CHEMICAL ENGINEERING THERMODYNAMICS II (0905323)
07. BUBBLE-T AND DEW-T USING RAOULT'S LAW

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Outline

- Difficulty Compared to Bubble-P and Dew-P
- Brute Force Solution of Bubble-T and Dew-T
- Bubble-*T*: Concept and Algorithm
- Dew-*T*: Concept and Algorithm
- Examples

Difficulty Compared to Bubble-P and Dew-P

- In Bubble-T and Dew-T, known are P and either **y** or **x**.
  - Temperature is not known
  - Therefore, vapor pressure is not known apriori.
  - Vapor pressure is a nonlinear function of T!
  - Consider Antoine equation, which is a simple vapor pressure model:

$$\ln P_i^{\text{vap}} = A_i - \frac{B_i}{T + C_i} \rightarrow P_i^{\text{vap}} = \exp\left(A_i - \frac{B_i}{T + C_i} \right)$$

  - Clearly, temperature dependence is exponential.

Brute Force Solution of Bubble-T and Dew-T

Bubble-T

$$P = \sum_{i=1}^{C} x_i P_i^{\text{vap}} = \sum_{i=1}^{C} x_i \exp\left(A_i - \frac{B_i}{T + C_i} \right)$$

Binary

$$P = x_1 \exp\left(A_1 - \frac{B_1}{T + C_1} \right) + x_2 \exp\left(A_2 - \frac{B_2}{T + C_2} \right)$$

Dew-T

$$P = \frac{1}{\sum_{i=1}^{C} y_i / P_i^{\text{vap}}} = \frac{1}{\sum_{i=1}^{C} \frac{y_i}{\exp\left(A_i - \frac{B_i}{T + C_i} \right)}}$$

Binary

$$P = \frac{1}{y_1 / \exp\left(A_1 - \frac{B_1}{T + C_1} \right) + y_2 / \exp\left(A_2 - \frac{B_2}{T + C_2} \right)}$$

Example: Bubble-T

- Consider the system: benzene, toluene and m-xylene (BTX). A liquid solution of these components has the composition **x** = {0.4,0.3,0.3} for the components in their respective order at P = 0.07145 bar. Wanted: find the equilibrium temperature and vapor compositions at the prescribed conditions.

Solution for Bubble-T

$$P = \sum_{i=1}^{C} x_i P_i^{\text{vap}} = x_1 P_1^{\text{vap}} + x_2 P_2^{\text{vap}} + x_3 P_3^{\text{vap}}$$

$$= x_1 \exp\left(A_1 - \frac{B_1}{T + C_1} \right) + x_2 \exp\left(A_2 - \frac{B_2}{T + C_2} \right) + x_3 \exp\left(A_3 - \frac{B_3}{T + C_3} \right)$$

	xi	A	B	C	P*i	xiP*i	yi=xiP*i/P
Benzene	0.40000	9.2806	2788.51	-52.3600	0.13811	0.05524	0.77317
Toluene	0.30000	9.3935	3096.52	-53.6700	0.04171	0.01251	0.17511
m-Xylene	0.30000	9.5188	3366.99	-58.0400	0.01232	0.00370	0.05172
					Pcal	**0.07145**	1.00000
					|Pcal-Pgiven|	0.00000	
Given P (bar)	**0.071449**						
Assumed T (K)	**300**			Ki			
				1.93291		α12	3.31143
				0.58371		α13	11.21155
				0.17240		α23	3.38572

Example: Dew-T

- Consider the system: benzene, toluene and m-xylene (BTX). A vapor phase of these components has the composition **y** = {0.4,0.3,0.3} for the components in their respective order at P = 0.02903 bar. Wanted: find the equilibrium temperature and liquid compositions at the prescribed conditions.

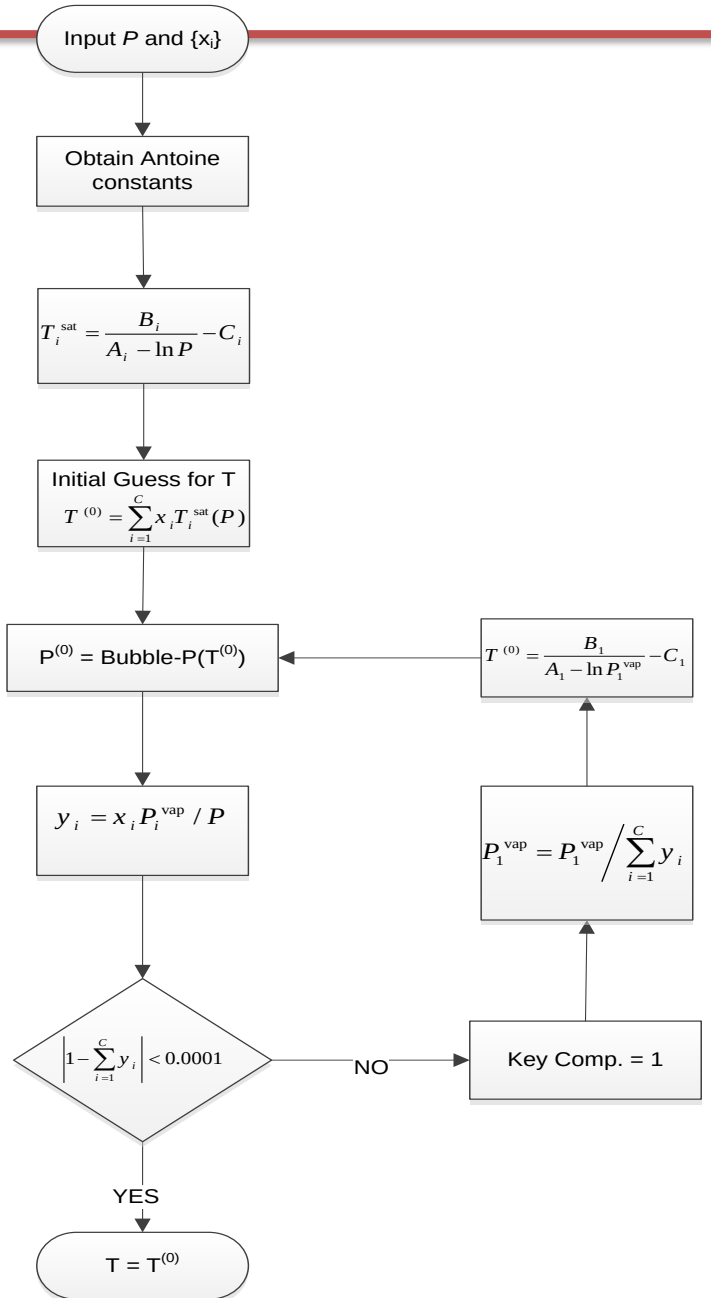
Solution for Dew-T

$$P = \frac{1}{\sum_{i=1}^{C} y_i / P_i^{\text{vap}}} = \frac{1}{y_1 / P_1^{\text{vap}} + y_2 / P_2^{\text{vap}} + y_3 / P_3^{\text{vap}}}$$

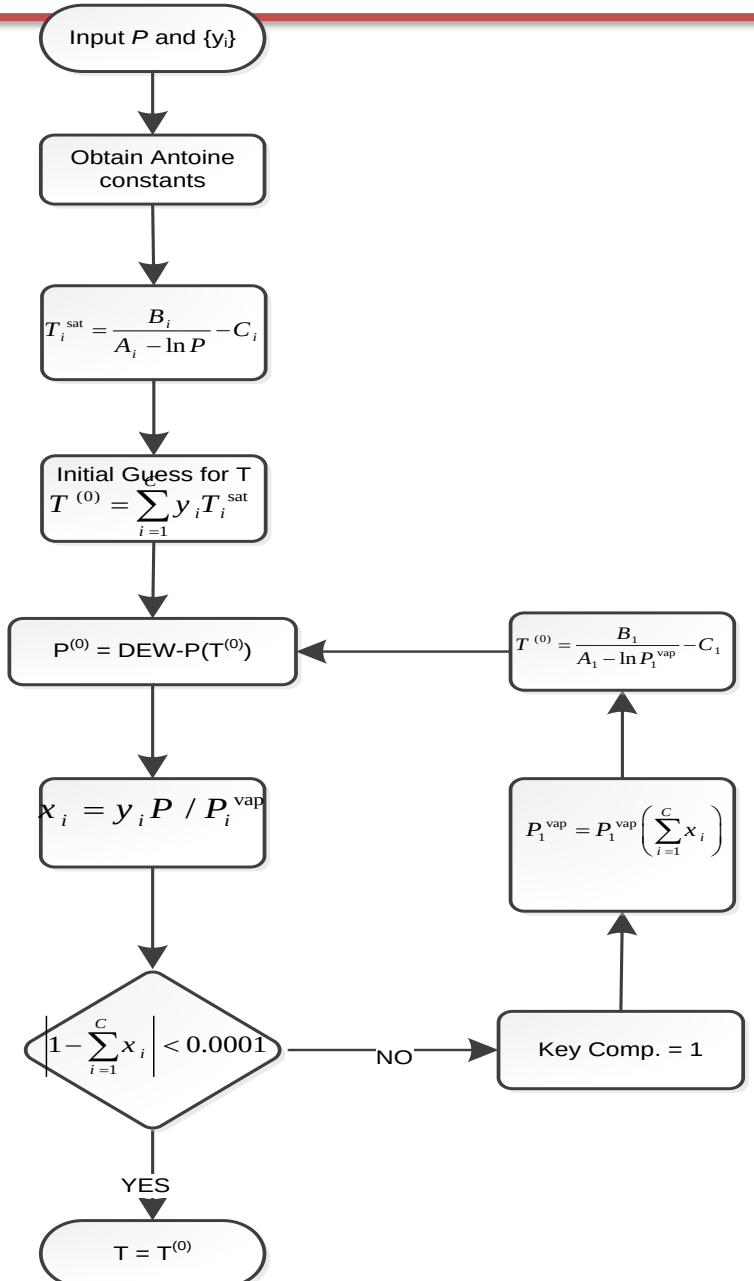
$$= \frac{1}{y_1 / \exp\left(A_1 - \frac{B_1}{T + C_1}\right) + y_2 / \exp\left(A_2 - \frac{B_2}{T + C_2}\right) + y_3 / \exp\left(A_3 - \frac{B_3}{T + C_3}\right)}$$

	yi	A	B	C	P*i	yi/P*i	xi=yiP/P*i
Benzene	0.4	9.2806	2788.51	-52.36	0.13809	2.89656	0.08409
Toluene	0.3	9.3935	3096.52	-53.67	0.04170	7.19388	0.20884
m-Xylene	0.3	9.5188	3366.99	-58.04	0.01232	24.35670	0.70707
					P	**0.02903**	1.00000
					|Pcal-Pgiven|	0.00000	
Given P (bar)	**0.02903**						
T (K)	**299.9983**						
				Ki			
				4.75697		α12	3.31146
				1.43652		α13	11.21178
				0.42428		α23	3.38575

Bubble-*T*: Concept and Algorithm



Dew-*P*: Concept and Algorithm



Example: Bubble-T Solution

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Solution using Excel

Example: Dew-T Solution

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Solution using Excel