln P_r &= 0.7 \\
\ln P_r &= 1.0 \end{align*} \]