Condensation of a natural gas stream (Double mixed refrigerant LNG process provides viable alternative for tropical conditions, Oil & Gas Journal, 100(27) (2002)) results in a liquid stream containing the following compositions. It is desirable to flash the liquid to 5 MPa to produce a liquid and a vapor stream in order to partially separate the components prior to distillation.

<table>
<thead>
<tr>
<th></th>
<th>$z_i$</th>
<th>$T_c$, °K</th>
<th>$P_c$, Mpa</th>
<th>$\omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHANE</td>
<td>0.8800</td>
<td>190.6</td>
<td>4.604</td>
<td>0.011</td>
</tr>
<tr>
<td>ETHANE</td>
<td>0.0758</td>
<td>305.4</td>
<td>4.88</td>
<td>0.099</td>
</tr>
<tr>
<td>PROPANE</td>
<td>0.0442</td>
<td>369.8</td>
<td>4.249</td>
<td>0.152</td>
</tr>
</tbody>
</table>

a) What is the bubble point of this mixture at 5 MPa? (This is the lower limit to the flash tank temperature).
   Use solver in excel and the shortcut method. Demonstrate that the method is appropriate after solving. Briefly describe the steps used in solver referencing parameters (not cells).

b) What is the dew point of this mixture at 5 MPa? (This is the upper limit to the flash tank temperature).
   Use solver in excel and the shortcut method. Demonstrate that the method is appropriate after solving. Briefly describe the steps used in solver referencing parameters (not cells).

c) If V/F is desired to be 50% what is the flash temperature?
   Briefly describe the steps used in solver referencing parameters (not cells). Demonstrate that the method is appropriate after solving.
   **How does this temperature compare to parts “a” and “b”?**

d) If the mixture were flashed at -43°C what fraction would be liquid?
   Briefly describe the steps used in solver referencing parameters (not cells). Demonstrate that the method is appropriate after solving.

e) For parts “c” and “d”, what is the molar ratio of methane in the vapor compared to the liquid phase? ($n_{Me}^V/n_{Me}^L$)
   What is the molar ratio of propane in the liquid compared to the vapor phase? ($n_{Prop}^L/n_{Prop}^V$)
   Comment on the goodness of separation in the flash process for the two cases.

$$\frac{n_i^V}{n_i^L} = \frac{(V/F) y_i}{(L/F) x_i} \quad \& \quad \frac{n_i^L}{n_i^V} = \frac{(L/F) x_i}{(V/F) y_i}$$
\[
\log_{10} P_r^{\text{sat}} = \frac{7}{3} (1 + \omega) \left(1 - \frac{1}{T_r} \right)
\]

\[9.11\]

1 Shortcut vapor pressure equation. Use care with the shortcut equation below \(T_r = 0.5\).

**Note:** The shortcut vapor pressure equation must be regarded as an approximation for rapid estimates. The approximation is generally good above \(P = 0.5\) bar; the percent error can become significant at lower pressures (and

\[
\sum_i z_i \frac{(1 - K_i)}{1 + (V/F)(K_i - 1)} = 0
\]

\[
K_i = \frac{P_i^{\text{sat}}}{P} \approx \frac{P_c, i^{10}}{P}
\]

Shortcut \(K\)-ratio

\[
\sum_i x_i = \sum_i \left(\frac{y_i}{K_i}\right) = 1
\]

\[
\sum_i y_i = \sum_i K_i x_i = 1
\]
ANSWERS: Quiz 11
Chemical Engineering Thermodynamics
March 30, 2017

a)

Bubble Point Calculation

<table>
<thead>
<tr>
<th></th>
<th>zi</th>
<th>Tc, °K</th>
<th>Pc, Mpa</th>
<th>w</th>
<th>Tr&gt;0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHANE</td>
<td>0.88</td>
<td>190.6</td>
<td>4.604</td>
<td>0.011</td>
<td>1.03964573</td>
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<tr>
<td>ETHANE</td>
<td>0.0758</td>
<td>305.4</td>
<td>4.88</td>
<td>0.099</td>
<td>0.64884243</td>
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<tr>
<td>PROPA NE</td>
<td>0.0442</td>
<td>369.8</td>
<td>4.249</td>
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<td>0.53584769</td>
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<tr>
<td>n-BUTANE</td>
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<td>3.797</td>
<td>0.193</td>
<td>0.46603122</td>
</tr>
<tr>
<td>ISOBUTANE</td>
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<td>408.1</td>
<td>3.648</td>
<td>0.177</td>
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<tr>
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<td>469.7</td>
<td>3.369</td>
<td>0.249</td>
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</table>

\[
\sum x_i = 1.0000002
\]

Solve sum xK to 1 by varying TK.  \( T_{BP} = 198°K \) \((-74.8°C\).  Tr’s >0.5 and Pr> 0.05MPa.

b)

Dew Point Calculation

<table>
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<tr>
<th></th>
<th>zi</th>
<th>Tc, °K</th>
<th>Pc, Mpa</th>
<th>w</th>
<th>zi</th>
<th>Tr&gt;0.5</th>
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<td>4.88</td>
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<tr>
<td>PROPA NE</td>
<td>0.0442</td>
<td>369.8</td>
<td>4.249</td>
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<td>0.60107848</td>
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<tr>
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<td>425.2</td>
<td>3.797</td>
<td>0.193</td>
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</tr>
<tr>
<td>ISOBUTANE</td>
<td>0</td>
<td>408.1</td>
<td>3.648</td>
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<td>0.64938567</td>
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<tr>
<td>n-PENTANE</td>
<td>0</td>
<td>469.7</td>
<td>3.369</td>
<td>0.249</td>
<td>0.55422034</td>
<td></td>
</tr>
</tbody>
</table>

\[
\sum y_i = \sum K_i x_i = 1
\]

Solve sum y/K to 1 by varying TK.  \( T_{DP} = 265°K \) \((-7.99°C\).  Tr’s >0.5 and Pr> 0.05MPa.
c) Solve \( \text{SumD} = 0 \) by varying \( \text{TK} \). \( T_{50\%} = 203^\circ\text{K} \) (-69.7°C). This is between the BP and DP limits for the flash tank. \( T_r > 0.5 \) and \( P_r > 0.05\text{MPa} \).

\[
\sum_{i} \frac{z_i (1 - K_i)}{1 + (V/F)(K_i - 1)} = 0
\]

Solve \( \text{SumD} = 0 \) by varying \( \text{TK} \). \( T_{50\%} = 203^\circ\text{K} \) (-69.7°C). This is between the BP and DP limits for the flash tank. \( T_r > 0.5 \) and \( P_r > 0.05\text{MPa} \).

L/F = 0.133. Solve for \( \text{sumD} = 0 \) by varying V/F. \( T_r > 0.5 \) and \( P_r > 0.05\text{MPa} \).

d) The ratios are given in the excel sheet in the bottom right for parts “c” and “d.” For the first case, there is good separation of propane to the liquid phase, 187 times the vapor phase. For the second case, there is good separation of methane to the vapor phase, 15 times the liquid composition.