Properties of Reservoir Fluids (PGE 362)

Quantitative Phase Behavior

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Ideal Solutions

From the previous example (L12):

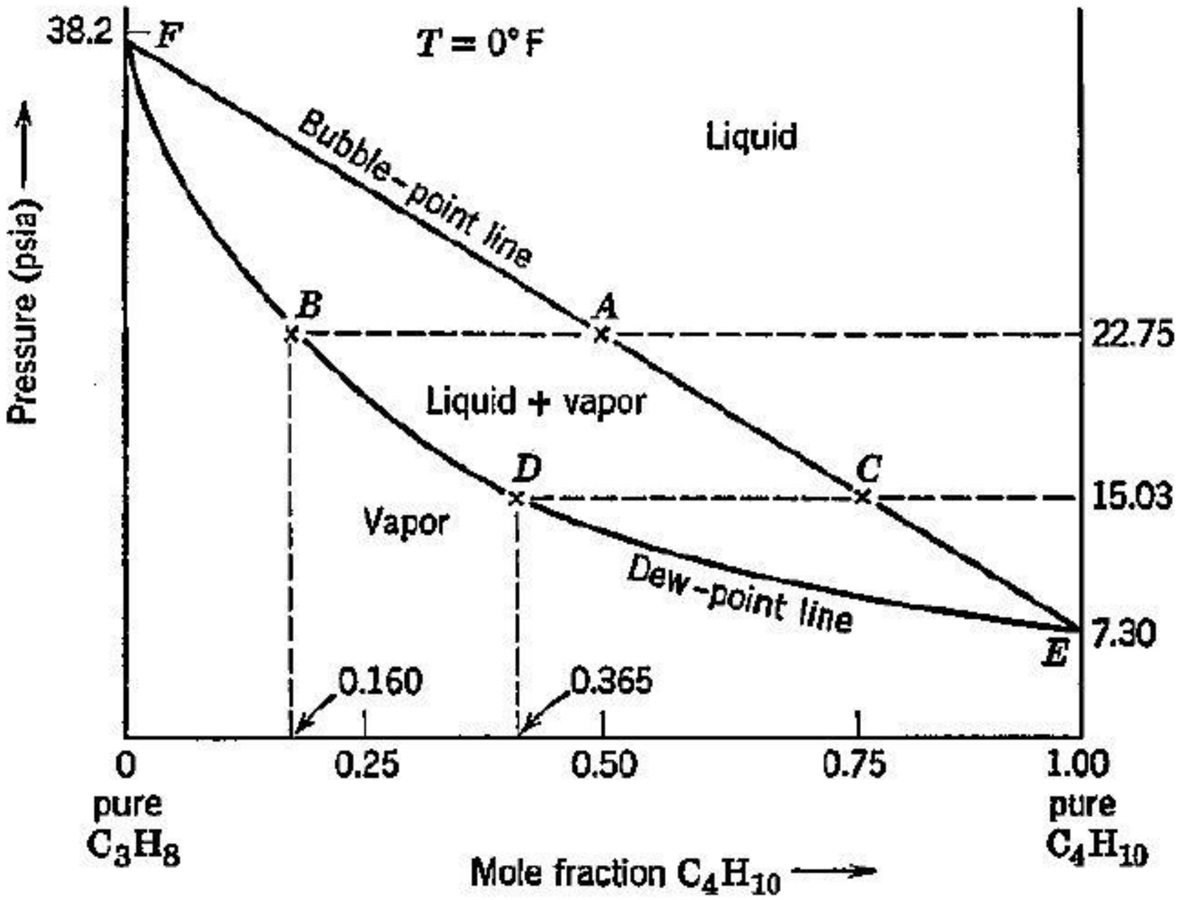
Component	P_i^0	x_i	$P_i = x_i P_i^0$	$y_i = P_i/P_T$
C_3H_8	38.20	0.50	19.10	0.840
C_4H_{10}	7.30	0.50	3.65	0.160

$P_T = 22.75$ psia

Component	P_i^0	x_i	$P_i = x_i P_i^0$	$y_i = P_i/P_T$
C_3H_8	38.20	0.25	9.55	0.635
C_4H_{10}	7.30	0.75	5.48	0.365

$P_T = 15.03$ psia

Ideal Solutions



Ideal Solutions

Why bubble point is a straight line:

Bubble point line is a linear function of composition.

$$BPP = x_1 P_1^{\circ} + x_2 P_2^{\circ}$$

Since $\boldsymbol{x_1 = 1 - x_2}$ for a **binary system**,

$$BPP = (P_1^{\circ} - P_2^{\circ})\, x_1 + P_2^{\circ}$$

$$y = ax + b$$

Ideal Solutions

Calculation of the liquid and vapor composition of two-component system in the two phase region:

Application of Raoult's Law:

$$P_T = x_1 P_1^\circ + x_2 P_2^\circ$$

$\boldsymbol{x_1}$ and $\boldsymbol{x_2}$: mole fraction of the two components in the **liquid** (generally, do not represent the overall composition of the system).

$$x_2 = 1 - x_1$$

$$P_T = x_1 P_1^\circ + (1 - x_1)\, P_2^\circ$$

Ideal Solutions

Solving for x_1:

$$x_1 = \frac{P_T - P_2^\circ}{P_1^\circ - P_2^\circ}$$

$$x_2 = \frac{P_T - P_1^\circ}{P_2^\circ - P_1^\circ}$$

If **Dalton's Law** is applicable to the vapor,

$$y_1 = \frac{P_1}{P_T} = \frac{x_1 P_1^\circ}{P_T}$$

$$y_2 = \frac{P_2}{P_T} = \frac{x_2 P_2^\circ}{P_T}$$

Ideal Solutions

Example:

Assuming **ideal solution behavior** calculate the composition of the liquid and vapor at **180° F** and **95 psia** for a system containing **one mole** of n-butane and **one mole** of **n-pentane**.

The vapor pressure of pure components at **180° F** are **160 psia** for C_4H_{10} and **54 psia** for C_5H_{12}. (Properties of petroleum reservoir fluids: Burcik – Appendix B)

Ideal Solutions

Solution:

$$x_{C_4H_{10}} = \frac{P_T - P_{C_5H_{12}}{}^{\circ}}{P_{C_4H_{10}}{}^{\circ} - P_{C_5H_{12}}{}^{\circ}} = \frac{95 - 54}{160 - 54} = \mathbf{0.3868}$$

$$x_{C_5H_{12}} = 1 - x_{C_4H_{10}} = 1 - 0.3868 = \mathbf{0.6132}$$

$$y_{C_4H_{10}} = \frac{x_{C_4H_{10}} P_{C_4H_{10}}{}^{\circ}}{P_T} = \frac{0.3869 \times 160}{95} = \mathbf{0.6515}$$

$$y_{C_5H_{12}} = 1 - y_{C_4H_{10}} = 1 - 0.6515 = \mathbf{0.3485}$$

Ideal Solutions

Calculation of the dew point pressure of a two-component system:

At dew point the system is essentially all vapor except for tiny amount of liquid.

$$y_1 = \frac{x_1 P_1^{\circ}}{P_T}$$

$$x_1 = \frac{P_T - P_2^{\circ}}{P_1^{\circ} - P_2^{\circ}}$$

$$y_1 = \frac{\frac{P_T - P_2^{\circ}}{P_1^{\circ} - P_2^{\circ}} P_1^{\circ}}{P_T}$$

$$P_T = \frac{-P_2^{\circ}}{\frac{y_1}{P_1^{\circ}}[P_1^{\circ} - P_2^{\circ}] - 1}$$

Ideal Solutions

Example:

Assuming **ideal solution behavior** calculate the dew-point pressure and the composition of the liquid at the dew-point at **180° F** for a system containing **one mole** of **n-butane** and **one mole** of **n-pentane**.

The vapor pressure of pure components at **180° F** are **160 psia** for C_4H_{10} and **54 psia** for C_5H_{12}.

Ideal Solutions

Solution:

$$y_{C_4H_{10}} = \frac{\frac{P_T - P_{C_5H_{12}}^{\circ}}{P_{C_4H_{10}}^{\circ} - P_{C_5H_{12}}^{\circ}} P_{C_4H_{10}}^{\circ}}{P_T}$$

$$\mathbf{0.5} = \frac{\frac{P_T - 54}{160 - 54} 160}{P_T}$$

$$P_T = \frac{-P_2^{\circ}}{\frac{y_1}{P_1^{\circ}}[P_1^{\circ} - P_2^{\circ}] - 1}$$

$P_T = 80.8$ psia = DPP

Ideal Solutions

Solution:

The composition of the liquid at the dew point;

$$x_{C_4H_{10}} = \frac{P_T - P_{C_5H_{12}}{}^{\circ}}{P_{C_4H_{10}}{}^{\circ} - P_{C_5H_{12}}{}^{\circ}}$$

$$x_{C_4H_{10}} = \frac{80.8 - 54}{160 - 54} = \mathbf{0.2528}$$

$$x_{C_5H_{12}} = 1 - x_{C_4H_{10}} = 1 - 0.2528 = \mathbf{0.7472}$$

Ideal Solutions

Solution:

The bubble point pressure;

$$x_{C_4H_{10}} = \frac{P_T - P_2^{\circ}}{P_1 - P_2^{\circ}} \qquad \mathbf{0.5} = \frac{P_T - 54}{160 - 54}$$

P_T =107 psia = BPP

$$y_{C_4H_{10}} = \frac{x_{C_4H_{10}} P_{C_4H_{10}}^{\circ}}{P_T} \qquad y_{C_4H_{10}} = \frac{0.5 \times 160}{107} = \mathbf{0.7477}$$

$$y_{C_5H_{12}} = 1 - x_{C_4H_{10}} = 1 - 0.7477 = \mathbf{0.2523}$$

Ideal Solutions

Solution:

1. BBP = **107** psia
2. Composition of vapor at BBP ($y_{C_4H_{10}} = \mathbf{0.7477}$, $y_{C_5H_{12}} = \mathbf{0.2523}$)
3. Composition of liquid vapor at **95** psia ($x_{C_4H_{10}} = \mathbf{0.3868}$, $x_{C_5H_{12}} = \mathbf{0.6132}$,

   $y_{C_4H_{10}} = \mathbf{0.6515}$, $y_{C_5H_{12}} = \mathbf{0.3485}$)

1. DPP = **80.8** psia
2. Composition of liquid at DPP ($x_{C_4H_{10}} = \mathbf{0.2528}$, $x_{C_5H_{12}} = \mathbf{0.7472}$)

Ideal Solutions

Solution: