Problem 3-19

Known: SAT liq-vapor H2O mixture; Ti = 490 K, x = 0.95
Tliq = 620 K, Pliq = 2.0 MPa, Vliq = 17.9/s

Find: Vliq, i

Sketch:

\[ \text{Tliq} = 490 \text{K} \quad \rightarrow \quad \text{Tsat} = 620 \text{K} \]
\[ x = 0.95 \quad V\text{liq, sat} = 17.9/s \]

Assumptions:
1) No mass generation
2) Steady-state process

Analysis:
Apply the conservation of mass:

\[ \frac{d}{dt}(m_{liq} + m_{vap}) = 0 \]

\[ m_{liq} = m_{vap} \quad \Rightarrow \quad \rho_{liq} V_{liq} = \rho_{vap} V_{vap, out} \]

To find \( \rho_{vap} \), look up density of water at 2.0 MPa, 620 K
From Table D.3 (superheated vapor): \( \rho_{vap} = 7.25 \text{ kg/m}^3 \)

To find \( \rho_{liq} \), use Table 6.1 at \( T_{sat} = 490 \text{ K} \)
\( \rho_{l} = 844.22 \text{ kg/m}^3 \) and \( \rho_{g} = 10.942 \text{ kg/m}^3 \)

Use quality:
\[ \rho_{liq} = (1 - x) \rho_{l} + x \rho_{g} \]
\[ \rho_{liq} = (1 - 0.95) (844.22 \text{ kg/m}^3) + 0.95 (10.942 \text{ kg/m}^3) \]
\[ \rho_{liq} = 32.606 \text{ kg/m}^3 \]

With \( \rho_{liq} \):
\[ V_{liq, in} = \rho_{liq} V_{liq, out} \]
\[ V_{liq, i} = \frac{P_{vap, out}}{\rho_{liq}} \]
\[ V_{liq, i} = 2.345 \text{ m/s} \]

Comments: The key steps were using quality to find \( \rho_{liq} \) and recognizing that the output flow was superheated vapor.
**Problem 3-24**

**Known**: Cylindrical tank, D, H, \( \rho \), \( d \), \( V_i \)

**End**: \( t_{\text{full}} \)

**Sketch**: 
- \( D = 1.0 \text{ m} \)
- \( H = 3.5 \text{ m} \)
- \( V_i = \frac{2}{3} \)
- \( d = 5 \text{ mm} \)

**Assumptions**: 
- Constant inlet velocity
- Constant density
- No mass generation

**Analysis**: 

The conservation of mass equation:

\[ \dot{m}_{\text{in}} - \dot{m}_{\text{out}} + \dot{m}_{\text{inlet}} = \frac{dM}{dt} \]

\[ \dot{m}_{\text{in}} = \frac{dM}{dt} \]

\[ \rho \frac{\pi d^2 V_i}{4} = \frac{d}{dt} \left( \rho \frac{\pi d^2 h}{4} \right) = \rho \frac{\pi d^2}{4} \frac{dh}{dt} \]

\[ \frac{dh}{dt} = \frac{d^2 V_i}{D^2} \]

Integrate from \( H/2 \) to \( H \):

\[ \int_{H/2}^{H} dh = \int_{0}^{t_{\text{full}}} \frac{d^2 V_i}{D^2} dt \]

\[ H - H/2 = \frac{d^2 V_i}{D^2} t_{\text{full}} \]

\[ t_{\text{full}} = \frac{H - H/2}{\frac{d^2 V_i}{D^2}} = \frac{7.5}{0.003^2 \times 4} = 7500 \text{ s} = 2.08 \text{ hrs} \]

**Comments**: The assumption of constant density made the problem easier as the inlet density and tank density cancelled out.
Problem 2-10

Known: \( V, M, P, T \)

Find: \( \rho, u, h \)

Analysis:

\[
\rho = \frac{M}{V} = \frac{6.621 \text{ kg}}{2 \text{ m}^3} = 3.311 \frac{\text{kg}}{\text{m}^3}
\]

\[
\rho = 3.311 \frac{\text{kg}}{\text{m}^3}
\]

\[
u = \frac{U}{m} = \frac{19,878.5}{6.621 \text{ kJ}}
\]

\[
u = 3.002 \frac{\text{kJ}}{\text{kg}}
\]

\[
u = 3.002 \frac{\text{kJ}}{\text{kg}}
\]

\[
h = u + Pr = u + P \left( \frac{1}{\rho} \right)
\]

\[
h = 3002.266 \frac{\text{kJ}}{\text{kg}} + 1 \times 10^4 \frac{\text{Pa}}{3.311 \text{ kJ/ m}^3}
\]

\[
h = 3002.266 \frac{\text{kJ}}{\text{kg}} + 1 \times 10^4 \left( \frac{1}{3.311 \text{ kJ/ m}^3} \right)
\]

\[
h = 305,025.8 \frac{\text{J}}{\text{kg}}
\]

\[
h = 305.02 \frac{\text{kJ}}{\text{kg}}
\]

Comment: The enthalpy is much higher than the internal energy because of the large pressure value.
Problem 2-11

Known: \( \bar{C}_{V,N_2} \bigg|_{1000 K} = 24.36 \frac{kJ}{mol \cdot K}, \quad \gamma = 1.3411 \)

Kind: \( \bar{C}_{P,N_2}, \quad \bar{C}_{P,N_2} \)

Analysis with \( \gamma = 1.3411 \):

\[
\bar{C}_{P,N_2} = \gamma \bar{C}_{V,N_2} = 1.3411 \left( 24.36 \frac{kJ}{mol \cdot K} \right) = 32.704 \frac{kJ}{mol \cdot K}
\]

\[
\bar{C}_{P,N_2} = \frac{32.704}{28.013} \frac{kJ}{mol \cdot K}
\]

\[
\bar{C}_{P,M} = 1.167 \frac{kJ}{mol \cdot K}
\]

Comments: This was a simple calculation using the specific heat ratio and the molecular weight of \( N_2 \).
**Problem 2-24**

**Known:** \( T_1 = 300 \text{K} \), \( T_2 = 1000 \text{K} \)

**Find:** mass specific enthalpy change using:

1) Table C.2
2) \( \Delta h = c_p \Delta T \)

**Analysis:**

1) From Table C.2:

\[
\begin{align*}
h_{300K} & = 300.19 \text{ kJ/kg} \\
\Delta h & = h_{1000K} - h_{300K} = 1046.04 - 300.19 \\
\Delta h & = 745.85 \text{ kJ/kg}
\end{align*}
\]

2) From Table C.3:

\[
\begin{align*}
\frac{c_p}{300K} & = 1.007 \text{ kJ/kg.K} \\
\frac{c_p}{1000K} & = 1.141 \text{ kJ/kg.K} \\
c_p, \text{avg} & = \frac{1.007 + 1.141}{2} = 1.074 \text{ kJ/kg.K} \\
\Delta h & = c_p, \text{avg} \Delta T = (1.074 \text{ kJ/kg.K}) (1000 - 300 \text{K}) \\
\Delta h & = 751.6 \text{ kJ/kg}
\end{align*}
\]

**Comments:** The difference is small — less than 1%. The approximation using the average specific heat is valid for this temperature range.