1) 2.16 An adiabatic turbine expands steam from 500°C and 3.5 MPa to 200°C and 0.3 MPa. If the turbine generates 750 kW, what is the flow rate of steam through the turbine?

2) \( R = 8.314 \text{ J/(mole \ °K)} \)

3.11 A well-insulated tank contains 1 mole of air at 2 MPa and 673 K. It is connected via a closed valve to an insulated piston/cylinder device that is initially empty. The piston may be assumed to be frictionless. The volumes of the piping and valve are negligible. The weight of the piston and atmospheric pressure are such that the total downward force can be balanced with gas pressure in the cylinder of 0.7 MPa. The valve between the tank and piston/cylinder is cracked open until the pressure is uniform throughout. The temperature in the tank is found to be 499.6 K. Air can be assumed to be an ideal gas with a temperature-independent heat capacity \( C_p = 29.3 \text{ J/mol\-K} \).

(a) What is the number of moles left in the tank at the end of the process?
(b) Write and simplify the energy balance for the process. Determine the final temperature of the piston/cylinder gas.
3.4 A distillation column with a total condenser is shown in Fig. 3.3. The system to be studied in this problem has an average enthalpy of vaporization of 32 kJ/mol, an average $C_P^L$ of 146 J/mol°C, and an average $C_P^V$ of 93 J/mol°C. Variable names for the various stream flow rates and the heat flow rates are given in the diagram. The feed can be liquid, vapor, or a mixture represented using subscripts to indicate the vapor and liquid flows, $F = F_V + F_L$. The enthalpy flow due to feed can be represented as: for saturated liquid, $F_L H_{satL}$; for saturated vapor, $F_V H_{satV}$; for subcooled liquid, $F_L H_{satL} + F_L C_P^L (T_F - T_{satL})$; for superheated vapor, $F_V H_{satV} + F_V C_P^V (T_F - T_{satV})$; and for a mix of vapor and liquid, $F_L H_{satL} + F_V H_{satV}$.

(a) Use a mass balance to show $F_V + V_S - V_R = L_S - L_R - F_L$.

[For parts (b)–(f), use the feed section mass and energy balances to show the desired result.]

(b) For saturated vapor feed, $F_L = 0$. Show $V_R = V_S + F_V$, $L_S = L_R$.

(c) For saturated liquid feed, $F_V = 0$. Show $V_S = V_R$, $L_S = L_R + F_L$.

(g) Use the mass and energy balances around the total condenser to relate the condenser duty to the enthalpy of vaporization, for the case of streams $L_R$ and $D$ being saturated liquid.

(h) Use the mass and energy balances around the reboiler to relate the reboiler duty to the enthalpy of vaporization.

**Figure 3.3** (a) Overall schematic of a distillation column with a total condenser showing five sections of a distillation column and conventional labels; (b) a partial condenser; (c) schematic of liquid levels on bubble cap trays with the downcomers used to maintain the liquid levels.
### Table

<table>
<thead>
<tr>
<th>P (10^5 Pa)</th>
<th>T (°C)</th>
<th>f(VaJ/kg)</th>
<th>f(VaL/kg)</th>
<th>f(KJ/kg)</th>
<th>S(KJ/Kg·K)</th>
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</thead>
<tbody>
<tr>
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<td>279.62</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

### Notes
- The table provides values for various properties as a function of temperature and pressure.
- The properties include f(VaJ/kg), f(VaL/kg), f(KJ/kg), and S(KJ/Kg·K).
- The values are given in degrees Celsius (°C) for temperature and in 10^5 Pa for pressure.
- The table is structured in a grid format with two columns and multiple rows, each row representing a different pressure level.

### Further Information
- Additional data and explanations are available in the referenced article or source material.
- The values are likely part of a thermodynamic or chemical property table, useful for calculations or reference in scientific research or engineering applications.

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### Additional Resources
- [Reference](https://example.com) for further details on the table's content.
Answers Quiz 3
Chemical Engineering Thermodynamics
February 5, 2015

1)

2.16 An adiabatic turbine expands steam from 500°C and 3.5 MPa to 200°C and 0.3 MPa. If the turbine generates 750 kW, what is the flow rate of steam through the turbine?

\[ \dot{m} \Delta H = W = -750 \text{ kW} = \dot{m} (2865.9 - 3451.6) \text{ kJ/kg}, \dot{m} = 1.28 \text{ kg/sec} \]

2)

3.11 A well-insulated tank contains 1 mole of air at 2 MPa and 673 K. It is connected via a closed valve to an insulated piston/cylinder device that is initially empty. The piston may be assumed to be frictionless. The volumes of the piping and valve are negligible. The weight of the piston and atmospheric pressure are such that the total downward force can be balanced with gas pressure in the cylinder of 0.7 MPa. The valve between the tank and piston/cylinder is cracked open until the pressure is uniform throughout. The temperature in the tank is found to be 499.6 K. Air can be assumed to be an ideal gas with a temperature-independent heat capacity \( C_p = 29.3 \text{ J/mol-K} \).

(a) What is the number of moles left in the tank at the end of the process?
(b) Write and simplify the energy balance for the process. Determine the final temperature of the piston/cylinder gas.

\[ \text{Initial State} \quad \text{Final State} \]

\[ \begin{align*}
\text{Tank} & \quad \text{Tank} \\
\end{align*} \]

(3.11) A well-insulated tank contains 1 mole of air at 2 MPa...

a) from initial conditions:
\[ n_{\text{tank}} = \frac{RT}{P} = \frac{1(8.314)(673)}{2797.6} = 1.68 \text{ cm}^3, \]
\[ n_{\text{tank}} = \frac{P_{\text{tank}} V_{\text{tank}}}{RT_{\text{tank}}} \]
\[ n_{\text{tank}} = (0.7)(2797.6)/8.314/499.6 = 0.471 \text{ moles} \]

b) This problem is easiest taking the overall system.
\[ n'U' = nU + -P\Delta V - PV_piston + n'U_piston = -RT_piston + n'U_piston \]

subdividing the system at the final state into the tank and piston,
\[ n'U' = n'U_{\text{tank}} + n'U_piston \]

choosing reference state, \( T_k = 300 \text{ K}, P_k = 0.1 \text{ MPa}, U_k = 0 \), so \( U = C_v(T-300) \).
\[ U_{\text{tank}} = 4189.3 \text{ J/mol}, U_piston = 20.986(T_piston-300), U_f = 7827.8 \text{ J/mol}, \]
\[ 0.471(4189.3) + 0.529*20.986(592.6-300) - 7827.8 = -8.314*592.6 * 0.529 \]
\[ T_piston = 592.6 \text{ K} \]
3) 3.4 A distillation column with a total condenser is shown in Fig. 3.3. The system to be studied in this problem has an average enthalpy of vaporization of 32 kJ/mol, an average \( C^L \) of 146 J/mol°C, and an average \( C^V \) of 93 J/mol°C. Variable names for the various steam flow rates and the heat flow rates are given in the diagram. The feed can be liquid, vapor, or a mixture represented using subscripts to indicate the vapor and liquid flows, \( F = F_V + F_L \).

The enthalpy flow due to feed can be represented as: for saturated liquid, \( F_L H^\text{sat} \); for saturated vapor, \( F_V H^\text{sat} \); for subcooled liquid, \( F_L H^\text{sat} + F_L C^L (T_F - T^\text{sat}) \); for superheated vapor, \( F_V H^\text{sat} + F_V C^V (T_F - T^\text{sat}) \); and for a mix of vapor and liquid, \( F_L H^\text{sat} + F_V H^\text{sat} \).

(a) Use a mass balance to show \( F_V + V_S - V_R = L_S - L_R - F_L \).

[For parts (b)–(f), use the feed section mass and energy balances to show the desired result.]

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(c) For saturated liquid feed, \( F_V = 0 \). Show \( V_S = V_R, L_S - L_R + F_L \).

(g) Use the mass and energy balances around the total condenser to relate the condenser duty to the enthalpy of vaporization, for the case of streams \( L_R \) and \( D \) being saturated liquid.

(b) Use the mass and energy balances around the reboiler to relate the reboiler duty to the enthalpy of vaporization.